Environmental Impacts of International Civil Engineering Projects and Practices

AMERICAN SOCIETY OF CIVIL ENGINEERS
FOUNDED 1852

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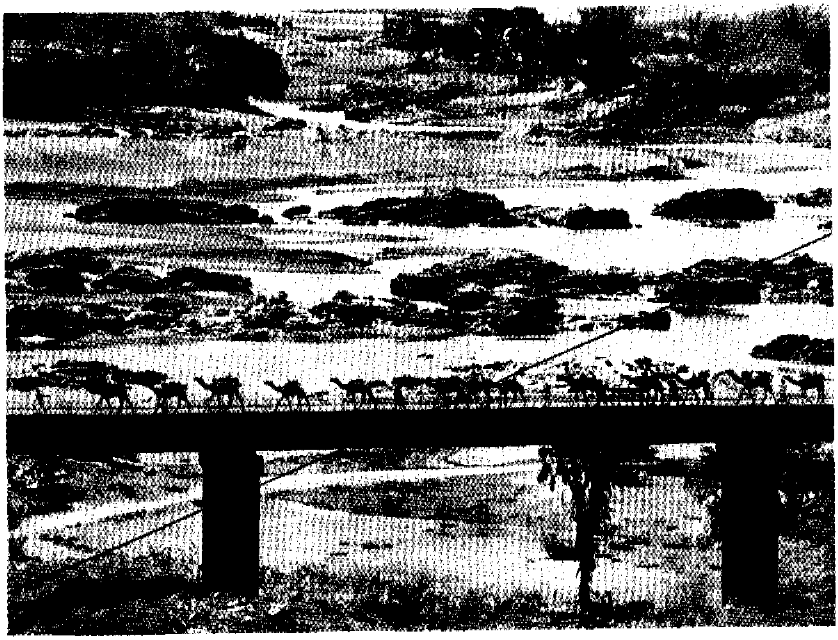
Cover photo: Construction of Roseires Dam across the Blue Nile (World Bank Photo)



Modern and traditional transportation technologies in the Sudan. Bridge was constructed with Roseires Dam as part of 3600 km^2 (900,000 acre) irrigation project. (World Bank Photo)

AMERICAN SOCIETY OF CIVIL ENGINEERS

ENVIRONMENTAL IMPACT ANALYSIS

Research Council

FOREWORD

Since World War II, there has been a large number of international reconstruction development and assistance programs and projects. Most of these include a civil engineering component. Reconstruction programs have generally been successfully completed and emphasis has shifted to development where successes are combined with failures or indifferent results. Civil engineering practices have contributed to this mixture of results. Because members of ASCE have been very much involved in international work, the Environmental Impact Analysis Research Council (EIARC) and its Committee on Environmental Impacts of Large International Civil Engineering Projects convened a workshop to identify factors leading to program successes or failures. Emphasis is on those factors not ordinarily included in the conventional wisdom of civil engineering practice. These include public participation, economic measures, public health, environmentalism, and appropriate technology.

The workshop was organized around two sessions, the first devoted generally to case studies presented by practicing engineers. The second session concentrated on discussions of socioeconomic and environmental considerations and their impact on civil engineering. Case studies included transportation, impoundment, irrigation, water supply, and waste disposal. It is the aim of EIARC to identify and develop guidelines for international civil engineering program and project planning and implementation which will lead to greater acceptance, utilization, and economic viability of the projects to which civil engineers contribute.

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Impacts of Large International
Civil Engineering Projects, EIARC

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ENVIRONMENTAL IMPACTS OF TRANSPORTATION PROJECTS

by
Thomas L. Weck[1]

INTRODUCTION

It is known that transportation projects can have profound impacts on shaping a country's economic growth, social patterns, and environmental quality, but it is only recently that the full range of impacts associated with transportation investments has begun to be addressed comprehensively. While today environmental analysis is being carried out for all types of transportation investments, the scope and depth of this analysis, particularly with regard to developing countries, can best be illustrated by road projects. There are two reasons why road projects are most representative in a consideration of the environmental impacts of transportation projects:

1. Many of the most sophisticated analytic techniques have been developed in conjunction with environmental impact studies of road projects; and

2. In developing nations, the most common transportation investment is in roads.

The principal focus of this paper is upon one highway project - the proposed Darien Gap Highway, a project which illustrates a number of key environmental issues. Where important environmental issues are not treated in depth by the studies which have been undertaken for the Darien Gap Highway, other road projects have been selected to illustrate these issues.

[1]Vice President and Director of Environmental Studies, Louis Berger and Associates, Inc., East Orange, New Jersey

In several cases, these projects include studies of roads in the United States. This is true where:

1. The analytic techniques developed for the issue in question are universally applicable to developed and developing countries; and

2. The issue in question has been thoroughly documented by a domestic project.

The environmental issues discussed in this paper are broken down into four sections:

I. The Economic Environment focuses upon impacts on production output.

II. The Biological Environment addresses impacts upon disease control, aquatic ecology, terrestrial ecology and endangered species.

III. The Social Environment deals with impacts upon community/tribal structure and cultural resources.

IV. The Synthesis of Environmental Impacts includes a brief discussion of methodologies which have been developed (such as matrices, weighting techniques, and computer mapping techniques) to evaluate overall environmental impacts.

A BRIEF OVERVIEW OF THE DARIEN GAP HIGHWAY

Before examining the environmental issues raised in the Darien Gap Highway project, it will be useful to review briefly the history of the project. On May 6, 1971, the United States, Panama and Colombia signed agreements for the construction of the Darien Gap Highway. The purpose of constructing this 250 mile highway is to connect the northern and southern sections of the Pan American Highway in order to open up both land communications between Panama and Colombia and land trade routes between North and South America.

The project extends from just south of Panama City to the Rio Leon Bridge in Colombia. Approximately 101 miles of the southernmost section of the highway remain to be cleared and graded. An environmental impact statement has been prepared for this section; strong opposition to the adverse impacts of constructing this section has resulted in the issuance of a preliminary injunction by the U.S. District Court, District of Columbia, on October 17, 1975, halting further United States funding for the project. This injunction was still in effect as of May, 1977.

I. THE ECONOMIC ENVIRONMENT

The primary purpose of an infrastructure investment such as a road is to foster economic growth. The impact of a road investment upon the production of goods and services forms the basis for the justification of the project from an economic viewpoint. Traditionally, road projects have been evaluated solely on the basis of the enhancement of user benefits - that is, savings due to reduced operating costs or freight and passenger charges from improved operating conditions and shortened time and distance. While this concept has application to the Darien Gap Highway project (namely in the user benefits stemming from modal diversions from passenger and freight sea transport to road transport between North and South America), by itself it provides an incomplete picture of the project's potential economic impact. In this type of project, where large areas of land will be opened up for development, an economic evaluation must also include consideration of regional development benefits. These benefits are composed of the net increases in output in sectors such as agriculture, forestry, fishing, commerce, and industry which are attributable, in part, to the proposed project. In evaluating these benefits, it is necessary to assess the degree to which present lack of adequate access has hindered the development potential of a region. This includes a determination of the region's natural resource development potential, the region's comparative economic advantage, the present structural and socioeconomic characteristics of the economy in the area, the availability of human and capital resources, and institutional constraints. The net increases in output attributable to the project are determined by calculating the value of increased production and subtracting from this value the total cost of inputs necessary in order to realize the increased production. These costs include not only the cost of a road but that of other infrastructure such as water resources, power, social services, agricultural extension services, credit, fertilizers, etc.

In the case of the Darien Gap Highway, the improved access could result in a substantial expansion of land under cultivation. In Panama, nearly 750,000 acres of undeveloped land in the Darien region are potentially suitable for farming. The project could also lead to a substantial expansion of animal husbandry and lumber production. In the latter case, in conjunction with the highway project, there are present plans for a new lumber mill in the Darien region with a capacity of 50 million board feet per year. Panama is currently a net importer of 20 million board feet annually. This project could assist Panama not only in meeting its own lumber requirements but in generating foreign exchange through a new export commodity. In Colombia, there is potential for significant increases in crop production as a result of the access provided by the proposed highway.

With regard to the potential economic development impact of a penetration road, such as the Darien Gap Highway, or of a feeder road, there are two key issues to consider:

1. The extent to which the identified potential will be realized once the road project is completed; and

2. The extent to which development can be controlled in order to minimize potential adverse impacts upon the biological and social environment.

The first of these two issues is discussed briefly in this section of the paper. The second issue is discussed under the sections dealing with the biological and social environments.

While it is clear that transportation improvements and economic development are closely related, it has been only recently that this relationship has been addressed quantitatively with regard to road projects into new or relatively undeveloped areas. In the National Transport Study for Haiti, for example, a feeder road market survey was carried out in order to estimate the effect of the provision of new feeder roads upon the number of acres under cultivation, the agricultural production, and the value added. The study was carried out on a classical "with and without" basis; that is, rural markets with recently built feeder roads were compared to rural markets without feeder roads. In order to isolate the factor of accessibility, care was taken to select market areas for this study which had similar characteristics with regard to other important determining factors such as soil suitability, topography, climate, cultural patterns, etc. While the study was not of large enough scope to yield definitive answers on the impact of improved accessibility upon levels of economic activity, it did provide useful order-of-magnitude estimations. The rural markets with feeder roads were found to serve approximately twice the agricultural area as those without feeder roads. The markets with feeder roads produced three to five times more agricultural goods per unit of area cultivated as did the markets without feeder roads. Total tons marketed and value added averaged approximately seven times greater for markets with feeder roads than for markets without. While this Haitian study only scratches the surface of the dynamics of rural development, it does give an indication of the potentially dramatic impact of increased accessibility in rural and undeveloped areas.

II. THE BIOLOGICAL ENVIRONMENT

A. Plant and Animal Diseases

One of the principal concerns regarding the Darien Gap Highway is that it may facilitate the northward movement of animal and plant diseases and pests from endemic areas in Colombia and other parts of South America. The most controversial issue in this regard is the potential spread of aftosa, also known as foot-and-mouth disease. Aftosa is a highly communicable viral disease which primarily attacks cattle and swine but also can attack sheep, goats, and other ruminants. Because it can kill or debilitate whole herds, it is one of the most feared diseases of domestic livestock. The two most common methods of coping with an outbreak of aftosa are eradication through slaughtering and vaccination. Since there are still safety, effectiveness, and cost problems with presently available vaccines, outbreaks of aftosa in countries which are generally free from this disease are usually treated by slaughtering the infected and exposed herds.

There were three outbreaks of aftosa in the United States in the 19th century; there have been five outbreaks thus far in the 20th century. The largest outbreak in the United States took place in 1914 when over 22 states were affected. In order to control the outbreak, more than 3,500 herds had to be slaughtered. The last outbreak in the United States took place in 1929. Through the use of effective control measures, the outbreak was contained within the state of California. The most recent outbreak in North America occurred in Canada in 1952. In this case, the outbreak was confined to a small area by means of early detection and quick eradication. To give some idea of the potential magnitude of this disease problem, it has been recently estimated in a study completed at the University of Minnesota that an uncontrolled outbreak of aftosa in the United States would cause a loss of more than $10 billion in domestic livestock in the first year alone, with unpredictable losses to a wildlife population of some 20 million cloven-hoofed animals valued at between $7 to $10 billion. For countries where this disease is endemic, eradication programs themselves are very costly. For example, the aftosa eradication program in Mexico cost approximately $140 million and took over 10 years to implement.

In Colombia aftosa is endemic, whereas in neighboring Panama the disease is not present. The Darien Gap area has until now served as an effective natural land barrier against the spread of this disease from Colombia to Panama as well as to other parts of Central America, Mexico, and the United States. Panama maintains a very strict preventive program along the Colombian border. The Panamanian government has established a quarantine zone in the southern portion of the Darien Gap area into which no cattle are allowed. The remainder of the Darien Gap area is a control zone; cattle are allowed in but cannot be removed. One of the main concerns over the proposed Darien Gap Highway is that it would eliminate what has been until now a very effective barrier to the spread of this devastating livestock disease. The United States is concerned about the spread of this disease both for Panama's sake and as a matter of economic self-interest. The further south the disease can be contained, the less the risk of its entry into the United States.

In the interest of controlling the northward spread of aftosa once the highway is built, the United States has entered into a cooperative program with Panama and Colombia. This program includes establishment of a 25-mile, cattle-free zone along the entire Panama-Colombia border, with an additional 25-mile control zone in which cattle can be raised for local consumption only. The United States has appropriated approximately $8 million for the establishment and implementation of aftosa eradication programs in Panama and Colombia. As part of this program, a senior review group composed of technical advisors and specialists from the Colombián Ministry of Agriculture and the United States Department of Agriculture will be formed to review the progress of the aftosa eradication program in Colombia. There is to be no highway construction in Colombia until this program is operating satisfactorily.

Serious questions still remain, however, as to the effectiveness of this program in controlling the disease once the Darien Gap Highway has been built. One concern focuses upon the disease control problems associated with modern transportation. With shortened travel times, infected animals may not pass through the incubative stage to the clinical symptom state until after shipment into a disease-free area. Quarantine periods may be instituted to control this potential problem.

Another concern focuses upon the problem of illegal shipments. As would be expected, cattle from aftosa-free areas command higher prices than those from areas where the disease is endemic. A large price differential between Panama (aftosa-free) and Colombia (aftosa-prevalent) provides an incentive for smuggling. A highway connecting the two countries may facilitate smuggling activity. The government of Panama has stated that it would close the highway to traffic if an aftosa outbreak occurred near the Panama-Colombia border. It is still questionable whether all of the control measures envisioned will serve as an effective replacement to the natural land barrier which the Darien Gap area presently provides. Some experts, for example, feel that with the completion of the highway, Panama can expect aftosa outbreaks every six to ten years, the frequency with which such outbreaks have occurred in the normally aftosa-free areas of Europe.

B. Human Diseases

In work done over the past 20 years in the Darien Gap area, many tropical human diseases and disease vectors have been identified. Once the Darien Gap Highway is built, the economic development of the area will have to be carried out in conjunction with a wide range of disease control programs. Without such coordinated development, diseases prevalent in the area will exact a heavy toll upon settlers. A recent example of this occurred in a similar tropical region in Bolivia where a colonization program ended in complete failure because of epidemics.

The Darien Gap Highway itself will have both positive and negative impacts on human health. On the positive side, the improved access provided by the road will aid in the introduction of both preventative and curative medicine. It may also aid in the research of unknown or little-known tropical diseases.

On the negative side, the improved access may contribute to a more rapid and widespread distribution of infectious diseases which at the present time are localized medical problems.

C. Aquatic Ecology

The proposed alignment of the Darien Gap Highway crosses more than 20 rivers as well as numerous streams. All of these water bodies have high flows during the rainy season. Efforts to keep channel changes or other stream modifications to a minimum,and to limit construction in the vicinity of the streams to the dry season in order to control erosion and subsequent sedimentation,are expected to reduce potentially adverse impacts to the aquatic ecology. Subsequent development in the area, however, may have a profound impact upon the aquatic ecology.

In many highway construction projects, impacts on aquatic ecology are among the most critical and controversial. This is very often the case in proposed construction projects through wetlands. The recent study of part of the Interstate System in the United States provides the classic illustration of the importance of the issue. The project in question dealt with a proposed connection of I-195 and I-295 in Southern New Jersey near the Delaware River. The original alignment for this project was developed in the late 1950s and included the location of both the I-195 and I-295 links, as well as the interchange connecting them, on an embankment within a marsh area known as the Crosswicks Creek Wetlands.

When the environmental impact study for this project was carried out in 1975-77, the major focus was on the impact to these wetlands. The impact analysis consisted of two distinct phases:

1. A detailed inventory to assess the ecological value of the wetlands area as a whole and of specific subareas within the wetlands; and

2. An assessment of the impacts of the proposed project upon the ecological value of the wetlands.

The Crosswicks Creek Wetlands is a freshwater tidal marsh with important ecological functions both within its own boundaries and with neighboring systems. The marsh structure consists of numerous biological components. The determination of the condition of each of these components was used as the primary indicator of the value and health of the whole marsh. Key components included vascular plant vegetation, algae, invertebrates, fish, birds, and water chemistry. While each component was studied separately, all were assessed as interdependent entities. The marsh, therefore, was analyzed as an interacting *system of organisms* rather than a set of independent components.

The marsh ecosystems were also analyzed in terms of their influence on bordering ecosystems. For example, in the case of the Crosswicks Creek Wetlands, the interactions of anadromous fish cycles and the removal of nutrients are illustrative of the ways in which the marsh is of value beyond its own internal system.

The conclusions of the inventory were that the Crosswicks Creek Wetlands, as the largest single tract of tidal marshlands in the middle portions of the Delaware River, constitutes one of the most significant natural sites on the upper Delaware Estuary. The wetlands functions as an important source of food organisms for both its own foodweb and for those of the estuary and beyond. It serves as a breeding and nursery area for resident and migratory fishes and a habitat for a variety of birds, including some rare or endangered species. It also performs a valuable function of nutrient exchange. During the spring and summer and early fall periods, both point sources and nonpoint sources of water pollution, such as stormwater discharge and agricultural runoff, contribute heavy loads of nitrogen and phosphorus to streams, often during their low flow period. As these enriched waters flow into the wetlands, they are assimilated by algae and higher plants and thus serve as part of the foodweb. Some of this plant material is carried into the estuary where it provides a winter food source for waterfowl, fishes, and invertebrates.

In order to assess the value of specific subareas within the wetlands, a grid analysis system was developed in which a 58-cell grid was superimposed over the wetlands. Each cell was further subdivided and an evaluation was made of the functional value of the wetlands for each cell. The criteria for the evaluation included such characteristics as the amount of tidal marsh, the type and condition of vegetation, and the extent of tidal circulation. Both field observation and vegetation maps were used in this determination. Each cell was then assigned a value ranging from one to ten, depending upon its relative contribution to the marshland ecology. This system of analysis provided a rapid means of assessing the impacts not only of the originally proposed alignment but also of alternative alignments upon the ability of the Crosswicks Creek Wetlands to continue to function as a productive tidal marsh.

The impacts of the proposed project upon the wetlands were divided into two groups:

1. Primary impacts, which included the effects associated with dredging, filling, clearing, operating heavy equipment, and other construction activities; and

2. Secondary impacts, which included the effects from the presence or operation of highways such as siltation, flow modification, pollution by runoff, and disturbance due to noise and movement.

The results of the analysis showed that the originally proposed alignment would have a severe adverse impact upon the wetlands in that it would reduce its functional value by approximately 11%.

Additionally, the proposed alignment would cause other serious aquatic ecological impacts, including the following:

1. An adverse impact on one of the tributary creeks through the diversion of storm water discharge from a proposed 60-inch drainpipe. During storms, the sheer volume of water would scour the stream channel, flushing out resident organisms and radically modifying their habitat. With return of lower discharge, entrained sediment would be deposited downstream.
2. An adverse impact on a rare fish species through the dredging of the Delaware River for construction of the proposed embankment. Additionally, the proposed embankment for the roadway would raise the possibility of the leaching of heavy metals from the dredge material.

The severe impact on aquatic ecology associated with the originally proposed alignment indicated that potential mitigating measures be explored. These measures included such features as:

1. a major change in alignment,

2. building portions of the interchange still in the wetlands on structure,
3. providing a closed drainage system to avoid any adverse impact to tributary creeks, and
4. limiting the area of access to the contractor during construction.

If all these mitigation measures were implemented, they would reduce the functional loss in the wetlands from the 11% cited above to less than 1%. These measures would entail approximately $20 million of additional expenditure or approximately 12% over the cost of the original proposed project. It should be noted that if the mitigation in this case involved only the change in alignment, the construction costs would be less than for the original alignment. While mitigation usually involves extra dollar costs, this is not always the case. With extensive mitigation, it is likely that the issue of the impact on the Crosswicks Creek Wetlands will not act as a barrier to what is a badly needed transportation improvement. This one case provides a good example of the kinds of costs that may be required in order to bring transportation planning more harmoniously into balance with the biological environment.

D. <u>Terrestrial Ecology</u>

The Construction of the Darien Gap Highway would require the deforestation of approximately 4,000 acres in Panama and Columbia. This represents less than 0.03% of the land area in southern

Panama and northern Colombia. Since these areas are largely forested, a similarly low percentage of forest habitat would be removed by construction of the highway. There are several endangered species reported in the eastern Panama/western Colombia area. Since construction of the highway involves such a small percentage of the forested area, it, in and of itself, would have little impact on these and other species.

Of much greater concern, however, is the potential deforestation due to secondary development which will likely occur once the highway is built. Extensive cultivation, animal husbandry, and lumbering in this area could have significant adverse impacts on rare and endangered species as well as on other terrestrial wildlife. The Republic of Panama is considering establishing a National Park along the entire Panama/Colombia border in order to preserve a large segment of national forest. While it is theoretically possible to minimize this type of impact through well conceived and judiciously implemented land use planning, it remains to be seen whether this, in fact, will be the case.

The importance of avoiding adverse impacts to rare and endangered species should not be underestimated. In the United States, for example, there have been major modifications to highway projects in order to eliminate or mitigate such impacts. These modifications include such measures as basic changes in alignment, restrictions on construction methods, and restrictions on the seasons during which the construction can take place.

III. THE SOCIAL ENVIRONMENT

A. Community and Tribal Structure

The principal areas of concern regarding the proposed Darien Gap Highway are its potentially adverse primary impact and, more importantly, its secondary impact upon two indigenous Indian populations, the Choco Indians and the Cuna Indians. These two Indian populations constitute approximately 25% of the total population in the Darien Gap area (Choco Indians, 22% and Cuna Indians, 2%). The remaining population is composed of Libres of African descent (71%) and colonists of Spanish descent (5%).

The Chocos are transient and live in small communities along the rivers of the Darien Gap area. The Cunas inhabit both the mainland and the San Blas Islands and live in permanent settlements. Both Indian groups are agrarian in nature. They practice slash-burn type of agriculture which causes minimum disturbance to their tropical environment. Both groups supplement their diet by hunting and fishing and are dependent upon their immediate environment for construction materials, clothing, and other necessities of life. This lifestyle requires a substantial amount of forest area for subsistence.

The main concern vis-à-vis the Darien Gap Highway is that it will open up the area to modern mechanized agriculture, large-scale animal husbandry, and extensive commercial logging. These activities, along with the growth of towns to support these industries, would necessitate a substantial deforestation of the region.

The economic development of the region would cause social and cultural disruption to these two Indian community groups. It may very well bring about their cultural extinction. Unless definite land use plans are formulated and implemented prior to the completion of the road, it would seem unlikely that the existing, traditional cultures of these two Indian groups will survive intact.

Studies of Indian groups in other parts of Latin America indicate that rapid transformations from a traditional society to a technological society have resulted in sociological disruptions and deterioration in quality of life for indigenous cultures. While incorporation of the Choco and Cuna Indian groups into the mainstream monetary economy will undoubtedly bring with it certain advancements in educational opportunities and health services, these benefits may not outweigh physical and psychological hardships which will result from removing the economic foundation of these traditional societies. The disappearance of traditional societies may, unfortunately, be an inevitable price of opening up new areas to modern economic development.

B. Cultural Resources

The concern for the impact of road projects on archaeological and historic resources has intensified significantly during the 1970's. While the preliminary surveys for the Darien Gap Highway have revealed no archaeological or historic sites of significance, the presence of known or suspected archaeological or historic resources can have a profound impact upon the location and ultimate fate of transportation projects. Again, the I-195/I-295 project cited earlier provides a classic example of the potential significance of cultural resources upon a project.

The original alignment for this project traversed an archaeological area of both national and international repute known as the Abbott Farm Site. In order to determine the impact of the project upon this archaeological site, a detailed survey of the site was first undertaken to verify its archaeological value. This involved a field reconnaissance study which included the digging of numerous test pits by trained archaeologists. The survey yielded artifacts from civilizations dating as far back as 10,000 B.C. Many of these artifacts were found in an "undisturbed" setting, rendering them extremely valuable for archaeological interpretations of early civilizations.

Subsequently, an assessment of the impact of the proposed highway upon these identified resources was carried out. This assessment concluded that the proposed project would have severe adverse impacts upon the site by taking approximately 20% of the area for the right-of-way and, possibly, an even higher percentage of the most valuable resources in the whole site. The severe impact on cultural resources of the originally proposed alignment indicated that potential mitigating measures be explored. These measures included such features as:

1. the development of an alternative alignment which would require only 15% of the Abbott Farm Site.

2. the provision of substantial funds to undertake further detailed archaeological investigations to determine the exact nature and value of resources within the right-of-way prior to any construction.

3. depending upon the results of the above further detailed investigations, the provision to build portions of the roadway on structure rather than embankment in order to preserve, to the maximum extent possible, the cultural resources of the site. If all of the sections of roadway in question were built on structure, it would leave 36 additional acres undisturbed and 41 additional acres cleared during the construction phase but not built upon. The incremental cost for preserving this acreage would be approximately $27 million.

4. severe restrictions on construction methods in order to limit disturbance of the Abbott Farm Site to the immediate right-of-way.

This case illustrates dramatically the cost magnitudes that can potentially be involved in the preservation of archaeological and historic resources.

IV. SYNTHESIZING ENVIRONMENTAL IMPACTS

It is common in environmental impact studies to present a summary of impacts, both beneficial and adverse, which have been identified as a result of the technical studies and investigations of the project. The use of matrices is often employed to direct attention graphically to the type and magnitude of impacts for each of the various alternatives under consideration. While this kind of graphic display can in no way be treated as a substitute for the detailed written analysis upon which it is based, it does serve a useful purpose in highlighting the significant areas of impact for all of the alternatives in one compact format.

The most straightforward impact summary matrix usually consists of a 5- or 7-point scale ranging from "highly adverse" to "highly beneficial." In this type of matrix, each environmental parameter (e.g. air quality, aquatic ecology, etc.) is assessed on its own merits and not in relation to other parameters. Therefore, no direct comparisons or trade-offs can be made, for example, between a severely adverse impact to aquatic ecosystems under one alternative vs. a severely adverse impact to archaeological resources under another alternative.

In an effort to overcome this limitation, efforts have been made to develop impact summary matrices on a uniform numerical scale in order to relate quantitatively the impacts among the various environmental parameters in the matrix. In this type of matrix, each parameter is given a relative numerical "importance weighting." For each parameter, this weighting is then multiplied by an "environmental quality index" which numerically ranks the environmental quality of the given parameter for each alternative. The principal difficulty with this numerical approach is arriving at mutually agreeable values for the "importance weightings" of each parameter.

In the area of assessing the trade-offs among the full range of environmental consequences of a proposed project, one technique which has been used successfully in transportation projects is computer mapping to assist in alignment selection. The technique is basically the same as that of the uniform numerical matrix described above, with the addition of a computer to "map" the numerical results. This technique, which permits a synthesis over a wide range of environmental parameters, consists of four basic steps:

1. creation of a geographical base file,
2. preparation of topical data,
3. creation of computerized data banks, and
4. compositing according to different weighting schemes.

The geographic base files are selected so that the computer map is able to distinguish the smallest geographic unit for which environmental data are collected. Topical data are collected for four basic elements: economic, social, environmental, and transportation. Data for these elements are collected in accordance with the units established in the geographic base file. The parameters within these elements are then coded according to an "environmental quality index." For example, in the environmental element, the parameter aquatic ecology might be described by the following code and overprint symbols. The overprint symbols are for computer mapping purposes.

Aquatic Ecology

Description	Code	Overprint Symbol
Low Density, Low Diversity	1	.
Low Density, Medium Diversity	2	+
Medium Density, Low Diversity	3	X
Medium Density, Medium Diversity	4	θ
High Density, Medium Diversity	5	[illegible]
High Density, High Diversity	6	[illegible]

An "importance weighting" is then assigned to each parameter according to a set of value judgments. Different sets of value judgments are usually introduced in order to reflect different environmental preferences and to test the sensitivity of the output to changes in "importance weightings." Under each of the different value sets, computer composite maps are then printed out. Environmentally sensitive areas are shaded darkly and environmentally acceptable areas are shaded lightly. Additionally, highly sensitive environmental areas (such as an area serving as habitat to a rare or endangered species) are typically "red flagged" on a separate or overlay map. Using this technique, it is often possible to identify basic corridor alternatives which minimize the degree to adverse impact to the environment. In a complex transportation project, with many environmentally sensitive issues, this is a useful environmental planning technique.

SUMMARY AND CONCLUSION

Transportation projects can have profound impacts on shaping a country's economic growth, social patterns, and environmental quality. These impacts are well illustrated by road projects. Case studies of potential increases in agricultural and livestock production resulting from improved transportation include the proposed Darien Gap Highway and recent work on rural feeder roads in Haiti. Transportation projects can have major impacts upon the biological environment. Particular areas of concern include disease control, aquatic and terrestrial ecology, and endangered species. Control of aftosa (foot and mouth disease) is one of the key issues of the proposed Darien Gap Highway. Impacts of highways upon wetlands and aquatic ecological systems are of special concern. Transportation projects can also impact profoundly community tribal structure and cultural resources. The Darien Gap Highway project provides a case study of potential impacts upon indigeneous tribal groups. Recent studies in the United States illustrate the magnitude of potential impact of road projects upon archaeological resources. Where adverse impacts have been identified, it is usually possible to reduce or eliminate them through mitigating measures. These measures often add significantly to the cost of the project. Methods to evaluate overall environmental impacts have been developed. These include the use of matrices, weighting techniques, and computer mapping techniques.

Environmental impact analysis has become a major part of transportation planning in the United States during the 1970s. Environmental issues are now becoming more important in the planning of transportation projects in developing countries. This importance will intensify in the 1980s and beyond.

ENVIRONMENTAL IMPACTS OF FOUR AFRICAN IMPOUNDMENTS

by

Letitia E. Obeng[1]

Introduction

Dam construction is not new. Throughout human history, it has been used to provide for a number of needs including the control of floods and storage of water to assure reliable supply. Since then, the enormous importance of dams for energy production (now an absolute necessity), fisheries, navigation, recreation, and general development to satisfy current basic social and economic needs has become quite apparent. Harnessing power from water is an old practice. Slow water wheels have provided direct power for factories. Fast rotating turbines provide large quantities of electric power for distant factories.

During the years following the last world war, many large dams have been constructed all over the world for multipurpose use. Some of them, apart from being engineering feats, are objects of sheer beauty. It is with these large dams that undesirable environmental effects have become associated.

For Africa, the period between 1958 and 1968 may rightly be designated the "Decade of Large Dams." Within the period, four major dams were constructed to create enormous manmade lakes: Lake Kariba on the River Zambezi in Zambia/ Rhodesia; Volta Lake on the Volta River in Ghana; Lake Kainji on the River Niger in Nigeria; and Lake Nasser on the River Nile in Egypt.

These four large dams were constructed after length periods of deliberations, investigations and studies; they were planned for multipurpose use to make definite contributions to national development. It is reasonable to claim that these dams have fulfilled the intended objectives but not without setting in train a number of problems.

[1] United Nations Environment Programme, Nairobi, Kenya

By the very nature of dams, large tracts of land have been lost in the process of their construction. At its highest elevation, each dam creates a surface of over a thousand square kilometers. Together, they have inundated and covered a total land area of over 20,000 km^2. The Volta Lake, currently the world's largest single manmade lake, occupies 3.6 percent of the entire country.

Inundation is not the only effect of these large dams. Perhaps, for the first time in Africa, the creation of these dams has brought into sharp focus the implications of water storage systems for both aquatic and related terrestrial ecosystems. In the past, it was the practice in studies and planning of such basin engineering projects to emphasize the economic and social consequences which, to some extent, were measurable. It seemed perfectly normal to ignore environmental consequences of the projects which were identifiable through complex interactions of ecological, biological, hydrologic, even aesthetic, and other impacts, but which could not be quantitatively assessed. Where hazards were obvious, as for example the destruction of a game park and wildlife, some protest would be registered by the public. These large dams have now produced such massive and far-reaching ecological, social and economic changes, especially in tropical and sub-tropical areas that their impacts cannot now be ignored. Because of the sheer magnitude, severity and complexity of the unexpected or undesired effects of dams, they tend to overshadow the benefits derived from such multipurpose projects but in order that the full benefit of dam projects may be realised it is necessary not to ignore these effects.

Case Studies of Four Large Reservoirs

Associated with the irreversible flooding of land, there is invariably loss of subterranean minerals, trees, vegetative cover, farms, homes, and towns. Other major effects are the displacement of populations and enormous social, economic and cultural upheavals. While the enlarged water volume may promote increased fish production, even that advantage also poses problems with respect to continued suitability of boats for safe transportation and the effectiveness of the fishing gear and technology used previously on the river.

As the lake becomes an additional hydrologic storage system, it has an influence on the regime of stream flow. Even the discharge of water from the lower levels of an artificial dam (instead of from the surface as would happen in a natural lake) has an effect on downstream water quality and ecology. Depending on the geologic character of the basin and lake bed, there may be seepage into the surrounding area. Changes in gross surface evaporation and the water balance of basins are known. The exposed area of large impoundments provides an interface for air-water interaction with a complex of dynamic situations involving winds, surface levels, and heat, water, and gas exchange. Wave action influenced by these interactions often affects profoundly the distribution of suspended and dissolved materials, temperature and fauna. There are some indications of reservoir influence on local thunderstorm and precipitation and on cloudiness.

Stored in large quantities, water causes strains and stresses in the earth's crust and there are situations where tremors and seismic activities have become aggravated because of dams.

Perhaps the most obvious effects are the alterations in the physical, limnological and biological systems of artifical impoundments. As a rule, river flow carries eroded silt, soil and other debris out to sea. A dam creates a barrier and encourages the accumulation of such material as sediment on lake beds. In general, in young lakes, there is a long period when suspended material reduces the transparency of the water enormously.

Excesses of nutrients brought in by inflowing tributaries or precipitation encourage algal and aquatic weed growth. Under suitable conditions, a variety of invertebrate populations become established. In endemic areas, inadequate water supply and unsafe human waste and refuse disposal systems may aggravate water-related diseases. Dams, large and small, when inefficiently managed, contribute greatly to the spread of schistosomiasis and other vector-borne diseases. Shore and basin vegetation in areas of high humidity may provide the appropriate ecological setting for tse-tse fly habitats.

Another rather serious impact is the displacement of wildlife. Invariably, their habitats are destroyed. Upstream of dams, fish spawning and breeding grounds may be drowned. Downstream, the reduction of water flow may change the ecology with detrimental effects on fauna. The geographic location of dams together with a number of conditions determine the range of the adverse effects which they cause. The African dams share some of these problems in common but the issues differ in detail, extent and severity.

Lake Kariba was formed by damming the Zambezi at the Kariba Gorge in December 1958. The first of the large African lakes to be built, it was primarily intended to provide hydroelectric power for Zambia and Rhodesia although a dam project had been considered as far back as 1912 as a basis for irrigation.

Kariba inundated an area of 5,544 km^2, 280 km long, 40 km wide, up to 120 m deep, with a volume of 160 km^3. Resettlement was an early problem. A total of 50,000 people were moved and resettled on new land. Relocation goes beyond the provision of land and amenities. Displacement disrupts deep-seated and stable cultural systems, sometimes irreparably. There are records of curtailment of some traditional customs among relocates on Kariba which could have precipitated severe cultural crises. An unsatisfactory settler/host relationship led to a long, drawn-out conflict over land tenure below the Kariba. Settling down to farming also had its problems because of improper timing of planting and harvesting programmes against flood periods. The people faced severe food shortages on a strange new land and, ironically, inadequate water supply until a system for pumping water from the Zambezi was installed. It required 13 miles of pipe, storage, tanks and it cost an initial £42,000. Shortage of suitable water for re-settled people has been a widespread feature of Volta resettlement also.

During filling, the earth's crust, largely cretaceous sandstones and limestones, must have reacted to the strain of accumulated water. Seismographic measurements undertaken recorded persistent mild activity from when the lake level had risen 60 m. Previously there had been no tremors in the basin.

There were initial long periods of deoxygenation, and stratification was recorded at a very early stage in the formation of the lake. In comparison with preimpoundment data, there was an increase in dissolved salt content, especially of phosphates and nitrates, soon after the closure of the dam due to inflowing waters. Generally, a good level of nutrient salts would aid productivity. However, work done on plankton suggested that there was a decline in species number between 1959 and 1963 although the invertebrate benthos was rich in molluscs.

On the other hand, the explosive growth of *Salvinia auriculata* on the lake in 1959 was serious and spectacular and it received world-wide attention. It was a serious resource problem, a flagrant interference with the defined objective of the dam; a gross hindrance to the use for which the lake was intended; in short, it was a hazard for a resource of the environment. The plant took much of the nutrient out of circulation and for its own growth and, upon death, kept it locked up in the sediments of the lake.

As was to be expected, there has been some loss of alluvial nutrients to downstream as sediments have been deposited by inflowing water while upstream, fish feeding grounds and wildlife habitats have been destroyed. Rescued wildlife were, however, rehabilitated.

A major health problem has been schistosomiasis. The records show that the vector snails increased in density after 1964 and by 1967 the snails, *Bulinus globosus* and *Biomphalaria pfeifferi* were abundant and human infection was heavy. Even where the resettled people were already exposed to a disease, new conditions made matters worse. For example, incidence of trypanosomiasis went up on the South Bank of the Kariba. There have been instances where resettled people have succumbed severely to new diseases for which they had no previous experience.

However, the Kariba Dam is producing hydroelectric power as planned and the stocked lake yields large quantities of fish. There is a fisheries institute to assure satisfactory management of this benefit of the dam.

Lake Kainji was intended for hydroelectric power production, navigation, flood control and fisheries. The dam was originally considered in 1951, started in 1964 and it was completed in 1968. The lake extends 137 km upstream, with a maximum width of 24 km and it flooded an area 1,280 km^2.

Resettlement involved a total of about 44,000 people who were mainly farmers and cattle traders by occupation. The distribution of people in the basin was uneven and especially sparse in the *Simulium* infested areas. The displaced people were resettled in 139 new villages and provided with public facilities at the cost of ₦10,700. The lake, however, destroyed the range land for about 2,750,000 cattle and pasture improvement programmes were later undertaken. Farming was improved through irrigation with lake water. Although adjusting to resettlement was not easy, there have been many benefits.

The lake area had savannah vegetation with scant trees and shrubs. The soil ranged from a sandy to a loamy texture. The water supply to the Niger is interesting. The Niger goes through two floods annually, the "white flood" with a heavy discharge of about 8,000 m^3/sec originates from local tributaries and it is rich in silt and salts including sodium and potassium. The "black flood" from the headwaters of the Niger has a smaller discharge and less silt, but higher oxygen content.

The lake basin was made up primarily of Nupe sandstone. There has not been any indication of earth tremors. Some amount of investigation was undertaken prior to the formation of the lake and there is valuable 3-year preimpoundment information available.

The approach to the Kainji impoundment was different from the others in one respect. In order to forestall possible deoxygenation of the water during the filling period, the area to be inundated had been cleared at much cost. This has not been seen as having produced any special advantage, so that strip clearing would have been equally effective.

Following inundation of the area, there was an initial blue-green algal bloom consisting mainly of Microcystis and Anabaena but plankton was generally scanty. The water was highly turbid over frequent periods and the lake was oligotrophic in character.

A number of species of aquatic weeds invaded the area and became quite widespread, Pistia stratiotes and Salvinia nymphellula among them. These with marginal plants including Polygonum have also contributed to the establishment and spread of snails and other disease vectors.

Fish catches on Kainji have risen to expectations. Quantities have increased from approximately 3,000 metric tons of river fish to an estimated 10,000 tons per year. There is evidence that some fish species were lost and others reduced in number during the early lake formation period. It is estimated that downstream fisheries were reduced by about 50 percent because of the dam.

Kainji has not escaped the schistosomiasis menace. Although the transmission in the resettled villages did not increase, infection especially of children on experimental farms (even before the introduction of irrigation) was as high as 57 percent, while the lake-shore itself was relatively free from snails. After inundation, schistosomiasis became prevalent especially in the weed covered shore areas where Bulinus globosus was abundant. In 1972, 31 percent out of 1,656 persons examined in four shore villages were infected but there had been no epidemic and only limited areas were affected. The high level silt and the fluctuating water levels have kept a substantial area free of the snails and the disease.

Simulium damnosum previously had numerous breeding sites and onchocerciasis was a major health problem in the basin with 5.7 percent of 66,000 sampled in 1956 blind. The vector has been controlled with DDT. Above the dam, the breeding sites of the fly have been submerged.

Trypanosomiasis has not become evident even though Glossina palpalis and G. tachinoides had both existed in the basin and a very small percent of people were infected.

Malaria continues to be hyperendemic. Anopheles funestus breeds in the quiet and slow rivers and swamps, and A. gambiae in the man-made pools, pits and other foci.

On the whole, the Kainji project appears to have been better handled than most through preconstruction studies and the incorporation (to some extent) of the experiences gained in the investigations undertaken during the planning and preconstruction period.

Lake Nasser has a background basically different from the other three dams. The Aswan High Dam enlarged a previous lake on the Nile. The impoundment is surrounded largely by desert conditions, the Sahara to the west and the Eastern Desert which extends to the Red Sea. The high dam holds both Lake Nasser in Egypt and the Lake Nubia in the Sudan. The construction of the dam started in 1960 and was completed in 1970. The entire impoundment has an area of about 5,300 km^2, a mean width of 18 km, and it is very deep with a maximum depth of about 130 m. Like the other lakes, it is elongated, having a length of about 290 km. At its maximum height, it holds over 150 km^3 of water.

Although the area immediately around Lake Nasser was uninhabited, over 100,000 Nubians had to be resettled earlier. The human problems around the lake also had a different flavour. Although resettlement as such has not been a necessary feature in the Egypt dam project, there has been the problem of settling some 5,000 fishermen living in quite appalling conditions, in most cases in their boats, on Lake Nasser.

Perhaps the construction of the dams on the Nile has stimulated more international controversy and excited public opinion than any other large dam. There was the threat to ancient archeological monuments; then there was the alleged loss of rich silt to the farming land south of the dam; and then there was the severe increase of bilharzia infections as the abundant water made perennial irrigation a widespread practice. Bad farming and irrigation practices following the availability of abundant water has also affected the land in the area by causing later-logging and salinisation of previously viable land.

The dam was intended to contain floods, store water, produce electricity, and contribute to fisheries, but it is the adverse effects, most of them environmental, affecting the quality of the resource and adjacent ones, and also affecting the health of people that have brought the most criticism of the project. Lake Nasser, like the other dams, had early limnological disturbances of turbid water and algal blooms. The significant limnological feature was the rich amount of silicates during flood periods. Plankton samples were for a period dominated by colonial Volvox and reasonably represented. Fish population that has developed is not as rich as on the Volta although the genera represented are typical. There are substantial annual yields of Mormyridae, Cichlidae, Characidae, Clariidae and others. While escalation of schistosomiasis in the Nile basin has been the most serious environmental problem, there has also been an increase in malaria vectors. A *redeeming feature* however has been the protection of archeological treasures which should continue to encourage tourism. Lake Nasser has been severely criticised because of the interference of the silt flow downstream and the effect of water storage on delta and shore fisheries.

Comparative evaluation of benefits and disadvantages would most likely indicate an exaggeration of the adverse impact of the lake. What is certain is that there is an assured water supply which is an asset. The experience demonstrates that inadequate planning or subsequent inadequate management of any aspect of dam projects will produce environmental as well as economic setbacks.

Volta Lake, the largest of the four impoundments, provides an opportunity for examining most of the benefits, the disadvantages and the undesirable impacts that have been manifest also on the other lakes. The Volta project which was considered as far back as the early 1920's was well-studied and planned. However, perhaps due to pressing economic considerations, forestalling possible environmental impacts did not receive adequate attention during construction and, soon after the construction of the dam, problems began to show.

Resettlement of some 80,000 people affected was well-studied in advance of dam construction but delays and inadequate timing of some operations resulted in serious problems. Water supply for the settlements was inadequate. There was a shortage of food during the early stages. The villages that were built were, in some cases, most unattractive. Land allocation was delayed and farming had serious setbacks at the beginning but the situation has been greatly improved.

Like the others, the Volta Dam has fulfilled the intentions for which it was built. There is a large accumulation of water providing a high potential for extensive irrigation; electricity is being produced not only for Ghana, but also for neighbouring countries; there has been a boom in fisheries (up to 60,000 metric tons per year) and the lake is being used as a waterway and effectively providing for goods transportation between the north and the south of the country.

The lake, at an elevation of 85 m above sea level, stretches 402 km and provides contact laterally with the greater part of the country. It has a surface area of over 8,000 km^2 and a maximum width of about 30 km. It holds an estimated 165 km^3 of water with a depth ranging from 19 to 75 m.

During the initial limnological changes which were also influenced by the large quantity of submerged vegetation, there were serious alterations in the faunal composition. Oxygen depletion as well as some physical factors resulted in the loss of some species. Truly riverine fishes perished or migrated to more suitable ecological situations on the lake. But generally, in the periods following, there was a boom in productivity. Algal blooms, Microcystis and also Volvox were experienced though the zooplankton remained relatively less abundant.

The onset of aquatic weed explosion was a remarkable stage. Large fields of Pistie stratiotes developed especially in the shallower areas. Salvinia nymphellula, Azolla africana, Spirolella polyrhiza and Lemna spp, all small plants, formed extensive coatings which were quite a nuisance. On the shore, marginal plants including Vossia cuspidata, Polygonum spp and Althenanthera spp became a problem. The mayfly Povilla adusta became associated with the submerged trees and vegetation and provided food for some fish. Associated with the weedy areas, there were massive populations of a range of invertebrates among them vector snails Bulinus spp which greatly encouraged the spread of urinary schistosomiasis on the lake.

Schistosomiasis on Volta Lake has been a serious problem. Currently, WHO is undertaking a study for control. Upstream of the lake, however, the risen waters have drowned the breeding sites of Simulium damnosum which had been extensive in the rapids. Downstream, Simulium still breeds profusely. The proposed construction of an additional dam further downstream of the present one will perhaps remove these breeding sites.

Prevention of Adverse Impacts of Large Dams

Aquatic ecosystems have definitive characters and complex operational systems. Each component factor, physical, chemical or biological, has a close but complex functional relationship with others within the composite ecological systems. Mobile rivers differ markedly from stationary lakes. The construction of a dam across a river converts it into a lake, strange at first because it has unsettled conditions and not entirely lacustrine but equally also different from an uninhibited river. It has to be expected that there will be changes in structure, composition, character and functional activities in the water. There will be alterations which will affect physical, chemical and biological factors individually and jointly. The water body created by a dam, whether large or small, will be different from the river in major ways, and a single engineering work will bring into force an array of consequences which affect water and other resources of the environment, human beings and their supporting systems directly.

There is no question about the importance of dams. It is also clear that countries will continue to construct dams. The real question is, what precautions can be taken to prevent unsatisfactory environmental impacts? Bearing in mind that the consequences of dam construction are due to complex social, cultural, economic and ecological (including human) changes, it is necessary to approach the subject by considering it from all relevant angles and draw upon experiences and expertise available from appropriate disciplines. It means detailed studies of conditions and projections of possible changes well ahead of the start of the planning of the project. It is important that at this early stage close contact among people from different disciplines be established. Geologists, hydrologists, surveyors and others can contribute to the decision to be made by civil engineers by providing expert information to assist with the decision on the location or design of the dam in order to avoid earthquake tendencies, excessive seepage, disturbance in water tables and water balances, etc. Information on possible fauna and flora and limnological changes, shoreline ecological character and population distribution would probably assist in designing dams which are safe from the health viewpoint. This multidisciplinary cooperation should continue during construction and include monitoring of the changed environment once the dam has been completed.

From the experience of four African dams, some features of tropical dams which do not favor the environment have emerged. The most serious has been the enhancement of conditions for the establishment of water-related diseases, especially bilharzia, in endemic areas. While some studies and evaluation are needed, it would seem that uncontrolled human contact with lakeshores, inadequate sanitation and water supply are major contributory factors of the spread of diseases.

The Volta and Kainji experiences indicate that shallow waters in low-dying areas provide excellent conditions for the establishment and spread of vector snails and insects. Such areas also seem most favorable for aquatic weed growth with which many invertebrate groups tend to be associated.

At Lake Volta people were seriously affected by an increase of schistosomiasis. In contrast to the Volta, Kainji and Kariba impoundments, Lake Nasser, formed in the midst of a desert seems to have caused less environmental problems in the immediate surroundings. On the other hand, the downstream effects associated with it have been serious, ranging from a reported increase in schistosomiasis and malaria vectors in the perennial irrigated areas to a decrease of fish yields in the Eastern Mediterranean Sea due to a decrease of nutrients previously carried by the Nile River.

These factors and others provided from various disciplines must be incorporated into the design of safe dams. New lakes must be so created as to provide for wildlife and waterfowl habitats and reduce the potential for an increase of disease vectors. In other words, to make dams safe, it is vital that the engineering design does not stop at the erection of a dam, but should consider possible designs for conditions downstream and upstream of dams, even though at present it would seem that some effects are physically impossible to control. For example, how can one consider controlling the movement of the twenty thousand or more fishermen on Volta Lake? How can one even think of planning the control of movement of people over the extensive and dentritic shorelines (some 4,800 km on Volta)? It seems impossible, or at least extremely difficult, and excuses will be made. Nevertheless, as a minimum, both beneficial and detrimental impacts must at least be evaluated prior to construction.

Unfortunately, the matter of controlling contact does not as a rule receive any attention either on small impoundments and on even small ponds. In endemic areas, small village ponds can be as effective transmission sites as large dams.

It would be easy to continue to build dams which product unsatisfactory environmental conditions. Even where impact statements are prepared, reasons are easy to find for not implementing recommendations. It is always easy to consider recommended measures either too expensive or too difficult to achieve. Often, we are not certain what the impacts will be and hesitate implementing measures which may or may not have the desired results.

Fortunately, such excuses are less and less valid as more effective tools become available to predict environmental impacts. For example, the case studies discussed in this paper provide valuable lessons which can help prevent similar undesirable impacts, now that we have been alerted, often painfully, of the effects a lack of foresight can have when we disturb the environment with our construction activities.

IRRIGATION AND PEOPLE

by

Michael Welbank[1]

1. INTRODUCTION

Major irrigation projects in the semi-arid zones of the world must be regarded as important rural development projects and not just as large scale engineering works. Nowhere is this more critical than in Sudan and two projects from that country are examined from the viewpoint of rural development namely the Rahad Irrigation Project and the Kenana Sugar Project.

There are three main parts to this paper. In the first part, brief descriptions are given of two irrigation projects in Sudan. In the second, a number of key social and environmental issues from these projects are examined and lastly a number of general conclusions are drawn from the examples.

2. IRRIGATION IN SUDAN

The projects examined lie in the band of savannah land running across Africa, south of the Sahara from the Ethiopian highlands in the east, to the Atlantic coast in the west. Within the Democratic Republic of Sudan, this savannah land is a vast flat clay plain with a rainfall lying within the range of 350mm to 450mm per annum. The land is fertile if watered, and each year, during the annual rains in July, August and September supports either wild grasses or rain fed farming. Growth lasts three or four months before the land returns to the condition of parched clay scrubland for a further nine months of the year and the cycle recommences.

Such land is of critical importance to Sudan for two reasons:-

i) it is one of the few major natural resources of the country that can be exploited in economic terms and, in the circumstances of Sudan, cannot be neglected;

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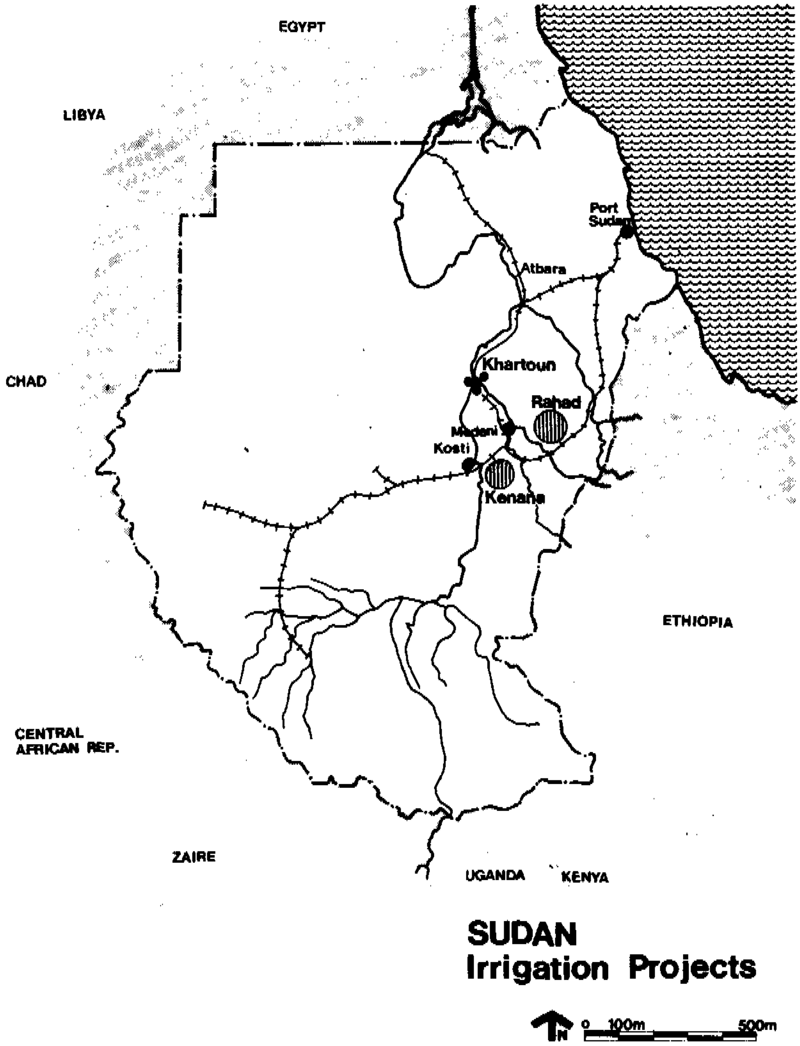
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Rahad
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FIGURE 3.1

and

ii) the traditional nomadic pastoral areas in Sudan are now, through over use, moving into critical decline with "desertification". To save these people from disaster new approaches to the exploitation of agricultural land are required and major irrigation projects are a key element in this.

These two reasons must always be viewed together and one must never be over emphasised at the expense of the other. The objectives of major irrigation and agricultural projects in Sudan are thus both economic and social and the potential for them is enormous. The facts are as follows:-

a) Sudan is the largest country in Africa containing 1 million square miles (625 million acres), that is 8% of the land area of Africa. It is 1,300 miles long and 1,100 miles wide;

b) the population of Sudan is 17 million people;

c) the known potential agricultural land for crop and pastoral farming within the country is 200 million acres (120 million arable and 80 million acres rangeland);

d) there is a probable further 100 million acres of land that could be exploited for agricultural purposes;

e) the present extent of agricultural land in use is 17 million acres; that is only some 8% of the known potential; of this total 13 million acres are rain fed and 4 million acres irrigated;

f) within its boundaries Sudan contains some 70% of the unexploited agricultural land of the Middle East.

This simplified picture helps to focus attention on the nature and the impact of major irrigation projects in Sudan. It also helps in understanding the country's enthusiastic acceptance, at the World Food Conference in 1974, of a role as "Bread Basket of the Arab World". However before considering two recent projects in more detail there are a few general aspects worth special mention.

Firstly, in opening up and irrigating new agricultural land the engineering works involved are huge; the initial investments enormous; the 'lifts' high, the canal lengths long and the areas vast. This scale of operation means that often the funding and the implementation skills are brought in from outside the country; in addition the problems of execution of the works sometimes dominate the thinking of those with overall responsibility for the project. Such factors can result in a set of 'top down' proposals for the community of the project area.

Secondly, on the day of first water, dramatic changes take place in the project area. Everything undergoes change, and most of it happens fairly quickly, - in the flora and fauna, in the use of the land, in the ecology generally and even in the micro-climate. Few events bring such speedy change to the natural scene and the assumption has always been made, with irrigation projects, that the impact will be benign. There is an almost moral quality attached to the act of bringing water to land which makes any critique of its effect appear the action of a blackguard.

Thirdly, on the day of first water dramatic changes are also set afoot in the society of the area. In Sudan this usually means the creation at speed of entirely new societies - the creation by inward migration within one season of communities of up to 60,000 people. This rate of migration may not be fast compared to the rates of growth of great metropolitan cities with unplanned expansion but in comparison with planned communities, it is lightning speed. At the peak of the British Post War new towns programme, the fastest rate of growth achieved by any town was 5,000 new arrivals in a year.

Fourthly, large irrigation projects are characterised by their finite quality. On completion of a project, every bit of land will have been utilised for farming except the land allocated for villages, warehouses, canals and roads etc. But the population of the area will grow; with economic prosperity they will develop new requirements and need new facilities; in short the pattern of development and growth will be like that of any other developing community. Yet the community within an irrigation area will not easily be able to find land for expansion and for new employment opportunities. Indeed, the numbers directly employed on agriculture may be expected to decrease in the future and this is where irrigation schemes can impose constraints on development. There is the possibility of conflict between the success of the irrigation project in agricultural economic terms and the free development of the communities within them.

3. THE RAHAD IRRIGATION PROJECT

The area of this project forms a band some 50kms wide and 120kms long on the east side of the River Rahad running south east away from the town of Wad Medani. Wad Medani is the sixth largest town in Sudan with a population of some 80,000 people and itself is some 200kms south east of Khartoum. The northern tip of the project area has a latitude of 14° 20' and longitude of 33° 70' with an altitude of 450 metres. The project will eventually bring into cultivation about 780,000 acres of sparsely populated semi-desert and the first phase, now under construction, consists of some 300,000 acres. The first phase is in turn divided into three approximately equal areas or 'groups' related to sectors of the canalisation system.

Water for the project is brought by supply canal from the Blue Nile to the Rahad River valley near Hawate. From a barrage further north the water is taken into an unlined main canal running roughly parallel to the Rahad River to be released to flow along a system of irrigation canals and channels draining back towards the Rahad River.

The project area consists of a clay plain with a cross fall of 6 metres at its widest point and a fall of 4 metres along its length. A series of granite outcrops or 'jebels' rising to some 400 metres above the level of the plain give some visual identity to the area. Apart from these the only physical constraints will be those created by the canalisation pattern. The area varies from 'semi desert grassland on clay' in the north to 'woodland savannah (low rainfall) on clay' in the south, and the whole area lies between the 350mm and the 450mm isohyet

The majority of the existing population are concentrated in the northern sector closest to the town of Wad Medani. The central and southern parts are not populated at all apart from settlements along the riverain strip of the Rahad valley and from nomads traversing the area. Although in statistical terms there was little requirement for overall inward migration to the project area, there was the need for a major redistribution of population within the area. The present inhabitants rely on dura cultivation and animal husbandry but the proposed cultivation is mainly for cotton and ground nuts with some land allocation for market gardens and for livestock. As will be realised from the small numbers of the existing population in the project area the inward migration will be enormous. The initial population of

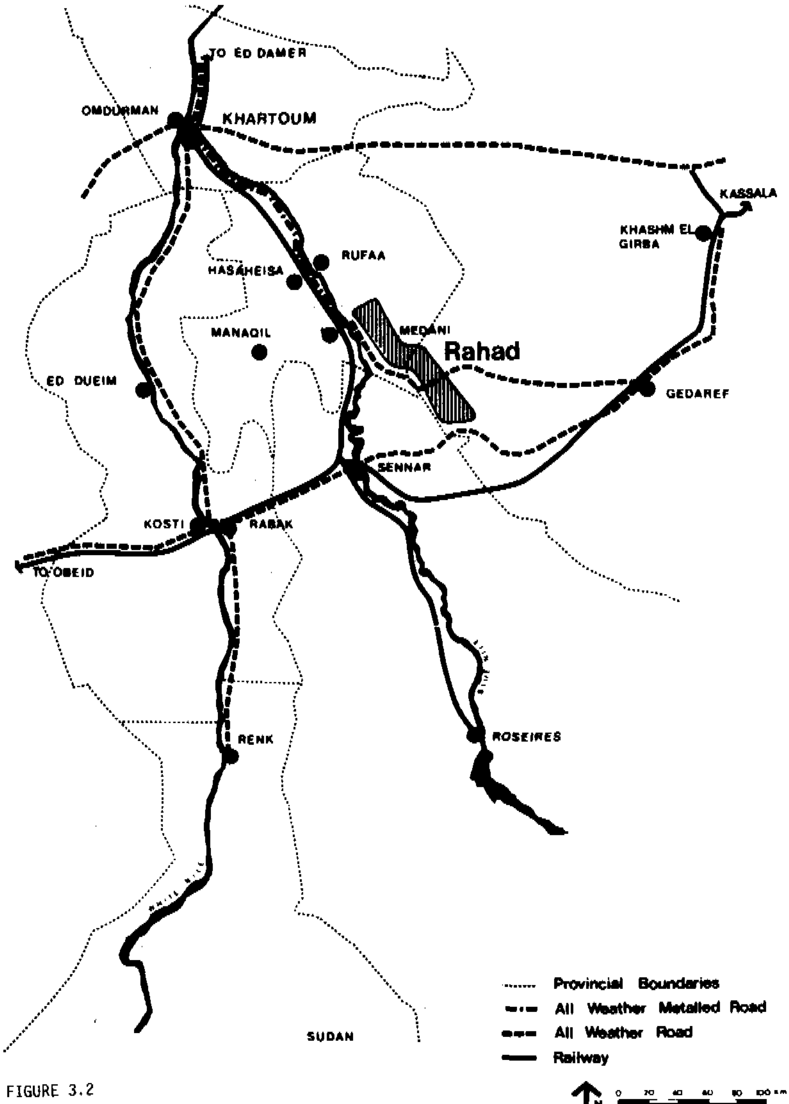

FIGURE 3.2
Rahad irrigation project

the first completed area of 100,000 acres with some 15,000 tenancies will be around 60,000 people growing to around 115,000 people after 30 years.

The responsibility for the development and management of the project is vested in a public body - the Rahad Corporation. The financing is by way of a loan to the Sudan Government jointly by the World Bank, the Arab Fund for Arab Economic Development, the Saudi Development Fund, the Arab Fund for Economic and Social Development and the United States Agency for International Development. The project consultants are Sir Murdoch MacDonald and Partners, Consulting Engineers of Cambridge, England.

The farming is carried out by the granting of farm tenancies, each of 24 acres for a normal holding or of 5 acres for a market garden holding, to suitable applicants and such tenancies are secure for life and for the descendants of the tenant so long as the land is farmed satisfactorily. The tenant farmer has to conform to the agricultural regime of the Rahad Corporation who also purchase and market the crops but his financial rewards do relate to his own efforts on his own tenancy. Additional to his allocation of fields, the tenant farmer receives a plot of ground in a village and a cash grant towards the construction of his house.

Primary processing of cotton and groundnuts is to be carried out in the project area by the Rahad Corporation who also run a seed farm, a research station, agricultural machinery depots and repair workshops.

4. THE KENANA SUGAR PROJECT

The project area lies on the east bank of the White Nile and forms a lozenge shaped zone some 30kms deep and some 30kms wide at its widest part with one tip of the area lying some 20kms to the south east of the town of Rabak. Rabak is situated on the east side of the river opposite to the main town of the area, Kosti; together they have a population of some 90,000 people. Kosti and Rabak both on the White Nile lie some 200km south west of Khartoum. The nearest point of the project area to the river has a latitude of 13° 37' and a longitude of 32° 32' with an altitude of 380 metres. The project will eventually bring into sugar cultivation about 120,000 acres of savannah land.

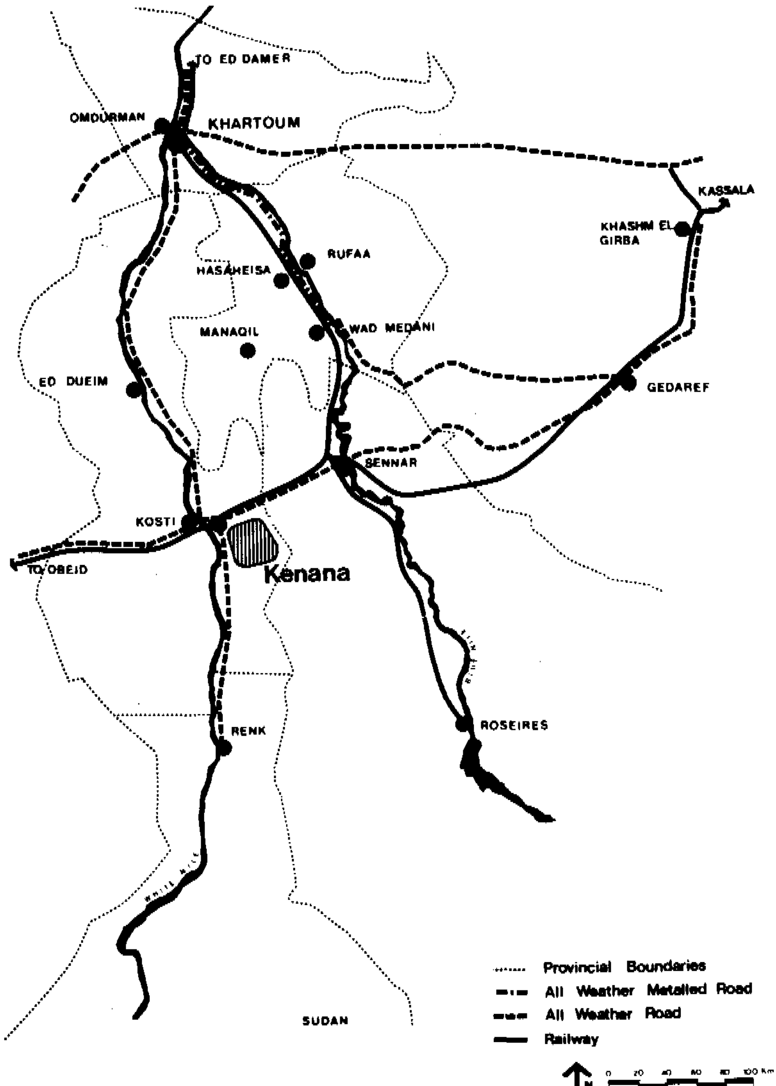

FIGURE 3.3
Kenena sugar project

Water from the project is brought some 28km by main canal from the White Nile by a series of pumping stations, and from this main canal running centrally through the project area water is discharged into lateral canals which in turn feed a system of canals and channels which distribute irrigation water to the fields draining back in the direction of the river.

The project area consists of a clay plain with a fall from the far boundary of the site back to the river of about 10 metres. The area lies on the 450mm isohyet and can be classified as "woodland savannah (low rainfall) on clay, with thornland alternating with grass areas".

The permanent population of the area on completion will be around 50,000 people which is a major increase over the existing population of the area, estimated to be some 5,000 people dependant on rain fed dura cultivation. The proposed cultivation is entirely for sugar. There will be a considerable inward migration of permanent workers for the plantation and also of seasonal labourers. In terms of employment, sugar cultivation produces a distinctive pattern which is as follows:-

i)	permanent staff and workers	3,500
ii)	seasonal workers employment <u>for periods of nine months</u>	8,000
iii)	migrant workers <u>for periods of six months</u>	12,000
iv)	total employment	23,000

This employment pattern creates a particular pattern for the development of the area namely:-

a) the tendency for there to be a social and economic division between permanent employees and the seasonable and migrant workers

b) the potential problems arising with a large area of land worked as a single estate supporting a large paid work force with no permanent homes in the area.

The development and management of the project is being undertaken by the Kenana Sugar Company. This Company has as its majority shareholder the Sudan Government and the other shareholders come from a wide range of governments and international investment funds including the Kuwait Government, the Arab Investment Company with export credit support from France, Japan, Austria and Britain. The consultants are Messrs. Howard Humphreys and Sons, Consulting Engineers of Reading, England.

The farming is carried out by the Kenana Sugar Company through its permanent staff and paid labour force. The sugar is processed in a single sugar factory which itself accounts for about half the investment in the whole project. The factory will be in operation for most of the year and forms a major concentration of activity for the whole estate in terms of mangement workers and transport. It is sited adjacent to the main township of the estate. This sugar estate will be the largest single estate in the world and will, on completion, be producing an output of 330,000 tons of sugar per year.

5. KEY ISSUES

The items noted here are those key matters which may be said to have been strongly affected by the planning, environmental and design studies which are summarized here. It would be quite incorrect to say that such studies were the sole influence acting on these items. Certainly villages would have come into existence in any event. Nevertheless, planning has created, without any significant extra costs, better settlements and thus hopefully a happier population which must benefit everyone and benefit agricultural production as well.

The same issues were significant on both projects in Sudan but for the sake of brevity, reference is only made here to one or other of the projects under heading.

5.1 Sub Regional Strategy

No regional or sub regional plans existed for the areas in which the projects were sited and so, starting from the proposed irrigation scheme, sub regional concepts were put forward to create firstly a planning context for the project and secondly a framework which related together all the existing projects and new proposals in the area.

The Kenana Sugar Project is within the hinterland of the urban centre of Kosti/Rabak where the existing population within a radius of some 80km of the centre is approximately 180,000 people. The sugar project will introduce into this hinterland a further 50,000 people concentrated into a comparatively small area and they will have a reasonable expectation of economic prosperity with the direct benefit of the provision of new infrastructure investment.

One issue was whether to view the project and indeed the other projects in the area as relatively self contained growth points or whether to attempt to channel some of the results of this growth to places outside the project area which would provide more direct and convenient benefits to the sub region as a whole. The latter policy was proposed to avoid the dangers of creating an ever-increasing gulf between the population of the agricultural projects and the diffused traditional life patterns of the area.

A very simple plan was devised to allow for the growth of the towns of Kosti/Rabak along a corridor towards the main new agricultural projects of the area. Whenever possible new developments and facilities would be sited in this corridor.and thus would be convenient and accessible to both the old towns and the new developments. The pattern of infrastructure within the project area was planned to help this proposed pattern.

5.2 Employment Opportunities

On completion an agricultural irrigation project will not go on creating employment opportunities. This poses a problem because the population in the area will grow but direct employment opportunities in agriculture will not, although some employment opportunities will be created by the expansion of services to the population and by the growth of the informal sector. Rural non-agricultural based employment can easily rise to 10% of the direct agricultural employment but this figure is not really high enough to cope with the increasing numbers of people reaching working age in these areas.

If these people stay in the project area then the numbers of people supported by one farmer and the per capita income will decline. It is unlikely that the growth of farmers would be adequate to reverse this decline. Alternatively there is an outward migration; the key problem then is to where? Such migrants make for the big cities in the universal belief that such cities are the universal providers of work. Even if this were true, the forceful outward migration of the second and later generations from rural areas is to the detriment of the rural community economically and socially. It reflects the urban bias inherent in so many development policies.

The implications are that those bodies developing agricultural and irrigation schemes must take on responsibilities for a wider ranging concept of development than a strictly agricultural one. This often raises problems with the funding agencies which probably had agreed to capital expenditure for works and equipment strictly related to economic returns on an agricultural development and not to intangible returns related to general community development.

At both Rahad and Kenana projections of the population were formed and the numbers of potential additional job seekers in the next thirty years assessed. Using crude job density per acre a total land allocation for future new agricultural employment was made in our plans that could absorb 75% of the future job seekers to the end of the century. This land allocation was distributed amongst all the settlements in the area although the major element - some 50% of this total - was concentrated in the biggest town within the project area.

To create the jobs to go onto such land however, is a new and separate task and is not one usually undertaken by agricultural development agencies. Employment creation is recognised as a specific task in urban redevelopment or improvement projects.

5.3 Community Development

Whether the agricultural developer be a public sector agency or a private sector company conflicts can easily arise between the economic objectives of the developer and the communities of the project area. Who rules?

The agricultural managers or the communities? The truth is, neither as they are inter-dependant and have to learn to respect each other's objectives and maybe modify their own on the basis of mutual understanding. How does this affect planning? Communities within the project areas have other needs besides work. Indeed successful work may well lead to economic prosperity and to a proliferation of aims and aspirations which a rural population never held previously. Unless these are accepted and some provision made for them then conflicts can arise.

Land must be available locally to accommodate the requirements of the communities now and for a reasonable period ahead. This means that a higher proportion of land in a project area will be devoted to non-agricultural uses. Thus to achieve any given total of utilised irrigated land the gross area of the project will show an increase, with some resultant increase in the cost of the irrigation and civil engineering works. This is a trend ~~which~~ I ~~consider~~ must be accepted and in the longer term will give considerable benefits for very modest initial costs.

In the Rahad Irrigation Project land has been allocated for the following purposes over and above the initial settlement necessary for the incoming farmers and permanent labourers:-

- non agricultural employment expansion
- housing for population through natural growth
- expansion of facilities generally
- gardens and horticultural plots
- tree groves for firewood and for building purposes
- livestock grazing areas and pens
- livestock routes.

It may be argued that all of these items are a waste of good irrigated land. Without them, however, community development would be stunted and agricultural production can quickly fall off in these circumstances.

In the Rahad Project provision has been made for some of the land scheduled for future settlement expansion to be used as irrigated land in the short term. If the forecasts are inaccurate - the history of planners' forecasts is not too good - the land will remain as farmed land.

5.4 Hierarchy of Settlements

An equitable distribution of social and physical infrastructure to the whole area is an important objective but often difficult to achieve in irrigation and agricultural developments. There are pressures on the one hand to disperse the population widely and evenly through the project area to obtain the closest possible relationship between the workers and fields and on the other hand to concentrate them into settlements to allow the provision of social and physical infrastructure.

In the Rahad project the problem became one of how to arrange for farmers to live within 5km of their fields but to form settlements which will support a primary school and a dispensary. The minimum support for a primary school in Sudan is a population of around 3,000 and with an average size of the incoming households of 5.5 people, this gives a mimimum settlement of around 300-600 households. Allowing for the mix of tenant farmers with standard holdings of 24 acres, tenant farmers with fruit and vegetable holdings of 5 acres, permanent labourers and others, than the land area farmed related to such a village is around 5,000 acres. With such dimensions it is possible to locate a farmer's village so that no farmer lives further than 5km from his fields.

A farmers village would provide initially, over and above the required housing:-

- one boys' school
- one dispensary
- souk (or market)
- town park
- tree nursery
- animal compound
- potable water system
- irrigation system.

At the Kenana Sugar Project where the arrangements for the field work are different, a farm village with the facilities listed above together with a number of associated satellite villages within 5km are planned. Thus farmers would be living within 1km of their work but up to 5km from any facilities, apart from their housing and potable water supply.

The second level of the hierarchy are settlements lying within 10km of all farmers' villages which would have secondary and primary schools, a health centre and a rural hospital and a large souk.

The third level is a regional town, within a day's trip reach of everyone within the project area, providing again a higher order of services and offering opportunities for the provision of specialised services, markets, agro-industries, recreational facilities etc. In the Rahad Irrigation Project this town contains the management headquarters of the whole project, is central geographically and is at a main junction of the internal road system. The initial population of this town will be some 15,000 people but has land capacity to expand to around 75,000 people. It will be a major urban centre providing services to a population of around 300,000 people in the project area.

5.5 Integration of Population

One particular problem that arose in the settlement planning on the Rahad Irrigation Project was that of integrating people from differing tribes and villages into single settlements. Traditionally in Sudan when people of different origins settle together, they establish separate settlements, although they may share certain facilities such as a well or grazing land. The result is often a grouping of small hamlets spread over several kilometres all rather confusingly under the same name. There was, however, a need to seek to modify this traditional pattern of settlements for the following reasons:-

i) to fit within the canalization and field layouts;

ii) to give that concentration of people necessary to form an adequate basis for the provision of minimum social infrastructure;

iii) to minimise costs of provision of physical infrastructure;

iv) to reduce social conflicts and hostilities.

Other projects and settlements in Sudan with populations of mixed origins were studied and the following principles were defined for the Rahad project settlements:-

i) all sectors of the population would be housed in any settlement - including permanent labourers, tenant farmers, non-agricultural based population and management staff;

ii) each group would have its own housing area but would share common facilities;

iii) each housing area should be able to develop in an individual and traditional manner at differential rates without disruption or friction to adjacent areas;

iv) routes from any housing area to outside the village and to any shared facilities should be through common ground and not through other housing areas;

v) potable water points to be provided either to each plot or in such numbers that different tribes or village groupings would each have their own outlet;

vi) animal grazing land at a village to be shared and to have its own watering points.

All settlement plans were developed on these principles. No existing village was destroyed; each was incorporated as one housing group within a new settlement plan.

5.6 Consultation and Participation

One aspect of the planning work worth mention from the Rahad Irrigation Project is the manner and the extent of consultation with tenant farmers in the detailed planning of their villages and their responsive participation. Even before that stage, extensive social surveys were undertaken both of the population already living in the project area and also those likely to move to it, in order to gain some understanding of the likely problems and conflicts.

The procedure adopted by the settlement officer of the developing agency has been to call all the prospective tenants of any new village together on the village site, to explain to them the principles embodied in the settlement plan and to show them the site. The villagers were then asked to divide themselves into groups of tenants who would be content to live in close proximity with each other.

When this was done and the size of each group established, a leader from each group was selected. These leaders then decided amongst themselves which sector within the village each group would occupy. As a result of this process the settlement officer would then register specific plots to specific tenants. In this way the farmers themselves actually decided the final layout of the village.

5.7 Environmental Standards

It is not usual to have environmental concepts established for agricultural and irrigation projects because it is assumed that the whole area will be turned into a green and pleasant land. However, within the project area there will be large tracts of urban and industrial land, roads, railways, and all the paraphernalia of a modern industrial society. The issue is to determine what standards should be adopted for such areas. Some of the standards cost nothing to achieve, some very little and, for those considered too expensive immediately, then provision must be made for them to be adopted at a later date. In this way a programme for environmental standards can be set down to be achieved as and when money is available and social pressures demand.

At Kenana there is a mammoth sugar factory to which the main town of the project needs to be closely related and the environmental problem at the present is basically one of pollution. Plans were devised that all wastes from the factory had their own drains segregated from the irrigation channels and running away from the settlements; this also included all escape drains. The smoke discharge from 'bagasse' burning proved an intractable problem. Although the factory is sited down wind from the settlement at all seasons of the year the worst circumstances arise when there is no wind at all and the ash deposit is spread evenly around. Here the environmental standard accepted was smoke cleaning but this was put down for later implementation.

Another environmental matter is the minimisation of health hazards and in particular bilharzia control measures. There is a general rule of thumb in Sudan to provide a 300m separation strip between any canal and any development. With canals spaced regularly at 1.2km centres this only leaves zones some 600m wide for settlement development between canals. This can be very limiting without canal realignment. The creation of the 300m band has become a fetish based on a belief that if it exists you are safe from bilharzia . The fact is that the purpose of the 300m band is to minimise the likelihood of casual contact with canal water and to ensure that a potable water supply will be closer to dwellings than canal water. But it is of no value without all the other elements of a bilharzia control programme. In both Kenana and Rahad an examination of the purpose of this band led to proposals to utilise it for controlled activities such as schools, playing fields and gardens. This achieves maximum use of land and improves the environment without any increase of health hazards.

A further example of the successful introduction of an environmental objective resulted in the provision of irrigation water supply within settlements for gardens and tree belts. This can be an expensive provision and at Kenana where the problem was a difficult one in irrigation terms because of levels, all sullage water from dwellings is discharged into the gardens to provide water for plants and trees. This has the added advantage of reducing the flow in the sewage disposal systems and the eventual amount of effluent for disposal which is a problem in clay soils.

6. SOCIAL OBJECTIVES AND PLANNING PRINCIPLES

At a national level, agricultural development and irrigation projects are usually seen as elements in plans for a country's economic growth. The purpose of economic growth is often stated to be social improvement, but human progress is not the automatic result of economic growth. To obtain the social benefits a society must allocate to human development an appropriate share of the wealth it produces, and moreover ensure that this wealth is produced in a human way.

6.1 Regional Development

Comprehensively planned regional development is an essential element in implementing such national policies. As such, it is also an instrument for a more equitable distribution of the means of production throughout the country and a tool for promoting human development. A national development strategy must establish urbanisation patterns that attract not only the rural migrants, but also new employment opportunities, avoid excessive concentrations, and help to bridge the gap between rural and urban living. Such development policies lead to the concept of a 'city-region' a system of settlements in which industrial complexes and zones of intensive agriculture and commerce and residential communities, as well as centres of culture, learning and leisure, blend with the environment. Such a policy has a basis in social justice and can be the beginnings of a reversal of the urban bias in attitudes and aspirations.

This general approach has been set down to emphasis that the turning of a clay desert into agricultural land is but the first step along the road to comprehensive development. It must be recognised as such.

6.2 Urban-Rural Conflicts

Urban-Rural conflicts must be minimised or eliminated. Rural areas are a major source of migration to the cities. Massive investments in agricultural projects producing food, increasing in the short term the numbers of local population and in the long term, their standards of living as well, being accompanied paradoxically at the same time by a vast migration into urban areas, where little or no investment can be found to provide employment, shelter or services. This problem will not go away by itself. Solutions are desperately needed and these are more likely to be found in the rural rather than the urban scene.

The social, cultural and economic forces acting on the average subsistence farmer of the world to produce a large family are so strong that no exhortation to change this traditional pattern will have much effect. A change in his standards of living will achieve this although the consequent changes in deep seated social and cultural attitude may take a generation or so to show through. This is the most powerful single reason to move from the concept of agricultural projects to that of rural development.

6.3 Social Objectives

The traditional approach to the handling of public investments, whether international, national or local is on the one hand to invest in 'productive' projects and on the other, 'remedial' projects. The first are judged by reference to clear economic criteria related to the return on the investment or some measurable impact on the economy. The second are a piecemeal set of investments made in the face of political and social pressures, or in desperation to tackle such phenomena as racial problems, juvenile deliquency, violence and crime, or the problems arising from some other disadvantaged sections of society.

The conflict arises that the investment in the first often provides the pressing need for the investment in the second, and may over a period of years, wipe out the benefits accruing from the 'productive' project. No 'productive' project therefore should go ahead without the social implications being closely examined.

In irrigation projects the main social objective must be to ensure that such projects allow,to the maximum possible extent, the free development of the communities within the area. To do this involves considering the short and long term position and a view of the future must be taken now to inform all current decisions. The funding base of such projects means that social objectives cannot dominate, but where alternatives are under examination, such factors can, and should, be brought into balance. Opportunities for the future should be safeguarded, not blocked under pressure from present expediency.

6.4 Hierarchy of Settlements

A wide range of elements are required now to provide services to a population now and in the future, such as schools, medical and welfare facilities, cultural and recreational facilities, commercial and business enterprises, etc. The level at which these are found at any one place characterises the quality of the whole development and the function of each settlement. It is partly related to the economic growth of the sub-region, partly to the politics for the provision of social infrastructure and partly to local initiative.

A number of planning principles can however be proposed for the distribution of facilities in an area whatever their precise extent and range:-

a) they should be distributed as equitably as possible in order that there are no disadvantaged groups.

b) the pattern of settlement should allow a minimum level of social infrastructure to be provided at every settlement.

c) this minimum level should be provided throughout the zone at the same time as the population begins to live there.

d) there will need to be, in addition, secondary centres, providing a higher level of facilities than the minimum level by way of health centres, secondary schools, cultural facilities, administrative centres, etc.

e) at the higher end of the scale regional centres should be envisaged of an order to challenge the facilities of major urban centres.

f) there should be easy accessibility to such regional centres, capable of being visited in a day from the hinterland they serve.

g) this hierarchy of centres should also be readily usable by population outside the actual irrigation areas because their support will:-

i) allow higher facilities to be sustained at each centre

and

ii) lead to the integration of these two sections of the population through the mutual use of shared facilities.

This leads to a concept of hierarchy of settlements for agricultural development, from the settlement with its minimum facilities, to an intermediate level, to a major town level and then, perhaps well outside the project areas, a metropolitan centre. Each level is inter-dependant, each supporting a higher order centre and in turn serving a lower order one. It is a basic means of meeting the aspirations of an expanding population and although the area will be basically an agricultural one, the focus must also be on the urban centres as part of a comprehensive regional plan.

6.5 Planning Principles

Besides the level of facilities offered by a settlement and its position in a hierarchy, its other characteristics are related to the principles governing its layout.

The problems are at their most acute in the smallest settlement - smallest in size, furthest down the hierarchy, easiest to neglect, the least powerful in social and economic terms and probably the least articulate community in the area. It is here that the conflict arises in its most acute form between population concentration to enable facilities to be provided to them.

To answer this problem involved integrated thinking between the agriculturalist, the engineer, the settlement planner and the administrator. Without such inter-professional work it will be impossible to achieve any satisfactory solution and it is an unfortunate fact that settlements can always manage to be popped into irrigation schemes at a late stage. If this last method is adopted then they are unlikely to achieve any objective other than just providing housing for farmers close to their fields.

The smallest farmer settlement must accord to the social and eoncomic needs of that community today, but it is likely to develop and grow; some indeed will emerge into more important settlements and some even into small towns. A key task in planning them is to allow such villages to develop on traditional lines but to provide, at the same time, the opportunities for major change and growth at a later date.

Settlements should thus be planned with the following long term objectives as well as meeting short term needs:-

a) growth to be accepted easily both to their centre and to their housing with the minimum of disruption and no destruction

b) services, such as pipe water, to be capable of expansion to all plots or dwellings

c) high levels of accessibility by cars, and vehicles should not be seen as having a high priority

d) the development and change from the traditional building to more permanent materials should be possible without destruction and reconstruction

e) the facilities of the settlements should be easily and equitably accessible to all parts of the settlement.

7. ENVIRONMENTAL STUDIES

Irrigation projects in semi-arid zones bring many irreversible changes to the life of the area. The needs of the new communities of such areas can be considered as a direct function of the development of the irrigation project, but in addition the impact of such schemes on the environment generally should be examined. This is not usually done although particular aspects may be picked up through political or social pressures such as the impact on nomadic tribes or on public health comprehensive environmental studies are necessary for all major irrigation projects.

Environmental impact studies can provide a clear coherent framework for knowing what is happening and what is likely to happen - a focus for all environmental issues. The forecasts may be accepted; modifications may be proposed or items highlighted for careful future monitoring. Subsequent action depends on the standards and aims of the society for whom it is produced but without such studies, knowledge is absent and action inhibited.

The need for such studies related to any major development projects in the western world is now unquestioned although there is still great debate over their exact nature in any particular instance. But many say that such studies are quite unimportant in the developing countries where major projects have quite enough problems in execution anyway, without further ones being added.

However, there is a much broader philosophical base for this approach which is questioning whether all major technological advances are of absolute benefit to humanity in the long run and whether we are acting responsibly towards the earth's resources. Man must take account of the effect of his actions on the balance of nature and he needs to use his skill not only for his own economic advancement but as a trustee for the whole of nature, its preservation and conservation.

For some the environment is the physical surroundings in which they live. For others it is the world in which we live - the whole gamut of human, animal and plant life and their inter-actions upon one another. The wider interpretation is the preferred one in which the whole human environment in the area affected by a project is considered. This includes mans' social and economic well being as well as his enjoyment of the physical and natural environment in which he lives and works.

It is believed that skills now normally deployed on the design of an irrigation project are adequate and competent to undertake useful environmental impact studies. What is not normally done at present is to give such studies a coherent form. The study need not and indeed must not be too complex. To that end they must be simple in form, concentrate only on significant impacts, accept the limitations of human knowledge, eschew hypothesising, be frank about value judgements and be cautious about speculation. The main purpose is to ensure that issues are raised clearly, are not forgotten and are brought up early enough in the scheme for them to be considered in a useful way.

There is a particular need for attractive buildings and personal settlements. It is particularly difficult to justify leaving structures and buildings on the face of the earth which are intrusive and ugly. This applies to all buildings whether they be in the middle of a city or in the middle of a desert. Ugliness is unnecessary.

Architects have been criticized by society in general over the last few decades for "losing their way". One source of inspiration to architects in this delemna has been the excellent, sturdy and simple constructional work of the nineteenth century engineers as found in the buildings related to railways, canals and docks. This tradition, admired by architects, appears abandoned by engineers.

There is abundant evidence that many engineers lose interest in the buildings which house and give shelter to the complex and expensive machines which they have designed with so much care and attention. Such buildings seem to be passed down the line in the engineers office with the instruction to "do something simple" accompanied by a sketch of three lines showing two walls and roof. The border between simplicity and banality is a narrow one and all too easy to cross. More often than not the results are appalling but is is these buildings that will be seen by the world for the next hundred years or so as part of the "visual environment" although the machines inside them will make far the greater impact on the environment.

There is a role for architects here and it does not follow that engineers should be fearful of their involvement on the basis that grandiose and expensive follies will result. Building construction is different from engineering construction and good architects do have the skills to produce effective and attractive buildings using the right materials for any particular project in a simple and appropriate way.

8. CONCLUSIONS

The feasibility study for an irrigation project is usually undertaken within given parameters of a technical nature related to soils, crops water and irrigation works. From the alternatives disclosed by such a study, a project can be defined and the orthodox path of design and implementation followed. Feasibility studies for such works usually have the following sections:-

- i) Resources - land, water, climate
- ii) Agriculture
- iii) Organisation and Management
- iv) Engineering
- v) Financial and Economic.

My concern is that the problems of people and community development are neglected at this critical stage. Irrigation works can fail if the water fails or if the engineering works collapse; disaster can strike if world markets for particular cash crops crash or if widespread disease hits crops. Schemes can also become failures if people are not motivated to work in them and to put their whole hearted effort into so doing. Such failures are not so dramatic as other types of failure but they are nonetheless real. The greatest success on this front will come from the creation of social contentment coupled with economic reward backed by technical competence.

Agriculture is not just a mechanistic or technical process; in any major irrigation project successful agriculture demands the participation and dedication of many thousands of people. The irrigation works are wasted if the people within the scheme do not work well together.

Their is however a particular characteristic of major irrigation schemes in the semi-arid lands in comparison to other agricultural improvement projects. In the event of irrigation water failure, the people of the scheme are not readily able to revert back to their former agricultural practices. These major developments are often opening up entirely new farmland many miles away from the traditional farmed areas and where rain retreat farming has not been practiced to any extent. In these circumstances their dependence on the authority a set up to safeguard the investment, develop the scheme and manage it on completion must not be allowed to obscure the basic concept of inter-dependance.

The point is that in relation to such an inter-dependant position the 'people' element is not adequately covered at the early stage of the feasibility studies nor are the costs ascribable to community development analyzed. Experience shows that such points have had to be brought up at later stages and a sort of reargued action fought to get them their proper place in the design and decision making process.

Large scale schemes with major investments linked to concepts of national prestige lead all too often to the authorities responsible being authoritarian in every way. This springs often from the limitation of a narrow sectoral approach. The primary concern is to see that the social and human issues get examined at feasibility stage to the same level of detail as all other aspects. Genuine inter-professional working to achieve this is essential and it should be established right at the very start and continued through all stages of the work. The inputs on such matters at the early stages are not very extensive but will be critical ones in establishing social objectives and planning principles for the project.

At feasibility stage to see people solely as a work force resource in the economic equation is a disastrous error. Human happiness is not the inevitable result of economic progress.To gain both must be the aim of all irrigation projects. The 'work force' approach can by definition miss out of consideration some 25% of the population because there is the ever growing rural non-agricultural population. How do they fit into the scheme of things? Are they going to be ignored and remain an under-privileged group in the midst of the affluence of an irrigation scheme? Are the services, land and facilities for such people required to be a charge on the project's funds or a burden on the project's funds or a burden on general funds for social infrastructure. It is at the feasibility stage that such potential problems should be defined and the general lines for their resolution agreed.

A general pattern of acceptable social change and desirable community development can be forecast at the feasibility stage and measures to minimise conflicts introducted at the design stage. Social change arising as a result of technological advance is neither inevitable and nor immutable whatever the consequences. The inter-action between technical advance and social development must be considered in parallel at all stages and this should start right at the very beginning of a project in its feasibility study.

ENVIRONMENTAL IMPACT OF WATER SUPPLY PROJECTS IN DEVELOPING COUNTRIES

(A Case Study of an International Civil Engineering Project and Its Environmental Impact)

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Introduction

A consideration of the effects that proposed water supply engineering projects have on the quality of the human environment in developing countries is relatively new. In the past, the traditional assumption has been that any unfavorable environmental impacts would be insignificant in comparison with the advantages derived from achieving a project's economic or health development objectives. This assumption is now under scrutiny.

In developing countries an evaluation of potential impacts on the environment began with projects financed by the U.S. Agency for International Development (USAID). These mirrored the environmental concerns shown in the United States in the late 1960's which resulted in the passage of the National Environmental Policy Act of 1969, requiring that an environmental impact statement (EIS) be prepared whenever a Federal agency proposed to take a major action having a significant effect on the quality of the human environment.

While the law does not define "significance" explicitly, it does set forth five requirements which must be addressed in an EIS: (a) the environmental impact of the proposed action; (b) any adverse environmental effects which cannot be avoided should the proposal be implemented; (c) alternatives to the proposed action; (d) the relationship between local short-term uses of man's

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environment, and maintenance and enhancement of long-term productivity; and (e) any irreversible and irretrievable commitments of resources which would be involved in the proposed action should it be implemented.

Contracts for recent overseas projects, including those not funded by USAID, frequently require a form of an environmental impact assessment of the project. However, the scope of such work usually states it is not the intent to prepare a comprehensive US-style EIS. For example, a recent Camp Dresser & McKee (CDM) contract with the Government of Egypt for the preparation of a master plan for water supply for Alexandria summarized the purpose of the environmental impact assessment:

> "To provide the clients and the lending agencies' decision makers with a comprehensive understanding of the reasonably foreseeable environmental effects of proposed actions and their reasonable alternatives so that the expected benefits of development objectives can be weighted against any adverse, short- or long-term impacts upon the human environment."

Impact Assessment in Developing Countries

Early EIS's, both in the United States and abroad, often were prepared with an overwhelming amount of extraneous baseline and background information. In contrast, the current tendency is to focus on "significant" issues and to present only relevant baseline and background data. One test of significance is the likelihood that an issue will have a material bearing on the decision-making process.

The principal merits of preparing an EIS in a developing country are (1) to identify all possible significant adverse or irretrievable impacts, (2) to suggest alternative solutions in order to minimize them, and (3) to suggest means of mitigating unavoidable adverse impacts. A potential bonus of preparing an EIS is the identification of beneficial impacts, both primary and secondary. Government officials often use the EIS to support efforts to obtain additional project funding in competition with other claims on scarce economic or financial resources. Development lending agencies are also keenly interested in the social and secondary benefits, as well as the economic and primary benefits, of projects they are being asked to finance.

One major difference between EIS's in the United States and abroad is the degree of public or citizen participation. This is a key element of EIS preparation in the United States but is usually not considered in developing countries. In addition, another difference is a frequent need to assess the relative merits of competing consumptive needs among municipal, irrigation, and industrial demands for very limited water resources in developing countries.

Consideration of a Recent Project in a Developing Country

To identify a satisfactory case history candidate for an overseas municipal water supply project in a developing country is difficult. Ideally, the candidate project should have included: (1) a comprehensive engineering report; (2) an environmental baseline study for the affected area; and (3) a retrospective assessment of the environmental impacts of the constructed or implemented project. Even in the United States there are few such examples of EIS's for major municipal water supply projects.

In 1976, CDM completed a project report in a developing country which satisfies most of these criteria, except for implementation. This was a study of water supply (and other municipal services) for the City of Surabaya, Indonesia.

Description of Surabaya

General

The City of Surabaya is located (see Figure 4.1) on an equatorial coastal plain, where the two principal rivers of East Java form large deltas lying north of a volcanic complex. Encompassing 290 Km^2 (112 square miles) within the City limits, Surabaya sprawls out along the northern distributary of the Brantas River. The City has a two-season tropical climate. Average rainfall is 1,320mm (52 inches) per year. However, the low permeabilities and high salinity of the delta deposits upon which the City is built limit the large-scale development of a groundwater supply.

Surabaya is the second largest city in Indonesia with a population in 1975 of over 2,000,000. Due to several decades of industrialization and a resulting increasing demand for labor, there has been a large shift of population in search of work from rural areas in Indonesia to Surabaya. The present net immigration is estimated at 40,000 people per year, which, when combined with a natural growth rate of 2.5 percent per year, results in a

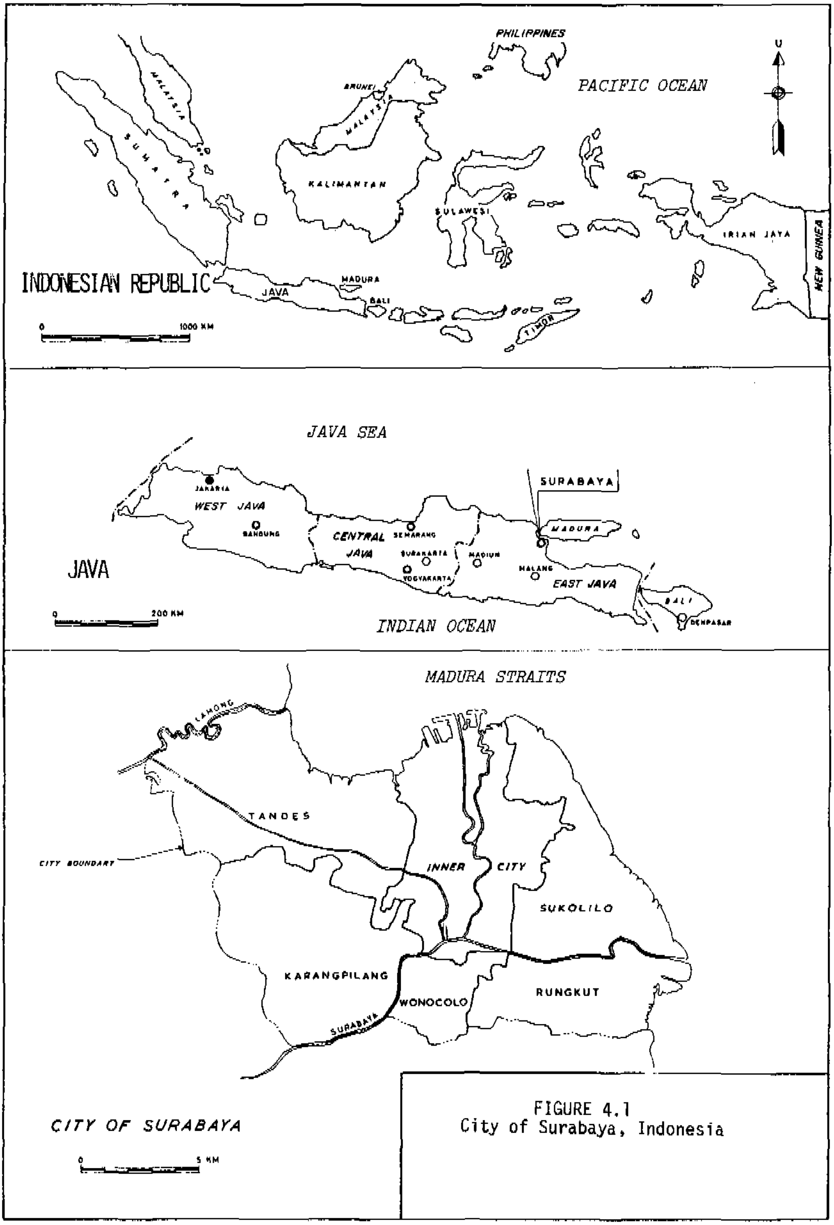


FIGURE 4.1
City of Surabaya, Indonesia

total growth rate of greater than 4 percent per year. Density in the City ranges from 255 and more persons per hectare (103 and more persons per acre) in the inner city to 15 persons per hectare (6 persons per acre) in the outer area. Average city density is 70 people per hectare (28 persons per acre). Figure 4.2 shows a typical street in an urban kampung.

Personal income distribution in Surabaya reflects conditions typical of developing nations. The average monthly family income is less than $60.

By the year 2000, the population of Surabaya is expected to grow to over 5,000,000. Based on the City's preliminary master land use plan, the future population growth of the municipality is expected to continue into the more rural districts, more or less concentrically. Core city population densities are expected to remain relatively unchanged. Industrial and commercial growth, predicted at an annual rate of 4 to 6 percent, should be primarily in textiles, beverages, machinery, and chemicals. Industrial growth is expected primarily in the outer districts of the City to the northwest.

Water Supply

Water is supplied to Surabaya by PAM[(1)], a semi-autonomous municipal agency. The PAM system has a present maximum capacity of

(1) An acronym in Indonesian for the English equivalent of Drinking Water Agency.

Typical street in an urban kampung in Surabaya

FIGURE 4.2

CARRIERS FILLING CANS AND CARTS FROM VENDOR'S STORAGE TANK
JALAN GRESIK

FIGURE 4.3

1.7 cubic meters per second (39 mgd). Plant expansion currently under construction is expected to increase this total to 2.2 cubic meters per second (50 mgd) in 1977. The remainder of supply is from springs to the south of the City. The sanitary quality of PAM water is satisfactory.

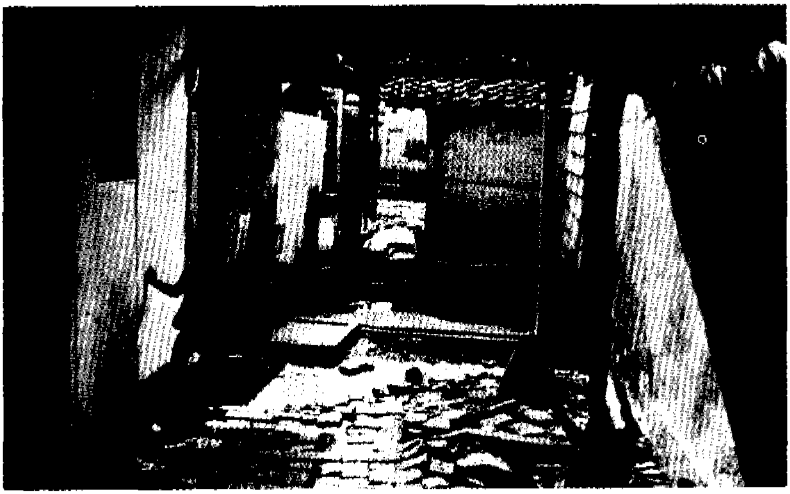
The distribution system consists of approximately 120 kilometers (74 miles) of transmission mains and over 300 kilometers (186 miles) of distribution piping. Existing pressures during the daytime are very low in most parts of the City.

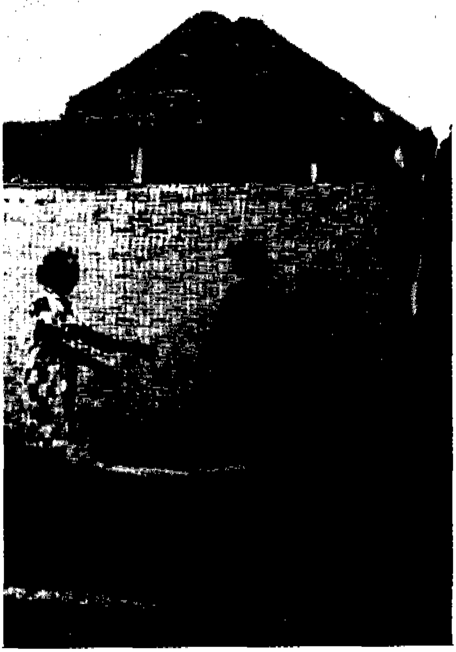
Only an estimated 17 percent of Surabaya's present population is served by direct connection to the PAM system. PAM also supplies water to about 4,000 vendors and carriers (Figure 4.3) who serve an estimated additional 27 percent of the population. Together, approximately 890,000 are served. The average daily water use is 80 litres per capita per day (21 gallons per capita per day).

Over one-half of the population of Surabaya presently relies on approximately 50,000 shallow groundwater wells (see Figure 4.4). The shallow aquifer supplying these wells is often contaminated (35% of sampled wells in 1976 showed high levels of coliform bacteria) and, because of high salinity, is only marginally used within large areas of the City.

Wastewater and Solid Wastes

Surabaya does not have a public sewer system. Most homes with toilets use septic tanks or discharge sullage water to street drains or nearby drainage ditches, gutters, or canals. There are about 600 public toilets





Shallow wells in urban Surabaya

FIGURE 4.4

operated by either PAM or other governmental agencies. Many of these facilities are in such poor condition that they discourage use. Service is provided to less than 1-1/2 percent of the urban population. There are an estimated 1 million inhabitants (one-half of the population) who have no access either to public or private toilet facilities.

The open drain system (see Figure 4.5) in the City carries surface water, domestic and industrial wastewater, septic tank effluent, sludge, and directly deposited excreta. It is also a repository for refuse and garbage. The lack of adequate wastewater controls results in a slow but steady pollution of local groundwater and surface waters.

Public Health

Because a large proportion of the population lacks both a safe water supply and basic sanitary facilities, Surabaya has a high rate of both cholera and dengue hemorrhagic fever as well as many recorded cases of malaria, typhoid, infectious hepatitis, and diptheria. In 1974, there were nearly 400 cases of typhus, over 160 cases of hepatitis, and more than 530 cases of diptheria reported by the City Department of Health. Although current health records and epidemiological surveys cannot, because of probable under-reporting, be considered accurate, they do represent a general overview of public health conditions in Surabaya. Infant mortality in Surabaya is startling, amounting to an annual death rate of greater than 50 deaths per 1,000 live births. This is 4 to 5 times the rate in developed countries. In some inner City districts, the annual rate for the incidence of cholera approaches 10 cases per 10,000 population.

Typical drainage canal in Surabaya

FIGURE 4.5

The high rate of enteric diseases, infant mortality and general public health hazards resulting from inadequate drainage, scattered refuse, and garbage and overflowing septic tanks aggrevate problems of malnutrition, crowding, and insanitary housing. Public health conditions in Surabaya appear to be deteriorating as the population increases.

Proposed Water Supply Projects

General

Based on detailed population projections and future land use considerations, the projected total average daily demand for 1985 was 286,000 cubic meters (188.7 mgd) rising to 714,000 cubic meters (75.6 mgd) per day in 2000. The proportion of the population to be served by piped water is planned to increase from the present 20 percent to 60 percent in 2000. Another 20 percent will be served through vendors. During this period, the total population is expected to more than double.

In order to meet these objectives, the number of service connections must increase from an approximate present 57,000 to 475,000 by the year 2000.

Source

Existing sources provide about 2.2 cubic meters per second (50 mgd) of the projected year 2000 maximum daily demand of 10.3 cubic meters per second (235 mgd).

Within a search radius of approximately 100 kilometers (62 miles), CDM identified technically feasible sources. Seven major sources were considered in detail, together with various layouts of dams, pumping facilities, transmission lines, and water treatment plants. More than 40 different plans and variations on location, capacity, and staging were prepared conceptually, together with their related approximate construction costs.

Three technically and economically sound alternatives emerged for further consideration. One alternative was for increased development of two existing spring sources lying south and southwest of Surabaya, followed by additional development of the existing surface water source through the use of a new raw water canal to bypass existing industrial point sources of pollution. A second alternative reversed the sequence of the first. The third alternative considered only the further development of the surface water source.

All three alternatives were essentially equal in overall capital economic costs. However, a present worth analysis,considering staging and operations and maintenance, resulted in the selection of the plan for early development of the existing spring sources followed by expansion of the surface water supply through the construction of a new raw water canal and construction of a new water treatment plant in 1995, (Figure 4.6).

Conveyance

Present conveyance facilities from existing spring sources lying to the south and southwest of the City are not large enough to accommodate the desired future flow. Accordingly, in the first stage of the project, a new 1,800 millimeter (71 inch) transmission main covering a distance of approximately 61 kilometers (38 miles) was proposed by CDM. The selected route traverses open rice fields rather than existing roadways over most of the distance. An inspection road for security and maintenance would be provided. Pipeline facilities include a series of dwelling units for PAM security staff.

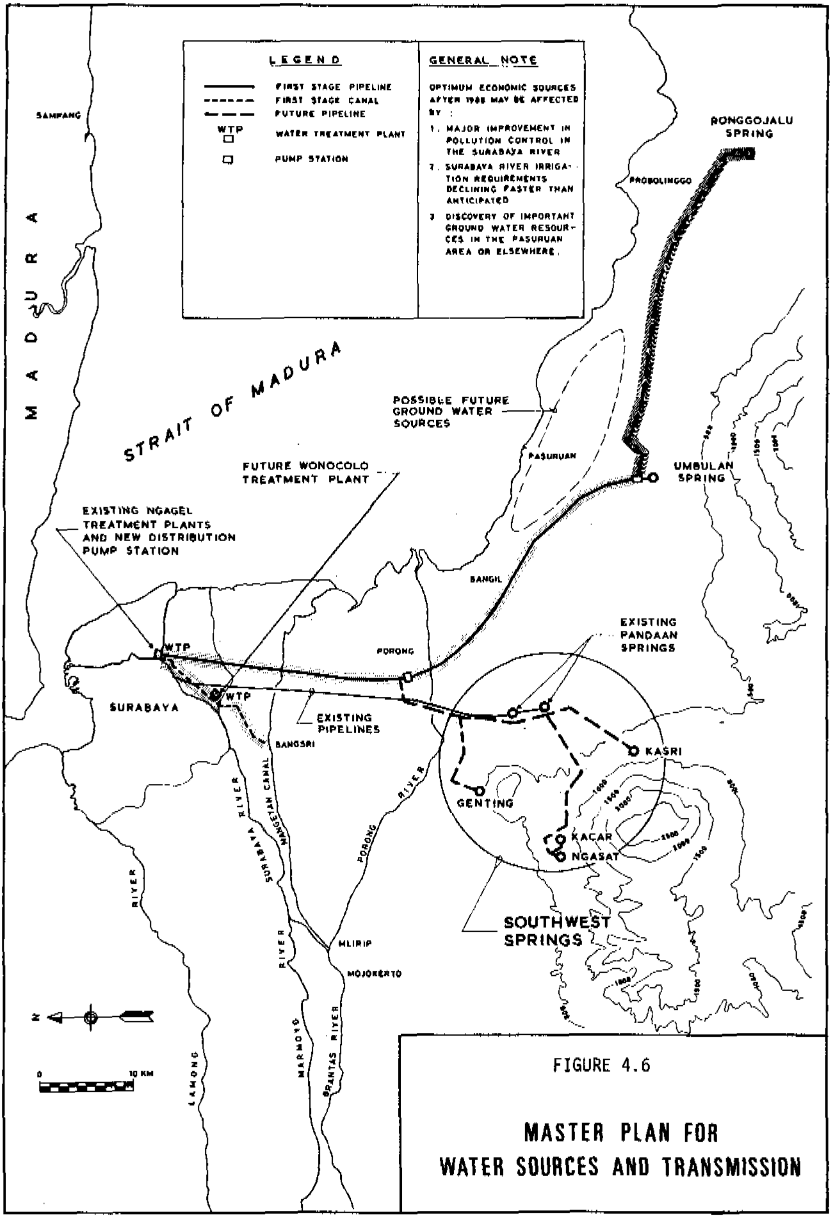


FIGURE 4.6

MASTER PLAN FOR WATER SOURCES AND TRANSMISSION

The second stage project includes a 14-kilometer (9-mile)-long raw water canal to convey water free from industrial point source discharges to an existing water treatment plant.

Treatment

The spring sources selected for development are of high water quality, requiring only disinfection. No new treatment works are required except for some improvements at the existing treatment plant including a storage reservoir and pump station to discharge to the distribution system.

Distribution

Two basic configurations of primary distribution mains to serve the projected population were conceptually developed and assessed. One configuration provides four major primary mains through the center of the City with secondary lines extending east and west to serve newly developed areas. These lines would be built largely through the heart of the built-up City. The recommended concept proposed a circumfrential distribution loop system enveloping the core City, resulting in less heavy construction in congested areas. This approach includes a major reinforcement of the smaller mains throughout the inner City plus a substantial program to extend service to "kampungs" (low-income, high-density neighborhoods) which contain a large portion of the present population not currently served. Because of the high cost of installing tertiary piping in these areas and congested conditions (Figure 4.2), CDM recommended a policy of encouraging the vending of water at several standpipe locations located within these high-density areas. Over 3,300 kilometers (2,050 miles) of distribution pipelines are planned for construction by the year 2000.

and could change the adjoining soil moisture regime by seepage, possibly resulting in excessive soil moisture for some types of crops now grown on adjacent lands.

The secondary impacts of the project relating to population growth are potentially more significant than the primary impacts. It is reasonable to assume that without the project, the population of Surabaya would not increase to the level which is presently projected. An adequate and safe public water supply in the City will act as an attractive force for increased immigration. The increment which could be attributed to the project (while of unknown magnitude) results in more people to feed, employ, house, etc., in an urban environment. Thus, while the project may not directly increase (except to the extent of improving public health and decreasing the mortality rate) the total population in Indonesia or the region in the vicinity of Surabaya, it may well help redistribute a significant portion of the population to the urban environment of the City of Surabaya, which is contrary to Government policy.

One of the severe existing problems is collection and disposal of human wastes. It is not financially feasible to expect that the year 2000 population can be served by sewers. The continued use of inadequate septic tanks will further contaminate the shallow groundwater which a portion of the population must continue to rely upon for its water supply needs. Also, there is the potential for drawing population to the vicinity of the vended water locations in areas generally unsuited for additional habitation. Squatter housing in flood plains or areas vulnerable to mosquito breeding could pose health hazards as great as those which municipal water service is intended to alleviate. Similarly, increased population densities and land coverage will result in increased amounts of accumulated refuse and surface runoff -- other potential contaminates of the groundwater.

The mitigation measures for these impacts go to the core of urban problems *in developing countries. There is a conflict between the perceived benefit to* the health and public welfare of the present and "normal" increased population and the reality of a lower quality of human environment which may result from the "additional" movement of rural people to the urban area, attracted at least in part by the early sanitary improvements. The resolution of this conflict lies in the ability of the central government to balance the timing, amount, and location of economic and population growth through the implementation of effective land use and population controls. Such measures are beyond the capacity of any overall program of physical development. They may even be beyond the capacity of any effort by central authority to implement.

Beneficial Impacts if the Project is Implemented

Recognizing, then, that the construction of any public water supply project is both only a partial solution to the economic and public health needs of a developing country and that an explicit decision to serve a projected increased population of the City was made by the governmental authorities, the beneficial impacts can be considered. The outstanding beneficial impact of the project is the provision of a safe drinking water supply to a high percentage of the present and future residents of Surabaya. The continued industrial contamination of raw water sources is avoided by the proposed project. The direct spread of waterborne disease will be reduced and the general health of the served population should increase accordingly. The pool of population infected with waterborne disease subclinically will decline, relatively, and will thus contribute to diminishing the spread of those diseases by other routes (such as food preparation). Health care resources committed to treatment of such diseases can be used for other health purposes, further enhancing public health. The economic productivity of the population employed should be enhanced because of generally higher levels of health.

Many of the benefits of the expanded public water supply should be reflected in an increase in property values.

The proposed project will allow industry to locate in more favorable locations such as along the Surabaya River, where the availability of river water for cooling and processing is most convenient. New industrial development in the south of Surabaya can be conveniently served by the distribution system. Construction and expanded operations will provide temporary and permanent employment to a number of workers both directly and as a result of the demand for local materials used during construction. The project minimizes expenditures in foreign currencies. The proposed rate structure will subsidize charges to lower-income, urban customers. The financing of the project should enhance the fiscal condition of the operating agency, allowing it to effectively maintain and operate the facilities.

Potential Adverse Impacts if the Project is Not Implemented (No-Action)

Even without an improved public water supply project, the population would continue to increase, although possibly at a lower rate. Without the project the present and future population would be subject to a higher incidence of waterborne disease and related mortality and morbidity. A higher proportion of resources would have to be devoted to public health activities. In order to protect water quality, industrial development on the Surabaya River upstream from the existing water treatment plant probably would have to be curtailed.

New industry in other parts of the City would not have access to an economical water supply. As a consequence, general economic development would suffer.

Summary

The expansion of the Surabaya municipal water supply system creates a number of potential environmental impacts, both adverse and beneficial. However, the public health needs are so pressing that it is difficult to conceive of any soundly engineered water supply project that would result in adverse impacts so great as to outweigh the probably benefits. The larger questions, such as whether the City ought to be encouraged to more than double in population over the next 20 years, go beyond the parameters of an individual engineering project. Presently, it is not possible that the proposed water supply project (or any similar project) could be modified to mitigate the adverse impacts characteristic of urban growth in developing nations.

Given that the environmental impacts of this water supply project in a developing country were fairly straightforward and were as anticipated at the start of the project, what is the value of the impact assessment procedure? First, there were several impacts identified which can be minimized by proper engineering (examples include mosquito control and the amount and duration of dewatering to protect trees in excavation areas). Second, the incremental costs of the re-allocation of resources and existing sewage, refuse and garbage disposal were brought to the attention of the client, focusing attention on the need for a future round of solutions.

The impact assessment procedure is an integral part of a continuing planning and engineering process in which the solution of each problem leads to the identification of related problems and the simplification of the context in which they must be addressed. There will never be a "final" problem for the Engineer to work on, nor a "final" solution for him to propose.

Appendix A

Scope of Work for an Environmental Assessment of a Water Supply Project in a Developing Country

The following is from the contract between CDM and the Government of Egypt, dated April 1977, for the Alexandria Water Supply Project:

"ENVIRONEMNTAL ASSESSMENT*

The CONSULTANT shall prepare an Environmental Assessment of Part I and Part II of the Waterworks Master Plan. The purpose of the Environmental Assessment is to provide AID and the MINISTRY's decision makers with a comprehensive understanding of the reasonably foreseeable environmental effects of proposed actions and their reasonable alternatives so that the expected benefits of development objectives can be weighed against any adverse short or long-term impacts upon the human environment.

Consideration shall be given to those effects upon the environment which adversely affect such aspects of the human environment as air, water, land, flora and fauna, and socio-economic conditions. Special attention shall be given, as appropriate, to problems involving solid waste, noise, hazardous substances and natural resources development, and in addition actions which:

i Degrade the quality of the human environment.

ii Curtail the range of beneficial uses of the human environment and its resources.

*It is specifically understood that "Environmental Assessment" as used in context of this Section shall be construed to be an "Environmental Impact Statement" as defined in U.S. Government regulations and further that said Environmental Assessment shall not require separate and independent reports.

iii May have both detrimental and beneficial effects, even if on balance the effect will be beneficial.

iv Have secondary effects which may be more substantial than the primary effects of the proposed action.

v Are likely to have an effect on any natural or cultural heritage, archaeological or historical elements.

This Environmental Assessment shall include, but not be limited to:

(a) A description of the existing environment without the proposed improvements relevant to the analysis of alternatives and determinations of the environmental effects of the Waterworks Master Plan.

(b) A description of the future environment with no action to improve the waterworks.

(c) An environmental assessment of the alternative programs studied. The significant direct and indirect effects of each alternative program shall be determined. Long-term, irreversible and induced impacts on socio-economic conditions, public health, etc., shall be considered in the selection process.

(d) A description of the future environment with the implementation of the Waterworks Master Plan. Direct and indirect impacts of the Waterworks Master Plan program shall be described giving special attention to unavoidable impacts and steps to mitigate adverse impacts. The signficance of land use impacts shall be evaluated, based on current and projected population within the Project Area.

GRAND PLANS FOR WATER

by W. R. Derrick Sewell [1]

INTRODUCTION

The United States faces a critical dilemma in its plans for economic and social development: how to satisfy a burgeoning demand for water yet prevent environmental disruption and have sufficient capital to invest in the many other things that Americans regard as necessary services. The signs of the dilemma are already clear in the West and the Southwest. Soon they will be evident in many other parts of the country too. Present trends suggest that the solution to impending water scarcities will be sought through the traditional 'extensive' approach to water management, in which supplies are sought progressively further and further afield, and delivered by structures which are of ever-increasing size, cost and complexity (Sewell, 1966). It is also evident, however, that this approach will receive growing resistance on economic, social and environmental grounds, and that planners will need to re-orient their thinking towards a more 'intensive' utilization of existing supplies. Not only is there mounting concern about the problems of ecological and social disruption caused by large scale water development (Goldman, et al, 1973) but there are criticisms that the 'extensive' approach inevitably

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(1) Professor, Dept. of Geography, University of Victoria, Victoria, B.C., Canada.

encourages waste, and on an increasing scale.

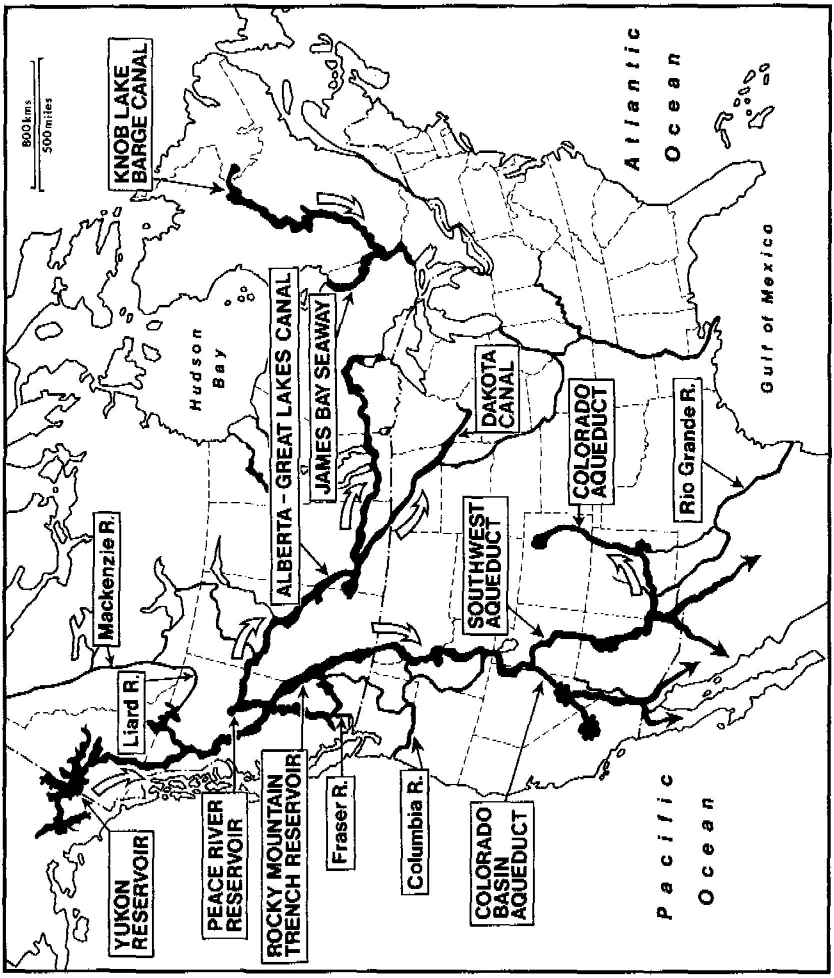
These concerns have considerable relevance for proposals which are now being considered with respect to major inter-basin transfer of water in North America. The notion of water transfer, of course, is not new. There were numerous examples in ancient China and in Mesopotamia (Warwick, 1969) and there are many more recent illustrations in Europe and North America. What is new is the scope and scale of the schemes that are now being proposed. Some, such as the West Texas and Eastern New Mexico Scheme contemplate the diversion of as much as 34 million acre feet (41.94 km^3) from the lower Mississippi and Arkansas Rivers. A number of the proposed schemes are even larger, involving massive diversions from one part of a continent to others. A scheme proposed for development in the Soviet Union, for example, contemplates the diversion on the northward-flowing Ob and Yenisey Rivers southwards and across the Turgay Divide, into Central Asia and Kazakstan (Micklin, 1977). Some 255 million acre feet (315 km^3) would be diverted, representing about one third of the combined average annual flow of the two rivers. In India consideration has been given to the construction of a Water Grid. This would involve the construction of a 1988 mile (3200 km) canal network, dams and pumping stations, to bring surplus water from the Ganges River in the mouth to irrigate arid regions in south central and western India. (India Central Water and Power Commission, 1973). Other massive diversion projects are contemplated for South America and Africa (Nace, 1973).

By far the largest scheme proposed to date, however, is the North America Water and Power Alliance (generally referred to as NAWAPA). Outlined initially in 1967, by a Los Angeles firm of consulting engineers, (Parsons, 1975), if forms the basis of several other major diversion proposals that have been suggested since that time (Alberta Department of Agriculture, 1968; Quinn, 1973). While the NAWAPA scheme has never been put forward by the U.S. government, it has been seen by many in the United States and Canada as an official plan. It has aroused considerable controversy on both sides of the border, not only because of concerns about the potential impacts of some of its elements but also because there is skepticism of the approach to water management which it embodies.

THE NAWAPA SCHEME

The NAWAPA scheme would divert water from rivers in Alaska and British Columbia to serve the needs of the western and southwestern parts of the United States, the Prairie Provinces, and the midwest of the United States. (Figure 5.1).Briefly, this would be accomplished by damming the Yukon and Tanana Rivers to reverse their flow, thus creating a common reservoir; damming the headwaters of the Copper River and diverting its flow via a tunnel to the Yukon-Tanana reservoir; pumping water from the Yukon-Tanana reservoir into the Peace River reservoir from which it would be transferred either to the Rocky Mountain Trench reservoir or the

FIGURE 5.1



Scheme for North American Water and Power Alliance

Alberta Great Lakes Canal; pumping water out of the Trench into the Columbia-Snake system, and thence into the Colorado River system; diversion into a Southwest Aqueduct, serving Arizona, New Mexico and Mexico, and into a Colorado Basin Aqueduct, leading to California and Mexico. Other potential elements of the scheme include the Hudson Bay Seaway, North Dakota Barge Canal, James Bay Seaway, and the Knob Lake Barge Canal.

The scheme is massive in every detail. It would require the construction of 240 reservoirs, 112 irrigation systems, and 17 navigation channels. Some of the dams would be well over 1000 ft (313 meters) high. The Chitina Dam on the Copper River, for example, would be 1, 781, 000 ft. (543 meters) high, more than 1 1/2 times the height of the Nurek Dam in the USSR, which, when it is completed in the later 1970's will be the world's highest. The Yukon-Tanana Reservoir in Alaska would have a capacity of almost 2837 million acre feet(3500 km^3), some 20 times that of the Bratsk Reservoir in the Soviet Union and nearly 75 percent of the average volume of Lake Michigan.

The key feature would be the Rocky Mountain Trench reservoir. It would be created by damming some 1300 miles (500 km) of the 1800 km valley which extends from Montana to the Yukon border in Canada. It would impound some 561 million acre feet (693 km^3) of water, gathered from the Columbia, Fraser and Kootenai systems, as well as water diverted from the north.

The initial diversion would be about 14 million acre feet/year (18.5 km^3/year), and could be realized within about a decade. The design transfer of 110 million acre feet/year (136 km^3/year) could be attained in about 20 years. At a further stage diversion might be increased to 249 million acre feet (308 km^3). The design diversion is about 17 percent of the average annual runoff in the drainage area encompassed by the scheme.

The project would be costly, probably in excess of $120 billion at 1977 prices if all of the elements are constructed. But the benefits claimed for it are also massive. Proponents suggest that at least 33 of the United States would gain directly, as would 7 provinces and territories in Canada, and 8 northern states in Mexico. (Parsons, 1975). Annual benefits to the three countries are set out in Table 5.1.

Proponents claim that the scheme would make possible major increases in water supply for irrigation and domestic and industrial uses, and would enable a massive expansion of electric power supply and navigation.

With all of these claimed advantages, why is the scheme not underway already? The answer seems to lie in doubts that have been raised about:

(i) the need for such a massive increase in water supply.

(ii) the relative efficiency of providing the claimed benefits by a huge diversion scheme compared with other alternatives.

(iii) the broad economic, social, political, and environmental implications of the scheme.

TABLE 5.1

THE BENEFIT TO CANADA, THE UNITED STATES AND MEXICO FROM THE NAWAPA SCHEME

	CANADA	U.S.A.	MEXICO
Additional Water (million acre feet)	22	78	20
Additional Irrigated Land (million acres)	9	21	6
Power (million kilowatts)	60	38	2
Annual Income (billions of dollars) National income from industry and agriculture	9	30	30

Source: Alberta Department of Agriculture, Water Diversion Proposals of North America. Edmonton, Alberta, December, 1968, pp. 7-8.

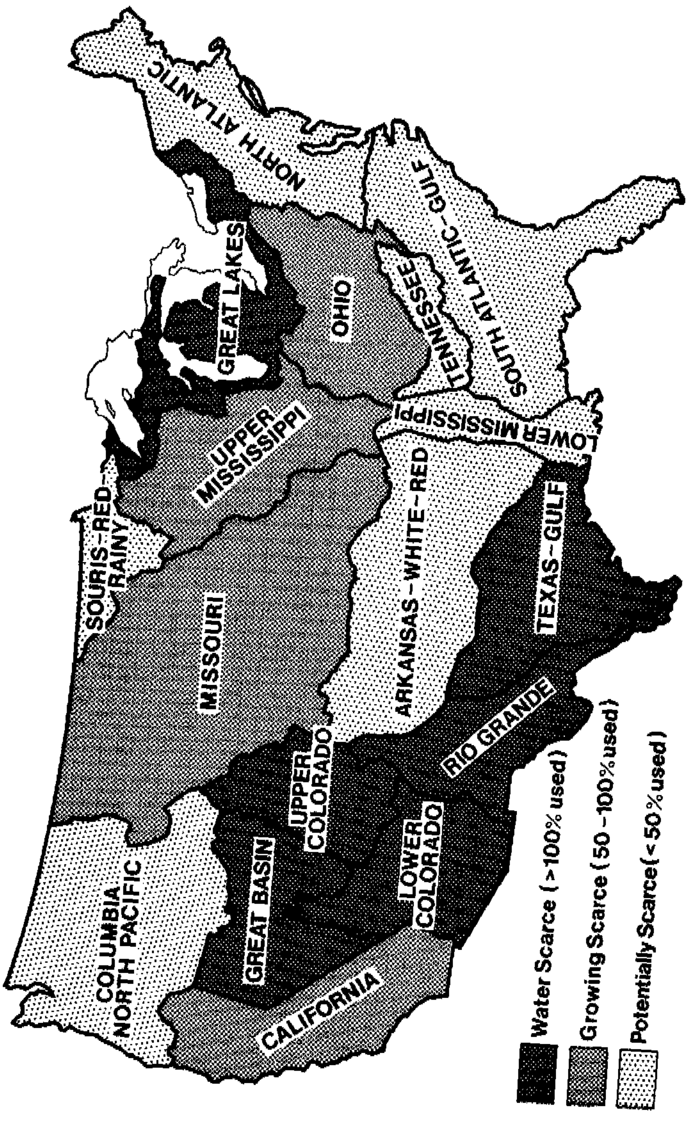
IS THERE A NEED FOR A CONTINENTAL SCHEME?

Most of the pressure for the NAWAPA scheme, or smaller versions thereof, has come from those who perceive a major water crisis in the United States by the end of the century. Amongst these, Western politicians, led by the late Senator Frank Moss of Utah, have been the most enthusiastic. They draw their evidence from a variety of sources, including the studies of the U.S. Water Resources Council (1968). The Council, in the first national assessment ever undertaken of the U.S. water situation, pointed out that the average discharge of rivers in the U.S. is about 1200 billion/gallons/day (4.5 billion m^3/day). Withdrawals in 1965 amounted to some 270,000 billion gallons/day (1 billion m^3/day). The Council projected by 1980 these would have increased to some 423 billion gallons/day (1.6 billion m^3/day) and by 2020 the demand would have grown to 1368 billion gallons/day, (5.2 billion m^3/day). At the latter stage, demand would have outstripped supply.

There are already shortages in some regions. These will become increasingly severe in the next two decades, especially in the West and Southwest. (Figure 5.2). These trends reflect both the increasing desire to find a place in the sun, and the tendency of those who come from more humid areas to transfer their cultural attributes with them. The 'green lawn syndrome' is illustrative. At the same time shortages are anticipated in some of the more humid regions, notably the Northeast. Here the problem is one of scarcities created by rapidly declining water quality. The solution perceived is generally not one of cleaning up but of bringing in purer water from elsewhere.

While it is clear that there is mounting pressure on water resources in the United States, it is much less certain that there is, or will be, a serious water scarcity there. For such a situation to occur it would be necessary to show that waste was minimal and that water was allocated to its most efficient uses. Neither of these conditions prevails. On the contrary, waste is not only enormous,

FIGURE 5.2



Water scarcity in the United States

it is mounting. A few illustrations will suffice. At present the largest single water use is irrigation, accounting for more than 130 billion gallons per day (out of the total withdrawal of 370 billion gallons). Of this, more than half is wasted in over-generous watering of crops. In many cities more than 20 percent of the water supply leaks out of the delivery system before it reaches the consumer. At the domestic level, Americans pride themselves in the 5 gallon toilet flush to do a job that neither requires pure water nor 5 gallons of it. Toilet flushing accounts for more than 40 percent of household use in North America. Use of the much more efficient toilet systems, such as those in use in Europe could reduce this requirement by more than one half. (Rybczynski, et al, 1973).

Not only is there massive waste but there is misallocation as well. Water is not always used for purposes for which it has the highest value. Many anomalies result from present laws and policies, as was illustrated by the recent California drought. Residents of Marin County severely restricted their consumption while those in the Beverly Hills area of Los Angeles had enjoyed such luxuries as water fountains. Farmers all over the State continue to use water inefficiently while the major cities thirst for more supplies and have to go further and further afield to obtain them. The same can be said of many other parts of the country too.

The conclusion that one must reach is that there is no demonstrable need for a scheme like NAWAPA. The more urgent requirement is to find ways of reducing waste and improving the efficiency of water use.

DOES THE SCHEME REPRESENT THE MOST EFFICIENT MEANS OF PROVIDING THE BENEFITS?

Even if it could be shown that there was a real shortage of water emerging in the United States, it would be necessary to demonstrate that the proposed scheme is the most efficient means of providing the benefits claimed for it. To do this one would need to examine possibilities of:

(a) supplying additional water;

(b) make more efficient use of existing supplies.

It is not possible within the confines of this paper to examine any of these possibilities in detail. A review of the literature suggests, however, that not only may there be much more economic ways of supplying additional water, but also that strategies designed to make better use of existing supplies are even more attractive. While it is difficult to estimate exactly how much water from the NAWAPA scheme might cost, if one bases estimates on recent California experience, it is probable that it would be at least $100 per acre foot. (Bryan, 1973). Studies by Howe and Easter (1971), and others have shown that even such options as desalination which are currently considered to be uneconomic in many parts of the United States, would provide water more cheaply than would the NAWAPA scheme (Table 5.2).

The findings of the National Water Commission's investigations, however, make it clear that finding new sourc e of supply it not the

TABLE 5.2

ALTERNATIVES TO INTERBASIN TRANSFERS; ESTIMATED QUANTITIES AND RELATIVE COSTS

Source	Estimates of quantities available per year	Indicated range of costs per acre-foot
	maf	
Reduction of conveyance losses:[a]		
Colorado Basin	1.5	$2-42
Great Basin	0.6	2-42
Pacific Northwest	3.4	2-42
South Pacific	2.0	2-42
Missouri	1.6	2-42
Evaporation retardation from small ponds and reservoirs	0.5	12-24
Transfers from agriculture		
Arizona	1.2-1.6	28
Colorado	not known	15-32
Texas High Plains	4.0	81-119
California	0.8	18-106
Additional surface development:		
Western Gulf	11.0	3-19[b]
Central Pacific	21.0	3-41
Weather modification (Upper Colorado Basin)	1.9	1-2[c]
Wastewater reclamation:		
Southern California	0.7	13-32
Desalination	unlimited	100 + [d]
Vegetative management and snow fencing	9.0	2-23[e]
Phreatophyte and riparian vegetative control	not known but potentially large	1-57
Mininum total availability	59.2	

[a] Assuming 80 percent efficiency, representing a 43 percent decrease from the 1965 losses.

[b] Impoundment costs only.

[c] Cloud seeding costs only.

[d] Cost at plant.

[e] Does not include storage costs.

Adapted from: Howe, C.W. and Easter, K.W., Interbasin Transfers of Water, Johns Hopkins Press, Baltimore, MD, 1971, p. 134.

optimal route. (U.S. National Water Commission, 1973). Attention needs to be turned instead to such strategies as improving ground-water management, the re-use of municipal and industrial wastewater, the reduction of losses, transferring water rights to most efficient users, and the introduction of economic principlies in charges for water supply and effluent discharge. It is evident from the research undertaken in recent years that present laws and policies in the United States lead to inefficient use of capital and misallocation of water among alternative uses. (Hinschleifer, 1969; Haveman, 1972). It is also clear that they encourage waste on a very large scale. The substitution of an 'intensive' for an 'extensive' approach would remedy these deficiencies. It would also avoid some of the economic, social, political and environmental problems facing proposals for large scale inter-basin water transfers.

PROBLEMS OF IMPLEMENTATION

The NAWAPA scheme has been described as "bold and imaginative" and "a challenge to engineering ingenuity". There is foundation for both statements, for the problems to be overcome in the implementation of a scheme of this magnitude are truly enormous. At its full scale of development, it would require agreements among 3 national governments, at least 7 provinces in Canada, 22 states in the United States, and States in Mexico. Experience with the negotiation of the Columbia River Treaty which took more than 20 years of study and negotiation on a problem infinitely much smaller, indicates the magnitude of the potential difficulties. More serious, however, are the various objections that are likely to be raised about the potential impacts of the scheme. (Bryan, 1973).

Firstly, it would be extremely expensive and would require more than three decades to complete, tying up capital for a long time before benefits would accrue on a large scale. It has been argued that such funds might yield much higher returns in alternative occupations, notably energy development, where the needs are perceived as being even more urgent. Secondly, grand designs of this kind are highly inflexible. Development of the first part inevitably involves commitment to the whole scheme, even though it may turn out that better ways have been found or that social values have changed.

Thirdly, it would undoubtedly have profound effects on settlement and the environment. The scheme would result in the inundation of numerous communities and east-west transportation links, particularly in the Rocky Mountain Trench. In addition, it would result in the blockage of many of the last remaining salmon streams of the West Coast, and the large scale destruction of wildlife habitat, involving a wide range of rare species. (Royce, 1967; Bryan, 1973). The flow of many rivers would be severely reduced, particularly in their lower reaches. Illustrations of the potential effects are already evident in the effects of the Bennet Dam on the Peace-Athabaska Delta. (Environment Canada, 1972). Even more critical might be the effects of reducing the fresh water inflow into the Beaufort Sea and Arctic Ocean, particularly in the increase of salinity that would inevitably result, possibly producing a major change in climate. (Nace, 1973).

More speculative but of potentially greater damage are the possible consequences of the construction of large dams and reservoirs in a seismically active area. Several of the same would be more than 1000 feet (313 meters) in height, and many of them would be located in the area traversed by the Denali fault. A tremor of the magnitude of the Alaska earthquake of 1964 would undoubtedly cause such structures to fail, resulting in disastrous inundation in areas downstream. In addition, there are fears that the impoundment of the huge volumes of water in this zone might itself induce crustal disturbances or induce landslides. (Nace, 1973).

Thus far there has been little investigation of the potential consequences of the scheme. Almost all of the planning has been devoted to the preliminary design of control and diversion works.

PRESENT STATUS OF THE SCHEME

The NAWAPA scheme was put forward initially in the early 1960's. It aroused only minor interest in the United States at that time, except from a few Western politicians, notably the late Senator Frank Moss of Utah. (Moss, 1967). In contrast, it became a matter of widespread concern in Canada, where the late General A. G. L. MacNaughton described the scheme as "a monstrous concept, a diabolical thesis." (MacNaughton, 1967). There was general opposition to the proposals on the Canadian side of the border, largely on the grounds that Canada had very little to gain and a great deal to lose. (Bocking, 1972). Although much of the opposition was based on emotional considerations, it did emphasize an extremely important fact: there are limits the 'extensive' approach to water management, imposed not so much by technology but by economics ecology and human values.

CONCLUSIONS

The experience with the NAWAPA proposals has provided a valuable opportunity for Americans to re-assess their approach to water management. The challenge is similar in many ways to that posed by the energy crisis. It is one of making much more efficient use of resources that have been harnessed already, and discovering alternative ways of producing goods and services that are heavy users of water. Undoubtedly, it will call for changes in the present institutional framework of laws and policies, to enable water to be allocated to its most productive uses. It will also require the engineering profession to take an expanding view of water management, notably by turning its attention to such neglected alternatives as recycling, wastewater renovation, groundwater recharge and land use regulation, as well as to the identification and measurement of the impacts of development. They already have the expertise to determine whether developments are technically feasible. Increasingly they will be expected to demonstrate whether they are socially desirable.

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FOUR DEVELOPING COUNTRY WASTE DISPOSAL PROJECTS

By Robert L. White and Gary D. Beers[1]

INTRODUCTION

Throughout most of the world, major investments in wastewater treatment and disposal have lagged behind those for water supply. The principal reason for this is the fact that water is an absolute necessity for the existence of a community, whereas the treatment and disposal of human wastes often has been viewed as providing benefits which could be foregone. However, there has been an increase in investment in wastewater treatment and disposal in the last fifteen years. This trend has been most evident in the major industrialized countries where the public has been concerned with ecological damage or with aesthetic improvement and where the investment capital for these improvements has been available. In the United States this trend began, perhaps, with the first Federal funding for wastewater treatment plants in 1956, and it has accelerated since then. Concern with the environment has been expressed in an increasing volume of Federal and state legislation as exemplified by the National Environmental Policy Act with its codification of the environmental impact assessment process and by the Federal Water Pollution Control Act.

These same trends have become evident in a number of developing countries, although their experience is of necessity several years behind the United States and Europe. It does not follow, however, that the American and European experiences can be translated directly for application in less developed nations. The development of engineering alternatives for wastewater treatment and disposal and the evaluation of the potential environmental consequences of these actions must be made within the context of the entire technical, social, and economic situation in these developing nations.

ENVIRONMENTAL IMPACT ASSESSMENT

The major differences in social and institutional structures, economic conditions, and technological capabilities between the United States and less developed nations result in both constraints and opportunities for the engineer who is attempting to develop and analyze wastewater disposal systems. Assumptions, approaches, and techniques used in developed nations must be reconsidered and usually modified before they can be applied in other parts of the world.

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In most countries there is little or no tradition of public involvement in technical decision making. Citizen advisory committees, now so common in the United States, and indeed required by law, are almost unheard of elsewhere. To a great extent this is due to lower levels of education, poorer economic conditions, and the lack of established mechanisms for public involvement. When it is expressed, public concern is usually directed toward immediate problems which affect the economic well-being of the community.

In most countries environmental standards and regulations are less well developed than in the United States. Usually standards are expressed in general terms, and the engineer must develop specific criteria for a project. Although in one sense this makes his work more difficult, it also provides the opportunity in many cases for developing solutions that are more cost-effective than would be possible in similar situations in the United States. For example, the United States Federal law requires that the minimum treatment afforded to domestic wastewaters be secondary treatment. This requirement is entirely independent of the receiving water situation. Most knowledgeable engineers agree that secondary treatment of domestic wastewaters is often inappropriate if the effluents are to be discharged to the marine environment. Thus, in countries which do not have this requirement it is often possible to develop wastewater treatment schemes which can be tailored to the local requirements and which will cost significantly less than they would in the United States while maintaining an equivalent level of environmental protection.

In most waste disposal projects in the developed countries major consideration must be given to the institutional problems associated with various wastewater disposal alternatives. This is often not a consideration in other countries. In many of the less developed nations wastewater disposal is the responsibility of a state or Federal agency. Even in those situations, in which wastewater disposal may be the responsibility of a municipality, there is little opportunity or necessity for considering alternative institutional arrangements. Frequently an engineer is able to concentrate on those measures which will reinforce the effectiveness of existing institutions.

Desirable as it might be, in developing nations it is seldom possible to make detailed analyses of potential environmental consequences of specific proposed actions. Usually a wastewater disposal project has developed in response to grossly unsanitary or environmentally unsatisfactory conditions rather than as a result of lack of compliance with a government requirement. This fact, coupled with a general lack of previous studies which could provide background or baseline information, makes it almost impossible to predict accurately what changes might occur in the environment if the physical situation were to be changed. In most cases, the time and resources required to conduct adequate environmental surveys are not available.

This situation is not as unsatisfactory as it might at first seem. The potential improvements from doing almost anything are frequently so great that prediction of the exact future ecological conditions seems of relatively small importance.

To provide a basis for comparing the differences between environmental impact evaluation in the United States and in the less developed nations, four examples are presented in the following pages which describe the decisions and recommendations that have been made for wastewater disposal in four different parts of the world (Figure 6.1).

(1) Montevideo, Uruguay. Disposal of domestic wastewater to the Rio de la Plata and the potential effects of this disposal on tourism.

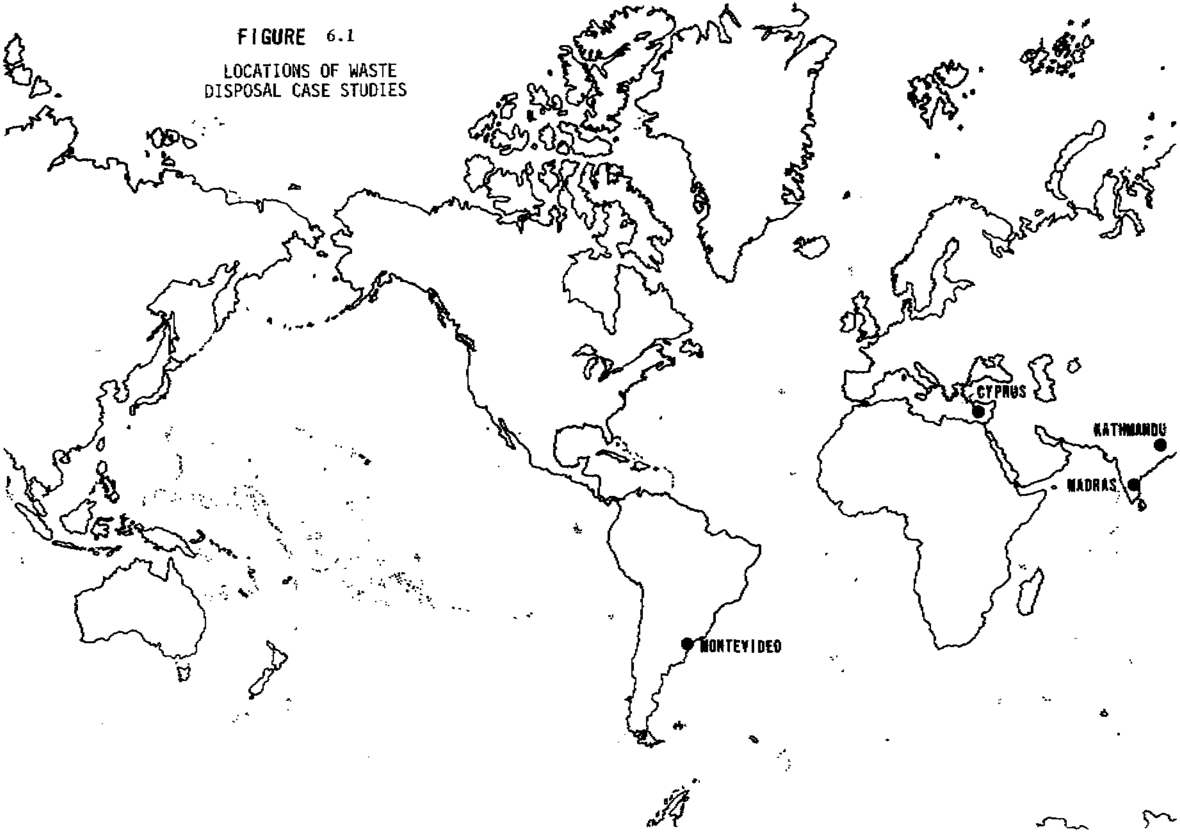
(2) Morphou Bay, Cyprus. Disposal of industrial wastewater to a Mediterranean bay and the impact of this disposal on aesthetics and marine ecology.

(3) Kathmandu, Nepal. Disposal of domestic wastewater to the Bagmati River and the effects of this disposal on water quality.

(4) Madras, India. Land disposal and reclamation of wastewaters and the interaction with the area's water supply problems.

FIGURE 6.1

LOCATIONS OF WASTE DISPOSAL CASE STUDIES



Case Study No. 1: Montevideo, Uruguay

Problem

Tourism is the third most important source of foreign exchange for the country of Uruguay. Revenue generated by tourism during the 1960's represented from 20 to 30 percent of the country's foreign exchange. Furthermore, almost 15 percent of this South American country's imports were financed in the 1960's by tourism's contribution to the balance of payments.

Montevideo, a complex of beautiful beaches and commercial establishments, is the focal point for more than 80 percent of the foreign visitors who come to Uruguay. Between 1947 and 1971 the number of tourists has increased four-fold from 169,000 to 614,500 visitors per year. Although beach resorts stretch along the coast of Uruguay from Colonig through Montevideo to the border of Brazil, over 60 percent of the tourists prefer the Montevideo beaches, the most important natural resource of this city.

In the late 1960's, it was realized that continuation of the existing wastewater disposal methods would soon result in severe water pollution problems in the vicinity of Montevideo's prized beach areas. The urbanized area of Montevideo which had a resident population of about one million people in 1970 is served by a combined sanitary-stormwater collection system (Figure 6.2). In three suburban communities of Montevideo (Colon, Barrio San Fuentes, and Barrio Instrucciones) treatment is provided for the collected wastewaters. However, the remaining Montevideo area is either unsewered or served by a collection system that discharges directly to the waters of the beach zone.

During the early 1970's, steps were taken to develop a wastewater management program that would control the problems of beach pollution in the Montevideo environs and permit the continued growth of the tourism industry.

Study

A major study (Reference 1) was undertaken in 1972 to accomplish the following four objectives:

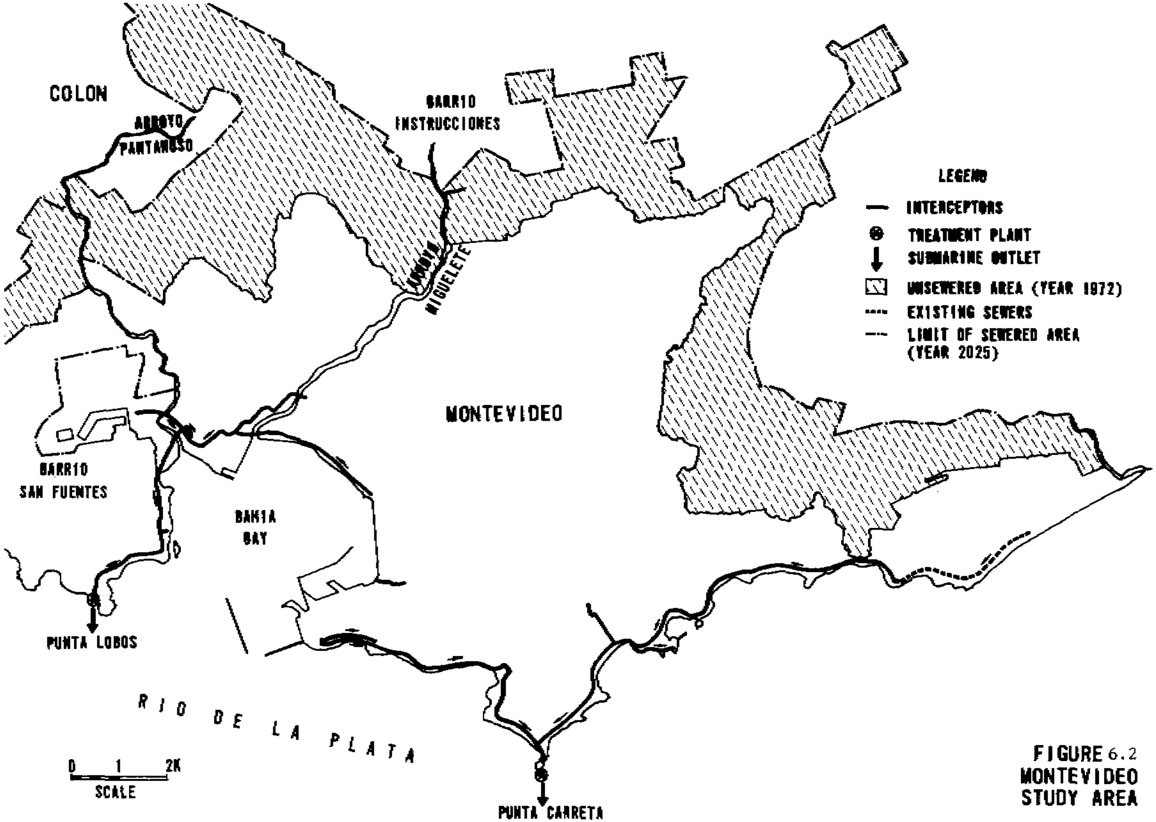


FIGURE 6.2
MONTEVIDEO
STUDY AREA

(1) to develop recommendations on the optimum approach for handling combined sewer overflows,

(2) to recommend a detailed program of additional preliminary engineering work needed to obtain preliminary designs of required facilities,

(3) to prepare up-to-date cost estimates of the needed works, and

(4) to recommend administrative and financial plans for implementing the proposed system.

Field studies included characterization of wastewater quantities and qualities in the various branches of the collector network and development of a preliminary descriptive model of the hydrodynamic and chemical features of the nearshore marine waters bordering Montevideo.

Project

The major elements of the recommended project were a major interceptor along the shore to collect all of the dry weather flow and a portion of the wet weather flow, a 6.7 m^3/s advanced primary plant (using dissolved air flotation) and a 1.8 m diameter outfall extending 1600 m into the estuary. Conventional primary and activated sludge treatment alternatives were considered, but the advanced primary process was selected because of a relatively high degree of floatables removal, small land area requirements, and lower costs. Several outfall locations were analyzed. The final plan recommended construction of two outfalls, one at Punta Carreta and the other (to dispose of wastewaters from the heavily industrialized bay area) at Punta Lobos.

Case Study No. 2: Morphou Bay, Cyprus

Problem

The water of the Mediterranean Sea is especially noted for its transparency. This quality certainly applies to the waters surrounding the island country of Cyprus. Here water transparency is nearly that of one of the clearest lakes in the world, Lake Tahoe.

A major copper-ore reduction facility is located on the shore of Morphou Bay, Cyprus' largest bay (Figure 6.3). Several hundred cubic metres per day of iron-laden (greater than 20 grams/liter) wastewater are discharged from this industrial facility through a submerged outfall to the bay at a depth of 75 m, some 2750 m offshore.

Enough iron has been released to Morphou Bay during the many years of operation of the reduction plant to result in substantial discoloration of certain segments of the bay waters, especially in the vicinity of the outfall terminus or along the sea floor near the discharge zone. Under certain meteorological and oceanographic conditions, discoloration of the surface waters can extend 30 to 40 kilometres along the northeast coast of Morphou Bay.

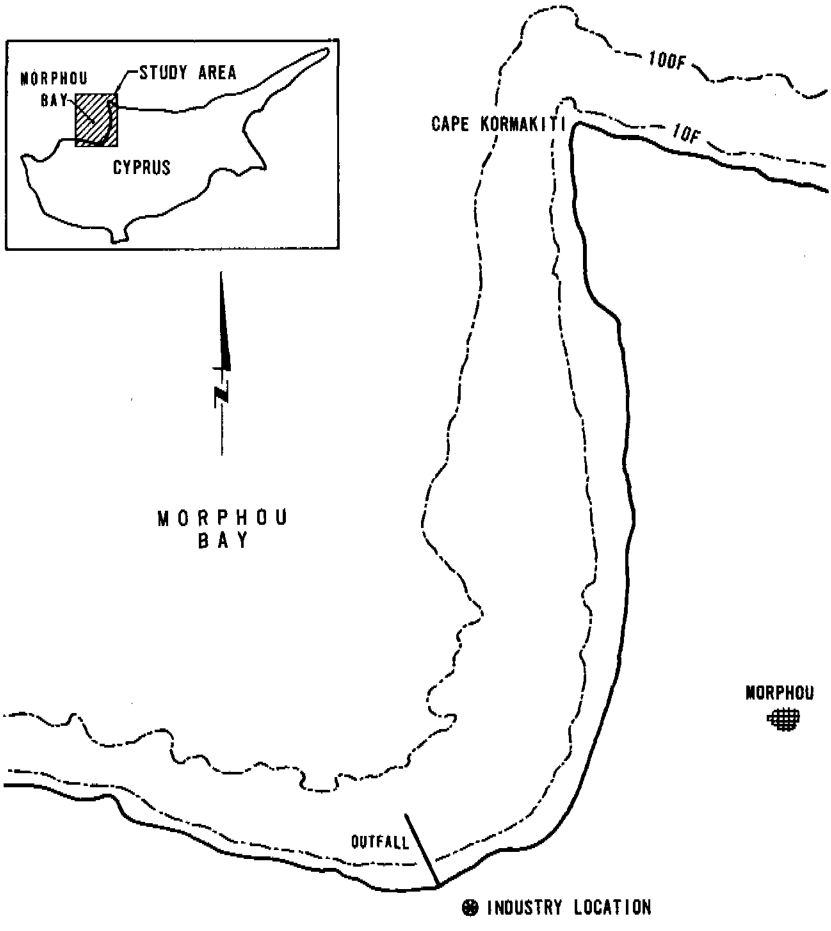
During the late 1960's the copper-ore industry initiated a project to develop a marine wastewater disposal management system that would significantly reduce the impact of discoloration of local portions of Morphou Bay.

Study

An oceanographic study and a wastewater characterization program were undertaken in 1969 and 1970 (Reference 2). To develop an adequate information base for the formulation and evaluation of various outfall-diffuser system alternatives, the following activities were performed:

- Characterization, during winter and summer periods, of the hydrodynamic and physico-chemical properties of Morphou Bay,
- Characterization of the discharged wastewater, and

FIGURE 6.3
MORPHON BAY STUDY AREA



In-situ and laboratory experimentation with the behavior of the iron-laden wastewater when diluted with various volumes of sea water.

The dilution afforded a wastewater is determined by the density structure of the receiving water, the current patterns of the receiving water, the characteristics of the wastewater, and the design of the diffuser section of the outfall system. In each coastal zone situation, all of the preceding parameters except the last one are independent and uncontrollable. The development and evaluation of disposal alternatives emphasized the potential dilution provided by various lengths of diffuser sections placed at various locations in Morphou Bay.

The critical water quality parameters of the wastewater in Morphou Bay were color, pH, and precipitate formation. Due to the lack of existing criteria for these parameters, appropriate objectives had to be developed. A dilution of 1:280 is required to raise the pH of the wastewater from pH 2.5 to pH 6.0. At dilutions of 1:10 and less the wastewater/sea water solutions were relatively clear but exhibited an intense bright orange color. The dilutions between 1:10 and 1:50 were very turbid and exhibited a pale orange color. Dilutions between 1:50 and 1:300 were relatively clear and exhibited a pale yellowish-orange color. At 1:1000 dilution the solution was the same color as the 1:200 solution, but the floc particles in the water column were light and reasonably dispersed. Based on the receiving water quality objective of no deleterious effect on the visual esthetics of Morphou Bay, it was concluded that a dilution of the wastewater in excess of 1:1000 would be desirable; however, a dilution of 1:200 might be acceptable.

Project

Short-term and long-term solutions to the disposal problems were recommended. An interim solution would be an outfall system consisting of an extruded plastic pipe floated into place and sunk into position. A series of weighted collars would be used to hold the pipe in position. The long-term solution involved the installation of permanent pipe along the sea-floor to a depth of about 120 m where the interplay of the diffuser operation, wastewater, and receiving water dynamics would result in dilutions of 1:200 or greater.

Case Study No. 3: Kathmandu, Nepal

The City of Kathmandu, the capital of Nepal, lies in the high foothills of the Himalaya Mountains. The present population is about 600,000 and is expected to increase to about 1,000,000 in the year 2000. It is a very old city, but today it is probably best known as the last major city on the route to Mount Everest.

The urban complex is traversed by the Bagmati River (Figure 6.4). The three streams that merge to form the Bagmati River rise in the mountains some 15 kilometers to the northeast of Kathmandu. The upper parts of the Bagmati River are steep and boulder strewn, but through the Kathmandu Valley it is wide and extremely turbid during most of the year. Upstream from Kathmandu the river passes one of the holy places of the Hindu world, the Pashupatinath Temple dedicated to the Lord Shiva. This passage by the Temple endows the Bagmati River with a special religious significance.

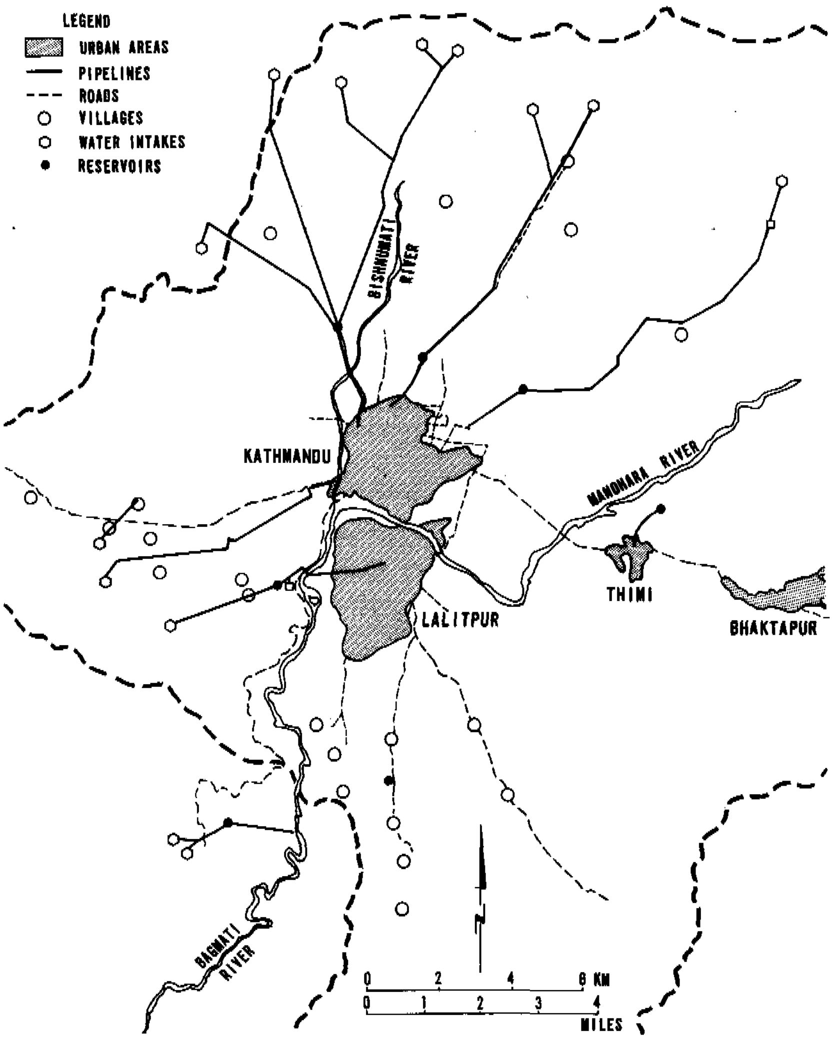
As the river flows through the urban area it receives flows from several tributaries some of which serve as open sewers for the urban area.

Flows in the river vary widely. During the Monsoon the flows exceed 30 m^3/s; during the low flow periods the flows are less than one cubic metre per second.

Water is withdrawn from the Bagmati River as part of the domestic water supply. The river is used extensively for washing clothing, cleaning household utensiles and personal washing, and bathing. Because of its religious significance the river is also used for ritual bathing. Other uses of the river include livestock watering and crop irrigation.

Except for a small area of the old city, most of the Kathmandu-Lalitpur areas are unsewered. Most of the people defecate on the river banks, in the fields, or on waste ground. There are some hand or cistern-flushed latrines connected to open drains, septic tanks, and cesspits. This lack of hygiene is reflected in the high incidence of enteric diseases in the area. As a result of these conditions the urban area should be regarded as a diffuse source of pollution. There are some point sources of wastewaters discharging to the streams, but to a great extent the waste loads reaching the streams are dependent on rainfall. During the dry periods human and animal excrement, household refuse, and other debris

FIGURE 6.4
KATHMANDU STUDY AREA



accumulate in the streets and on the river banks. When the rains come much of this material is flushed into the surface waters.

Studies

Master planning and engineering studies conducted over the last five years (Reference 3) were concerned primarily with finding the hydrodynamic and water quality characteristics of the Bagmati River system, developing water quality criteria and standards that could be used for design of wastewater management systems, and determining the best methods and locations of wastewater treatment. These problems were particularly difficult to analyze in this area because of the lack of water quality data and the fact that there were very few point sources of wastewater which could be analyzed.

The two major considerations that influenced the recommendation of water quality standards for the Bagmati River were (1) the need to maintain a level of water quality that would support the desired beneficial uses and would provide protection to public health, and (2) the attainability of the standards from both the technical and socio-economic points of view. The standards that were selected were as follows: dissolved oxygen, 5 mg/l; total coliform concentration, 1000 MPN/100 ml; and ammonia nitrogen, 0.5 mg/l.

The use of a criterion for ammonia nitrogen was based on minimizing the toxicity of any wastewater effluent that would be discharged to the stream. Toxicity resulting from industrial discharges (such as heavy metals) was not considered to be a problem because of the low level of industrialization in the area.

Analyses of water quality conditions to be expected under various waste loads indicated that the effluent should have a BOD of 70 mg/l and a dissolved oxygen concentration of 1 mg/l to maintain the 5 mg/l dissolved oxygen concentration in the river at most times. Additional effluent quality criteria were a total coliform concentration of 2000 MPN/100 ml and an ammonia nitrogen concentration of 1 mg/l.

Project

The results of the engineering studies (Reference 4) indicated that two wastewater treatment plants should be constructed. The largest, the Dhobigat Treatment Works is designed for an average flow of 15,000 m^3/d with a maximum hydraulic capacity for all structures of 38,100 m^3/d. The plant is a three-stage pond system with an anaerobic primary pond, a facultative secondary pond and an aerobic tertiary pond. The limited land area available, 30 ha, makes the use of mechanical aerators necessary.

The Kodku Treatment Works is designed for an average flow of 1,000 m^3/d. At this site there is sufficient land area so that the ponds can be sized and operated without mechanical aeration.

Case Study No. 4: Madras, India

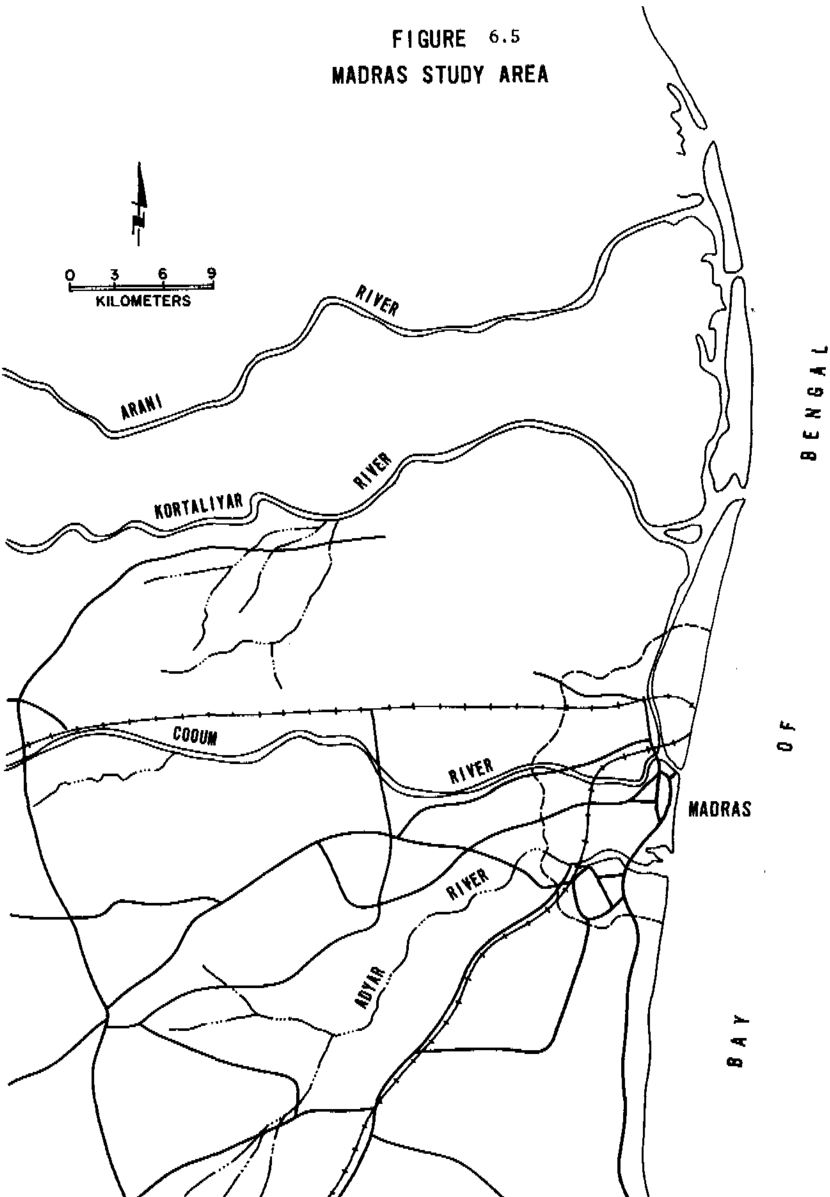
Madras is situated on the southeastern coast of India (Figure 6.5). It is the fourth largest city in the country and at present has about 4 million people in the metropolitan area. The city is the major port in this part of India and it has a developing industrial base; it is also a major agricultural center.

The sewage collection system was begun in 1872 in the oldest part of the city, Fort St. George. The Master Plan for the sewage collection and treatment system for the city was developed by the British in 1907. The facilities planned at that time envisioned a maximum population of 650,000 people. All of the wastewaters were collected throughout the city and carried to the ocean and discharged through a very short outfall just north of the port. This plan was followed until 1961 when a new comprehensive plan was developed by the City of Madras. That plan divided the City into a number of zones and contemplated the construction of wastewater treatment plants at a number of inland sites on the periphery of the urban area.

Problems with implementation of these plans have resulted in gross pollution of the coastal water in the vicinity of the ocean discharge and of the two major rivers that run through the city. The sewer collection system is surcharged in many areas even during dry weather. These conditions are due both to clogging of the sewers and to pumping stations which not only are physically inadequate but also are operated inefficiently.

There are approximately 40,000 head of cattle within the city limits and much of the dung from these cattle is disposed of through manholes into the sewer system. The high content of solids and straw in the dung leads to rapid clogging of the sewers. This problem is further compounded by the custom of washing metal bowls and pots with sand and disposing of the sand-laden wastewaters into the sewer system.

FIGURE 6.5
MADRAS STUDY AREA



Study

In 1976, the World Health Organization acting as the executing agency for United Nations Development Programme and World Bank funds initiated a Master Plan program for water supply and wastewater treatment and disposal for the Madras Metropolitan area. This Master Plan study (Reference 5) is presently under way and the conclusions and recommendations of the study have not yet been formulated. Nevertheless, certain problems and directions are becoming evident.

It is likely that the results of the Master Plan will support, in at least broad outline, the current directions of the city's wastewater management planning. Three major secondary wastewater treatment facilities are presently under construction and tenders have been received for the construction of a fourth secondary treatment facility. It is also planned to divert wastewaters which are presently disposed of to the ocean to one of these four treatment facilities, thus it is intended that all of the wastewaters generated in the urban area will be either reclaimed for industrial and agricultural use or will be disposed of on land.

DISCUSSION

The four areas described above are typical of areas in which increasing growth of commercial and industrial activity and of wastewater discharges has far outstripped the ability of either government or the environment to cope with the resulting problems. In Montevideo the sewer collection system has carried the wastewaters directly to the beaches and discharged them at the shoreline. The result has been gross pollution of a major resource of the area. In Kathmandu and Madras the grossly inadequate sewage collection systems have resulted in close contact between people and sewage and in extremely high rates of various enteric diseases. In Morphou Bay the problem has been severe damage to the local fishing industry and major aesthetic impact on the waters of the bay. In each of these cases, then, the major requirement is to eliminate, or at least drastically reduce, the potential contact between people and the wastewaters.

In almost all of these and similar situations in the less developed countries massive measures are required. Seldom is it a question of making minor improvements or upgrading existing treatment. Often there are no existing facilities, or where facilities exist, they are antiquated, insufficient in capacity, and incapable of being repaired economically. In Madras many of the major sewers are of brick arch construction with cement mortar joints, and they are more than 100 years old. As would be expected, in an extremely flat area with high temperatures, hydrogen sulfide generation has resulted in serious deterioration of the sewers. Thus, the planner and the designer are usually faced with the problem of recommending massive capital expenditures.

Long-range planning and the implementation of major facility plans can be accomplished efficiently only in a situation of political stability and well-established institutions. Almost by definition it is unreasonable to expect these conditions in the less developed countries. The relative lack of stability and experience must be considered by the planner in his evaluation of engineering alternatives and in his assessments of the environmental impacts of these alternatives. The impact assessment process cannot be done in a vacuum considering only its technical aspects.

The relative newness of political and technical institutions in the developing countries has a number of consequences. Implementation of major projects will often be much slower than it is in the United States. This may be due to a combination of factors such as difficulties in international financing, changing priorities of governmental agencies, inexperience of contractors who will construct the works, high rates of inflation, and difficulties in establishing rates for service charges to pay the continuing costs of the facilities.

A second major area of difficulty is the general lack of technical skills and experience in these countries. In many cases people who are technically trained are in managerial and executive positions, and people at the operational level have inadequate training and experience. Even if facilities have been designed and constructed properly, there is usually a serious lack of the skills necessary for proper operation and maintenance of facilities. This problem may be compounded, depending upon the country in question, by problems of obtaining parts for foreign made equipment and of foreign exchange.

All of these factors tend to bias the evaluation alternatives in favor of relatively unsophisticated solutions which do not require high levels of operation or maintenance skills. Thus, there is the tendency to favor pipelines which will remove the wastewaters to an area in which they can be highly diluted in the environment over solutions which might call for advanced waste treatment and discharge of the treated wastewaters close to population centers.

The situation in Madras provides an interesting exception. Water supply is probably the most critical problem in Madras. The municipal water supply system is able to deliver only about 40 litres per person per day from relatively good quality surface sources outside of the city. As a consequence there are approximately 6,000 shallow wells within the city used as supplemental sources of water. Most of the water drawn by these wells is grossly contaminated. Because of the water supply situation, there is an urgent requirement to utilize every possible source of water--including the reclamation of wastewater--so that available higher quality waters can be used for domestic water supply. This need is so extreme that is more than justifies attempting to solve the difficulties that will be met in the construction and operation of secondary wastewater treatment plants.

Construction impacts which can be of great concern in projects in urban areas in the United States are generally not viewed as seriously in the less developed countries. This is partially due to the fact that there is less awareness of noise and dust or traffic disruption as a source of major public concern. It is also due in part to the fact that a major public works project can provide a substantial amount of employment for unskilled labor. This latter view can in itself result in adverse environmental impacts. In a current master planning study the consultant found it necessary to abandon a recommendation for oxidation ponds as an interim treatment method which could be implemented quickly. The reason for deleting this recommendation from his report was the fact that the government has a firm policy that major excavation such as would be required for the ponds must be done by hand labor, i.e., no earth-moving machinery would be permitted. When the project was analyzed with that constraint, it was found that it would take about three years to complete instead of the six to nine months that would have been required if earth-moving machinery were used.

Staged implementation of a wastewater management system is often used to spread the costs of constructing the system over a significant period of time. In some cases this can be done without serious detriment to the environment. For example, in Rio de Janeiro a system was designed to collect wastewaters from the southern part of the city and to discharge them through a marine outfall off the Ipanema Beach. This plan stopped the previously serious pollution of both the Ipanema and Copacabana beaches. The system was designed so that a treatment plant could be constructed at a future data if this was found to be desirable. The offshore current conditions are such that there is a high degree of dispersion of the raw wastewaters discharged from the outfall, and it appears that treatment will not be necessary for many years.

In the case of Montevideo the receiving water conditions were such that it was felt that the discharged wastewaters should be treated to remove grease and floatables before discharge and this was recommended for early implementation. At Punta Carreta, onshore currents are frequent enough that the potential return of grease and floatables is a major source of concern.

In summary, environmental impact assessment of wastewater management projects in developing countries must necessarily be less sophisticated than in the United States or Europe. Generally, there is an almost total lack of baseline environmental data and there is seldom the opportunity or the funds to obtain such data. In most cases the environmental impact of present wastewater disposal methods is so adverse and so directly affects the population that potential concern over relatively subtle ecological effects is overwhelmed by the immediate necessity of alleviating gross public health and aesthetic problems. It is quite probable that as the standard of living and the per capita income levels in these countries improve more resources will be available and there will be a greater degree of public concern for the types of environmental impacts which we are familiar with in the United States.

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HEALTH ISSUES IN DEVELOPING COUNTRY PROJECTS

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INTRODUCTION

For hundreds of years man's socio-economic development has been marked by his modification of the environment. The Civil Engineer has served as a major agent of change through his designing and building projects to benefit mankind. He can be proud of the dam, roads, irrigation schemes, water and sanitation systems, power plants, etc., that have been built. But, at the same time he must be acutely aware that these efforts can be a two edged sword. For example, in addressing the Conference on "The Ecological Aspects of International Development" Dr. Barry Commoner said (1): "While nearly all of the projects described in the Conference were conceived as specific technological advances - the construction of a hydroelectric plant, the development of an irrigation system, enhancement of crop fields by chemical control of insect pests - they were in operational fact powerful intrusions on large-scale geophysical and ecological systems. Most of the difficulties which have been recounted at the Conference result from the failure to recognize this basic fact." He went on to point out that: "Nearly every irrigation project reported to the Conference has been followed by outbreaks, some of them disastrous of waterborne diseases of humans..." Thus, while most of the projects could be considered engineering successes one could well

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conclude that many were less than successful from the health and/or environmental point of view.

An engineer working abroad must be keenly aware that the developing countries have limited resources, have many areas in urgent need of attention and have much to lose from any misapplication of their scarce human, financial or technical resources. Therefore, when one designs and/or builds in a developing country, they must be knowledgeable about a number of diseases and environmental impacts that are seldom considered major problems in the United States such as: malaria, schistosomiasis, river blindness, chagas diseases, filariasis, malnutrition due to large scale population relocation, etc.

As one examines the nature of the projects being built and/or planned for the developing countries, it becomes increasingly important that design teams for projects in these areas be truly multidisciplinary, and that they include someone who has at least working knowledge of environmental impacts of epidemiology, disease vectors, as well as disease patterns and control techniques. For, very often the designer will have to provide measures for a number of physical impacts that are usually supplied by what we in the developed world would considered as "normal infrastructure" (i.e., basic sanitation, health surveillance, etc.).

Experience has shown that effective control measures are often neither costly nor difficult to implement, <u>if</u> they are incorporated into the project <u>during</u> the design stage. But, the same measures are very costly and often difficult to implement <u>once</u> the project has been built. In this regard, the World Bank reports that currently the "additional cost attributable to environmental and health safeguards in nonenvironmental projects (i.e., those other than for control of air pollution, soil erosion, reforestation, pest and disease vector control, etc) has ranged from zero to three per cent of total project costs, with the high end of the range applying where precautionary measures were added on the projects already well advanced." (2)

At the same time it should be recognized that as the number and complexity of future projects increase it may be necessary to take more extensive and expensive measures to control the various impacts to health and the environment. Thus, by postponing these measures from the pre-to-post-design period, the developing countries can expect to incur substantially increased expenditures.

In this paper the author will try to show some of the more common health and environmental problems one should expect in the developing countries. Then, using a multipurpose dam project, and irrigation scheme and a road scheme as examples it will be shown how these problems did (or could) affect those living and working in the project impact area. Finally, a check list of some of the major impacts that are currently being experienced in the developing world will be presented.

DESIGN ISSUES IN DEVELOPING COUNTRIES

As one seeks to design, build and operate large civil engineering projects (such as a multipurpose dams, irrigation schemes, etc.) in developing countries, we must be aware of the fact that while many of the technical design assumptions may be quite similar to those used in developed countries, there are fundamental differences in the types and kinds of health impacts that the designer must expect that the project will have on the area where it is to be installed. For example, one must be keenly aware of three essential facts:

1. The disease and environmentally related problems of a developing country project can be very widespread, longlasting and be very difficult to control once they get they have gained a foothold;
2. The disease patterns in developing countries are quite different from those found in developed countries thus invalidating many of the assumptions that are often made about the protective measures

that must be taken if the project is not to become a health and/or environmental problem; and

3. The health and environmental sectors of developing countries usually have very limited capabilities to assist large scale projects and control any adverse impacts.

Disease - A Major Impact.--As one examines the resources that would have to be brought to bear on the various adverse impacts that could potentially result from large scale engineering projects in developing countries, it usually becomes quickly obvious that a major potential problem area for the designer will be that of disease control. For it is here that the social and financial costs of prevention become clearly evident when compared again against the costs of controlling the "geni" once it has left its "Bottle." The "benefits" of such things as increased amounts of electric power, changed water quality, new life styles, greater crop potential, etc., cannot be realized unless the population in the impacted area can enjoy good health (i. e., not the mere absence of disease but, the total physical and mental well-being of the human beings). For, without health, the other benefits may be of little importance. Thus, unless those living in the impacted area are to suffer the "costs", while those living outside the area enjoy the "benefits", the designer must ensure that a healthful environment is established and maintained on a long-term basis in the project area.

As one examines the elements that must be considered in controlling disease (human-beings, the vector parasite, a transport medium and opportunity for infection) it becomes increasingly clear that water plays a key role in determining the types and kinds of impacts that large scale projects can have on an area. For example: 1) Access to, or lack of water will affect the basic sanitary conditions, and will be a major factor in determining the degree of sanitation that can be provided to the workers and those living in the area; 2) Water often serves as the transport medium for many of the diseases parasites. (For example, Schistosome eggs must find water within a month, where they must find a snail within 24 hours or die); 3) In other cases water will serve as the breeding media for one of the stages of the vector. (For example, mosquitoes breed in still water, the vector of Onchocerciasis breeds in rapidly flowing water whereas the vector of Filarisas breeds in dirty stagnant water); 4) Water can be the physical agent that forces people to move (physical change) as the reservoir fills. This may seriously affect the nutritional level of those living in the area as they learn to grow crops at their new living sites; 5) It can serve as a source to increase food supplies in the area (fish, irrigation, etc.) and 6) It can serve as a means of increased transportation and commerce, a fact that can bring people in close and constant contact with water and result in the spread of diseases such as schistosomiasis.

Thus, from the above one can see that the presence or lack of water will determine to a large degree the types and kinds of health and environmental impact that the designer can expect.

Disease Patterns.--In designing projects for the developing world one must be aware that the types, kinds and causes of diseases are quite different from those found in the developed countries. (See Table 7.1).

TABLE No. 7.1

Percentage Distribution of Deaths by Cause in Selected Model Populations*

Cause of Death	Model Developing Country	Model Developed Country
- Infectious, vector borne and respiratory diseases	43.7%	10.8%
- Cancer	3.7%	15.2%
- Diseases of the circulatory system	14.8%	32.2%
- Traumatic injury	3.5%	6.8%
- All other causes	34.3%	35.0%

*Adopted from World Bank Health Sector Policy Paper, pag. 10.

From the above, it can be seen that in developing countries the principal modes of spreading diseases are through: 1) Poor sanitation measures; 2) Vectors such as mosquitoes, snails and flies; and, 3) The respiratory secretions of infected persons. While all three are directly related to basic sanitation, personal hygiene and/or public health measures, poor nutrition is a major contributing factor as it impairs the normal responses to disease thereby reducing acquired immunities.

In comparison, the major diseases of the developed world are: circulatory system diseases (heart problems, hardening of the arteries, etc) and cancers. The sanitation/vector/respiratory diseases are 1/4 those of the developing world.

While diseases are the major adverse impact, there are many others that must be considered. Table No. 7.2 presents a summary of the check list of the other areas that should be considered in examining the health and environmental impacts of large Civil Engineering projects in developing countries.

As one examines the health statistics for the developing countries he finds out that their reporting and recording is a complex problem in itself, with no one ideal source of information. Not only is their reporting often very incomplete but, the degree of incompleteness varies, not only from country to country but, disease to disease. While recognizing the limits of the data, the annual statistics of the World Health Organization are probably the best source for country-wide mortality/morbidity data. To obtain data for specific diseases one should contact the national and/or provincial Ministries of Health, the national statistical services, the national or provincial planning offices, as well as the local representatives of the World Health Organization. But, one can usually expect the data to be scarce and incomplete.

Health and Environment in Developing Countries.--A designer for a developing country project must be aware that a major civil engineering project will often place heavy demands on weak or almost nonexistent health and

Table 7.2 The Most Common Impacts to be Considered in Developing Country Projects

1. Diseases Most Commonly Related to Large-scale Project Development	2. Social Impacts Resulting from the Project	3. Ecological Changes Resulting from the Project	4. Work Related Impacts
Malaria	- Social Dislocation	- Water Quality	- Job accidents
Diarrhea	- Deterioration of sanitation conditions	- Quantity of Water	- Works exposures to chemicals and/ or local diseases.
Schistosomiasis	- Changes in nutrition patterns	- Timing of water (i.e., irrigation)	
Onchocerciasis	- Changes in source and quantity of food stuffs	- Increase or decrease of disease vectors	
Filariasis	- Changes in family structure	- Changes in ecological balances	
Trypanosomiasis		- Chemical changes	
Trachoma		- Environmental changes	
Cholera			

environmental infrastructure. For, while the introduction of such a project will call for many social and medical services for the workers, their dependents, those living in the area and the camp followers attracted to the area, often, many normally expected public health measures such as food, water and disease monitoring, must be provided by the project because one will find that there is no infrastructure in the project area to provide them or because the government will not have enough out-of-budget funds to finance the additional services.

As there is a pronounced tendency for the services developed by the project to "spin off" and become national responsibilities as the project matures, the provision of health and environmental services should be done in close collaboration and in accordance with national systems and their philosophies. In this regard, it is interesting to note that there is an increasing trend for countries to require the planning and financing of environmental and health care facilities by project authorities. In addition, the World Bank now allows countries to include environmental considerations in their loan requests (2). Thus, health and environment are more and more being considered and costed as project elements.

In the United States, the various elements of social infrastructure (i.e., health, environment, etc.) are usually viable, responsible and able to bear the health and environmental impact burden of the projects that are built within their jurisdiction. Whereas, in most developing countries the health and environmental agencies are weak, undermanned and limited in coverage. For example, in 1975 the Pan American Health Organization reported "that some forty seven percent of the population of the Americas did not have access to even minimal health services" (3). In addition, the number and type of health and environmental impacts in developing countries are much greater and often are more widespread than in developed countries. Therefore, the designer should not expect that these sectors will solve many of the problems he creates. He must be aware of the potential ecological problems resulting from his efforts and, design their solutions into his own projects!

Another problem that must be faced is that often the engineer is involved mainly in the initial and construction phases of the project. Then,often plays only a minor role once the project has been built and is operating. Whereas the public health and environmental authorities often only have a minor role in the planning and construction phase but then they fall heir to the resulting problems . Thus, in order for a multidisciplinary group to be truly effective there must be a close working relationship between the short-term group (designers and builders) and long-term group (public health and environmental officials).

IMPACTS OF DEVELOPMENT PROJECTS (25,26, 28)*

As the aim of a development project must be to "benefit" mankind, the designer should strive to make sure that his action is not going to make matters worse. Too often those living in the impact area of the project have been "allowed" to suffer while the benefits of the project were "enjoyed" elsewhere. As examples of this, let's look at two actual cases and one potential one:

Volta River Dam--The Volta River hydroelectric project of Ghana,in Africa is a classic example of a carefully studied development project where the power is provided for cities and industries outside the immediate project area. It was known that the reservoir would cover over 3,000 square miles (about four per cent of the total land surface of the country), and the work was estimated to cost 145 million dollars. As the planners were aware of possible public health problems and exceptionally detailed and excellent study was made of the project. (The Report of the Preparatory Commission for the

*Indicates references that provide in-depth materials

Volta River Project in West Africa-1956). This document should be considered as a classic model for the planner who is responsible for considering the impact of such projects on human health (6). At the same time, it is disappointing to note that the Commission's recommendations were not fully and effectively implemented as the health aspects of the study were overlooked as political and financial problems grew.

When the reservoir was filled, it was estimated that an area of about 26,000 square miles (about 7.5 times the reservoir area) were impacted. Within this area (about one fourth of the land area of Ghana) live 1.3 million people (nineteen per cent of the total population). Of these, 78,000 had to be resettled over a period of three years at a cost of eight million pounds (more or less US$2.6 million). To achieve this, fifty two new settlements were created; seven hundred and thirty-nine villages were destroyed; 14,657 households were distrubed; and 973,000 domestic animals were moved. The impact of the change was terrible to behold. Houses had to be made into homes. Those being resettled had been forced by circumstances beyond their control to leave familiar surrounding and life patterns. The adverse health that many experienced cannot be attributed solely to the new environment. Change alone has been shown to have harmful effects (7). Many of those being resettled near the Lake were not fishermen but, had pursued various occupations such as farming, trading, etc... Thus many found themselves in strange surroundings facing new and unknown occupational hazards.

Within months after dam closure, snails began to appear and shortly thereafter, schistosomiasis was on the rise. There was an increase in the population of tsetse fly (Vector for African Sleeping sickness). And, while one of the vectors of River Blindness was eliminated by the flooding caused by the lake, another continued to breed in the chatchment areas. Authorities expect both diseases to increase, unless costly control measures are installed. It is interesting to note that an international coalition of bilateral and multilateral development assistance agencies (UNDP, World Bank, WHO, etc.) are mounting a $120 million twenty-year program to attack river blindness in the Volta River Basin. And, this is only one of a number of diseases that could be impacted by this dam!

Gezira Irrigation Project (8)--The Gezira, a triangle-shaped area lying between the White Nile and the Blue Nile, south of Khartoum, was a sparsely populated, semi-arid savanna until the completion of the Sennar Dam on the Blue Nile. This made possible the reclamation of nearly half a million hectares of land. Within a few decades, the Gezira became the most densely populated and the most prosperous agricultural region of Sudan.

At first the reclaimed land was almost exclusively planted with cotton. This crop permitted the simple and effective mosquito control measure of drying out the peripheral irrigation ditches at least once a week-- the time required for the life cycle of mosquitoes from egg to adult. Gradually, secondary crops were added: Millet, wheat, rice, etc., and the periodic drying out of the canals was abandoned. The result was that malaria became established in the area which had previously been free of this scourge. By 1975, in some villages more than half of the people were infected with malaria.

Since the building of the High Dam at Aswan, schistosomiasis has also started to increase as it is imported by workers moving back and forth between the various areas.

A major effort is now under way to control these diseases which will include spraying, drugs, larviciding and molluscicide programs. But, at the moment these diseases have endangered one of the most promising and dynamic developments of this type in Africa.

Darien Gap Vs. Foot-and-Mouth Disease (9)--Today there is only one break in the Pan American Highway that stretches from Patagonia to Alaska. This is a 400 kilometer stretch between Panama and Colombia called the "Darien Gap."

Construction work in the Gap has been held up for a number of reasons, including administrative delays, lack of financing, and the difficult terrain that has to be crossed.

As these obstacles are overcome, ecological concerns come to the forefront. Health officials now warn that the highway's completion would remove a major obstacle to the spread of foot-and-mouth disease from South America, where it is still an ever present problem, to Central and North America which are free of the disease. Being free of this disease means that Central America and Panama can export their cattle to any part of the world without trade restrictions. If foot-and-mouth disease were to be reestablished in the area a valuable industry, and a source of foreign exchange, could be lost.

If the road through the Gap is completed (now considered to be engineeringly possible) the disease could be reintroduced into those areas which have been made free of the disease. This could be an ecological horror story waiting to happen.

While one reads of the problems of construction and finance, little has been said of the increased cost to the health sector of Panama that will result from numerous workers going into an unhealthy and dangerous area. These costs coupled with those for the needed foot-and-mouth disease measures, will result in substantial expenses for Panama and Colombia, while the benefits will be enjoyed by those outside those countries.

HEALTH AND ENVIRONMENT CHECK-LIST (7, 10, 16, 25, 26)

As one seeks to control the impact of a project they must break the problem--How to maximize benefits--into its various health and environmental parts. The following is a check-list of the factors to be considered in examining possible health impacts of large-scale projects in developing countries.

1. Direct Impact Caused by Project on Those Living in the Project Area

1.1 Impact on Communicable Disease Patterns

1.1.1 Introduction of new strains of locally endemic diseases.
1.1.2 Introduction of new diseases not normally found in the area.
1.1.3 Extension of the area of locally endemic diseases.

1.2 Impact of Local Sanitation Measures

1.2.1 Failure of local sanitation measures because of large influx causing increase of diarrheas, etc.
1.2.2 Increase of respiratory pollution due to overcrowding.
1.2.3 Increase of environmental pollution due to inadequate disposal of human excreta and/or solid waste.
1.2.4 Increase of venereal diseases.

1.3 Impact of Water Resources

1.3.1 Deterioration of water quality because of contamination of groundwater, lakes, streams, etc., because of the burden of increased waste disposal.
1.3.2 Deterioration of water quality due to leaking, etc., from materials used by and/or disposed of in the project.
1.3.3 Deterioration of water quality due to increased diversions for project needs.

1.4 Impact on Ecological Balance

1.4.1 Fish kills due to reduced oxygene content of impounded water can cause a lowering of nutrition standards.
1.4.2 Long-term decline in fish spawning with persistent deoxygenation.
1.4.3 Thermal pollution of power plant operations can effect types or number of aquatic growths which can influence disease patterns.
1.4.4 Discharge of toxic effluents into the air and/or water courses.

1.5 Impact on Agriculture

1.5.1 Expose farmers to new diseases. For example, schistosomiasis in irrigation projects.
1.5.2 Reduced nutrition levels due to limited food supplies being bought up by project workers.
1.5.3 Reduced food supplies due to increased soil salinity.

1.6 Miscellaneous Impacts

1.6.1 Increased exposure of local population to traffic accidents.

1.6.2 Risks from certain industrial processes: accidental release of chemicals; excessive air pollution; discharge of chemical wastes such as mercury, etc.; excessive noises.

1.6.3 Adverse psychological effects due to displacement of from ancestral homes.

1.6.4 Dietary changes can result in serious side effects (diarrhea, cramps, etc.) from lactose intolerance.

2. Direct Impact on Project Workers

2.1 Exposure of Many Nonimmune Persons to Locally Endemic Diseases

2.1.1 Malaria is often underestimated as to distribution, ease of control (even with anti-malarial drugs) as well as severity.

2.1.2 Onchocerciasis is of particular concern on water resource projects in East and West Africa; Guatemala (Western slopes) Southern Mexico, Northern Venezuela and Amazonas in Brazil.

2.1.3 Schistosomiasis is of concern in water resource projects in Sub-Sahara Africa, Arabian peninsula, the Nile Valley, Iran, portions of the Middle East, Brazil, Venezuela, the lesser Antilles and Puerto Rico, China, Japan and the Philipines.

2.1.4 Tryponosomiasis (African sleeping sickness) which occurs in a very wide band accross the middle of Africa (between 15° N to 20° S) is generally fatal if not treated in its earliest stages. The American form, Chagas disease, is found mainly in South America (principally Argentina and Venezuela) and in much of Middle America.

2.1.5 Two forms of human filariasis are prevalent in vast areas of the world (more or less 250 millions in 1967) especially in South-east Asia extending along the coastal region as far north as Korea and into Indonesia.

2.1.6 Trachoma is widespread in the Middle East, in Asia, along the Mediterranean Littoral, and in parts of Africa, as well as parts of Haiti. High prevalence in generally associated with poor hygiene, poverty and crowded living conditions, particularly in dry, dusty regions.

2.2 Exposure to Chemical and Physical Hazards

2.2.1 Chemical hazards include: Dust, fumes, vapors, toxic liquids, etc.

2.2.2 Physical hazards include: vibration, temperature, pressure, radiation, noise, etc.

2.3 Nutritional Status

2.3.1 By providing low-cost food and/or supplementary foods the health and productivity of workers has been improved as well as reduction in accident rates.

3. Indirect Impact Due to Disease Vectors

3.1 Introduction of New Diseases

3.1.1 An example of this is the "sleeve" distribution of sleeping sickness in the settlements along roads, tracks and communicating streams of Africa.

3.1.2 The snail vector of schistosomiasis can be spread into an area carried on the mud on the underside of a car. A single snail is capable of quickly colonizing a new habitat.

3.2 Reinfection of Areas Previously Cleared of Disease

3.2.1 Control programs should aim at a combination of four actions: A) Erradication of the cause of the disease; B) Breaking the chain of transmission; C) Isolating the victim; and D) Strengthening the resistance of the victim.

3.2.2 Major emphasis is usually on vector control and treatment, with education in prevention an important element.

3.2.3 Once erradication has been achieved strict vigilance is required to avoid reintroduction of diseases (such as malaria) through reinfection of surviving vectors by feeding on infected humans who come from outside the area.

3.3 Increased Propagation and Spread of Existing Vectors

3.3.1 Increase in propagation of vectors

3.3.2 An increase in mosquito population results from the early stages of clearing, trash heaps, etc., therefore, engineering control measure and residual spraying must be used to control it.

3.3.3 The explosive growth of water plants can favor the massive reproduction of snails. Thus starting the disease chain for Schistosomiasis.

3.4 Spread of Vectors

3.4.1 Breeding of the fly vector of Onchocerciasis is generally arrested by the still water of a reservoir but, breeding sites are increased around spillways and below the dam where higher velocities and turbulence provide a favorable habitat. Treatment of the stream with insecticides is usual control method.

4. Impact on Existing Health Services

4.1 Heavy Demands on a Weak Infrastructure

4.1.1 Project creates a new force for a number of social and health services (i.e. medical care, etc.).

4.1.2 Project creates the need for increased surveillance; inspection, monitoring and action.

4.2 <u>Overwhelming of Locally Available Resources</u>

4.2.1 New demands often exceed budgetary possibilities of local authorities.

4.2.2 Many of the increased services are temporary (i.e. life of the project--sanitation surveillance) while others are long-range (Malaria, etc.).

4.3 <u>Provision of Additional Facilities as a Project Cost</u>

4.3.1 Project authorities should at least plan to provide sanitation and vector control measures during construction phase.

4.3.2 Designer should incorporate long-term measures into project (swamp drainage, lined ditches, piped water to relocated inhabitants, etc.).

4.3.3 National authorities should insist on assigning part of the project revenue to Public Health sector to allow it to develop needed long-term infrastructure in the area.

HEALTH PROTECTION FOR THOSE LIVING IN THE PROJECT AREA (4)

The first step in developing any project is the writing of the feasibility study. It is here that the health and environment components must be first considered along with the geological, engineering, economic and social aspects in order that <u>all</u> of these elements can be combined into a financially viable project. In doing so, the long-term impacts and costs of the health and environmental protection measures must be weighted against the short-term needs to build the project as quickly and inexpensively as possible. It must be realized that two groups of people are to be placed at risk. The first group (the project staff and project workers) will have a short-term exposure, i.e., a few years. Whereas the second group (those living in the impact area, those displaced by the project and those immigrating to the area) will be exposed to the designers mistakes for many years to come.

<u>Protection for Project Staff and Workers</u>--The protection for these individuals should start with the initial survey teams. It should be pointed out that such surveys are often carried out by persons from outside the project area. Therefore, the first protective measures are providing them with information on the diseases and hazards of the area, needed protective immunization

(such as shots for yellow fever, smallpox, tetanus, polio, typhoid and cholera) proper safety precautions (such as avoid wading in the stream in schistosomiasis infested areas, spray work areas to reduce trypanosomiasis and/or malaria) and available prophylactic medicines (such chloroquine for malaria).

The major tropical diseases and their vectors are shown in Table 7.3.

Table 7.3. Common Water Related Vectors and Diseases

Vector	Disease	Condition of Water at Vector or Parasite Breeding Site
Mosquitoes		
	Malaria	Quiet or standing in ponds
	Filariasis	Stagnant and polluted
Snails		
	Schistosomiasis	Slow moving
Flies		
	Onchocersiasis (River Blindness)	Rapids or turbulent waters
	Sleeping Sickness	Breeds near water
Bugs		
	Chagas	(Lack of water creates unsanitary conditions in which the disease can be spread)

Most of the diseases have a man intermediate host to man chain of infection in which water and/or lack of sanitary conditions play a major role. It has been said that the disease of standing clear water is malaria (1, 4, 12, 13, 14, 15, 16, 17); of standing polluted water (i.e., latrine, drainage diches etc.) is filariasis (1, 4, 7, 15, 16, 17), of slow moving water (irrigation ditches, streams, etc.) is Schistosomiasis (1,4, 8, 10, 15, 16, 17, 18, 19, 20, and 21); and, of turbulent water (i.e., rapids, turbine discharges, etc.) is Onchocersiasis (1, 4, 7, 8, 10, 15, 16, 17, 23, 24). A major insect borne disease related to man living habitat is trypanosomiasis (1,4,6,15,16,29,30). In Africa this disease is called sleeping sickness and its vector is the tsete fly (as the fly breeds in the trees near water its incidence can be reduced by selective removal of brush from around streams and water holes). In the Americas it is called Chagas disease, and as it is spread through contamination of conjunctive, mucous membranes and abrasion of skins wounds by fresh infected bug feces (vector in Reduviidae or cone nose bugs), sanitation of the living environment and spraying are major control mechanisms.

Problems Concerning Relocated Persons and Immigrants--In considering the impacts on relocated populations, one must be aware that the change itself is often a traumatic experience. To this is often added the problems of malnutrition as the limited food supplies of the area are bought up by the higher pay project workers. To these are added the problem of physical planning of the new villages, (preferably off the shorelines of the new lake or away from the irrigation ditches to avoid schistosomiasis), the provision of adequate quantities of safe water (at least 30 liters per capita per day) as well as the safe and sanitary disposal measures for human wastes (to avoid Filariasis and Trypanosomiasis).

The second group to be concerned are the immigrants, as they can serve as the reservoir to be infected with diseases that are found in the area or they can serve as the source of new diseases for vectors that are carried into the area or were already there.

AREAS OF FUTURE DEVELOPMENT

During the coming decades billions of dollars will be invested in the social, industrial and economic sectors of the developing world. Many of the countries are feeling intense pressure to develop their energy measures, to improve their agriculture, to provide new lands and job opportunities for their growing population.

As one examines the future growth patterns of developing countries, it becomes clear that the areas of food and energy production will be two of the critical factors in any long-term development effort. Because large-scale water resources projects, such as multipurpose dams, can provide cheap, dependable and "clean" electricity as well as new land for food production, their development is virtually assumed.

When one couples the fact that the largest remaining uncultivated but arable lands in the developing world are in Africa and South America (10)--eighty four per cent of potentially arable land in Asia is already cultivated--with the fact that these two areas have developed only ten to fifteen per cent of their hydropower potential (11), it is obvious that these regions will be the site for many of the large-scale water resources projects of the future.

While nuclear power is being considered in many countries its widespread use will require a high level of technology that is often not available in many developing countries. Whereas, dam construction and irrigation schemes can be made highly labor intensive to fit the conditions of the developing world.

Thus, one can expect that growing numbers of large-scale water resource projects (i.e., multipurpose dams and irrigation schemes, etc.) will be built in the developing world. Providing the techniques for preventing the various detrimental impacts that these projects could and/or will have on those living in its area of influence is the role of the project design team.

To do this, they need some professional guidance to help them undertake realistic health and environmental impact studies. For, it is only when those in the decision making process understand the long-range "costs" of these impacts can they make truly economic (i.e., social plus financial) technical decisions, instead of the financial technical ones that are often made because the decision maker does not fully understand the consequences of his decisions. What designers would condemn millions of people to suffer river blindness, rather than provide a pipe into the turbine discharge for mixing insecticide? (When sized at one micrometer in diameter and mixed at the rate of 1/40 ppm, DDT keep 70 miles of Nile rapids free of the vector-the blackfly (simulium)-of this dread disease that currently affects 20 millions).

To help develop realistic assessment analysis techniques the Pan American Health Organization (PAHO) has established Environmental Impact Analysis (EIA) as the primary area of work of it Human Ecology and Health Center (ECO) for the next three years.

HEALTH AND DEVELOPMENT

As mankind seeks to "develop" new lands, areas and projects, he often finds that he has to modify his environment. To do this the designer needs to combine the three Ms (men, many and materials) into a project that will have the minimum of adverse impacts. For, as Ian Burton states "A measure of the success of people in harnessing science and technology to their ends is not to be found in the degree of complexity or sophistication or newness of what is employed, but in the degree to which it preserves and enhances those values and qualities of life that are considered important."

As we examine the technologies that are available to design and build the roads, dams, irrigation schemes, etc., one is impressed with the need for better use of resources and techniques that already exists. It appears to the writer that often the failure to insist on using available knowledge results from a lack of indepth understanding of the potential health an environmental impacts of not doing so.

As the fundamental role of the health and environmental sectors are to act as catalysts in seeking the highest quality of life for the population at large, they have the obligation to see that the impacts cost of each project are properly and adequately considered. For, unless the various factors that seek to change existing men-environmental relationship are viewed in an integrated manner and in an ecological (health and environment) framework, "development" will be hallow word to many in the project areas!

In view of the lack of supporting infrastructure in many developing countries, only a multidisciplinary team of engineers, public health officials and environmentalists can ensure that the project will be an engineering, public health and an environmental success.

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PUBLIC UTILITY PRICING AND POLLUTION CONTROL

by

Jeremy J. Warford and Patricia L. Rosenfield 1/

1. Introduction

Shortcomings in the traditional means of measuring economic well-being--namely, per capita income--are well known, and recent years have seen a spate of literature on alternative approaches that may be adopted. One class of problems is headed by the difficulties of handling a number of expenditures that in large part are incurred in order to deal with past economic growth. Of these, possibly the most important is expenditure on pollution abatement. Another class of problems relates to the question of incidence; per capita income figures may mask considerable inequalities, and a positive rate of economic growth in aggregate terms might well be associated with a decline in real income for certain elements of society; in many instances the "trickle down" effect may be too slow to be a useful economic concept.

This paper examines the relationship between these two sets of problems in a developing country context. In discussing the types of environmental problems commonly found in developing countries, our emphasis is not on those relatively few, highly visible, large-scale engineering projects which invariably command the attention of environmentalists, and which are

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normally subject to government approval and supervision. Rather, our concern is with the problems of controlling a massive number of smaller-scale activities which cumulatively, and by an insidious process, may have a much more significant environmental impact. The "growth versus environment" issue as it relates to developing countries is briefly examined, and methods of controlling environmental pollution caused by individual activity are discussed. The pros and cons of pollution charges versus regulation are considered in light of certain relevant characteristics of developing countries, such as the large income inequalities, the relatively localized nature of the pollution problem; the particular drawbacks of using national income data to measure economic welfare, and the acute fiscal needs. From the foregoing, it is concluded that public utility pricing and investment practice in developing countries--specifically in the water and wastes sector--offers valuable lessons regarding the way in which environmental pollution more generally may be handled.

2. Environmental Problems in Developing Countries

The negative environmental impacts of large-scale engineering projects in developing countries have received much attention in recent years. The dangers of increased malaria and schistosomiasis transmission from man-made lakes and irrigation systems, soil erosion from improper land-clearing techniques, destruction of flora and fauna resulting from highway and railroad projects or the construction of thermal power plants are well documented, and formal acknowledgement of the need to ameliorate such effects is made by most governments. The political will to deal properly with such problems, however, may be lacking, but that is not a subject that concerns us here. What does concern us is the fact that, while it is difficult to deal with the environmental aspects of large-scale engineering projects, it may be infinitely more difficult to deal with the pollution problems caused by a myriad of small-scale activities. The problems of political will arising from the cumulative effects of small-scale activities are similar; those of measuring and controlling environmental damages, however, are of a different order of magnitude in their complexity. 1/

In developing countries the environmental manifestations of small-scale private activities are typically encountered in urban areas in which rapid population growth is unmatched by investment in infrastructure. It is typical to find urban slums containing large numbers of people whose drinking water is polluted, who have no means of satisfactorily disposing of wastes, and therefore pollute existing sources; whose homes are surrounded by solid waste, filth and excreta; who have to breathe the foul air that this generates, and wash their clothes in waterways that are to all intents and purposes, open sewers.

Although it is probably true that the poor always suffer more from environmental degradation than the rich, the unequal burden appears to be particularly marked in developing countries. The relatively localized nature of the above type of problem suggests that the rich can take evasive action, for example, by buying homes in less-congested areas, or where adequate water supply and sanitation services are available. In contrast, in developed countries, even the poorest members of urban society usually have access to adequate water and sanitation services, while even the rich find it difficult to escape from the pervasive pollution of industrial activity.

1/ Small-scale polluting activities may, of course, be associated with large-scale development projects. The resettlement villages that are usual components of man-made lake schemes may have inadequate water supply and sanitation systems which are particularly serious due to the increased concentration of the displaced population.

3. Growth, Pollution, and Basic Needs

In development literature, the problem of poverty has traditionally been approached by advocacy of rapid economic growth, the implied assumption being that the benefits of that growth will be disseminated in a reasonably equitable manner among income classes. Experience, however, has shown that, particularly in the developing countries, the necessary distribution of the benefits of growth has not in fact occurred. It is now widely believed that even with a shift in development strategy that stresses employment creation, 1/ it is unlikely that the problem of poverty can be satisfactorily addressed without a more direct strategy, namely a commitment on the part of governments to ensure that all members of society can avail themselves of certain basic needs. These basic needs have been defined to include an adequate supply of food, shelter and clothing, as well as access to a number of essential services such as safe drinking water, sanitation, public transport, and health, cultural and educational facilities. 2/

While adequate water supply and sanitation are clearly fundamental elements of any campaign to deal with environmental pollution or to satisfy basic needs, we still have a long way to go in determining, for example, how much water, of what quality; what degree of access; and whether its disposal should be by means of open drains, water-borne sewers, or some intermediate technology. Solid waste disposal, it would appear, should often be included as a basic need, particularly as in those cases in which solid waste blocks drainage canals, spilling water-borne waste and contaminating water supplies. It is, however, not our intention to attempt to define basic needs; this,

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1/ H. Chenery, et al, Redistribution with Growth, Oxford University Press, London, 1974.

2/ Meeting Basic Needs, International Labor Office, Geneva, 1977.

of course, is a matter of continuing analysis which has to be carried out on a case-by-case basis. Instead, we address the types of policies that, in a developing-country context, are most likely to bring about an improvement in the urban environment.

Acceptance of the basic-needs approach does allow us to some extent to assume away the distinction and much-publicized conflict between environment and growth for the underprivileged urban dwellers of less developed countries. Environmental improvements, plus the other indicators noted above, might be better proxies for real income and growth than national income figures, at least as far as the urban poor are concerned. For example, while urbanization may be associated with national income growth, the increased wages earned by urban workers may not adequately compensate for a deterioration in their working and living conditions. The problem may in fact be compounded in those instances in which productivity may be impaired by the decline in public health that results, and which may prevent the underprivileged from breaking out of the vicious circle of poverty, disease, unemployment and moral degradation that they are now in. Should this view be accepted, namely that certain of such improvements are the ultimate ends of economic activity, national income figures and economic benefits notwithstanding, the question then becomes one of determining how these basic needs can be met as quickly as possible. While generalizations about the appropriateness of policies for developing countries are difficult to make--as defined by the World Bank, that group includes countries as diverse as India and Chad, Brazil and Fiji--a number of characteristics such as low per capita incomes, skewed income distribution; rapid population growth, particularly in urban areas; and acute fiscal problems are, by definition or otherwise, normally associated with developing countries. We now briefly examine these characteristics with special reference to their relevance for environmental policy.

4. Income Levels and Distribution

The one characteristic that by definition unites the 111 countries currently classified by the World Bank[1/] as "developing" is their relatively low levels of income. With the exception of Israel, Greece and the oil-producing countries, all had per capita incomes of under $1,850 in 1973. Over 70 countries had annual per capita incomes of less than $500. In addition to low average incomes, the distribution of income is generally more skewed than in the more developed countries, so that a large proportion of the total population is often living in poverty even in countries where the average income may be moderately high.[2/]

The combination of absolutely low per capita incomes and maldistribution of income is generally associated with a totally inadequate provision of basic needs. For example, when considered in global terms the magnitude of the problem in the water supply and sanitation sectors is staggering. The World Health Organization has estimated that in 1975, 127 million urban dwellers (out of a total urban population of 577 million) were without a reasonably adequate water supply, and 140 million were without adequate sanitation facilities. In rural areas the situation is even worse, with only 22% of over 1.4 billion people having access to reasonably safe water and 15% having rudimentary sanitation. Just to serve the 1975 urban population through a combination of house connections and public standposts and to provide minimal sanitation would cost nearly $17 billion. To provide access to

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1/ See World Tables 1976, World Bank.

2/ See, for example, Harry T. Oshima, "Income Inequality and Economic Growth. The Post War Experience of Asian Countries," The Malayan Economic Review, October 1970, p. 13.

safe water for everyone by 1990 (as recommended by the World Habitat Conference and endorsed by the 1977 UN World Water Conference) would cost in excess of $60 billion at today's prices plus as much as $200 billion for waste disposal.

While by definition, per capita incomes in developing countries are relatively low, the per capita costs of providing access to service (of a given quality) in the water and wastes field do not differ systematically from per capita costs in developed countries. For example, a recent bid for sewer construction in a Middle Eastern city amounted to $1,000 per capita, which is about five times as great as per capita income in that country. In relation to incomes, therefore, the costs of water and waste disposal are highly significant, and in consequence, measures to avoid wasteful use of these facilities are of critical importance.

5. Population Growth

The problem is compounded in developing countries by rapid population growth rates that increase demands for service on the one hand while eroding the growth of per capita income (and thus ability to pay) on the other. This point is amply demonstrated by comparing the growth rates of developed and developing countries during the period 1965 through 1973. The real gross domestic product of less developed countries as a group increased at an impressive average annual rate of 6% compared with 4.6% for the industrialized countries.[1/] However, when one looks at per capita growth rates the figures are 3.5% for the developing countries and 3.6% for the industrialized countries.

The urban areas of developing countries often exhibit an explosive rate of population growth, generally two to four times the already high

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1/ World Tables 1976, World Bank, p. 392. The industrialized countries group excludes centrally planned economies which grew at an average annual rate of 4.8%.

national population rate. This frequently results in the establishment of large, unplanned squatter settlements, usually located on the urban fringe. Population movement is often too rapid to permit the enforcement of zoning or other planning ordinances, and city administrations are frequently overwhelmed with the problem of providing basic amenities such as potable water, sanitation facilities and adequate transportation to places of employment for this segment of the population. The problem has been compounded because haphazard and unpredictable patterns of growth deny the possibility of planning efficiently to meet future needs. Water supply and other authorities are constantly "patching up" or just meeting the most critical emergencies as they arise.

6. Inadequacy of Public Savings

The fiscal consequences of the rapidly accelerating demands for infrastructure on the one hand and the consequent engineering inefficiencies in supply on the other are clearly profound. The highly publicized fiscal problems of US cities pale into insignificance in comparison with the burdens of many cities in the developing world--such as Djakarta with its 1,125,000 squatters and slum dwellers and Calcutta with its 1,710,000.[1/] This, however, is but one manifestation of problems generally encountered in developing countries, namely an inadequate rate of public savings. This inadequacy is, of course, in large part explained by absolutely low levels of per capita income, and no short-term solution to this problem is in sight. However, other measures are feasible and can be used to ameliorate the problem. In examining alternative measures, it is well to bear in mind that the importance of non-monetary income, and the fact that building progression into the tax

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1/ See, for example, Urbanization, Sector Working Paper, IBRD, June 1972.

system requires a complex, sophisticated machinery that is not usually available, cause special difficulties in developing countries. As Squire and van der Tak[1/] have pointed out:

> "....in general, redistribution can never be costless and that, in particular, redistribution in developing countries may be so costly as to be prohibitive. With regard to the general argument, all fiscal measures have an administrative cost and, at least in principle, a cost resulting from an unfavorable effect on incentives. With regard to the particular argument, the very unequal distribution of income-consumption in most developing countries and the difficulty of raising additional revenue indicate severe constraints on the government's use of the fiscal system. These constraints typically reflect an inability to raise sufficient revenue because to do so is not administratively feasible and an inability to tax the rich sufficiently because of that group's political power. Moreover, the general fiscal system of most developing countries (and, in fact, most developed countries) cannot possibly reallocate the benefits and costs of projects as varied and geographically dispersed as those usually found in these countries."

The foregoing suggests that investment policies may be judged according to the following criteria:

- economic efficiency, i.e., the goal of maximizing the excess of project benefits over costs;
- income distribution, whether on the cost or benefit side;[2/]
- mobilization of financial resources, for the relatively limited goal of ensuring the continued viability of the agency controlling the investment, or more broadly, to increase public savings.

The operations of public utilities in developing countries are increasingly being evaluated in such terms,[3/] but general environmental

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1/ Lyn Squire and Herman G. van der Tak, Economic Analysis of Projects, World Bank, Johns Hopkins Press, Baltimore 1975.

2/ Squire and van der Tak advocate the incorporation of weights for public savings and income distributional effects into cost-benefit calculations.

3/ See, for example, World Health Organization, Report on Community Water Supplies, paper presented at UN World Water Conference, Mar del Plata, Argentina 1977.

policies usually are not. However, it appears that recent thinking regarding the role of public utilities in achieving development objectives is highly relevant for general environmental strategy. We therefore now examine the way in which utilities--specifically water supply authorities--in a number of developing countries are beginning to grapple with the above issues.

7. Water Supply Pricing and Investment Policy in Developing Countries

As the previously quoted data on access to service suggest, the performance of water and sanitation authorities in developing countries is far from perfect. However, there are encouraging signs that utilities are beginning to adopt measures that will bring about a considerable improvement. Indeed, compared to other public institutions, their record is already fairly good. Particularly at the municipal level, public utilities, largely by virtue of financial policies aimed at recovering from beneficiaries operation and maintenance costs and debt service plus some contribution to capacity expansion, often stand out as relatively efficient, self-contained entities in a general administrative structure that is financially deprived and poorly managed. While national and municipal authorities--as is usual--are desperately short of funds, public utilities, by exerting their local monopoly power and having the sanction of depriving consumers of supply in the event of non-payment, have considerable potential for good or ill; the challenge is to use this potential to assist achievement of social objectives, of which the improvement of environmental quality is one.

The problems of low and unequally distributed incomes and fiscal constraints are now being addressed in two main ways in the water supply sector: (a) by pricing policies in which initial consumption is subsidized, after which subsequent units are charged at a much higher rate, often approaching the full incremental cost of supply and disposal, and (b) by variation in service standards, such as provision of public standposts. In this regard, policies that are now common in developing countries may be seen in stark contrast to those in the developed countries. Thus the urgency of avoiding waste and of providing basic needs is clearly recognized in the developing world; in consequence most water authorities employ some form of increasing block rate. In contrast, the American waterworks industry continues to advocate the wasteful and inequitable policy of declining block--or promotional tariffs.[1/] As for service standards, while there is not much prospect--or indeed justification--of lowering water supply service standards in the United States, there may very well be developments of this kind in the waste disposal field. A study currently underway in the World Bank on alternative waste disposal methods, although primarily directed at developing countries, may have valuable lessons for the developed world.[2/]

The use of a multi-step tariff in which the price for a minimal amount of consumption is subsidized, and in which subsequent consumption is charged the full incremental cost of supply and disposal is clearly consistent with the "basic needs" philosophy. Furthermore, since the unit costs of water supply are rising, it can usually also be associated with financial profitability, making possible still further extension of service to those currently unserved.

1/ Although acute water shortages in some parts of the US are now forcing utilities to reconsider the merits of the traditional approach. For a further discussion, see Jeremy J. Warford and DeAnne S. Julius, Water Rates in Developing Countries, Report No. PUN 27, Energy, Water and Telecommunications Department, World Bank, March 1977. Note also that the progressive tariffs normally employed by water authorities in developing countries are particularly beneficial for those consumers who would otherwise have to pay exorbitant prices to private water vendors.

2/ This project is described in Appropriate Technology for Water Supply and Waste Disposal in Developing Countries: A World Bank brochure, June 1977.

While we have attempted to define away the environment-growth conflict for the poorest elements of society, we cannot avoid the issue that a shifting of funds to consumption must be at the expense of some savings, which are necessary if the achievement of basic needs in future years is not to be impaired. However, the pricing and investment strategy described above is not only conducive to the provision of basic needs, but also discourages wasteful use of water by larger (generally wealthier) consumers, thereby forcing the necessary redistribution of real income to take place. The advantages of such a policy are threefold. First, mobilization of the necessary financial resources to meet basic needs is conducted in a way that minimizes the burden on public funds, since redistribution takes place within the sector. Second, due to the impact of higher prices on consumption for larger users, it may also effect resource savings[1/] that can contribute to future economic growth. Third, the provision of basic needs might be expected to improve the health of beneficiaries with a consequent increase in their productivity.

The foregoing strategy affords important lessons for environmental policy in general. It is now generally recognized that user charge policies are a critical element of any strategy to improve water supplies in developing countries. The tendency to argue that because something is "good," it should therefore be subsidized, is now, with regard to water supply, giving way to a more realistic attitude.[2/] However, the role of financial policy in supplying basic needs to the underprivileged, in curbing wasteful use of resources, and generating public savings has considerable scope in other areas of environmental concern.

8. Charges and Regulations

Economic incentives are, of course, not the only means of achieving improvements in the environment. In addition to financial policies such as

1/ The potential savings may be considerable, since in most developing countries, a relatively small number of consumers are responsible for a disproportionately large share of total water consumption.

2/ WHO: Report on Community Water Supplies, op. cit.

user fees or effluent charges, regulations are used as a means of controlling or preventing environmentally harmful acts. Arguments for and against the use of economic incentives and regulation have been extensively debated, and we do not propose to examine them in detail here. In brief, however, the arguments tend to boil down to the position that while a system of regulations may achieve a desired standard of environmental improvement with greater speed and certainty, the incidence of pollution control costs will tend to be allocated more efficiently under a system of effluent charges. Since self-interest in maximizing profits will lead polluters to reduce pollution up to the point that the cost to them of a unit reduction is equal to the amount of the charge, a given degree of pollution abatement will be obtained at least cost to society as a whole.

Much of the debate on the merits of charges and regulations has centered on the amount of information on pollution control costs and benefits that is required by each method, on administrative difficulties, certainty of results, and problems of monitoring and policing the activities of polluters. It is somewhat fruitless to attempt to draw general conclusions from these arguments regarding the procedures that are universally appropriate for developing countries, but because of the extreme shortage of public funds, and the extreme difficulties of mobilizing funds for investment by traditional fiscal means, the effluent-charge approach becomes relatively much more attractive in the developing than that in the developed world. As in the case of water supply, unit costs of environmental pollution appear to be increasing. Whether revenues from polluting activity are channeled to government for general purposes or are ploughed back into environmental improvement projects, such as collective treatment or disposal of wastes, or expansion of water supply facilities, the potential for generating public savings is clear.

In this regard, it is instructive to compare the methods that are normally used to control the discharge of trade effluents into rivers with the methods employed to control discharge of wastes into public sewers. Typically, the first is controlled--if at all--by regulation alone, while the second relies heavily upon user charges, combined with certain regulations. One reason for the difference in approach is quite apparent: sewage collection and disposal requires an on-going system expansion, and operation and maintenance costs and debt service have to be covered. On the other hand, the costs of discharging wastes into a water course are primarily borne by those firms and individuals who are unfortunate enough to be located downstream. A case can, however, be made on the grounds already referred to--namely economic efficiency and mobilization of financial resources which could be used either for collective pollution abatement measures, or for other purposes entirely--for collecting fees from polluters of rivers, just as is normally done for those who make use of public sewers.

9. Conclusions

The need to coordinate various environmental improvement activities is apparent. It is still true that in some countries there is little coordination even between water supply and sewerage investment and pricing policy, and an integrated approach to environmental control is virtually unknown in the developing world. Clearly, the enforcement of a sewerage fee is not likely to yield optimal results if the waste can simply be discharged into a river at no cost to the polluter. Similarly, solid waste controls, whether charges or regulations, need to be accompanied by appropriate controls over the burning of waste matter. This suggests that environmental sector studies, based on large metropolitan areas, should be routinely carried out. Encompassing at least water supply, sewerage, river pollution, and solid waste, the scope for user charges and controls should be analyzed, in light of certain defined basic needs goals. Implementation of the appropriate policies will frequently require the establishment of a local authority with overall responsibility for environmental improvement. The variety of policy tools at its disposal should be wide-ranging, and include water and sewerage charges, fees for solid waste collection and disposal, effluent charges and regulations.

The institution should be financially autonomous as far as possible, with subsidies from government only for highly specific purposes. The performance of its management would be judged on the basis of expansion of service or degree of environmental improvement (for example, meeting certain basic needs targets), subject to achieving a satisfactory (i.e., standard public utility) financial performance. Just as water authorities in developing countries are now hastening to expand service to all by a variety of means, including progressive tariff structures, the more diffuse goals of the environmental agency should be defined in equally measurable terms so that its performance can be effectively monitored. It is recognized that the political and administrative difficulties of establishing and controlling such a powerful multi-purpose authority would often be immense. However, the goal of improving the environmental well-being of the poorest people in the world suggests that the effort would be eminently justified.

ENVIRONMENTALISM, DESIGN, AND PERFORMANCE STANDARDS

by

Beatrice E. Willard[1]

I. Introduction

It is always a privilege for me to have an opportunity to interface with engineers. Ecologists and engineers make an excellent complement for one another--the one investigating the complex interacting processes operating in our environment; the other applying tools to design means for bringing man's physical needs and activities into concert with our environment. One has the what, the other the how. But this is not an easy set of tasks. It is complicated, especially when viewed on the world scene against the widest array of cultures, ecosystems, and individual needs. However, by pooling our resources and forming a team, we can accomplish much.

Recently, Robert Katz, geographer at Clark University, pointed out a significant fact in relation to environment that is relevant to our deliberations today. He said, "Natural hazards are beneficial to the operation of Earth's systems; they only become human catastrophes when man takes too much risk in regard to them." At first glance, this sounds crass and cruel. But he expands by means of examples to show that humans have the unique capability to understand Earth's processes and principles, and to plan their activities to avoid inordinant risk to himself or his surroundings.

Now I know this concept is going to fly in the face of you who have been trained to surmount risk and who pride themselves in their capacities to engineer solutions in face of great risk. I have not presented it in my introduction for the purpose of offending you, but rather to focus your thought on where we are TODAY. Further, I recognize that not all situations will fit into this category of hazard turned catastrophe--they won't. I also know that much is gained under specific circumstances by taking a certain amount of risk. But that is not what is meant here.

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What I hear Dr. Katz saying is what I heard William Putnam, a California geologist, saying to me when he told of how, in the 1930's, he went to the Los Angeles Department of Water and Power when he heard of their plan to drill through the Mono Craters in Eastern California, instead of taking the new aqueduct around the end of these volcanos that had erupted as recently as 2000 years before. When Dr. Putnam shared his knowledge of the risks involved, the engineers told him they had not sought his advice and intended to proceed with their plan, which they did. Some time later, they literally were in hot water inside the Mono Craters. It took three more years of effort and untold amounts of money to complete the job that easily could have been accomplished in a much more simple, direct manner with low risk.

You can say, "But that was more than 40 years ago and times have changed," except that we went through a very similar situation in Colorado with the Straight Creek Tunnel construction in the 1960's. Again the geologists pointed out that the route was in a major fault zone of the Continental Divide. And, we all have watched with chagrin the same situation with Teton Dam very recently.

What does all this mean? That we should fold our hands and stop developing? Not at all! Fortunately for all of us, there are natural principles operating on Earth from which to derive applicable criteria for guiding our planning. There are facts and figures that assist in deciding which direction to take. There are numerous observations on how Earth's systems operate that are useful in developing designs and plans, as well as guiding their implementation. It does mean that we be more intent on knowing and understanding the natural principles operating in our environment. It means that we orchestrate our activities <u>with</u> natural principles as the National Environmental Policy Act directs, rather than at counterpoint to them, as we have been doing frequently.

Before we look at these principles, I would like to define a group of terms--not because I think you do not know their meaning but because certain specific meanings of these words are particularly useful in deliberations such as these.

1. <u>Environment</u>. Sum total of the physical and chemical factors--climate, water, soil, etc., in which living things live; for man, environment also includes economic, social, political, and cultural factors.

2. <u>Ecology</u>. The science that investigates the nature and operation of ecosystems as entities. This science has been practiced by professionals here and abroad for over a hundred years. "Eco" comes from the Greek, meaning "home" or "habitat" and is the same root as in economics. This is not mere coincidence; in Ancient Greek, "economics" and "ecology" were interchangeable terms and can be again.

3. Ecosystem. Any recognizable unit of the landscape--desert grassland, tropical rainforest, Arctic tundra, etc. Ecosystems are composed of environmental factors, living things including humans, and the dynamic interactions that operate among these components. The components and processes vary considerably from one ecosystem to the next, so each ecosystem type merits individual attention.

4. Environmentalism (conservation). A philosophy of management. Teddy Roosevelt termed it "wise use." It leads to developing an ethic about human relationships to land, air, water, living things, people, ecosystems. People of various backgrounds are environmentalists.

5. Growth. The New Webster Dictionary defines "a gradual development toward maturity" (which is defined as perfection or excellence). Interestingly, this definition omits reference to increase in number, size, or amount.

6. Need. Urgent requirement for something essential, or desirable, that is lacking.

7. Demand. To ask for boldly, urgently...as with a right, with authority; to call for as necessary.

8. Design. To create, plan, or calculate for serving a predetermined end.

II. Natural principles provide guidelines for balancing resources, environment and growth

The process of balancing always involves making choices. In order to make choices, we must see the options clearly. Basic natural principles define one set of options open to humans. Overlooking the operation of these principles defines another set of options. I would like to explore with you a series of choices that, when made in the direction of basic ecosystem principles, are proof that we are taking into account the full consequences of our actions for the benefit of the world, its people, other living things, and whole ecosystems alike. Basic natural principles are not laws that can be changed by humans; they are discovered by science; they are in operation all the time. Interestingly, several of these natural ecological principles are either stated directly or implied in Section 101 of the U. S. National Environmental Policy Act.

What are some of these choices that we can make?

1. We can choose either to think that our actions are quite separate from other living things, from the ecosystems in which we live, and from the world; or we can recognize the primary principle of ecology: that everything affects everything else, directly or indirectly. The organizers of this session see this in their international work.

It may be easy to believe that our actions are limited in effect--especially in the wide open spaces of the western U. S., Peru, or Sudan. For example, we do not readily see the effects of removing plants from what seem to be barren hills. So is there an effect?

If we observe more closely, we discover reduced soil-holding capacity, more gullying with silt and clay washing into the streams, lakes and oceans. This increased erosion leaves less organic nutrients for plant growth and changes the quality of the waters. Less plant productivity means fewer animals, so fewer successful photographers and hunters, so potentially fewer tourist dollars spent in a region, so fewer inhabitants. And so, on and on--short-range and long-range effects generating ripples of unknown magnitude--even on to desertification.

The U. S. National Environmental Policy Act requires that we prepare environmental impact statements in advance of making decisions so as to determine the number, kind, direction and size of these ripple effects radiating from *people's actions. Doing this enables us to evaluate in advance how closely our* designs will harmonize the proposed projects with the ecosystems of the region, how well they measure up to the ecosystem principles. Several other countries are now in early phases of implementing similar laws.

An engineer is usually brought into the picture after his client has identified a need and has some idea about how it should be met. The engineer ordinarily prepares his plans and specifications so as to meet the need. He, together with the regulatory agencies, the lending institutions, and occasionally his clients' neighbors, have the choice to go ahead and do something now, then find out later what short-term and long-term disruptions have been brought to our environment, our resource base, and our economy; or it can be to calculate in advance what effects our actions will have on the economic, social and aesthetic features, as well as physical, chemical, and biological resources of our environment--our ecosystems.

For example, such choices were before the executives of the Climax Molybdenum Division of AMAX, Inc., in 1966 when they started to plan for developing the new Henderson Mine in Colorado. They chose to design with a maximum of environmental concern, to minimize the disruptions a large mine inevitably brings to ecosystems, in spite of the fact that environmental laws at the time required far less. Early on, they proposed that a committee be established to explore what environmental problems might be encountered and to recommend how they could be alleviated. This committee, dubbed the "Experiment in Ecology," was composed of five Climax executives in immediate charge of developing the plans for the mine, together with five citizen conservationists--executives of the Colorado Open Space Council.

The "Experiment in Ecology" committee met periodically over an eight-year period--intently exploring the many environmental ramifications of developing the mine and how to minimize them. The first meetings were tense, each person uneasy about the proverbial black and white hats associating. But, from the outset, it was the policy of the committee that each person be candid, ask any question and make any comment they wanted to, with no thought of forbidden subjects. This policy soon revealed that sincerity was inherent in all involved; and the black and white hats dissolved.

Then the committee members settled into being a body of ten people, dedicated to balancing development, environment, and growth by designing, planning and overviewing construction of a large mine so that it would have the least possible environmental impact on the beautiful high mountain scenery of central Colorado. New concepts soon emerged, such as placing the tailing pond 14 miles from the mine in an out-of-the-way valley on the other side of the Continental Divide, where the incoming and outgoing waters could be completely controlled and recycled through the mill. This required tunneling ten miles uphill through the hard rocks of the Continental Divide. Yet this was clearly seen by the executives as the most acceptable choice for solving this problem.

Sound too ideal? You would not be the first to say so. The committee met once with a group from another mining company, who went away saying it was all too good to be true. This reaction set the committee to some evaluation, which only reaffirmed what they thought was happening. The mining people really were developing a concern for environment; they were learning what was required to design a mine in harmony with the ecosystems of the area. As proof, they told of how their concern for and information about environment was being effectively transmitted to all who worked for them. An example of this was a foreman saying to his boss, "Bill, if we move that access road over ten feet, we can save those six trees." Another was selecting a route for a survey road through the forest by merely removing rocks, logs, and a few live trees, so four-wheel-drive vehicles could traverse the area, instead of carving a road out of the forest with a bulldozer. After four months of use, I traversed this route and could barely discern that vehicles had used it, so little disruption had been done to the ecosystem.

In addition, the environmentalists really were hearing the problems, needs and constraints under which mining engineers operate; they were becoming more understanding of mining and were working with the engineers to devise acceptable balances between environment and development.

In instituting the "Experiment in Ecology" these mining and conservation people were seeing their activities as an integral part of a much larger set of systems. Result: design and development of a large mining complex has been achieved with full measure of wise environmental choices and minimum of delay.

2. We can choose either a linear model that provides for sequential use of materials and a highly consumptive pattern of energy use; or we can select an interactive model for our activities similar to the life-support systems of which we are a part, by recycling and reusing materials and goods, and by using energy in the most effective, efficient, and economic manner possible--and frugally. There are many examples worldwide of the multiple economies of recycling materials and of conserving energy. In the near and mid-term, conservation of energy is mandatory. Hopefully in the longer term it will be integrated into our way of life--for the second law of thermodynamics is inevitable. Dr. Margaret Meade once commented that the real tragedy of the energy crunch was that people were holding their breath until they could "return to normal," not recognizing this inevitable, inextricable principle of the universe--that with each use of energy we lose some forever.

I admire the people of Stockholm for their integrated system of power production and space heating that is conserving a large percentage of energy produced.

3. We can choose either to foster consumption of land by uncoordinated expansion of business, industry, housing, roads, or we can choose to recognize the return on investment from maintaining agricultural lands and mature, diverse, stable ecosystems. We can choose to identify and design to avoid consumption of these croplands and mature life systems. We can determine the comparative dollar returns of maintaining versus consuming these systems by applying information now coming from the Man and Biosphere Programme of UNESCO. Such a comparison was made of salt marshes of the East Coast by an ecologist, Dr. Eugene Odum at the University of Georgia. He and economists working with him calculated that undisturbed system was doing work of benefit, consisting of the total productivity, including byproducts, with a value to humans of $82,000 per acre per year, while consuming the system by land fill and building houses on it would bring an initial $2,000 per acre sold.

When it is necessary to disrupt existing systems, we can also choose to retain and restore enough components so that a reasonable facsimile of the original systems eventually can develop. This is being done by Miami Copper Company in Arizona with their tailing ponds. They put topsoil on the surface and planted seeds and saplings before each rainy period for several years. The vegetation cover has increased several fold in the ten years I have known the area. The natural rehabilitation processes are taking over and increasing diversity. Their years of work to reestablish rudimentary desert ecosystems on tailing have set in motion processes that will eventually result in mature ecosystems. Similar work is underway at the various coal mines in the West, as well as on highway cuts.

Wherever possible, we can choose sites for construction that are already disturbed, rather than ones that are in stable and diverse systems. A few years ago, I had the opportunity to do just this for Public Service Company of Colorado. I made an ecological reconnaissance of the route across the tundra with the design engineer, locating both the permanent, mature and the transient, disturbed, unstable ecosystems within the route of the transmission line. This information enabled the engineer to locate transmission towers so as to avoid touching mature stands. Without this advance knowledge, the engineer could have eradicated thousands of years of ecosystem development with a few days' work. The ecological benefits of this engineer's choosing to learn about the ecosystems on his proposed route in advance far outweighed the moderate price of a day of professional counseling and slight realignment of the line.

4. Lastly, we can choose either to believe that as long as there is space, there is no limit to the number of houses, highways, industrial complexes, reservoirs that can be developed on any given segment of land. Or we can recognize, as livestock and wildlife men long have had to do, that any given piece of land has a definable capacity to "carry" a given use and still produce at an optimum level. We can see that there are limiting factors in each ecosystem for productivity, and for sustaining human growth and development without disruption. Engineers use these principles all the time in designing to construct for safety and durability. All of us use them in various ways, for we make no attempt to carry horses in the trunks of our cars because it is obvious they won't fit. Yet few serious attempts have been made at discovering optimum sizes and numbers of people for neighborhoods or optimum numbers of industrial complexes, power networks, irrigation systems, highways, etc., for any given ecosystem or region.

I have heard much discussion and many allegations about "limits to growth." An experience of an eminent ecologist at a Limits to Growth symposium five years ago may help to clarify these viewpoints. This symposium held on an Eastern campus had vociferous protestors disrupting its proceedings over the two-day period. These protestors represented labor, youth, women, and minority groups. The ecologist--a person highly sensitive and sympathetic to human needs--became increasingly disturbed by the protests, yet could not identify what their problem really was until suddenly he realized that subconsciously they were linking "limit to growth" to the beginning of decline and utlimately death. When he spoke, he pointed this out and went on to discuss that, in ecosystems, following a short period of rapid growth and productivity, there is a leveling out with continuing slight incremental growth as the system recycles, replaces and renovates. For example, when farmland is abandoned, weeds and other rapidly growing plants invade and cover the surface in a few years. Then, much more slowly, plants and animals that once inhabited the system before it was cleared for farming colonize the area. Gradually they crowd out the weeds and first wave of plants, making room for other species to colonize. Over a period of 40 to several hundred years, this process of succession continues until finally a grouping of organisms develops that will reach a dynamic equilibrium maintained for hundreds, even thousands, of years unless disturbed again. This culminating stage exhibits a tight economy of nutrients and energy. As leaves fall, the nutrients decompose and return to the system. The ecologist showed how human systems can do the same thing, as is being done with the Stockholm power and heating system. So zero growth does not have to mean decline; it can mean operation in dynamic equilibrium.

The American Indian tribes had an inherent concept of dynamic equilibrium in ecosystems, of carrying capacity of land, and of limiting factors operating in these systems. It was basic to their very survival. They knew how much to harvest, how many people were optimum for each region. They managed their affairs to balance their numbers and activities with the productivity and capability of the land to support them and their activities. In contrast, early white settlers put so many cattle and sheep on grasslands of the West that the high productivity of these systems was quickly lost. Recent reports indicate that 25% of these grasslands are now in poor condition and 50% more will be in a decade if we do not reverse the trend. This resource potential could be regained and maintained if a design for rehabilitation were developed and closely adhered to. The same is true of many forest systems in the tropics.

But you say, "I don't want to go back to the old life styles." We do not need to in order to incorporate ecological principles in management of development. But we do need to use more balance and order in designing our development.

The same basic principles apply to design and operation of urban areas. For example, recent studies[2] done by the Council on Environmental Quality in cooperation with HUD and EPA have shown that financial costs of developing suburban neighborhoods can be reduced as much as 44% by careful design and planning to achieve diversity of housing type and arrangement--single-family homes interspersed with townhouses, walk-up apartments, and apartment complexes--with somewhat higher density. This study shows that not only can careful organization of neighborhoods cost less dollar-wise, it also can reduce air pollution 45%, retain 55% more land for open space and recreation, and can reduce costs for utilities and roads by 50%. Planned neighborhoods with diverse types of housing units also can conserve up to 55% of the overall energy use, decrease water consumption by about 35%, and decrease maintenance and operational costs by 10%. In summary, this study showed that the prevalent concept of urban sprawl as the cheapest way of increasing housing is false on a total of 54 different counts, and that careful analysis of proposed development from an environmental standpoint, an energy standpoint, a social and psychological standpoint, as well as an economic standpoint can reduce all costs of development. This is true progress and significant growth, meeting real needs rather than wishful demands, in the way we defined these four terms earlier.

Another recent study done by the Council, in cooperation with EPA, complements the Costs of Sprawl. In it, 53 cases of what happened to land use following the installation of interceptor sewers were examined. Results showed that the expected economies of scale--i.e., building interceptor sewers with 50-year growth expectancy--were in fact dis-economies. Results showed it is actually considerably cheaper to build for present and immediate future demand, and to construct additional needed interceptors later when need develops. Funding oversized interceptors promotes poor land use practices because municipalities have to promote development to pay off that portion that is not immediately needed. Subdivisions occur in a haphazard fashion dictated by sewer size and location rather than the balancing processes of rational decision-making. Also, more municipal projects could be funded by reducing the scale of these grants.

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[2] Costs of Sprawl, Council on Environmental Quality, 1975, Government Printing Office.

III. Performance Standards

From these ecological principles, some general guidelines for performance standards can be drawn. These are:

- --Analyze carefully even seemingly unlikely relationships and potential impacts;
- --Maintain a maximum of diversity in ecosystems and on sites; clear or alter a minimum area;
- --Save topsoil and reuse it; utilize plants, timber, rocks, used building materials whenever these are in good condition;
- --Rehabilitate the cleared land; use native plants in rural areas and ornamentals in urban areas if their requirements are minimal;
- --Select for development ecosystems that have been altered rather than undisturbed ecosystems;
- --Maintain streambanks, streambeds, and lake margins intact;
- --Leave wetlands intact, together with marine marshes;
- --Recognize that the first two miles offshore in most oceans is generally the most productive region, so avoid changing it unless to remove pollution and disturbance.

With these guidelines as a basis, meaningful performance standards in various types of engineering projects can be worked out. Considerable specific investigation of specific types of projects in given ecosystems is necessary to provide the details for explicit standards needed for intelligent engineering design. At this point in time, the most satisfactory way to proceed is to retain a small team of local ecologists to draw up what is now known about the quantitative parameters of local ecosystems, i.e., their resilience, diversity, carrying capacity, limiting factors, etc., and to work with the engineers in outlining specific performance standards.

You may note some equivocation in the way I have phrased this procedure. There are several reasons for this, among which are:

- --To date, there has not been adequate investment of public funds in ecological research; therefore, there are gaps in knowledge and no manuals of data;
- --Biological systems of all types exhibit tremendous variability; therefore, what is known for one is not fully applicable to another.

These facts may pose problems to scientists you approach. Work with them and build their confidence in and understanding of you as people and you as a profession. Encourage them to realize you can help each other and therefore help the environment to be more viable. They may need this encouragement to overcome stereotypes of what engineers are like and of what they can do to ecosystems.

But such a procedure can produce truly interdisciplinary teams, working together to solve critical world problems while maintaining viable ecosystems.

IV. Conclusions

A. We all want to balance resources, environment and growth, so that none of them dominate our society and our world.

B. There are basic choices we can each make to promote this balance. We can choose to follow natural ecological principles in our lives, to accept their operation in systems where we plan projects, and devise means for working in harmony with them; or we can choose to ignore them. The first choice protects our life support systems and leads to more productive economic systems in the longer range.

C. Designing, planning and implementing in concert with ecological principles can result in more satisfying, integrated growth, environments, and economics for all.

D. Ecological principles provide useful guides to developing performance standards for projects. Specific local information can be developed by soliciting help from local ecologists.

E. Balancing massive, complex systems is greatly enhanced by interdisciplinary and intergroup efforts of a wide variety of types. Today, no single small group of people, no matter how talented, can adequately master the information and techniques needed to produce sound decisions and programs that will meet the needs of the present and future generations. All available talents need to be brought to bear to design for solutions. This is especially true on a world scale.

The real challenge is for humans as a species to utilize their brain power to discern means and innovate methods for harmonizing humans with their environment. It is high time we give an affirmative answer to Aldo Leopold's question asked 30 years ago: "When will man learn to treat the land as a community in which he is a member, rather than a commodity he has a right to exploit?"

PUBLIC PARTICIPATION AND ACCEPTANCE

By
Mary Elmendorf*

During the United Nations Water Conference in Mar del Plata in March 1977, the Mexican delegation suggested that the following wording be introduced in the Plan of Action:[1/]

> It is recommended that the effective participation of the public is the key for success of programs of water management and that the lack of local participation has frequently resulted in ineffective programs.

This implicit recommendation is in many ways a paraphrase of the opening statement made by the Secretary of the Conference, General Yahia Abdel Mageed[2/] and is consistent with several recognized concepts of water use and management such as those described in the now classic Drawers of Water[3/]

> Too much emphasis cannot be placed on early and continuous involvement of local populations, combined with understanding socio-cultural factors relating to organization, choices -- both of quality and quantity -- and natural logic in use and management.

The last phrase in the first quote, "lack of local participation has frequently resulted in ineffective progress" is confirmed by the Report on Community Water Supplies. "Rural water supply systems have sometimes been constructed at great expense, only to remain idle owing to lack of maintenance."[4/]

Without maintenance no water system will long continue to serve. Ancient Roman aqueducts could carry water to vital urban centers only because their channels were designed and built to standards that Roman aqueduct maintenance crews could deal with. Indigeneous Latin American water

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1/ 70/C.2/14 p. 42
2/ E/CONF. 70/17, p. 6
3/ Gilbert F. White, David J. Bradley and Anne U. White, Drawers of Water, U.Chicago Press, 197
4/ UN/CONF. 70/14 p.11

systems in some urban areas have functioned well where the technology dictating their design has been within the command of the maintenance capabilities of users. Split bamboo and carefully levelled rock channels -- all user - maintainable and renewable -- have traditionally been part of these systems. Such systems are maintainable by their users because they have essentially been user-built and planned. The parameters of system maintenance are determined by the design of the system.

The kind of maintenance needed is often a direct result of effective participation in planning. Many more factors are included in this seemingly simple statement than have usually been recognized in the past. Increasingly national and international organizations have become more aware of the potentials of village people for planning, learning, managing, and changing their patterns of water use -- when they become truly involved in understanding this process as a part of improving their standards of living. The example offered by Mexico is well worth review.

Since the Revolution of 1910 Mexico has sought to reach its rural populations through community development programs in which local participation has been a key factor, starting with the well-known programs of the Rural Cultural Missions, followed by the coordinating centers of the National Indian Institute, and more recent national programs, such as the Integrated Rural Development Program - PIDER.1/

CASE STUDIES

I. SANTA MARIA

The first case we will review here relates specifically to village water supply in Mexico. The project, designed and implemented 20 years ago, was a pilot demonstration in the value of involvement of the local population

1/ For instance, in rural road building involving village labor, Mexico was second only to China in the number of kilometers built this way between 1970-76. (SCOP-1976) through a number of innovative techniques. First, the impetus came from a village survey conducted by young rural women with primary school education being trained as grass roots "home demonstration" agents. As a result of interviews with village leaders and with the families in their homes, these young women, without promise or threat, helped the people define their resources and their needs. Safe drinking water emerged as their paramount "development" priority.

Second, two private voluntary agencies, CARE and the AFSC, looking for ways to combine their limited resources for maximum effectiveness in meeting community needs had arrived at the same conclusion: potable water was the greatest need for rural villages. With CARE in Mexico taking the initiative, the contributions of various agencies, international, national and local, were coordinated to respond to the locally defined needs. An engineer from the Government of the State of Mexico confirmed the feasibility of well-drilling as a source of good water in the area, and agreed to give supervision. WHO recommended a type of equipment (Bucyrus-Erie-W22) which they were using and offered to train operators. AFSC agreed to assign four volunteers for training for the project and CARE provided the equipment recommended.

Most significantly for this paper, the people in the village raised money and set up a special Bank account -- "Comite de Agua Potable de Santa Maria" - which proved sufficient to cover local costs for water pipe and gasoline for the drilling rig. The amount of money was not the most important thing. The process was. The community organized a hospitality committee so that nearly every family in the village shared in housing or feeding the volunteers. The initial result of all this was modest -- a simple handpump on the village square, but one which produced clean water, which people preferred to the polluted drainage water they had formerly had to use. Ten years later when I returned to the village the water from that same well was being pumped up electrically to a water tank and distributed throughout the village.[1/]

In the summer of 1969, ten years after the first well for potable water had been drilled in Santa Maria Atenco, I returned to the village unannounced, wondering if the pump would be broken, the well dry or perhaps just unused, and the villagers again using the handy but polluted drainage ditches they had depended on before the well. Even before I reached the central plaza by the church I could see a brightly colored water tower high above the adobe houses, complete with the insignia of the Ministry of Health clearly visible on it.

Where the old hand pump had been, there was now a small square structure, the pumphouse for the tank which towers above it. As I stood looking at these unexpected facilities, the Chairman of the old "Comite de Agua Potable" came out of his house across the street, called me by name and looked proudly but sadly at the pumphouse. ..."It's broken now. The fuse burned out. We really should have left the old pump there for these emergencies. But now we're laying pipes to all the houses, so that everyone in Santa Maria can have water."...

Again in the summer, this time in July of 1977, I stopped in Santa Maria. The Chairman, I learned, had died five years earlier, but much to my surprise his daughter, now a member of the Committee, remembered me and many of the details of the original operation, even though she had been just 14 years old when the well was dug. But she recalled the celebration the coming of the Governor and the general rejoicing when good water was first

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1/ Film - World Our Hands Can Build, based on this village project, presented at the 1958 International Film Festival, was given honorable mention. Available from CARE: New York available. She began to reminisce ... "Now the little school has grown and the old plaza has nearly disappeared. Our streets are still unpaved, but there is bus service regularly to jobs and markets. Santa Maria is really becoming a part of greater Toluca."

..."But everyone has water now, piped to their houses. All the families pay ten pesos a month to have someone check the pump and maintain the water system. We even had enough water to share with San Isidro ... And now the Ministry of Health has drilled an even bigger well in San Mateo, so all ten colonias have good water. See that enormous tank there! ...But our water still comes from the same well."

And then we talked and talked about the various actors in this drama - the dynamic Director of the village workers, Alicia Godoy ..."there's a married woman here who was named for her when she born." And about Von, the red-headed Quaker ..."he came by to see us two years ago. We're so glad you all come back, that you remember. Can't you stay? Please come again.[1/]

1/ The on-going Research Project 671-46 at the World Bank on Appropriate Technology for Water Supply and Waste Disposal in Developing Countries emphasizes the necessity of planning for both services at once. Two communal latrines one for men and one for women, were installed, with village cooperation in building, outside the school on the town square. These were inaugurrated with a ribbon cutting ceremony and the U.S. Ambassador, asked for the honor of using the men's facility first.

On my frequent visits to the area in the later 50's the latrines were still there, but no paths led to their doors as they did to the village pump.

Now I asked about the latrines -

> "No, the latrines never worked out. They smelled so bad! No one liked them. Now a few of us have flush toilets - and tiled bathrooms. Would you like to see ours?" ...And it turns out that the inside flush toilets just drain into the canal!

In 1977 drilling for potable water may seem commplace; but 20 years ago in Mexico, this project created enough interest that it made front page headlines in the Mexican newspapers and appeared in the New York Times and other publications. One of the immediate results was a request from the governor of another state in Mexico to have a similar project. When he understood that the key to the success of the project was not the CARE rig nor the AFSC volunteers but the participation of local communities, village workers and concerned volunteers trained by specialized agencies, he successfully replicated the project using locally available equipment and young men from the area who were to work on the second project in place of the Quaker volunteers on the earlier project. The communities selected for this work were chosen on the same basis as the original villages after a community survey by extension workers. The new villages also offered home hospitality to the well-drillers. This hospitality, like the village survey, was an integral part of village awareness, orientation and education for effective involvement.

II. CHAN KOM

Our next case is in a mayan village in Yucatan where a 1976 study of "Socio-Economic Impact of Development Projects"[1/] revealed several interesting things. In the first place the potable water supply was considered the most important and beneficial change to come to the village once the opening of the road had taken place in 1971, much more important than

1/ Elmendorf, Mary - "The Socio-Economic Impact of Development Projects on Chan Kom: 1971 - 1976" (Working Draft - World Bank 1977).

electricity.[1/] Of the 81 households in the village, only 29 use the running water, 16 from private faucets in their patios and 13 from one of the four public faucets. All are charged the same fee. Unfortunately the distribution of the water is largely limited to the plaza area where the village elite live, with 14 of the 16 with private faucets living in masonry houses instead of thatched huts as do the majority of the village families.

Most of remaining 52 families live too far to carry all their water from the public standpipes especially if there are wells nearby. The installation fee for a private faucet - plus cost of pipe - is difficult for the majority of the villagers to afford.

During a recent month's visit by a study team we were without running water for the last three weeks, because the bearings of the pump had burned out. This was the first long breakdown since service started in 1972. Both women and men commented constantly on the inconvenience. By the third week people were noting an increase in illnesses particularly diarrhea and blaming it on the lack of safe drinking water. The women particularly were complaining of aches, pains and extra fatigue from hauling and carrying water. Even the women who have been getting their water supply at the corner faucets noticed the extra work as they hauled water from neighborhood wells.

The women in the <u>colonia</u> -- the group of houses farthest from the town square -- were showing increasing interest in having water during October and November when we were there, as the dry season started. These women still have to draw and carry their water from deep wells for household uses: drinking, cooking, bathing and laundry -- as well as to feed any small stock or cattle they have. The drawing of more water for very

1/ Even though more people had electricity because the distribution was villagewide and initial cost of installation and use lower, when asked, most women cited improved water in their homes as a first priority.

many plants and fruit trees, even though cherished by all, is just too much work. Energy and time are both things to be considered.

In spite of the scarcity of water in Chan Kom, practically everyone bathes daily and changes clothes, usually around sun down. A bathing area is set aside in most huts, often with a stone set in the earthen floor. Here with a pail of warmed water,1/ a bit of soap and henequen fiber, a small scoop made from a gourd-like fruit, people soap and rinse and emerge shining in their clean, but unpressed clothes. Women shampoo their hair every third day usually in the laundry trough the long tray hollowed out of tropical wood or moulded from plastic in a modern version.

Clothes, too, are washed with a minimum of water and a maximum of efficiency. The white huipiles, loose sheaths, are usually spotless even though they may be threadbare. Ashes from the hearth, special leaves and fruit, some detergents, bleaches and the bright sun are all used effectively with hours of scrubbing.

According to size and ages of family members, water needs vary. Most families use around 40 pails of water a day for household garden and stockwater needs. This amounts to an estimated 30 to 40 liters per capita per day. Women and children -- mostly the girls -- are expected to provide it. In 1971 all of this had to be drawn from the deep wells or the cenote water deposits in broken limestone. Now the fortunate few who have piped water on their property run hoses to fill the containers by the hearth - the traditional earthen jars for drinking and cooking and plastic and metal pails for other uses. No one in Chan Kom has a kitchen sink with running water. A few have put their laundry troughs near the outside faucet.

In 1973, the Instituto Nacional Indigenista (INI) proposed an

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1/ Several women set metal tubs in the patio area to be warmed by the sun instead of using their hearth fires since wood is getting scarcer and more time consuming to gather.

irrigation project to this same village. In reviewing the situation the former mayor (1970-73) explained that INI had hoped that this project, the first use of irrigation in Chan Kom, would benefit the neediest people in the village. He added that he had tried every way he could to interest the poorer families, but they either felt it was too much work or too expensive. "It seemed the only thing to do was to make it a demonstration so I and 16 other families, mostly from the ones who already have the most, joined the project. Now I think more people would be interested in having similar projects. We have proved it is a good thing."

Through their cooperative labor and with the direction by the agricultural engineer, they cleared 80 hectares of land, dug a well and constructed a water storage tank. Water is drawn from the well by a windmill backed up by a gasoline operated pump, and is stored in a large cement deposit from which the members run hoses to their plots when they need water.

Each family works its own four hectare plot independently and has exclusive rights to the produce. The project could be termed "cooperative" in that the labor force necessary to construct the irrigation constituted the group eligible to receive credit from the Institute. Each member contributes what he is able in addition to a required 10.00 pesos a month towards the maintenance of the irrigated area and the repayment of the debt. Most of the members spend one or two days a week working in their plots.

The irrigation system has enabled the members to introduce much more diversification in their agricultural products. They have planted many different types of fruit trees, including citrus, bananas, mamey, papaya, achiote bushes (bixo orrelana, a cash crop spice), chaya, beans and vegetables. They will begin receiving increased yields from their fruit trees next year.

This supplementary and diversified agricultural produce is not only a very important contribution to their diet, but an additional commodity which they can sell in and outside the village. Trucks came from Can Cun for the tomatoes. No attempt has yet been made to sell cooperatively.

Gradually, the women who helped from the beginning on this irrigation cooperative are taking over more of the work. Some are selling the produce as a way to earn cash income as well as to supplement their family diet. Individual women have seen this as a real opportunity for small scale marketing and make up to 100 pesos each trip to Valladolid or to Piste. A number of families, particularly the women, who have water in their solares, have planted some of the cutting, seeds, etc., from the sociedad at home so they can have them at hand to eat or sell/swap.

In November 1976 an engineer from Secretaria de Obras Publicas (SOP) (Ministry of Public Works) completed a three-month socio-economic study of Chan Kom for inclusion in PIDER planning for the area. He was particularly interested in setting up a large scale irrigation project, preferably related to a potential cash crop, achiote, whose seeds give a red color and flavoring much like saffron. According to information from the engineer and from both men and women in the village, there has been a very negative response to this proposed irrigation project.

In the first place, very few people seem to know exactly what the project entails because the engineer has talked only with the mayor and a few village officials. The reason most often given for lack of interest was that the engineer wants people to plant achiote as a cash crop. "You can't eat achiote if you don't sell it -- it's better to have citrus or papaya or tomatoes -- something you can eat. Suppose you can't sell."

A second criticism of the proposed irrigation project was that it was to be big -- and big irrigation seemed to bring back memories of working in henequen and sugar plantations. "We do not want to be serfs or slaves again -- we have our ejido -- we are a free municipality."

The idea of working on a planation or a big project, as paid laborer or even as members of a cooperative where a cash crop such as achiote is raised, is not acceptable to the men and women of Chan Kom. The third reason never really expressed as such was the risk factor. Indirectly the ex-mayor said this when he said that only those who had the most could afford to take the chance to prove that it was a profitable venture.

KINDS OF PARTICIPATION

The basic significance of the "dialogue" between village residents and those proposing the large project is that, by their consideration and rejection of it, they have, in fact, "participated in planning." Even though the outcome was negative it did represent the community's decision.

Effectively opposing the proposed large-scale irrigation project does represent community participation in planning in that an unwanted project, an expensive investment which would probably have been underutilized was avoided. Further participation by the villages and a planning approach which allowed their defined wishes to be met could well have resulted in a project which answered expressed interests and which they would have continued to support and manage.

As I said earlier when referring to the historical 20-year old village well-drilling project in Mexico, numerous agencies, governmental and intergovernmental, are now involved on a large scale in helping local communities meet their needs for water. The urgency of these needs was pointed out at the U.N. HABITAT Conference in 1976 and has been reinforced at the recent United Nations Water Conference in Mar del Plata. The scholarly literature on the need for local participation in management and use is readily available and clear. The issues and background papers on the subject presented at the Conference and the Plan of Action arrived at reinforced the value of community involvement.

When it is reported that 30% of the small village water supply systems built in Mexico are no longer functioning, one wonders what the breakdowns are.[1/] Can real local participation, not a psuedo-participation without communication or involvement, be carried out when village level projects get large? The PIDER project in Mexico, a large nationwide effort at integrated rural development where planning and supervision is coordinated on a state level in micro-regions, has a lower percentage of inoperative systems than the overall record, but there is still opportunity and need for more village level participation.

Irrigation projects have much better rates of survival than potable water systems in all areas. What are the reasons? Growing crops are easier to see than growing parasites. Income from crops is easier to quantify than quality of life and health from inadequate domestic supply of water. Cost/benefits are more easily quantified. And the women, who although playing well defined roles in real life management and use are often (nearly always) left out of planning, supervision and management by officials and agency representatives when new projects are introduced.

Involvement of local people in the total process from initial

1/ Schumacher, World Bank Seminar, May 5, 1977 planning can be a part of Development from Below, as defined by a group of anthropologists and other social scientists. Too often big projects become development from above.

> Far more attention needs to be paid to the differing social contexts of development, especially at the grass-roots level, and to the complexity of the social relations involved in the exchange of goods and services.1/

As Apthorpe pointed out so clearly the gap between the "Peasants and Planistrators" is difficult to bridge, but Carl Widstrand2/ and others feel that there can be real planning at the village level if the social fields are recognized and communication is reached.

The World Bank Bura Irrigation project on the Tana River in Kenya is a case in point. Here we have a proposed project in which more than 60,000 marginal farm families from various tribes in the overcrowded central plateau were to be selected for resettlement in villages as laborers in government-owned irrigated cotton fields. Communication between the various ethnic groups to be settled is a great need. Furthermore, the hostile environment makes the problems to be faced enormous and difficult to define. The Techniques for stimulating local participation in early planning are also complicated by linguistic and cultural factors. One can project the future problems of this settlement scheme from similar ones, realizing that most anthropologists, including Thayer Scudder,3/ feel that the spontaneous communities rather than the planned ones are the most viable. This is due primarily to the fact that in urban squatter settlements or rural pioneer communities there has been real local participation in planning and execution. It is difficult to plan the spontaneous

1/ Pitt, David, Development from Below, The Hague, Movton 1976:17
2/ Widstrand, Carl, "Rural Participation in Planning" in Development from Below David Pitt, Ed. The Hague Movton 1976
3/ Scudder, Thayer, "Social Impacts of Integrated River Basin Development on Local Populations" UNDP/UN Seminar on River Basin Development, Budapest, 1975

when selection is to be controlled, and when heads of families are being selected and sent ahead.

Certain problems can be anticipated from studies of various settlements. The emergence of community trust and participation for common goals will be fraught with difficulties unless careful steps are taken to involve the settlers in water supply and waste disposal.

The training as well as participation is a key in such a project with community education rather than just the usual public health education being an integral part of the on-going process. Building small communities of families of 50 or 60, with shared operation is one highly recommended component, but the possible difficulties of the socio-cultural impacts can not be exagerated. Along with irrigation, plans call for village water supplies including bathing areas to reduce the present use of drainage canals - sure sources of contamination and exposure to schistosomiasis.

Let me reiterate by quoting Warford and Saunders:

> No matter how badly (in the opinion of an external appraiser) a village 'needs' a better water supply system, if the population itself does not perceive the 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 be more likely to have its contributions completed and its payments submitted on time. It will usually attempt to see that the system is used and well maintained, and will report any problems it is having with the system ...
>
> 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 community water program promoters. Unless community or village enthusiasm is present, however, 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.1/

Vicariousness, the ability to imagine how the project will feel to the people of the project area and their perceptions of it are usually the most neglected aspects of planning.

The reasons for failure and successes are seen primarily as managerial, organizational or institutional rather than as being related to the following significant factors:

> ... Willingness to find out the values and beliefs with which the target population begins; the efficacy of suggested action; the involvement of local people from the beginning; and consonance with the prevailing patterns of social action ...2/

To effectively involve village people as local labor, along with local materials and technology, can have real potential impact not just on immediate cost to country by shadow pricing as discussed in Village Water Supply but also for long term costs - human and monetary - if management and use are considered.3/

Thinking in terms of cost/benefits in a broader way than just dollars (pesos) and time, practical building and maintenance, local participation becomes many things. It becomes education in the broadest sense, awareness, motivation, understanding, learning, caring, controlling, managing, changing. When the public accepts a project/program as the solution to a felt need, their participation is more effective, their village wisdom is a guide to the choice of appropriate technology, and their understanding of the institutional arrangements can facilitate

1/ Village Water Supply - Economics and Policy in the Developing World Robert J. Saunders, Jeremy J. Warford (page 109)

2/ White, Gilbert - "Water Supply Service for the Urban Poor: Issues" Working Paper - World Bank 1976

3/ Village Water Supply - Economics and Policy in the Developing World - Robert J. Saunders, Jeremy J. Warford (pages 61, 112 - 138) effective follow-up.

> "... the role of water-whether of safe water for people or enough water for fields or for protection against waterborne disease-is central. And it will quickly be discovered that just as an effective water policy for cities demands social changes, the need is no less urgent in the countryside. If the developing world is to achieve the annual food growth target put forward at the Rome food conference in 1974-4 percent a year for the next 15 years-a large part will have to come from introducing or improving irrigation."1/

CONCLUSIONS

Engineers can do the technical planning to solve the problem of water for people and for fields, but the human element at the grass-roots level must be included for effective utilization and management. When, as in Santa Maria, full participation (meaning village-wide and from the beginning stages of planning) is evident, the new technologies and/or new approaches to meeting felt needs are usually possible. Involvement of top officials - governor, mayor, etc. - at the successful completion of such a project as well-drilling for potable water both rewarded the efforts of the community and served to stimulate diffusion of the model to other villagers in the area, to other states, and ultimately, in this case, to other countries with Peace Corps volunteers.

In Case II in Yucatan we have several levels of participation. The example of water for the pilot project, carried out with a group of the village elite who could afford the capital risk and the time, proved to others the usefulness of the windmill and year-round water for cultivating fruits and vegetables for consumption and sale. Other members of the community are now eager to have a similar project. The new irrigation project being discussed with the mayor is not getting village acceptance. Instead of finding out why, this negative participation (reaction) is being

1/ Ward, Barbara - London Economist - February 5, 1977 interpreted as no interest.

The lack of equity in potable water distribution in this ejido town is less acceptable on the part of the families away from the town square now that they are aware of the energy and health benefits. In installing electricity, lines were run throughout the village-and later metered charges were added at the request of the non-elite, many of whom have only one single electric light bulb and knew they were using less electricity than their "uptown" neighbor with refrigerators and televisions. These same families are beginning to question the present water distribution both potable and for small-scale agriculture. Participation will probably result in extension of service to other areas and/or different charges for public and patio use.

In the Tana River Project in Kenya, the engineering has been made with concern for the health and well-being of the population to be settled. Planning for their full participation in advance will require the best of social engineering, related to settlements in general and cultural constraints of the various regional groups.

Recommendations

1. -That members of the community be involved during the early planning stages is gathering basic line data, preferably as part of household survey.

2. -That simplified methodology for collecting such data be adapted to village needs/wishes so that it might eventually be incorporated into rural community.surveys which gather statistical information about water needs, health, nutrition, and village perceptions of same. Local people, in analyzing their present situation, become involved in the process of change and apply their peasant wisdom to development alternatives.

For instance, the school principal in most Latin American villages, as in Cases I and II, makes annual reports on school attendance. Either teachers with students and/or members of the Parent Groups can be willing, able and effective field workers and data gatherers as a beginning phase of community education, understanding and involvement.

3. -That structuring of the survey gathering be designed so that data is available on a community zone basis in order to make supervision easier and to elicit early evidence of inequities or special needs.

4. That the sharing of information about various alternatives for water supplies and waste disposal be made at public meetings - with families present -- men, women, and children - in order to broaden the basis of understanding and hopefully, support.

a) On an individual basis, reactions from men, political leaders, officials and tradesmen, will be forthcoming usually without any special effort. b) If, however, care is taken that both women and men become involved as promoters, evaluators, extension agents or in other ways in the initial survey and follow-up, evidence of women's real and/or potential role in community growth and development can be incorporated in the total community participation analysis. c) Another dimension to be incorporated is insight into the roles the children can plan, not only as contributors to the household labor needs and budget, but also as interpreters to their families of the new concepts and innovations being presented.

5. -That recognition be given to the importance of information about membership in formal and informal networks and interest groups, so that group decisions related to cooperative efforts can reinforce individual decisions for raising the standard of living and increasing the productivity and quality of life of all the rural households.

APPROPRIATE TECHNOLOGY IN CIVIL ENGINEERING

By Michael G. McGarry[1]

INTRODUCTION

In recognition of the many unhappy experiences incurred while trying to foster development through urban and industrial projects in the developing countries, international assistance organizations are now being advised to 'think small', while placing rural development as their first priority. Technology has become recognized as an important component of any development package. It is difficult, if not impossible, to effect change in a foreign economy and culture without building the development package around some kind of technology, whether it be a hydro-electric dam, water supply system, new variety of crop, or fish culture pond. Much of the technology offered over the past three decades has failed to engender the kind of changes that are now considered desirable. Honest efforts are being made now by many to rectify these mistakes through a new medium or message called 'appropriate technology'. For the most part, the intent behind appropriate technology projects cannot be criticized. However, it is the simplistic nature in which they are being formulated and implemented that is most disturbing. Appropriate technology has come of age; it is now a movement, if not, to some, a religion. Unfortunately, it has found its roots

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in the industrialized states of the West, and not in the Third and Fourth Worlds, for which is largely intended.

The same international development agencies that have made serious mistakes in the past are taking up the appropriate technology banner. It is becoming our new message to them. Again, overly simplistic solutions are being carried across to solve the same complex problems of development. The 'technological fix', as the panacea of development, is again being promoted by the West. This time, however, it focusses at a lower technological level, on an even more vulnerable and more complex sector of the developing country.

The need to reduce the dependency of the poorer nations on the more wealthy is well recognized, yet new appropriate technology organizations are being formed in the industrialized states to foster the rediscovery, innovation, and development of appropriate technologies at home for later dissemination to the poorer societies. This can only increase dependency and continue to reduce self-confidence and self-reliance.

There are a host of definitions for appropriate technology in the rapidly expanding literature on the subject and I don't intend to add to it here. However, the word 'appropriate' doesn't provide adequate description, other than indicating that the technology should be 'good' or 'relevant' in any context in which it is placed. It would, therefore, be useful to list some of the general characteristics of appropriate technology - at least within the context in which this paper is written. Appropriate technology should:

- be aimed at the poorest and most underprivileged sectors of society;

- raise the self-confidence of its maker or user;
- be not only economically viable but also socially, culturally, and politically acceptable;
- consist not only of the physical technology - the hardware, but also the software intangibles such as organization, education, extension services, supportive institutions, and surrounding economic considerations;
- be accessible to the poorer sector of the society intending to use it and be of proven technical efficacy under local conditions;
- foster a more equal distribution of wealth and power in the community and/or society it serves; and
- preferably be innovated, developed, disseminated, and maintained using manpower, institutional and material resources within the developing country itself.

Two of the above attributes need emphasizing. The first is that appropriate technologies should result in a more equal distribution of wealth. There is a natural inclination to support the more educated, organized and wealthy, inasmuch as they have the greatest resource base, have more capital to invest, are more technically competent and offer the easiest route to project implementation with the least chance of failure. Appropriate technology should support the less wealthy and less powerful. This can be accomplished through careful design of the technology, extension and educational services, and collectivization of the users. This approach contrasts sharply with the industrialization policies propagated in the past, and will likely prove to be a major stumbling block to the Appropriate Technology Movement.

The elite of society, who have prospered through industrial development, are unlikely to support the introduction of technologies and systems which may disturb their power base. On the other hand, appropriate technologies are likely to gain more official support by governments which are well motivated toward improving conditions in their rural areas and committed to more egalitarian distribution of wealth.

Secondly, there is an undesirable tendency for development agencies in the industrialized nations, which inherently lack first-hand experience in rural villages,to attempt innovation of technological solutions to what they feel are the highest-priority problems of the community. Villages are assumed to be of uniform character throughout the developing world. Worse still, the innovator of the West all too often develops a technology in answer to an imagined problem first, and then proceeds to search overseas for situations in which to apply it. This approach, which is based on a critical lack of information, is highly subject to failure at high cost to the innovator and his funding agency, and more importantly, to the developing country itself and to the community he involves in the project. The entire process of identification of needs, innovation or adaptation, implementation, and institutional support development should take place in the country in which the technology is applied and by nationals of that country.

EXPERIENCES WITH TECHNICAL ASSISTANCE

Undoubtedly, there are many technical assistance programs which have achieved success in introducing change for development.

There are, however, a disturbingly large number which have not. There are several inherent features in the donor/recipient relationship, and of the donor agency itself, which presuppose failure. The donor countries tend to be ethnocentric and paternalistic in their aid programs: "What we have is best; we know best who needs it; and how it is best delivered".

Aid is seldom altruistic. Often it is intertwined in political and economic strings, which result in net negative benefits to the recipient, who may well have been coerced into accepting the aid package in the first place. Earlier development strategies aimed primarily at maximizing output, while emphasizing the heavier industries. Such strategies are recognized today as not only ineffective in achieving their goals of economic growth but also as a contributing factor to social setbacks and disruption. They are largely responsible for the uncontrollable growth of slums in the primate cities, and a widening gap between the modern and traditional sectors of society.

Assistance to the manufacturing industry, either through aid or on a commercial basis, is often in the form of outdated, inappropriate technology transferred to the developing country. This is aimed at import substitution of consumer goods by local manufacturers for the higher income markets. It has not placed the developing country in a competitive position on the world market. A recent USAID survey of U.S. multinational corporations with branch plants in the Third and Fourth Worlds illustrated that they are loath to invest funds and engineering time in changing product design suitable to developing country conditions. "The development or adaptation of simplified, but modern products for low-income markets by the large multinationals has not occurred often in the past and does not seem likely to expand in the future." (2)

Mendis (9) speaks against the large-scale commercial system which has been propagated by the West and adopted by many developing countries, including his own, Sri Lanka. Despite the existence of productive capability in traditional technologies, which could have been improved and focussed on appropriate technologies, a process of imitative development has been followed. This has seen the import of large-scale, production-commercial systems. There are several deficiencies associated with such direct transfer of technology to an essentially non-industrial state. Apart from the environmental consequences of the centralized factory and the rural-urban migration, labour-saving devices have reduced the worker from an apprentice and craftsman to a minder of machines. Further, import of modern manufacturing capability in Sri Lanka has been shown in many cases to compete with existing small-scaled, rural-based industries. (2) For example, the village pottery industry had been supported by the Department of Small Industries and could have formed the basis of a rural ceramics industry. Instead, a foreign ceramics manufacturer was invited to establish a large factory in Colombo. It successfully suppressed the traditional pottery industry by penetrating the rural market and creating new demands for its products, thereby forcing the market by creating such demands instead of responding to its real, but limited needs. Mendis gives several other examples, amongst which is the introduction of centralized electricity supply through a national grid to replace decentralized, dispersed, hydro-power sources used on rubber and tea estates since colonial times. Now that energy costs are rising, desperate efforts are being made to locate alternative, decentralized sources.

One of the most denigrating consequences of foreign assistance arises from reliance on foreign advisers or experts. Short-term or long-term, these consultants are welcomed by aid agencies as a means of giving aid funds but keeping them 'in-house'. They are also useful as absentee scapegoats when mistakes later surface and someone must be blamed. Undoubtedly, the practice of using a foreigner as a change agent has its advantages; but it ultimately results in overshadowing local professionals. In the eyes of the bureaucrat, the foreigner is always right; overseas technologies and methods are always superior to the indigenous. In face of this, the local professionals are relegated to a second-clâss status and seldom given the opportunity to acquire the necessary self-confidence and esteem.

The process is termed dependent development; unfortunately, the tendency to rely on overseas assistance persists into subsequent projects and activities. Other, well-known, negative side-effects of this kind of aid arise from assistance through overseas education programs in the form of the 'brain drain' from the developing to the developed countries. The cream of the student crop is first selected for training in the donor country. This is paid for by funds which, again, are spent 'within-house'. After graduation, the graduate returns to his country, often under a bonding arrangement; but his professional advice is widely ignored, if indeed he is asked for it at all. Consequently, he frequently welcomes the opportunity to return to the country of his education - as part of the brain drain. Funds spent on his education are spent in developing educational facilities in the industrialized state, not at home; similarly, his education and research work also pertain to the developed economy and are frequently inappropriate for application at home. Inappropriate technologies continue to be perpetrated through the overseas educational system; lack of adequate educational facilities in the developing country persists and so does dependency on external aid sources.

APPROPRIATE TECHNOLOGY GROUPS

There is nothing new or mystical about appropriate technology in the developing country. Presently, however, international attention is becoming focussed on it as a new medium through which aid can be given. A bewildering array of groups have been formed to advance the cause of appropriate technology, which has been capitalized and elevated to the state of an Appropriate Technology Movement.

Appropriate technology groups may be broadly classified into three categories. In the first category are the rural peasant and indigenous industries of the developing countries themselves which have innovated and applied relevant technologies through the centuries. There are probably millions of appropriate technologies employed in rural areas of the world, covering a much broader range of activities than the newly formed intermediate technology groups would suggest. Examples given by Jéquier (5) include the windmills of the coastal flats of Thailand, used to raise seawater to evaporate in shallow ponds for the production of salt. Another is the Philippino entrepreneur who built a starch separation plant from second-hand washing machines and gave such competition on the market that he forced closure of a newly built, 1½ million dollar 'modern' plant.

The second group of appropriate technologists are more formally instituted and are to be found within government, private or semi-public institutions, or universities. They are primarily concerned with the development of hardware and may consist of an individual research effort, such as Dr. H. Montemayor's village-scale infiltration gallery research at the Panamanian Polytechnical, or a multidisciplinary team of researchers such as that within the Ministry of Local Government and Lands, of Botswana, investigating alternatives to urban sewerage.

The third category is represented by the multinational groups, such as the Intermediate Technology Development Group (ITDG), of London; or the Volunteers in Technical Assistance (VITA), of the United States. It appears that most of the driving or motivational force and certainly the funding for the Appropriate Technology (AT) movement comes from the industrialized states. Indeed, most of the activity is taking place in the industrialized states. This has given rise to accusations that appropriate technology is yet another form of neo-colonialism. Rybczynski points out that the "colonial connection could bear further inspection, as the Appropriate Technology movement is firmly grounded not, as one might expect, in an underdeveloped country, but in Great Britain. Recently it has spread to Holland, France and the United States".(10)

Funds are readily available for application of appropriate technology to international development. It appears that the large sums becoming available will surpass the capacity of the developing countries to absorb them effectively. By its very nature, appropriate technology is small and widely dispersed over the rural areas. The huge sums spent in the past on capital-intensive projects oriented toward the growth of the industrial/urban sector will be difficult to spend effectively on appropriate technologies. The engineering consultant and equipment firms are not attracted to labour-intensive, simple technologies, however appropriate. Lower-technology projects cannot be used to manipulate development from the outside, as can hydro-electric dams. Consequently, we can expect to see a proliferation of AT groups in the West and an increased use of expatriates as managers of externally motivated AT projects in the developing countries.

The USAID is supporting development of the largest group of all: Appropriate Technology International (ATI). Although commendable in many of its objectives, ATI intends to involve U.S. business in appropriate technology programs in developing countries. This will be accomplished by facilitating direct investment or through organized transfer of relevant business management experience and technology. Serious suggestions are being made that monetary incentives should be offered to encourage U.S. business to consider alternative technology, such as the provision of grants to U.S. equipment manufacturers to encourage the development of appropriate technologies for less-developed countries. (2) Such activities are hardly likely to result in the development of innovative capabilities and self-confidence in the developing countries themselves.

The ATI objectives of improving communication among practitioners of AT, evaluating experiences, and assisting in-field projects are commendable. It is not the objectives themselves which are in question; it is how they may be achieved, who will implement them, and where. Past experience indicates that American institutions and personnel will be heavily involved, both at home and abroad. Funds are likely to be spent largely in-house. The ATI Board of Directors, which is responsible for policy decisions, is composed entirely of Americans; there is no developing country representation on the Board. There is much heavier representation of business on the Board of Directors of ATI than in most AID activities. The initial fund for this activity is $20 million.

The greatest concern of all is that along with increased involvement of the bilateral agencies in appropriate technologies comes excessive and short-term funding tied to the requirement of using donor country personnel. Even if these funds are untied, their very magnitude will necessitate their being spent on expatriate personnel in order to meet budget-spending guidelines. Expatriate personnel used to direct field projects seldom have adequate knowledge of or experience in the rural areas in which they are contracted to work. As a consequence, they and their projects are likely to concentrate on hardware, at the expense of social, cultural, and organizational aspects. This is a practice proven to be highly susceptible to failure. Examples are already starting to appear. A major alternative energy project in the Philippines, which is supported by UNEP, includes studies on biogas, fish culture, low-cost building materials, solar energy, and bamboo production. All but the bamboo research are dependent upon foreign consultants; all projects are heavily oriented towards demonstration of only the hardware.

With every good intention, UNICEF created the Village Technology Unit near Nairobi to act as a demonstration centre of appropriate technologies for farmers. A myriad of gadgets are on display; only a few are actually relevant. Unfortunately, management of the Unit is UNICEF and not Kenyan dominated. Less than 5% of visitors to the Unit have been Kenyan farmers; the vast majority of visitors have been international travellers representing the UN, other development agencies, and local bureaucrats from Nairobi.

Amongst all the rhetoric about appropriate technology also being concerned with the institutional and social aspects, and despite these aspects being the greatest constraint to dissemination of appropriate technologies, very little effective action is being taken by the West's AT groups and international agencies in these directions. Understandably, it is difficult, if not impossible, to account for such software under existing constraints of personnel, time, and distance, which beset the industrialized-states based groups. It could well be that as far as AT projects are concerned, the international AT groups would best:

(1) confine their funding to a level which can be absorbed and effectively managed by the developing country groups and practitioners;

(2) limit the use of contracted expatriate personnel within the developing countries; and

(3) focus more on global aspects of appropriate technology, such as information exchange programs and inter-AT project activities such as the ITDG is now doing.

THE PROBLEMS OF APPROPRIATE TECHNOLOGY

The difficulties of international involvement in appropriate technology efforts within developing countries have been described. These underline the need for the entire process of AT development to originate and be implemented within the developing country by nationals and institutions of that country. The process of developing an appropriate technology begins with a definition of needs. All too often, these needs are defined in Washington, London, or Ottawa, and are based on what are perceived to be village needs, in relative ignorance of the complexities of rural society and its economic determinants. These needs should be defined within the developing country and with full participation of the community concerned.

Not only needs identification but also the process of innovation should take place in the developing country. However, there is a basic lack of self-confidence resulting from years of dependance on the more wealthy powers for transferred technology. Potential innovative capability does exist and research institutions are growing in number and quality. There is, however, a stigma associated with the lower technologies. Researchers, many of them trained overseas, are often loath to address the real problems facing their rural peoples. They continue to respond to the demands of publishing internationally and thereby select research topics of greater interest to the industrialized country academic than local peasantry and small industry. Promotion criteria within research institutions relate to politics and seniority, not excellence. There is a need to free the researcher from these restraints and frustrations and for him to focus on the practical problems facing his society. Another potential resource which must not be ignored is the artisan, the peasant himself, the 'bricoleurs', whom although difficult to incorporate into the formal system, were primarily responsible for the technology of the Industrial Revolution, long before the advent of the R and D Department.

AT innovation requires an appropriate setting in which to work. It needs institutional support and facilities as well as competence through adequate manpower. Risks associated with research ventures have to be recognized as being legitimate and in this way, they need to be reliably and well funded. Communications with other research groups have to be strong and information systems well developed. Most of all, the researcher must find incentives to innovate which are not only monetary. He must perceive a real chance of his product being developed and marketed.

One of the primary functions of the multinational AT groups has been to disseminate descriptions and designs of technologies. Unfortunately, seldom are the technologies evaluated prior to dissemination. What evaluation is done is often limited to its reported success in a specific situation or geographic region. Sometimes the hardware is tested empirically under repeated cycles of operation, but only under laboratory conditions; the evaluation is thus limited to a purely technical evaluation. There is a great danger that such evaluations will be used to justify the application of the technology on a broad scale in other regions. The danger is not so much that the equipment will break down, but that when it does, the communities become sceptical of further technical interventions and resistant to suggestions of change from the outside. Failure of a technology is often a result of its incorrect introduction to a community (e.g., without appropriate regard to existing patterns of authority and decision-making); aesthetic unacceptability; incompatibility with the class, hierarchical structure, or the social mores of the society; or of its giving economic advantage to the more wealthy. Although some generalizations of village conditions are legitimate, evaluation of a given technology should be made on a case-by-case basis by the communities involved.

No matter how effective the technology is in the hardware sense, its success depends on an effective delivery and maintenance system which fosters its acceptance and continued use by the community. The rate of acceptance of the technology is greatly enhanced by the ability of the potential user to participate in its assessment himself.

> "Yet there are strong indications that a substantial proportion of the development projects based on appropriate technology are for the time being of a non-participatory nature: the beneficiaries of these innovations are not directly involved in the definition of their major needs, and they do not take any direct part in the development, testing and improvement of the technology which is offered to them." (1)

Some form of extension service, village capability or at least availability of spare parts, must be instituted to ensure proper use and maintenance of the technology. Extension services have not had an exemplary history inasmuch as they have tended (with some notable exceptions) to act as providers of information but not take adequate account of the need for local participation. The problem is not of the technology itself but rather the way in which it is introduced and the quality of continuing services provided.

Three examples of civil engineering technology delivery are given below. The first is the much-talked-about biogas plant which has had a checkered past, being too expensive for the individual farmer to afford but technically effective and relatively simple to operate. The second is the village water supply system, which although meeting technical design standards, almost invariably suffers from lack of institutional support for its continued maintenance and repair. Thirdly, urban systems of wastewater collection and disposal are considered and sewerage condemned,as being far beyond the means of the urban poor and therefore inappropriate.

THE BIOGAS PLANT

The biogas plant has recently gained wide publicity as a resource-recycling technology appropriate for developing countries. It operates on the same anaerobic digestion principle as the anaerobic digester used in conventional primary sewage sludge treatment. The tank, made of concrete placed in the ground or flexible butyl rubber, is daily fed water and organic farm and household wastes, sometimes including human excreta. The mixture ferments without air to produce a gas composed of carbon dioxide and methane which is used primarily for cooking and lighting in the household. The digested waste material comes from the tank in the form of a slurry which is essentially odourless, innocuous and can be reused as a fertilizer either directly or after drying or composting with other farm waste materials. The biogas bubbles out of the tank's digesting material and is caught in a gas holder shaped as an upside-down mug; it rests on the tank's liquid surface. The gas holder rises and falls with production and use of the gas, which is drawn off through a flexible tube to the nearby household.

Technically at least, the concept has considerable appeal and has gained wide popularity in the West with the rise of the AT Movement and the publication of several articles by Fry (3) and Singh (12). These praised the biogas plant's technical attributes without concern over its costs or how it might relate to the socio-economic and organizational patterns of the rural areas of the developing country. Many demonstration units have been built (few of them actually operating on a continual basis for want of input material) in the West. More serious fundamental research is being carried out in universities of the U.K., the U.S., and Israel, but the technologies being considered are too high to be applicable to the rural peasant. Biogas plant technology is indigenous to Asia. A great deal is published about the original work being carried out in India, where 36,000 have been built; few, however, realize that parallel developments have taken place in Korea and China, where 27,000 and 80,000 plants have been installed, respectively.

The international agencies and appropriate technology groups found biogas to be highly attractive, particularly the UN Economic and Social Council for Asia and the Pacific (ESCAP), which held meetings in India and the Philippines on the subject. These were attended by biogas technology proponents and focussed, once again, on the hardware and how it should be promoted across Asia without concern over its many failures in the past. UNEP has supported demonstration projects in biogas while UNIDO, UNDP, UNICEF, WHO, the World Bank, and the International Development Research Centre are taking a more cautious stance; the latter is particularly interested in technical, social and economic evaluation of biogas systems and is supporting activities in Asia towards this end.

Success of the biogas plant in Asia is varied, being affected by numerous interrelated factors. Dominant motivation for adopting biogas plants varies between and even within countries. The gas as used for cooking does, however, appear to be the primary benefit, with the manurial value of the slurry often being given only marginal emphasis. The more hidden benefits related to public health and reforestation are recognized only by the governments which provide grants or soft loans (but decreasingly so) to individuals interested in installing biogas units. Korea is now withdrawing its credit facilities to farmers wishing to install biogas units. Such credit has been regarded as essential to the expansion of biogas programs in both India and Korea. The major constraints to biogas in rural areas pertain to the software. In particular, extension services vitally needed for maintenance and repair are often lacking; similarly, credit facilities are commonly cumbersome. One fact which is common to most situations where the plant is individually owned is that the biogas plant can only be afforded by the wealthier farmer, as the landless labourer or tenant has neither the required capital to construct nor the animals to feed the system. Water and land also pose problems where they are not readily available; in particular, the land required for slurry drying or composting has a high opportunity cost in urban or peri-urban situations.

Evaluating the biogas plant is complex and site specific. A dearth of basic information exists with respect to the capital costs of the biogas unit, cost of land, the dung produced by animals, seasonal fluctuations on demands, availabilities and values of resource, inputs and products, product yields, etc. There is a dire need for site-specific, socio-economic evaluations, the innovation of less expensive designs, and the identification of those social and economic conditions under which biogas plants have the greatest chance of success before being propagated across the developing world.

VILLAGE WATER SUPPLIES

In the eyes of the so-called 'developed society', clean water is seen as a prerequisite for comfortable, healthy living. This is feasible because acquiring water takes up only a very small percentage of the American or European income, and the thought of a cholera or typhoid epidemic running through New York or London via the water supply is truly horrific. Consequently, there is a serious danger that we, the 'international water engineers', will transfer these concepts and practices to developing regions where such diseases as cholera and typhoid are commonplace, indeed endemic; where their normal transmission routes have little to do with the water supply; and where the people simply cannot afford to pay for water supplies. These regions tend to accept external help and with it externally determined development priorities which may have little or nothing to do with their real needs.

On the other hand, there are areas which are in dire need of improved water supplies, where during the dry season women must spend a good portion of the day walking five or even ten kilometers to scrape water from a muddy hole. These water-scarce areas justifiably demand first attention, but this justification is based on labour and time savings and not on health. There is too great a temptation for the politician, the UN delegate, the aid agency employee, the international consultant and the water engineer to simplify and generalize the solution using water as a panacea, and climb on the next international bandwagon with such catchy phrases as "Clean Water for All"!.

It's just not that simple. If limited finance and even scarcer human resources are to be effectively spent on improving health, we must recognize that water delivery is only one element in a complex matrix of activities which must go on if it is to have any significant effect on health. The question is not how many water supplies can be installed over a given period of time, but why and how they are implemented; to what effect; and most important of all, at what opportunity costs.

Rural water supplies have recently become the focus of international attention. The idea of clean water, plentifully available in an otherwise destitute rural village, is highly attractive to the politician. It also appeals to the international bank, and to UN agencies and aid organizations, who are now searching for ways in which to direct their efforts towards rural development. Despite their good intentions, international aid organizations are limited to participating through financial and technical assistance and thus have become highly technology oriented.

The result of all this will likely be the release of large sums of aid funds to provide inducement for a more rapid expansion of rural water delivery programs; but here money implies technology, and technical solutions will be sought and pressed into service to meet the construction targets set by the funds being made available. Unfortunately, there is a severe shortage of experienced manpower capable of implementing effective rural water delivery programs in both the donor agencies and recipient countries alike. This, coupled with the inherent difficulty of successfully introducing any kind of technology to the rural community, will likely result in gross errors and financial resources being wasted at high opportunity cost.

Examples of such failures are not difficult to find - they exist in most African countries, where lack of maintenance and repair capabilities in rural areas is exasperated by the import of inappropriate well-drilling equipment and several varieties of handpumps more suited to the back garden of the Western farmer than the centre of a drought-prone, populous village. Henry (4) gives an example of one Asian country in which approximately 50,000 village wells have been drilled in hard rock at a cost of $40 million in water-scarce regions; an estimated 80 percent of these wells are no longer producing water. The problem is not only technical; the pumps are installed with insufficient involvement with the village - the site for locating the pump is selected by the engineer, not the village leader. The villager views the pump as belonging to the government department which installed it and therefore he accepts no responsibility to look after it.

In Bangladesh, clean water supplies to villages are being installed through a major UNICEF program providing thousands of handpumps to villages to combat endemic cholera. The mere supply of handpumps has done little to alter water-use practices and hygiene in the home. Consequently, it was not a surprise when after two separate field investigations, the Cholera Research Laboratory in Dacca found no significant reduction in cholera in families using the handpumps for drinking water. (6)

There are some success stories: in Malawi, for example, village participation was the key to success in bringing piped water to over 150,000 villagers falling in the water-scarce category at a cost of less than $3/capita. The Department of Community Development and Social Welfare began on a small scale by physically demonstrating that one could transport water through pipes from a perennial mountain stream several kilometers away. Convinced, the villagers participated by digging all the trenches, laying the pipes and constructing the concrete aprons and soak-away pits around the village taps. This initial demonstration mushroomed; soon the demand for piped water outstripped the capability to deliver it. The barefoot engineer concept has been introduced in the form of rural water technicians for this ever-expanding activity. Three-week technical courses are conducted under tents for carefully selected, technically oriented men with limited education; this training also includes a major community development component. Initially the piped water projects were small in size and made use of demonstrations and examples so that the villagers knew exactly what they were getting into. Now, large public meetings are held to ensure that any commitments being made are fully understood and acknowledged by all. More importantly, this approach involves the people not only as labourers, but in decision-making roles so that they are, to a large extent, responsible for the success of the system and willing to be responsible for its continued maintenance and repair. (8)

The community development approach taken in Malawi took a decade of patience, understanding, and hard work to achieve. Unfortunately, the urgency with which international funds will have to be spent, the commercial drive of equipment manufacturers and the inexperience of agencies in dealing with rural peoples are likely to result in no heed being taken to this example of success.

URBAN SEWERAGE

It never ceases to amaze me how in designing interventions to reduce the incidence of gastroenteric disease, we go to such lengths to ensure that the water supply is 'pure', when water is only one of a multitude of inputs to the gastroenteric system. The problem is at the anus, at the source of contamination; would it not, therefore, be better to cut transmission at the beginning of the feedback loop <u>before</u> it spreads through the household environment?

When the Western environmental engineer does evolve solutions for urban excreta disposal, he almost invariably bases his design on waterborne sewerage. This method of excreta management involves dilution of the waste in its most concentrated form with treated potable water solely for the purpose of its transportation.

The resulting sewage, made up of 99.9 percent water, is flushed through a system of subterranean pipes and pumping stations connecting all serviced buildings to one discharge point. Realizing that direct discharge of large volumes of waste is detrimental to the receiving resource, the objective becomes one of repurifying the water and reconcentrating and treating the waste. In short, this process of diluting waste for purposes of transportation and then concentrating it again at the treatment plant does not make sense, either economically or in terms of resource conservation.

Transporting faecal matter by water gained widespread popularity during the Industrial Revolution; the concept has remained unaltered to this day. Coming in the Victorian era when "cleanliness was next to Godliness", the concept of flushing away one's wastes was an attractive one indeed. Sewers were advocated as the solution to the human waste problem in the cities. The wastes had to go somewhere; most often they were discharged and effectively treated by the river. Inevitably, with the growth of the city and increased volume and complexity of wastewater, the self-purification capacity of the river was surpassed. Treatment before discharge became an expensive necessity.

Meanwhile, in China, the technological era had not arrived; human wastes were looked upon as a natural resource of nutrients for plants. Instead of the growing cities being regarded as an undesirable source of river pollutants, they were viewed as a valuable source of fertilizers, where the farmer could purchase excreta from the housewife at relatively little cost. The two approaches to essentially the same problem exemplify the philosophical disparities between the two societies. To Western thought, human excreta are useless, undesirable waste products to be disposed of as quickly and as inoffensively as possible. To the Chinese, nightsoil is a desirable resource. With economic and population growth, the exhaustability of our water resources is putting an end to indiscriminate discharge of wastes to the environment, yet alternative approaches which are socially acceptable in Western eyes are expensive. In contrast, the Chinese continue to utilize excreta for agricultural development and by doing so provide a positive monetary incentive for pollution control.

Sewers are expensive. On a per-household basis, they are far more expensive than coloured television sets. In the face of this, however, the urban planners insist that sewers are both desirable and necessary; but why? Firstly, there appear to be no alternatives: no technologies to fill the gap between the unsatisfactory pit privy and sewerage. Such is not the case. Systems are in use in developing countries which are appropriate and which could be upgraded and properly designed to provide adequate service at low cost. (11, 13) Secondly, concepts, practices and attitudes imported mainly from the West have artificially raised the desires of the policy-makers to technologies which simply cannot be afforded by their people. Thirdly, the dependent developing country often requests assistance from bilateral aid or UN organizations in the form of feasibility and master plans for wastewater collection systems. In keeping with the principle of spending aid funds 'in-house', Western engineering consultants are contracted. The consulting firms are constrained by lack of experience and expertise and limit their choice to piped sewerage. In several cases there has been outright refusal to consider alternative methods. This attitude is understandable: consulting engineering firms are professionally responsible for the designs they propose; their reputations, upon which their business is based, depend on the success of implemented schemes. As such, they can hardly be expected to endorse technologies with which they have had no experience. There is a case here for the purposeful development of local engineering capabilities in the Third World. They are familiar with conditions there and are not bound to design criteria and technologies of the industrialized states.

Under the guise that any planning exercises are worthwhile; that baseline data will be useful when sewers can be afforded; and that the plan was 'given' to the recipient country without cost, sewerage master plans continue to be developed. There are, however, many hidden costs to this exercise in negative aid. Firstly, the funds spent on developing master plans (normally approximately ½ - 1 million dollars) could be used elsewhere. Secondly, a large number of qualified personnel from the developing country spend valuable time on this useless planning exercise which they can ill afford. Thirdly, the plans which are developed, after being shelved for several years, fall out of date and are seldom used. The most adverse side effect of all is the perpetuation of the attitude that there are no other financially feasible methods of excreta collection and disposal, which results in indefinite postponement of rational attempts to solve the urban sanitation problem.

A cost-benefit analysis of sewerage was attempted (7) despite the inaccuracies of assessing the more intangible benefits. It served to demonstrate not the final, internal rate of return or benefit-to-cost ratio (which was less than one) but to illustrate economic characteristics of urban sewerage:

(a) the required construction periods are necessarily extended to very long periods due to budget constraints;

(b) the time at which benefits are likely to accrue from sewerage is in the distant future because the main sewer and lateral system need to be complete before significant numbers of house connections are made;

(c) heavy investments are required in sewer mains during the first stages of construction; these are not matched by early revenue returns or health benefits;

(d) in order for a municipality to invest in a sewerage scheme, a very high value must be placed on unquantifiable environmental and amenity benefits, as health benefits are minor relative to the capital outlay required for construction and maintenance of the system; and

(e) the health benefits are realized so late in the project that they tend to lack significance when discounted back to the time when the investment decision was made.

The developing countries are currently having considerable difficulty in providing urban wastewater management services. The central reason behind these difficulties is the inappropriate technology they are trying to apply. As transferred from the industrialized states, sewerage is very capital intensive and labour conserving during its operation: quite the opposite to those cost characteristics which are required.

CONCLUSIONS

In conclusion, I would like to emphasize five points, as follows:

1. To be appropriate in the developing country context, technologies must not only be technically viable but also account for the social, economic, organizational and cultural milieu in which they are found.
2. Wherever possible, the entire process of appropriate technology innovation, development, dissemination and implementation should be carried out by developing country nationals in the country in which the technology is to be applied. The intended user should also participate.
3. As priorities, international appropriate technology groups should focus on information dissemination and inter-project activities.
4. International funding of basic and applied research and development of appropriate technology should recognize the limited capacity in developing countries to effectively absorb such funds; funding should be constrained to suit that limited capacity and to avoid the temptation of 'delivery technology' via expatriate 'experts'.
5. There is nothing new in appropriate technology; it has been used in the developing world for centuries. Its newly found popularity emphasizes its considerable value as a means of reorienting development assistance programs to effect more

equitable distribution of wealth in the developing countries. There is, however, a dangerous tendency to oversimplify its dissemination and application, a process which is extremely complex - particularly within the rural societies.

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ENVIRONMENTAL IMPACTS OF INTERNATIONAL ENGINEERING PRACTICE

by

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INTRODUCTION

Professional concern over the environmental impacts of international civil engineering projects and practices is a recent phenomenon. Papers presented at this workshop (1-11)[2] reveal wide variations in individual, corporate, and agency attitudes toward the significance of these impacts and toward the manner in which they should be dealt with. While some of the differences are semantic, most of them are real and indicate the newness and unfamiliarity of environmental impact analysis. The workshop was designed to:

- identify, by means of case studies and interdisciplinary review and analysis, the impacts which results from international engineering practice; and to
- develop guidelines for program planning which will lead to greater public acceptance and utilization and to greater economic and environmental viability of the projects to which civil engineers contribute.

The environmental impacts being considered include behavioral, chemical, communication, cultural, demographic, ecological, economic, engineering, financial, food production, health and hygiene, institutional, physical, social, and transportation factors. The interrelationships between different factors are shown on the frontispiece where hydrology, impoundment, irrigation, transportation, economics, engineering, and cultural matters are connected in a single project.

Emphasis is on developing countries, although some of the examples and case studies presented in this workshop are from the wealthier nations. Table 12.1 shows the ranges of population, per capita income, and growth factors for selected countries throughout the world. Populations vary from 0.6 to 836 million, GNP per capita from $70 to $15,480, population growth from 0.2 to 19.7 percent, and GNP growth per capita from -3.3 to 20.3 percent. Note that the latter is not corrected for inflation so that disposable income is increasing at a lower rate.

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Table 12.1

1976 Population, GNP per Capita, and Growth Rates for Selected Countries (12)

	Population, Millions	GNP per capita (US $)	1970 - 1975 Growth Rates, % Population	GNP per capita
Bahrain	0.3	2410	4.2	20.3
Bhutan	1.2	70	2.3	-0.1
Canada	23.2	7510	1.4	3.3
China	835.8	410	1.7	5.3
Columbia	24.2	630	2.8	3.9
Cyprus	0.6	1480	0.2	-2.4
Egypt	38.1	280	2.2	1.3
Ghana	10.1	580	2.7	-0.3
India	620.0	150	2.1	0.5
Indonesia	135.2	240	2.4	3.5
Kuwait	1.1	15480	6.2	-3.3
Mexico	62.0	1090	3.5	2.3
Nepal	12.9	120	2.1	0.7
Nigeria	77.1	380	2.5	5.3
Panama	1.7	1310	3.1	2.2
Rhodesia	6.5	550	3.5	2.8
Sudan	15.9	290	2.1	3.8
Switzerland	6.4	8880	0.8	0.7
United Arab Emirates	0.7	13990	19.7	1.6
United Kingdom	56.1	4020	0.2	2.0
United States	215.1	7890	0.8	1.6
Uruguay	2.8	1390	0.4	-0.3
USSR	256.7	2760	0.9	3.1
Zambia	5.1	440	2.9	0.9

CASE STUDIES

Details of the case studies are presented in the original papers (1 to 11). Major negative environmental impacts, excluding those which the project is intended to remedy, which were recognized by the authors in preparing their papers for this workshop are indicated on Table 12.2 as solid circles. Additional project effects which should not be overlooked in analysis of environmental impacts of projects in developing countries are shown by open circles.

Darien Gap, Panama and Columbia (1)

This 160 km (100 mile) section is the final portion of the Pan American Highway which stretches from Alaska to Patagonia. Work on this section has been halted because of possible spread of hoof-and-mouth disease (Aftosa) from Columbia where it is endemic in cattle to North America where it has been controlled at great expense. Another area of concern is the possible cultural extinction of the Choro and the Cuna Indians who constitute 2% and 22% of the population in the area. This extinction would presumably be due to deforestation and other ecological change as the area is opened up to agriculture and lumbering. Political and diplomatic problems and local pollution problems await definition.

Lake Kariba, Zambia/Rhodesia, Lake Kainji, Nigeria, Lake Nasser, Egypt, and Volta Lake, Ghana (2)

These are major multiple-purpose projects designed for irrigation water supply, hydroelectric power, flood control, and navigation. Because of their impressive size and cost, these projects provide considerable prestige to the nations, officials, and engineers responsible for them. Obeng (2) qualitatively identified potential environmental impacts from reservoirs of flooding, population displacement, boating safety, fishing technology, water quality, seepage, evaporation and microclimates, shoreline erosion, distribution of nutrients, seismicity, aquatic weeds, and wildlife. Public health impacts include increased levels of schistosomiasis (bilharzia), African sleeping sickness

Table 12.2

IDENTIFIED (●) AND PROBABLE (○) MAJOR IMPACTS OF CASE STUDIES OF INTERNATIONAL CIVIL ENGINEERING PROJECTS (see text).

Project	Length km.	Area km^2	Design Population 000's (a)	Major Impacts																	Remarks and References
				Communications	Ecological changes	Economic	Employment	Energy	Financial	Food production	Health & safety	Inequity	Infrastructures	Institutional	Political	Pollution	Population	Resource allocation	Shelter	Social/Cultural	
TRANSPORTATION																					
Darien Gap	160	-	-		●	○		○	●	●	●	○	●		○	○				●	(1)
IMPOUNDMENT																					
Lake Kariba	280	5,500	50		●	○			○	●	●	○	○	○	○					●	160 km^3 (2)
Lake Kainji	120	770	44		●	○			○	●	●	○	○	○	○					●	15 km^3 (2)
Lake Nasser	290	5,300	100		●	○			○	●	●	○	○	○	○					●	150 km^3 (2)
Volta Lake	400	8,500	1,300		●	○			○	●	●	○	○	○	○					●	165 km^3 (2)
IRRIGATION																					
Kenana	–	490	50		○	○	●	○	●		●	○	○	○	○	●	●		●	●	(3)
Rahad	-	3,200	300		○	○	●		●		●	○	○	○	○	○	●		●	●	(3)
WATER SUPPLY																					
Surabaya	-	-	5,000				○		●	●	●	○		○	●	●	●		●	○	(4)
Nawapa	-	–	162,000(b)	●	●	●	○	○	●			●	○	○	●	○	○	●		○	(5)
SEWERAGE																					
Kathmandu	–	–	1,000			○	○		●					●	●						(6)
Madras	–	–	7,000			○	○		●					●	●			●			(6)
Morphou Bay	–	–	(c)				○		●					●	●						(6)
Montevideo	–	–	1,800			○	○		●					●	●						(6)
Surabaya	–	–	5,000				○		●		●				●						(4)

NOTES: (a) includes resettlement
(b) assuming 90% of Canada, 60% of United States, and 20% of Mexico populations for 1974. Estimated corresponding figure for 2025 is 342 million population.
(c) industrial discharge

(trypanosomiasis), river blindness (onchocerciasis). In an earlier publication (14), studies of potential impacts on the Volta Lake region are described. Economic, financial, political, institutional, and demographic impacts are yet to be quantified.

Rahad Irrigation Project and Kenana Sugar Project, Sudan (3)

The Rahad Irrigation Project lies some 200 km southeast of Khartoum and occupies 3200 km^2 along the Blue Nile. It will take advantage of some of the nation's prime economic resource, undeveloped land, and provide employment and food for Sudanese as well as a large amount of food for export.

The Kenana Sugar Project will form the largest sugar estate in the world. It involves converting over 400 km^2 of savannah into sugar plantation and construction of a company town and factory designed to produce 330,000 tons of sugar annually.

Both projects will provide immediate financial and economic benefits. These are expected to result in future population growth which will exceed the employment capacity of the agricultural industries being created. The consultant has accordingly recognized that some prime agricultural land will be needed for local manufacturing and services industries in order to prevent massive out-migration. He has provided for a hierarchy of settlements with populations of 3,000 to 75,000 which will maintain adequate infrastructures, services, and amenities for the area.

Welbank recognizes immediate public health problems due to bilharzia which may be ameliorated though not eliminated by land use planning. There will always be the problem of indiscriminate defecation in the fields and consequent disease transmission. He accepts uncontrolled air pollution from the sugar factory. Control of salinization will depend on efficiency of irrigation and drainage. Recognized ecological impacts include the immediate effects upon game migration routes; the long-term floral and faunal changes and interrelationships are not identified.

Long-term economic viability of the single-industry Kenana Project will depend upon future global political, economic, and agricultural conditions and events. These can confidently be expected to change with resulting favorable or unfavorable impacts on the project.

Surabaya Water Supply Project, Indonesia (4)

The Surabaya Water Supply Project is planned to serve Indonesia's second largest city which is expected to increase from over 2 million people in 1975 to more than 5 million by 2000. The present water system serves 890,000 people an average 80 liters (21 gallons) per capita per day by piped connections to 340,000 and by vendors to 550,000 people. The balance obtain their water from some 50,000 shallow wells. The aquifer is polluted by septic tanks and affected by salt water intrusion. Endemic water-borne diseases include cholera, typhoid, and hepatitis. Water-related diseases include malaria and dengue hemorrhagic fever. Cholera in some districts approaches 10 cases per year per 10,000 population. The project provides for improving existing spring supplies, realigning the supply channel to avoid industrial pollution, water disinfection, piped service to 3 million people, and vendor service to 1 million people. Community standpipes will be constructed in the kampungs. The service level is expected to reach about 150 liters (38 gallons) per capita per day.

Primary environmental impacts considered by the engineers (4) include temporary ones due to construction. There will be a permanent diversion of ground water from irrigation to municipal supply so that farmers will need to develop surface sources. Pipeline backfill may act as a drain affecting adjacent rice paddies. Since sewerage is financially impossible, there will be more ground water pollution and, near standpipes, there is likely to be more mosquito breeding. With the increased populations which the project is designed to serve, the net health improvements are uncertain.

Secondary impacts are recognized by the authors as more significant than the primary ones. These include increased in-migration and squatter housing in mosquito-infested areas. Ecological, economic, employment, equity, infrastructure, and institutional impacts remain to be quantitatively assessed.

Proposed North American Water and Power Alliance (5)

Unlike the other case studies, the North American Water and Power Alliance is still a proposal estimated to cost $120 billion. It has received enough official attention to make some people wrongly assign an official status to it. NAWAPA was first announced by the Ralph M. Parsons Company in 1967. Proposed water catchment areas would be in Alaska, Washington, Oregon, and Idaho, and in the Canadian provinces of Quebec, Ontario, Manitoba, Saskatchewan, Alberta, British Columbia, and the Yukon Territory (14). Interbasin transfers totaling 1.5 X 10" cubic meters (120 million acre feet) per year would provide for additional irrigated land as shown on Table 12.3.

Table 12.3

PRESENT AND PROJECTED IRRIGATED LAND UNDER NAWAPA

	Present Area	Projected Additional
	Millions of Hectares (acres)	
Canada (a)	0.4 (1.0)	3.6 (9)
Mexico (b)	3.3 (8.2)	2.4 (6)
United States (c)	16.9 (41.8)	8.5 (21)
	20.6 (51)	14.5 (36)

Notes

(a) 1967 data (15). Water distribution regions along a 100 km (60 mile) strip of southern Manitoba, Saskatchewan, and Alberta (14).

(b) 1966 data (15). Water distribution region along a 300 km (200 mile) strip of northern Tamaulipas, Nuevo Leon, Coahuila, Chihuahua, Sonora, and Baja, California (14).

(c) 1965 data (15). Water distribution region in 17 states west of 95^0 longitude and small areas of Minnesota and Illinois (15).

Assuming completion by 2025, an estimated 342 million people would be affected by the water transfer, power, and navigation aspects of the plan.

Sewell (5) points out that the ecological, economic, transportation and communications, and resource allocation and conservation impacts have not been adequately considered; that a limited analysis shows potential problems of inflexibility of grand designs and, most importantly, of political and diplomatic realities in and time (decades) required for negotiation of agreements involving 3 national governments, 7 provinces in Canada, 22 states in the U.S., and at least 6 states in Mexico. Other impacts which require study are those of financing the infrastructures needed for implementing the scheme, of adapting or creating the myriad of institutions to be involved, and of demographic, social, and cultural change.

Kathmandu Wastewater Treatment Project (6)

The population of Kathmandu, the capital of Nepal, is expected to increase from 600,000 to 1 million by A.D. 2000.

The Bagmati River is used for ritual bathing, domestic water supply, stock watering and irrigation. Waste loadings are largely due to runoff. A small part of the city is sewered but sanitation is mostly casual and dispersed. Present master plans prepared for the World Health Organization call for conventional sewers resulting in point sources of pollution which are in turn to be remedied by oxidation ponds. Economic and employment impacts of the technology selection are not revealed.

Madras Master Plan for Water Supply and Sewerage (6)

Difficulties with implementing an earlier master plan for sewage collection and treatment have resulted in current preparation of a new master plan to solve problems of disposal of domestic and industrial wastes, of cattle dung, and of sand from scouring pots and pans into overloaded sewers. The new plans are not expected to depart from previous and current long-range programs for sewerage and secondary sewage treatment. The latter is expected to result in industrial and irrigation use or in land disposal of all urban wastewaters now discharged to the ocean (average annual rainfall is 1270mm (50 in); the three dryest months have about 10mm (0.4 in) per month).

Morphou Bay Industrial Waste Disposal (6)

Located on the northwest coast of Cyprus, Morphou Bay is colored orange with copper refinery wastes up to 40 km (25 statute miles) from a discharge 2.75 km (1.65 mi) offshore into 75m (240ft) of water. Study indicated that initial dilutions of 200 to 1000:1 which would relieve the discoloration problem could be obtained by increasing the discharge depth to 120m (390 ft).

Montevideo Beach Pollution Elimination (6)

Located on the north shore of Rio de la Plata, the largest estuary in the world, Montevideo's beaches are heavily polluted by discharges of raw sewage. Beach use by tourists and residents has consequently been severely reduced in recent years. Preliminary engineering plans provide for a coastal interceptor, "advanced" primary treatment, and ocean discharge of municipal and industrial wastes.

Identified and Unidentified Impacts of Civil Engineering Projects

Table 12.2 shows the negative environmental impacts of case study projects which were identified by the authors and those additional impacts which can confidently be predicted. Some of the latter may have been considered during project development stages, or they may be implicitly included in some of the authors' analyses. Nevertheless, they are sufficiently important to have been examined in detail.

The significance of Table 12.2 lies in the variety of the authors' responses in identifying important considerations in environmental analyses of international projects. Financial, health and safety considerations were generally adequately addressed. In contrast, negative impacts of projects on communications and transportation, economic factors, energy requirements, infrastructures (hardware) and institutions (software), pollution, and resource allocation tended to be minimized or ignored. Remarkably, the issue of equity which often arises from (1) first-stage emphasis on investment in sectors or communities with high repayment capacity and/or environmental benefit, (2) misallocation of costs and benefits, or (3) from engineering implementation of development goals for income redistribution was identified only in discussion of Canadian-U.S. interrelationships for the proposed NAWAPA.

Most of the case studies presume a transfer of conventional North American or European technologies to developing countries, several reveal frustration or resignation resulting from lack of adequate institutions, infrastructures, or public participation, while some of the authors simply omit reference to environmental problems which spell success or failure of a particular project. The more important omissions are indicated by open circles on Table 12.2.

In the few cases where they are expressed, there are clearly wide divergences of opinion as to the roles of public participation and institutions. These include explanation/instructional meetings conducted for villagers (3), the view that requirements for public involvement and for consideration of institutional problems are generally unique to the U.S.(3,6), and that evaluation of future population, resource allocation, and other secondary impact problems likely to arise from successful implementation of a project are outside of the scope of individual engineering projects or physical development programs.(4). It should be noted that these issues arise when the engineers' attention is limited to the financial part of an economic analysis. It follows that full consideration of all economic factors including due regard for present and future public participation, institutional and political factors, and resource allocation is an engineering opportunity rather than a constraint.

PREDICTION AND MITIGATION OF ENVIRONMENTAL IMPACTS

The case study reports include a variety of factors to be considered in prediction and mitigation of environmental impacts of civil engineering projects and practices. There is a large body of other documentation which, by example and by checklists identifies factors to be considered in the planning and implementation of engineering programs. Some of the documents are particularly useful (see Bibliography). A recurrent theme is that engineering projects cannot properly be evaluated independently. Each project is a means to an end which lies in a larger context or program whose interrelationships are shown by a program planning helix developed by the ASCE Environmental Impact Analysis Research Council.

Engineering Program Planning Helix

Policy development leading to engineering works is a continuing process in which implementation of earlier policies is reflected in new or revised ones. Figure 12.1 shows the progression of decisions or actions which are involved in engineering projects and programs. As time goes on, policies and projects change in the helical manner shown on the inset.

The solid circles represent actions in which the engineer has major responsibility. Environmental assessments may require reiteration of some of the engineering functions.

The initial environmental assessment is critical. It is at this point that the engineer needs to "enter into and support programs for early public disclosure and public participation in the conceptual planning and implementation stages of civil engineering projects with particular emphasis on those actions where his or her special knowledge provides for an accurate assessment of public risk." (16).

Community Participation

The willingness to pay for construction, operation, maintenance, and protection of an engineering structure or system which contributes to meeting peoples' basic needs requires community participation and support throughout the life of the project

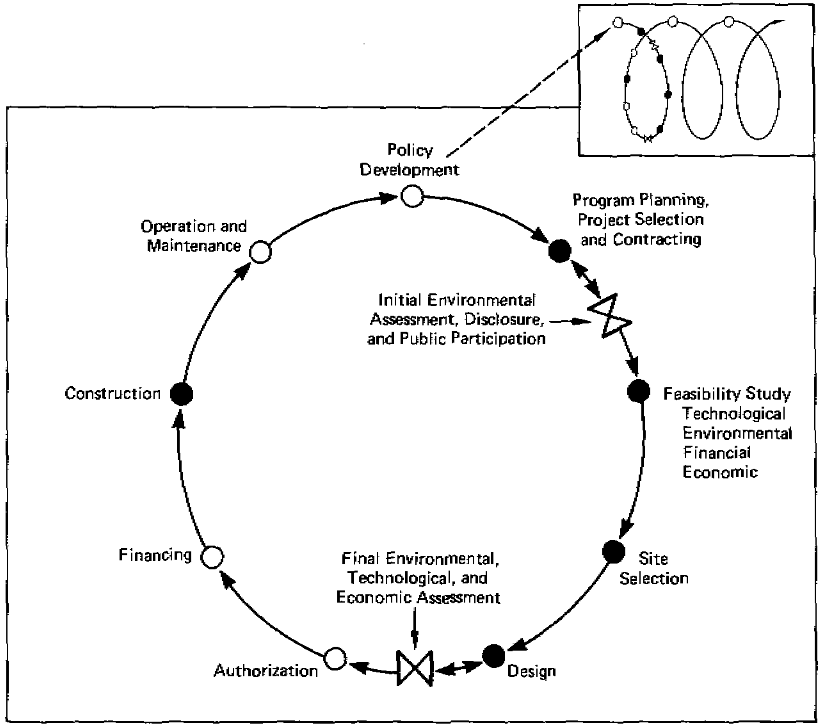

FIGURE 12.1 Engineering program planning helix. The front view of the helix shows the relationship of environmental, technological, and economic assessments to the progression of consulting engineering activities (solid circles) and political, administrative, and implementation activities.

or activity. Failure to obtain and retain this support is seen in a myriad of examples throughout the world including deterioration of roads, water supply systems and "low-cost" housing.

Basic needs include adequate food, shelter, clothing and essential services such as health services, sanitation, water, transportation, and cultural and educational facilities. For these to be realized, employment is a necessary concomitant. Furthermore, changing perceptions of basic needs ordinarily results in their improvement.

Examples of successful community participation range from the village self-help water supply programs investigated in Mexico by Elmendorf (10) and in Malawi by McGarry (11) to the Colorado mountains mining project described by Willard (9). Each author emphasizes the length of time required for these activities; two years to install a pump followed by eight years for individual house taps in a water supply in a Mexican village; ten years in Malawi villages; and eight years involvement with public interest groups for the Colorado mine. Also, the authors identify the lead agency or individual whose resources and personal commitments provided the driving force behind the successful participation. *In any event, implementation of community involvement programs requires* consideration of anthropological, sociological, educational, and communications arts and sciences.

ENGINEERING MEASURES FOR MITIGATING ENVIRONMENTAL IMPACTS

Performance Standards

Designers are familiar with establishing performance standards for engineering works and ensuring that they are achieved during the execution and implementation of their projects. As a matter of fact, in many countries engineers and architects customarily establish performance specifications or standards to achieve their objectives and do not prepare detailed designs specifications for the bidding and construction of the work to be undertaken. Performance specifications leave it to the manufacturer or contractor to submit proposals which will meet them.

Whether one or the other system achieves the design performance better is not the issue here. What is important is to recognize that civil engineering works indeed are designed according to established performance standards and engineers and designers are familiar with the concept. These performance standards cover only the essential purpose of the work such as the amount of water to be stored by a dam, the traffic which is to be accommodated by a port highway, the quantity and quality of water to be provided by a water supply project, the waste treatment effluent quality, or the type of shelter to be provided by a housing project. Standards cover such aspects as user safety, quality and reliability of services, and protection against service interruptions due to, say, fires, earthquakes or floods.

Willard (9) proceeds from the conventional performance standards described above and develops ecological principles and practices from which site-specific environmental performance criteria can be drawn. These principles are:

- everything affects everything else
- recycling of resources is essential because of the inevitable confrontation with the second law of thermodynamics
- sites that have already been disturbed should be exploited for engineering construction or activities because the environmental impacts will be less than in sites where there are stable and diverse systems
- there are optimum sizes and configurations for communities, industrial complexes, energy or transportation systems, etc. for any one region
- the variability in all biological systems means that what is known about one system is not fully applicable to another

Flexibility in design, staged construction of infrastructures, and conservation of resources are general guidelines for development of ecological performance criteria. These criteria, which can be just as enforceable as standards, are subject to change as greater investments are made in ecological research. All of this effort is to the end that engineers who have been trained to solve certain environmental problems will be equally effective in recognizing and, with the help of other disciplines, solving the ecological, economic, and other impacts listed on Table 12.2.

In sum, a setting of performance standards by designers of engineering works which affects the environment should be based on both conventional and environmental criteria. The designer can then measure the trade-offs between active performance and environmental protection and be able to achieve the most cost effective facility.

Service Levels

The single most important cost factor in any infrastructure, be it in housing, transportation, energy, communications, or water supply, is the service level. Where there are waste products, as in water supply or energy, the effect of service levels are magnified. For example, a 30 liter per capita per day water system using neighborhood standpipes will have a minimum unit cost of waste disposal. A 100 lcd supply using yard spigots will have waste disposal costs somewhat greater than supply costs. Finally, a 400 lcd service level, much of which is used for flushing wastes will require a community sewer system. Here proper disposal costs will be about three times that for supplying the water. The latter will often be deferred since the costs of water pollution, as well as those of other forms of individual or group environmental exploitation, are born by the larger community or region following the principle of Garrett Hardin's tragedy of the commons (17).

There are, of course, examples of service level decisions from other sectors. In transportation, there are immediately perceived benefits of all-weather reliability and dimly perceived ones of personal safety. In housing, a cost reduction due to, say, smaller area per occupant is apparent to the purchaser or lessee as well as to the designer.

Since resources are extremely limited in developing countries, the most important technological decision to be made by the engineer is whether to provide a few people with a high service level, say 400 lcd of water, or many more people with a low service level of 30 to 100 lcd. As noted, this technological decision has immediate economic and behavioral impacts.

Appropriate Technology

In 1973, E. F. Schumacher proclaimed, "Small is Beautiful" (18). That the book met a need is shown by the several score of recognized agencies or organizations dealing with appropriate technology and the 9000 references recently identified (19) by a computer search.

Appropriate technology is defined here as that which provides socially and environmentally acceptable, economically efficient services at a cost which is financially affordable by the consumer. Willingness to pay is essential but is another matter involving individual and community priorities. Here, public participation aspects described above apply.

McGarry's functional definition of appropriate technology (13) emphasizes that it must be of proven efficiency, small-scale, available to the poorest users and hence a factor in wealth and power distribution; economically, culturally, politically, and socially viable; and, perhaps most important, raise the self-confidence of its maker or user. The last means that it cannot be a technological dead-end.

A more rigorous statement is developed by Rosenfield et al.(19) from Schumacher's work in which appropriate technology is that technology selected by cost benefit analyses using shadow prices.

Examples of both appropriate and inappropriate technologies abound. The appropriate ones come from a variety of sources, including peasant artisans whose ancestors are identifed by McGarry as the progenitors of the Industrial Revolution. Many of the ancient technologies are still appropriate, a number of which are still in use today, and are described by, among others, Brill (20). Modern materials, design criteria, and techniques also support appropriate technologies which range from butyl sheets for rainfall catchments (21) to the 5 to 7 hp International Rice Research Institute's machines for tilling, seeding, weeding, threshing or drying (22).

Since appropriate technologies tend to be small, dispersed, labor-intensive and resource conservative, their impacts on the natural environment tend to be minimal. These characteristics promote innovation, improvement, and for physical infrastructures, staged construction.

Priorities and Staged Construction

It is stated previously that willingness to pay depends upon individual and community priorities. Here, McGarry (13) points out that sewer systems cost more than television sets. This suggests that, sooner or later, technological advances make the choice between personal enhancement and the public good ever more difficult, and one which is generally resolved in favor of the individual. It explains how technology feeds on itself, which is not to say that technology can solve the problems of technology. The issue quickly becomes an ethical one which Schumacher has recently addressed (23). In any event, the ultimate environmental constraints are even more rigid than the ethical ones. Two guidelines may be drawn. First, the engineer conducting the feasibility study needs to learn the communities' priorities and, second, he needs to identify the limiting environmental and economic parameters. He should not be surprised that, in this milieu of ethics, economics, and environmentalism, practitioners of appropriate technology become missionaries for it.

Priorities which are determined by the users are implemented by staged construction and successive improvements designed by the engineer. Users include individuals who prefer television to sewers and governments who select television stations, freeways, jetports, and national airlines rather than environmental protection. Even so, civil engineering works should provide for incremental improvements of service levels, bearing in mind the shortening of the design periods due to rising interest rates and the shifting balance between capital and labor intensive schemes due to market distortions.

Equally important are the demographic and economic constraints which may result in a first-stage project surviving for a long time which still must be capable of improvement to a higher service level at any time. If, for example, elimination of losses from a water system constitutes the first stage, other conservation and maintenance measures will have to provide for basic needs until a delayed second stage is implemented. In any event, it is generally true that the smaller the stages, the lower the total cost of the project. In other words, the more closely the demand and production are met, the more efficient the investment.

Health Effects

Donaldson (7) has identified potential impacts of engineering works on public health. These include

- introduction of foreign diseases and new strains of endemic diseases
- overloading and failure of traditional or advanced water-supported waste disposal systems
- food shortages
- air pollution
- environmental deterioration including fish kills
- increased malaria from mosquitoes in clean impounded water
- increased filariasis from enriched or polluted impounded water
- schistosomiasis from snails in slow-moving water
- onchocerciasis (river blindness) from flies breeding in turbulent water
- trypansomiasis (African sleeping sickness or American Chagas disease) from flies breeding near water
- emotional responses to relocation of residents or to loss of traditional resources
- overwhelming of local health services.

Advanced planning, allocation of funds, and community participation are needed for mitigation of these impacts. Short-term needs during construction can best be met by requiring that they be provided by the contractor to his staff, workers, and the local population.

Provision of 30 liters per capita per day of safe water, sanitary facilities, and the educational and participatory measures needed for their acceptance are required. These are needed during both the construction and the operation periods for control of water-borne (e.g., cholera), water-washed (salmonellosis), water-based (schistosomiasis), water-related (malaria) and fecal disposal (hookworm) diseases (24).

ECONOMIC MEASURES FOR MITIGATING ENVIRONMENTAL IMPACTS

The first class of economic problems defined by Warford and Rosenfield (8) of environmental protection in developing countries is that of precedence; today's pollution costs are due to yesterday's economic growth. While it is not essential that things get worse before they get better, the authors nevertheless suggest that environmental improvements are a useful index of real income and development for the urban poor. The second class of problems relates to incidence; the distribution of income which is low to begin with is skewed to the extent that economic growth in the country as a whole may be associated with a lower real income for the poor. Thus determination of basic needs and the manner of providing them are site-specific issues.

Shadow Pricing

In another paper (19), the same authors show that cost-benefit analyses, despite Schumacher's contention that it fails because incommensurate goods are measured, works when shadow prices are considered. The most common example of a shadow price is the black market value of foreign money. Failure to consider shadow pricing in engineering works often results in favoring capital-intensive alternatives. By removing from the analysis distortions due to political decisions, unemployment, minimum wage laws, overvalued local currencies, and development capital available at low rates, and by providing a framework for consideration of such social weights as non-quantified health or environmental benefits, cultural and religious factors, shadow pricing will identify the appropriate technology (19). Shadow pricing permits comparison of real investment costs for providing bamboo poles or using cement which requires construction of a cement factory which in turn provides for future employment, or for comparison of employment opportunities vs machine excavation of sewage oxidation ponds (6).

Block Tariffs

The public utility concept described by Warford and Rosenfeld (9) provides for accumulation of public savings for either system expansion or general expenditures. By imposition of, for example, effluent charges based on economic and environmental analyses, environmental protection is made feasible. Note that effluent charges are not necessarily a "license to pollute;" rather, they provide the framework for determining the real costs and benefits of pollution control. Where a discharger determines that the effluent charge is less than his incremental cost of treatment and dumps his wastes accordingly, the community will have received payment for its costs of environmental restoration. Similarly, by imposition of a tax on goods which end up as solid wastes, e.g., Wegman's penny-a-pound proposal (25), the community can accumulate funds to manage their proper recycling and the eventual disposal of the smaller amount of final residuals.

Developing countries, in contrast to the developed ones, are using increasing block tariffs for public utilities. In water supply and electricity this block tariff results in a socially just, financially viable and economically efficient method of producing revenues to pay for the cost of the services provided. The increasing block tariff is socially just because it provides a minimum amount of water for a very low price, usually set at a level far below production costs, so that even a low income consumer can satisfy minimum needs at something less than 5% of his income. The blocks of the tariffs increase the cost of water as consumption increases. For economic efficiency a two-block tariff, the first at a subsidized life-line break, the other at the marginal cost of water, is theoretically sufficient. It may take three to five blocks to satisfy social equity requirements. Very often tariffs are designed to match income distribution curves of a particular community. In a three-block case the top block, that is the most expensive one, is set at a price in excess of marginal cost, the second highest at marginal cost, and the total income from the tariff is designed to cover financial needs of the utility involved. The marginal cost recovery made possible by block tariffs is used to optimize economic performance in arriving at investment decisions.

Fees for Engineering Services

In order for engineers, architects and planners to satisfactorily perform the functions which are inherent in the tasks described in the previous paragraphs, it is necessary to reexamine how they are being paid. A typical example should demonstrate this point. Very often engineers are called upon to design water treatment facilities in order to increase the supply of potable water for a community. If the engineer designs a new plant which in due course is constructed by his client he is reimbursed for his services in accordance to a percentage of construction cost. If, on the other hand, the engineer proceeds to evaluate the performance of an existing plant which might have been constructed decades before and finds that he can improve the performance by introducing more efficient treatment methods and making process modifications, etc., possibly with the effect of eliminating the need to construct the new facilities, he will in fact be paid far less for work which might amount to the same effort. In fact, it might even be said that an engineer requires more imagination and expertise to improve an existing plant to achieve higher water production and quality levels than to design a new facility.

The problem is exacerbated when conventional engineering contracts based on construction costs are split into high- and low-technology sectors. For example, nuclear power plant design may be split into the reactor-generator component and the structural-mechanical component. The latter design often requires more engineering effort although the construction costs are less.

Other examples abound. The generalization that money saved at the planning and design stage usually results in far greater expenses in the execution of a project is true insofar as fees are based upon services performed by the engineer. Only in this way can appropriate, generally labor intensive, technologies become attractive to engineering consultants and equipment firms. Every one of the decisions which are taken in the planning and design process such as performance standards, service levels, technology to be used, the staging, etc., will have a direct impact on the cost effectiveness of the project. It is therefore important that not only the client but development agencies such as national and international lending institutions adapt the necessary changes in policies to permit the work required at fees which are adequate to attract responsible engineers and scientists.

Institutional Measures

Preparation of efficient terms of reference for engineering feasibility studies, plans, and specifications is only one of the problems which development agencies, host countries, and consulting engineering organizations need to face. Others derive from the engineering program planning helix shown on Figure 1. Fortunately, the ability to predict and ameliorate environmental impacts is improving. Even in remote parts of developing countries, aerial and ground reconaissance by specialists will minimize such impacts as those of automobiles turning off from the Pan American Highway onto the recently revealed 2000-year old desert markings of the Nasca Plain (26) shown in Figure 12.2.

Clearly, there are increasing needs for improving the utilization of educational facilities and their graduates and their organizations in developing countries. Responsibility for providing further training and experience, including that at higher levels, will continue to lie with the consultant. This will quickly result in improved awareness of local conditions, appropriate designs, and a high percentage of engineering studies, plans, and recommendations being implemented before they are outdated.

CONCLUSIONS

Conclusions drawn from this survey of civil engineering projects and practices in developing countries may be stated in the form of the following conclusions and guidelines:

1. Development agencies, host country ministers, and engineering consultants are involved in programs rather than limited projects. It is the aggregate, long-term environmental impact of these programs that is important.
2. The program planning helix shown on Figure 12.1 illustrates the necessity for early assessment disclosure and participation by the engineer in environmental and economic analysis. The engineer's special knowledge imposes a special responsibility for proper assessment of public risk.
3. Public involvement and participation is essential to a project's success. There are often long-term requirements for this.
4. Environmental constraints constitute performance standards.
5. Identification of alternative service levels and technologies is a responsibility of the engineer. Selection of appropriate service levels and technologies is based on engineering, economic, environmental, and behavioral consideration.
6. Shadow pricing is an essential tool for the selection of appropriate technology.
7. Increasing block tariffs provide socially, environmentally, and economically sound financing for public utilities.
8. Engineering fees based on services performed rather than construction costs provide for the optimum technological choices.

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