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A RESOURCE SIMULATION MODEL FOR WATER AND WASTE WATER TREATMENT IN LESS-DEVELOPED COUNTRIES

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A RESOURCE SIMULATION MODEL FOR WATER AND WASTE WATER TREATMENT IN LESS-DEVELOPED COUNTRIES

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A RESOURCE SIMULATION MODEL FOR WATER AND WASTE WATER TREATMENT IN LESS-DEVELOPED COUNTRIES

CHAPTER I

INTRODUCTION

In recent years man has begun to intensify his age-old quest to improve his immediate surroundings. This search for "better ways" has often resulted in conflict between societal mores and technological advances. In fact, social scientists are finding that one of the most challenging tasks facing society is that of adapting modern technology -- which is basically oriented to a modern urban Western society -- to the needs of people in less developed areas.

In many of the less-developed countries (LDC's), living conditions are crude. Basic sanitation services are needed for the prevention and control of communicable disease and for the promotion of physical, mental, and social well-being. Although sanitation services cover housing, food, sanitation, and vector (disease) control, increasing attention is being directed to the baseline problems of safe water supply and disposal of waste water.

The Progress Report of the Director-General on the Community Water Supply Program to the Twenty-Fifth World Health Assembly outlined the status of community water supply in 90 selected LDC's and projected the needs for the decade 1971-80. In 1970, of the total population within the selected LDC's only 23% had access to safe water. Within urban communities, 50% of the population obtained safe water through individual house connections while 23% used public standposts. However, in many of the piped urban supplies, service was intermittent — a situation which rendered a water system potentially hazardous to health.[1] In rural areas, the report revealed that more than 85% of the population -- more than one billion people — did not have safe water available to them.

The current situation is bad, but the prognosis for the end of 1980 is worse -- especially in rural areas. The Director-General's report sets forth goals for the decade which would see safe water service available to 100% of the urban population and 25% of the rural population. The total investment necessary to reach these goals is estimated at $13.2 billion; however, in rural areas the anticipated growth of population outstrips the projected growth of water facilities. Even if the goals are met, there will still be 50 million more people without safe water in 1980 than in 1970. Since population increases will inevitably result in increased water usage, similar increases can be predicted in waste water disposal problems. In fact, increases in sewage and waste water could negate a significant portion of planned capability by contaminating previously satisfactory water supplies.[2]

The overall picture of sewage disposal in the 90 selected LDC's is even more dismal than the problem of water supply.[3] On the basis of

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[1]World Health Organization, <u>Community Water Supply Programme</u>, Progress Report by the Director-General, WHO Document A25/29 (Geneva: World Health Organization, 1970).

[2]<u>Ibid</u>.

[3]Historically, we have dealt with water, then sewage. The modern approach is to accept them as one problem.

currently available data, the World Health Organization estimates that 50% of urban residents are served with public sewage systems and an additional 45% have individual household systems. In rural areas, it is estimates that 91% of the population have inadequate excreta disposal facilities -- more than one billion people are following primitive excreta disposal practices which lead to unnecessary illness, disability, and death.[4]

An adequate system for the collection and disposal of solid waste is a fundamental health requirement. Without such service, the incidence of pollution and rapid breeding of disease vectors, such as flies and rodents, could result in an intolerable burden being placed on medical services. However, the rapidity with which the waste and waste water problem is growing, not only in size but also in complexity, is now causing concern in many countries, both developed and developing. Lack of disposal sites or facilities, the ever-increasing quantities and variety of the wastes, and the limited financial and manpower resources available to meet the increasing demands are all factors contributing to this serious situation. In many cases, local resources are inadequate for the broad-based research and training programs needed, and assistance is required.

This need has been recognized for a long time. For example, a conclusion of the discussions of the Fifteenth Session of the WHO Regional Committee for South East Asia more than a decade ago was that:

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[4]World Health Organization, Community Water.

> In the present stage of development of the majority of communities of this region, the methods, equipment, and the basic design factors commonly used in the highly developed and wealthier countries are often economically and technically beyond reach.[5]

Clearly, there is an urgent need for the following basic sanitary measures: (1) greater availability of pure safe water; (2) improved practices in the disposal of sewage.

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[5]World Health Organization, "Community Water Supplies, Conclusions and Recommendations Arising Out of the Technical Discussions Held at the Fifteenth Session of the Regional Committee for South East Asia," SEA/Env. San./25 (New Delhi, 1962), p. 2.

Statement of the Problem

Water supply and sewage treatment have been seen largely as engineering problems, and the modern engineering methods, standards, techniques, and equipment that have been used in LDC's have been almost entirely transferred from the richer industrial societies. These are often found side by side with the long-established methods, if any, associated with a traditional culture. Thus in South America, it is possible to see a hand-operated pump or public standpipe within a short distance of the traditional public water tank. It is also possible to find that the pump is in need of repair, or that the standpipe is dry, and that the women are drawing water from the tank. The field of water supply and sanitation is replete with stories, often unsubstantiated and undocumented but frequently true, of instances where improvements have been made only to fall into disrepair and disuse.[6]

A commonly asserted view is that too often attempts are made to transfer a too sophisticated level of technology to the LDC's. The propensity to recommend or to seek to adapt the latest (and therefore generally most expensive) technology is seen as a major obstacle in upgrading LDC water and waste disposal systems. Instead, systems that are inexpensive to construct and simple to operate and maintain should be used. Measures must be found to make full use of local materials, local skills, and the principles of self-help. Research emphasizing environmental harmony will hopefully lead to standards for design, determination of

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[6] B. A. Dieterich and J. M. Henderson. Urban Water Supply Conditions and Needs in Seventy-five Developing Countries. (Geneva: World Health Organization, 1963), p. 14.

design periods, maintenance, operation, and management applicable to the conditions in the different sites within a selected community in an LDC.

Earlier programs of foreign assistance have shown that merely transferring an advanced country's technology will not, by itself, effectively solve an LDC's problems. In fact, there have been apparent contradictions between the aims and means of development. For example, foreign assistance programs have promoted rapid modernization through the exportation of new labor-saving technology even though the recipient country was plagued with a labor surplus. A second contradiction in such programs is that modern technology, developed in and for industrialized nations, is often so costly that available funds are insufficient for meeting the burgeoning needs of the LDC's. And a third contradiction is that the imported equipment is often too intricate and automated to be maintained by local technicians, resulting in excessive operational difficulties.[7]

For example, in the water resource development of Central and South America, the tendency has been to use the "latest" technology in water plant design, a case in point being the very modern, tape-operated, pulsation water treatment plant in Lima, Peru. Another is the installation of packaged, activated sludge units in the Caribbean Islands. These excellent plants require mechanical and electronic maintenance and operational skills that are simply non-existent on the Central and South

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[7]K. Margden, "Progressive Technologies for Developing Countries," International Labor Review 101 (May, 1970), p. 476.

American scenes. The result is that many such plants become inoperative within a short time because of the lack of proper maintenance and operation.

These apparent conflicts can partially be resolved by the introduction of simplified and adaptive processes which are specifically tailored to the local setting and individual problems. Simplified and adaptive technology often gives a higher productivity than the modern techniques and, at the same time, is sufficiently cheap and simple to be used advantageously in LDC's. With this approach, both foreign and domestic resources can be utilized with great effectiveness.

The problem, however, was the lack of a methodology for the selection and use of known techniques that would arrive at the simplest, cheapest treatment methods which take advantage of local conditions, including manpower, materials, and socio-economic goals. To develop such a methodology, which was a basic objective of this work, an array of water and waste water treatment processes, each having its sanitary, mechanical, and electronic capability criteria, was developed. The problem then became one of matching the total process to its local environment via a computerized simulation model.

Since the LDC's obviously are in different stages of economic development with varying resources, cultures, and settings, no single pattern of priorities in the several areas of environmental improvement can meet the specific requirements of all LDC's. Further, tasks such as water and sewage treatment, which are basic to LDC population health, often require coordinated action among contiguous nations and sometimes hemispheric cooperation. Thus, priorities and strategies for LDC water and sewage treatment must consider inter-country benefits, even at the risk of developing less than optimal operations for specific countries. On the basis of reasonably solid data and the experiences of the highly developed nations, some of the likely environmental changes in the LDC's can be predicted. Hopefully, previous successes will be emulated and the worst mistakes in dealing with such changes may be avoided.

Need

The Urban Development Staff of the U.S. Department of State indicates that the most frequently articulated and most heavily emphasized problem faced by municipalities in LDC's is the tremendous strain placed on urban infrastructure by the unprecedented rates of urban population increase and the concomitant increase in other urban activities (i.e., industrialization). Many cities have more than doubled in size over the past twenty years, while their facilities and services have expanded far too slowly to meet the need for more water and sewer systems. For example, in Cali, Colombia, where urban population has been growing at a rate of 6.5% for many years, 70% of the city's population has access to only 30% of its services and infrastructure. This situation has been described as "urban dualism" and has occurred in many cities which lack the resources to meet the service and infrastructure needs of their new populations.[8]

Inadequacies with regard to water and sewage are generally uppermost in the minds of officials and planners. However, the few studies available on public preferences indicate that the residents in unserviced and under-serviced areas seem to be more concerned with amenities, such as electricity, paved roads, and educational facilities. These studies have concluded that such amenities are highly symbolic of the new mode of life for which people came to the city.[9] Thus, official attempts to

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[8] Urban Development Staff, Focus on Urban Development: Perceptions, Problems, Approaches, and Needs -- A Potential Role for U.S. Foreign Assistance (Washington, D.C.: Department of State, October, 1972), pp. 34-35. (Mimeographed)

[9] Ibid.

concentrate resources on extension and improvement of water and sewage services are often lacking citizen support.

In spite of this recognition of the need for more appropriate technology and planning tools, little has been done, and the funds allocated for research and development appear to be pitifully small. Modest efforts have been made by the Intermediate Technology Development Group, Ltd., in London. These include a bibliography of low cost water technologies by Bateman[10] and a report of the introduction of rainwater catchment tanks and micro-irrigation to Botswana.[11]

Despite the obvious need for better water and sewage treatment in the LDC's, a major question still remains as to what research can be carried out to help solve or mitigate the problem. The following discussion pinpoints the reason for the research.

In 1970, the World Health Organization conducted a survey of community water supply needs in LDC's. The basic data from the questionnaires were analyzed and used in preparing document A25/29, "The Community Water Supply Programme, Report of the Director-General to the 25th World Health Assembly." That report identified the water supply needs of 90 developing countries. Research and development needs were only reported in a general way, because construction and project imple-

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[10] G. H. Bateman, comp., A Bibliography of Low-Cost Water Technologies, 2nd ed. (London: Intermediate Technology Development Group, Ltd., 1971).

[11] Intermediate Technology Development Group, Ltd., _The Introduction of Rainwater Catchment Tanks and Micro-Irrigation to Botswana_ (London: Intermediate Technology Development Group, Ltd., 1969).

mentation were the specifically identified targets. However, each country was asked to list five projects in decreasing order of priority. The first priority project was given a value of 5, second priority 4, and so forth. As a result, it is possible not only to determine the number of times that each subcategory appears as a suggested research project, but in addition to obtain a general impression of the global importance of each subcategory. Reviewing the tabulated data, one is struck by the paucity of proposals for research on new technology. Techniques exist which are capable of solving most of the apparent needs.

The single, most important need, according to the results of the survey, is the gathering of environmental data that are specific to the needs of each country. The recognition of this need was recorded 132 times, and on the average was classed as the most important need. The gathering of this background data is highly location-sensitive -- it can only be obtained within the country that needs the research results. The countries surveyed felt that help from outside should consist of technology transfer, supply of equipment and personnel, assistance in planning, and compilation of data; but in effect the need can only be satisfied by work within the country itself.

The availability of background data on water resources and related information as brought forth in the WHO Survey is an essential prerequisite if the water supply and sewage treatment goals of the United Nations Second Development Decade are to be reached. Since much of the data can only be gathered on a medium to long-range basis, it appears essential that the necessary studies be commenced as soon as possible.

One final point is that the questionnaire also asked about the capability of the LDC to conduct planning research. In practically all cases the response was that outside help would be needed to supplement the in-country capability. The LDC's realize that the task of supplying adequate quantities of safe potable water to a thirsty world is a task of gargantuan proportion, and therefore, the problem requires some assistance.

In summary, the World Health Organization survey has popularized the problem of water and sewage treatment and has clarified some of the reserach needs in this area. In this research study a water and sewage treatment method planning model has been developed to provide some "assistance in planning" for the identified needs of water and waste water treatment. This effort represents a positive step towards helping people in less-developed countries make more effective and rational decisions concerning the methods of treating of water and waste water.

Scope and Limitations of the Planning Model

In physical terms, water can never be limited. It is technically possible to deliver virtually unlimited amounts of water, if necessary, as gallon cans of purified sea water.

However, in practice there are severe constraints on most projects before initiation. Nearly all the water development authorities in the LDC's have received numerous proposals for water and sewage treatment schemes costing millions of dollars. These proposals are the result of initiative in the urban and rural areas by self-help groups, district or state development committees, international agencies, and even individuals. The model developed in this research effort is an attempt to set forth a simple, straight-forward procedure to help planning agencies select the most appropriate method for treating water and sewage, given the parameters of the local environment.

The limitations of the planning model can be classified into three specific categories: (1) technological considerations, (2) the specific population groups included, and (3) specific components of the water supply and waste water system considered.

The technological limitations are that:

1. Generally, the cost of operation of the facilities should not exceed the community's ability to pay.

2. The manpower skills to operate the plant should be available locally.

3. Supplies and materials for efficient operation of the plants should be available locally or accessable without undue effort.

The reason for setting these limitations was to insure the model's applicability to the LDC's for which it is intended. Obviously, more effective technological solutions might be reached if skills, materials, and financial resources were not constraints.

Secondly, the model is limited to organized communities or nucleated villages that range in population from 500 to 100,000 inhabitants. The logic in setting these limits was as follows. In sparsely populated areas (population less than 500), water quantity and quality is normally so marginal that any type of general planning model is inadequate and specific studies must be made. (If the water supply was good, the areas would not be sparsely populated). Conversely, in high population concentration areas, the more developed communities have largely been able to develop adequate systems without the need for a planning model.[12]

The third limitation of the study concerns the components of the water supply and sewage treatment that will be examined. By assuming a single community, the water system may be broken down into four sets. These are: (1) water resources, (2) delivery system, (3) use system, and (4) disposal system. Water Resources refers to the location, quantity, and quality of available water and other characteristics of the natural environment such as climate and topography. The Delivery System refers to the means available for developing the resources and supplying water to the point where it is to be used. (This will

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[12] D. Donaldson, "Progress in the Rural Water Programs of Latin America," Bulletin of the Pan American Health Organization, VIII 1, 1974, pp. 41-42.

encompass technology, engineering skills, and hardware from the most primitive to the most sophisticated levels.) The Use System refers to the purposes for which the water is employed and the quantities and qualities required for each. The Disposal System refers to the means available for taking used water and its content of wastes away from the household and returning it to the environment.

The water treatment phase of the study deals only with treatment of the water somewhere between the source and the ultimate user. In other words, the planning model is not involved with the location of water sources or the design of distribution systems. In the waste treatment phase, the study is concerned with returning the water and wastes to the environment so that pollution will be minimized. Transportation of wastes away from the household was not investigated. The reasons for these restrictions were time and cost restrictions, and the desire to limit model complexity. Also, these components were of primary interest to the author.

Plan of This Research Report

The remainder of this report begins with a brief examination of literature that has been written about problems and suggested solutions of water and sewage treatment in the LDC's. The literature review consists of four main subject categories. The first is the problem of water and waste water treatment in general terms. The second defines the role of the systems approach and its role in planning. The third examines the historical uses of management science techniques in the LDC's. The final part of Chapter II reviews the traditional ways that planning has occurred for water and waste treatment. Included in this section is a discussion on and the justification for the utilization of management scien e tools for the solution of problems of this nature.

With Chapter II as a background on the environment and the tools available, Chapter III sets forth the framework on the water and sewage treatment method planning model. The core of Chapter III consists of the model itself and its components. Initially, there is a brief discussion on the appropriateness of the systems approach. This leads to a discussion of the model itself and each of the components. The final portion of the chapter brings together these components to form a heuristic simulation model of the planning process at the community level.

Chapter IV shows the results of transforming the conceptual model into a workable tool for planners. Specific data requirements are given, and the format is presented so that planners can readily enter the variables into a computer. One section is devoted to analyzing the model's output and some suggestions on how this output should be interpreted. The chapter also outlines the specific logic involved in the computer analysis, plus directions are provided so that the model can be simulated, depending on the needs and variations suggested by planners.

Chapter V provides a summary of the objectives and procedures of the study, outlines implications of the findings, and presents recommendations for further research.

CHAPTER II

REVIEW OF RELATED RESEARCH

Introduction

In reviewing the literature, those papers, journal articles, research studies, and text books were selected that (1) indicate some of the special circumstances for the use of management science techniques in LDC's and (2) show the special needs and environment of the LDC's for water and sewage treatment.

Much of the literature on community water and waste treatment in LDC's is of a "fugitive" nature; that is, it is in the form of short reports reproduced in small numbers or in the form of articles in journals with varying degrees of accessibility. A great deal of work has been done under the auspices of the World Health Organization, some of which has been published. Other WHO reports containing data and evaluation of programs available on a limited circulation basis. The same is true in many cases for national government projects and for projects done under contract to various governments and foundations. Most of the material is available to scholars and researchers upon request to the appropriate source, but the unpublished form of the material often means that researchers are unaware of its existence.

Further, the literature is "spotty" in terms of areas. In general, there are numerous publications available regarding Latin American countries, especially for those who read Spanish and Portuguese. However, almost nothing (at least in English) is available on China, despite the recent strides there on rural water supplies and sanitation for over 800 million people. Also, there is not much available on the Russian experience in this field.

An early attempt to estimate the proportion of the population of developing countries adequately served with water was by Dieterich and Henderson. They estimated in 1963 that less than 10% of the population of 75 LDC's in Africa, Asia, and Latin America had piped water in their homes, including both rural and urban populations. They felt that urban water supplies were unsatisfactory and that rural sanitation would improve as a result of improved urban conditions.[1] In 1971, the World Health Organization estimated the total population of the world at 3,590 million people, with approximately 1,250 million of these living in rural areas of the LDC's who were WHO members at the time. Less than 10% of this 1,250 million were estimated to have access to safe water supplies.[2] More exact data have been presented by Donaldson for the Latin American countries. He reported that the rural population was estimated at 131 million (about 46% of the total population) with 24% considered adequately supplies with safe water and approximately 2% with

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[1]B. H. Dieterich and J. M. Henderson, Urban Water Supply Conditions and Needs in Seventy-Five Developing Countries, Public Health Paper 23 (Geneva: World Health Organization, 1963).

[2]World Health Organization, International Standards for Drinking Water, WHO/EH/71.2 (Geneva: Expert Committee on International Standards for Drinking Water, 1971).

adequate sewage disposal. He felt that for successful implementation of improved water supplies, there should be: (1) a focus on the concentrated rural population; (2) extensive use of trained technicians; and (3) promotion of intense local community participation.[3]

There are numerous terms used in discussing water supplies which do not have a consistent definition throughout the literature. One of these terms is "rural." In the compilation of data, the World Health Organization uses the term "rural" as defined by each of its member countries or regional branches. For example, in Kenya, the term may include both areas of small scattered farms and villages of 400 people and up.[4] In Peru, the term "rural" when used in connection with the water program applies to villages with 200-2,000 people,[5] and for Latin America, the term generally includes villages of 2,000 or less people.[6] These variations in the definition of "rural" make it difficult to tell just what is the target population for rural water programs. Furthermore, it is difficult to tell whether the global position is improving and if so, by how much.

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[3] D. Donaldson, Progress in the Rural Water Programs of Latin America (1961 - 1971) (Washington, D.C.: Pan American Health Organization, 1973).

[4] World Health Organization, National Development Programme for Community Water Supplies in Kenya: Report of the WHO to the Government of Kenya, WHO/CWS/69.6 (Nairobi, Kenya, 1969).

[5] "Country Situation Report," International Conference on Water for Peace 1 (Washington, D.C.: Government Printing Office, 1967), pp. 283-293.

[6] A. Wolman et al., "A Generation of Progress in Sanitary Engineering Facilities and Services for Latin America and Caribbean Countries," Boletin de la Oficina Sanitaria Panamericana, no. 6, English ed., (1972): 9-25.

Other terms that pose definition problems when applied to water supply include the words "adequate," and "accessible." "Accessible," for example, could mean a tap in the house, one in a courtyard, or one a 10-minute walk away. The problem with "adequate" is to determine just how much water people use under different circumstances. Water consumption has not often been measured. Although, there are plenty of rule-of-thumb guesses, many of these are based on urban consumption. One notable exception is the careful study by White et al. For scattered sites in both urban and rural situations, they found a range of 4-21 liters for the mean daily per capita use where people did not have piped supplies. Consumption was between 30-251 liters where the people did have connections.[7] The work was based on detailed field investigations in 34 rural and urban sites in East Africa. This study examined the amount of water used in each household and the other factors affecting use, such as social cost (including monetary and energy for obtaining it), the relationship between water quality, quantity, and the health of the user, and the way users choose alternatives among water sources. Similar usage patterns were found by Warner.[8] A third study by Lee found a slightly higher mean usage than White did for people without piped water in urban areas of India, and

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[7] G. F. White, D. J. Bradley, and A. U. White, Drawers of Water: Domestic Water in East Africa (Chicago: University of Chicago Press, 1972), pp. 109-149.

[8] D. Warner, "Formulating Guidelines for Rural Water Investment: the Case of Tanzania," East African Journal of Rural Water Development 3 (1970): 69-91.

approximately the same range for those with piped supplies.[9]

As the priority needs in water supply and waste water treatment shift away from the major metropolitan areas toward villages, smaller towns, and the "temporary" urban peripheral settlements, some changes in orientation are required. The technologies and the means whereby they are made available that have been so successful are often inappropriate, and the strengths of the work accomplished so far threaten to become its future weakness. Traditional planning approaches, models, and strategies become structurally incompatible with LDC's planning problems. It has become necessary to extend the scope of consciousness to include the environment, in addition to the sector itself. One way to extend the scope of planning is through the use of the now popular systems approach.

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[9] T. R. Lee, Community Water Supplies and Economic Development, the Scale and Timing of Development (Burlington, Ontario: Canada Centre for Inland Waters, 1972). (Mimeographed)

Dimensions of the Systems Approach

Since the model to be developed is being designed for both intermediate and long-range planning, a brief analysis is presented to show how the systems approach deals with the complex feedback interactions between all sectors and elements of the system under study. This inherently poses a challenge to the systems approach which generally does not come into sharp focus if short-range, reactive types of planning are the correct approach for changes in the systems environment.

In his book on the systems approach, Churchman indicated "that the systems approach really consists of a continuing debate between various attitudes of mind with respect to society."[10] This debate may be conceived to take place along at least two coordinates -- the "horizontal" and the "vertical." The horizontal emerges from continuous feedback interaction between the general and the particular. "Dimensionality" refers to the degree of systematic interrelatedness pertaining to different attitudes toward economic, social, demographic, political, and technological aspects, each of which may be further subdivided. The vertical may be discussed in a framework of the basic three-level structure proposed by Ozbehkan and others for planning.[11] The structures are composed of normative or policy planning, strategic planning, and

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[10] C. West Churchman, The Systems Approach (New York: Dell Publishing Company, Inc., 1968), p. xi.

[11] Hasan Ozbehkan, "Towards a General Theory of Planning," Perspectives of Planning, ed. Erich Jantsch (Paris: OECD, 1969), p. 153.

operational planning.

When referring to dynamic social systems, the notion of policy is concerned with the formulation of regulating principles. Vickers's view of policy can be applied here. He believes that it is "regulating a system over time in such a way as to optimize the realization of many conflicting relations without wrecking the system in the process."[12] At the strategic level, goals are general aims formulated in terms of outputs (missions) or functional outcomes. The difference between notions such as "making potable water available" and "drilling wells" illustrates the hierarchical relationship between strategic goals and operational targets. This outcome -- orientation of thinking -- enforces the adoption of at least a partial systems view. This is the essence of governmental planning in the framework of the Planning-Programming-Budgeting System (PPBS).[13] Only at the operational level is planning and action directed at fixed, attainable targets or technical products. To get to these targets poses a problem which can be solved in typical cases. The "ends and means" to which economic theory frequently refers are usually defined at the operational level. Operational planning is input-oriented, focusing on alternative ways of organizing inputs to attain fairly well-perceived targets.

The normative process of planning and change unfolds in the feedback interaction between these three planning levels. Churchman has

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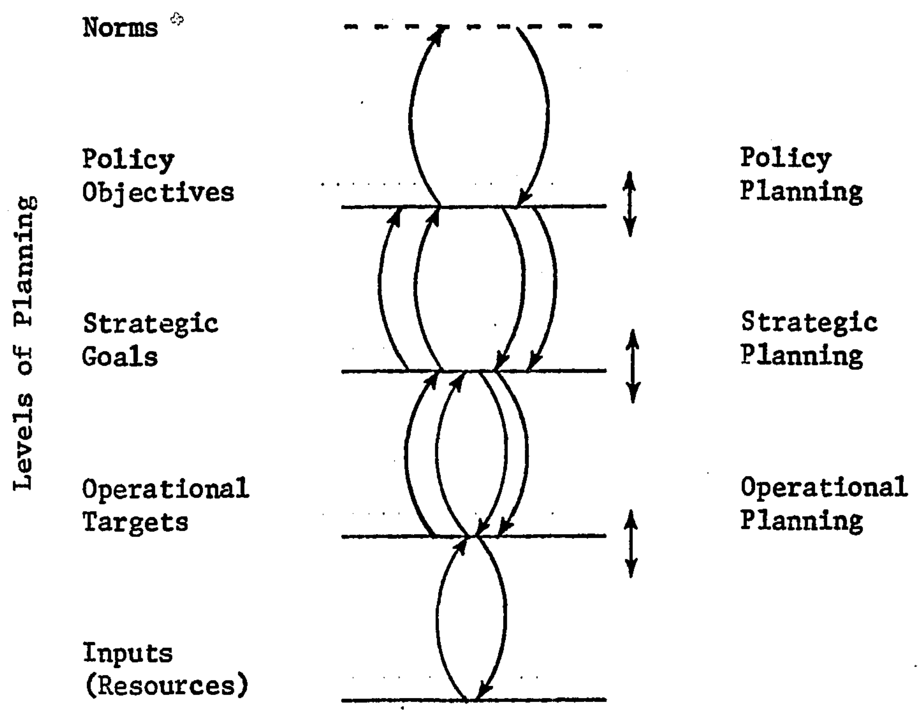
[12]Geoffrey Vickers, Freedom in a Rocking Boat, Changing Values in an Unstable Society (New York: Basic Books, Inc., 1972), p. 155.

[13]Erich Jantsch, Technological Planning and Social Futures (New York: John Wiley and Sons, Inc., 1972), p. 15.

written extensively on the concept that a normative systems approach involves planning for objectives, goals, and targets while inseparably searching for and questioning these objectives, goals, and targets in light of moral valuation.[14] Feedback interaction across the levels of planning can be depicted as shown below:



Each level of planning comes through two inter-meshed feedback loops, one reaching "upward" and one "downward," so that planning levels not only "touch" each other, but share feedback loops with adjacent levels. The feedback loops may be conceived as being themselves composed of

[14]Churchman, The Systems Approach.

small feedback loops representing the continuous fluctuation between attitudes pertaining to the creation and appreciation, and attitudes pertaining to synthesis and analysis. This constitutes the infrastructure of the learning process which is sometimes called planning, sometimes self-organization, and which characterizes human systems which include social systems. The important thing is that the learning process is not reduced to one or two levels. However, this is usually the case in most types of planning.

Forecasting itself may be viewed as a part of a feedback learning process by which it is linked to planning, decision-making and in the end, action. In the contemplation and preparation of social change, forecasting and planning represent two complementary aspects, again tied together by the same type of intricately interwoven feedback process as outlined in Figure 1. However, in forecasting, there is alteration between possibility and potential, input and absorption of ideas, and imagination and realistic attitudes of approaching future system states. Finally, forecasting is also linked to the outcome of action by the evaluation process which modifies continuously the information basis for forecasting, and more importantly, the value basis.

The systems approach can be used to contribute to the solution of problems of water and sewage treatment. In approaching these complex environmental problems one must be concerned with far more than the sciences of environmental degradation and the technologies of pollution control; one must also understand the problems of development, national priorities, and cultures of the peoples of the LDC's.

"Within the past half-dozen years the so-called systems approach has become a major instrument in government decision-making and is now widely viewed as a unique technique for helping to decide how to resolve many very different social problems."[15]

However, in spite of the extensive use of this technique in business and government there is no consensus among practitioners on what exactly it is. It is more like the proverbial elephant and the blind man -- one's concept depends on one's interface with the object. The systems approach is not easy to define because it is a set of attitudes and a frame of mind rather than a definitive and explicit theory. Herbert Simon has described it in this way:

> At its vaguest, it means looking at the whole problem again, hardly a novel idea, and not always a very helpful one. Somewhat more concretely, it means designing the components of a system and making individual decisions within it in the light of the implication of these decisions for the system as a whole.[16]

It is tempting to state simply that technological choices (the various treatment processes) should be selected on the basis of "system analysis" which is now becoming a popular word in planning circles. Clearly, arranging the alternatives and establishing criteria for selection among them within a framework of water and sewage treatment objectives is precisely what constitutes a system analysis in a specific

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[15] G. Steiner, Top Management Planning, (London: The Macmillan Company, 1962), p. 390.

[16] Herbert Simon, The New Science of Management Decision, (New York: Harper & Row, 1960), p. 15.

situation. The trick was to carry out the analysis in such a way so that the judgments incorporated into the analysis were clearly identified and not buried in a mass of statistics.

Management Science in Developing Countries

The potential contributions of quantitative techniques to the problems of LDC's have been both acclaimed as all-powerful and dismissed as impotent. For example, in 1957, Russell Ackoff, then president of the Operations Research Society of America, suggested that a role for operations researchers is both feasible and desirable.[17] He predicted that extremely high returns could result from addressing national planning problems with operations research techniques in these countries. In his conclusion, Ackoff said, "If other underdeveloped countries would use as competent planners as India and if they would supplement them with competent operations researchers, then, in my opinion, the term 'underdeveloped countries' would have to be dropped from our vocabulary in our lifetime."[18]

A somewhat similar view of the bright prospects to be expected from applying operations research techniques to major policy problems at a national level was also expressed by Johnson.[19] Johnson stated

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[17] Russell A. Ackoff, "Operations Research and National Planning," Operations Research 5 (August 1957): 457-468.

[18] Ibid., p. 468.

[19] Ellis A. Johnson, "The Long-Range Future of Operations Research," Operations Research 8 (January-February 1960): 7-8.

that "Operational research is badly needed in the U.S. State Department . . . I believe that it is in the State (sic) and in politics that the greatest possible advances in operations research can be made in the future, and that here there can be a tremendous use of symbolic logic and computers to provide for all the interrelations in a way that is presently beyond comprehension of any single human being or of any group of diplomats of responsible size."[20]

Ackoff's remarks have brought strong dissents from other distinguished practitioners of management science. For example, Charles Hitch, a subsequent ORSA president, characterized operations research as "the art of suboptimizing;" he urged caution in extending OR to national problems, and particularly urged caution in extending OR to problems in less developed countries.[21] Instead, Hitch urged the application of OR at a project or at most an industry level, and stressed the risks of over-selling what management science has to offer in the LDC at the level of national planning.

Additional cautionary views were expressed by O. M. Solandt and R. Dorfman. Solandt said that "systems research that is not based on a thorough knowledge of the elements that go into the system can become sterile. I think it is particularly dangerous for operations research workers to deal with continually larger and larger systems until they

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[20]Ibid.

[21]Charles Hitch, "Operations Research and National Planning--A Dissent," Operations Research 5 (October 1957): 718.

study the political and social systems of the whole world."[22] When commenting on the characteristics of problems which operations research can be most successfully applied (i.e., abundant and reliable data, a well-structured model, and a clear objective function), Dorfman concluded that the conditions most conducive for the use of operations research tend to occur in "routine and technical problems . . . at lower and middling levels."[23]

More than a decade has passed since these comments have been made. Therefore, it appears appropriate to examine some of the potential advances in light of two important developments that have occurred. First, the problem of assisting LDC's to achieve development has received considerable attention by scholars and statesmen. The expanding literature on the subject, as well as various world conferences and United States debates, seems to suggest that the development of the countries has become one of the great world crusades of our time. For many LDC's, it has become their main goal and preoccupation; it is looked upon as the final solution to the problems of poverty, overpopulation, and communist subversion. Second, additional research has been done on the development process, and a number of studies have been attempted which provide experience, data, and theoretical results not available when these statements were made.

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[22] O. M. Solandt, "Concluding Remarks" in "A Decade of Military Operations Research in Perspective -- A Symposium," Operations Research 8 (November-December 1960): 857.

[23] Robert Dorfman, "Operations Research," American Economic Review 5 (September 1960): 620-21.

There are, however, several difficulties which must be specifically recognized in applying quantitative techniques to development assistance problems. The major impediments to application are that:

1. Development is a complex social, political, and economic process. As such, many of its parameters are difficult or impossible to quantify, for the problems of measurement in the behavioral sciences are elusive.[24] The process itself may be constrained by "accidents" of natural resources, geography, or heritage. It may be distorted by the pressures of "rising expectation." Advances in development may even disappear under the weight of the population problem.

2. There appears to be no extensive history of development in the LDC's. While the United States has had extensive experience in studying, understanding, and even encouraging national growth, there is little history of the development of an LDC to one of economic viability and independence -- the stated goals of our foreign economic assistance programs. One exception to this is a study of U.S. economic aid to Nationalist China by Neil Jacoby of the University of California at Los Angeles.[25] David Bell, Administrator of the Agency for International Development, indicates in the Preface to Jacoby's paper that this was the first intensive study of the development process itself.

3. The development process itself may be discontinuous. Perhaps this is one of the most important contributions of Rostow's stage

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[24] G. A. Lincoln, Improving AID Program Evaluation (Washington, D.C.: Agency for International Development, October, 1965).

[25] N. H. Jacoby, An Evaluation of U.S. Economic Aid to Free China, 1951-1965, Discussion Paper 11 (Washington, D.C.: Agency for International Development, January, 1966).

approach to economic development -- the concept of "discontinuous jumps."[26] If development is a discontinuous process, then the solutions and methods may be markedly different from those customarily employed.

A serious example of the hazards of letting operations research run loose at a national planning level was provided by the influential paper that P. C. Mahalanobis wrote in 1955.[27] By basing his two sector model on the major and questionable assumption that investment in period t is determined by the domestic production of capital goods in t-1, Mahalanobis "derived" a solution which recommended a strong allocative emphasis on the capital intensive industrial sector, a conclusion that was very implicit in the basic underlying assumption of the model.

The above assumption, and the resulting model, ignored such other possibly important constraints on investment as the propensity to save, as Domar noted.[28] Furthermore, the Mahalanobis model ignored certain important opportunities for raising investment beyond the capacity of domestic industry to produce capital goods; for example, by increasing exports and using the resulting foreign exchange to import capital goods, or by the use of labor-intensive methods for construction purposes. When such opportunities are brought into the model, it turns

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[26] W. W. Rostow, The Stages of Economic Growth: A Non-Communist Manifesto (London: The Cambridge University Press, 1960).

[27] P. C. Mahalanobis, "The Approach of Operational Research to Economic Planning in India," The Indian Journal of Statistics 16 (December 1955).

[28] Evsey Domar, Essays in the Theory of Economic Growth (New York: Oxford University Press, 1957), pp. 223-230.

out that the optimal solution is dominated by several alternatives as Komiya has noted.[29] A somewhat similar view of the Mahalanobis model has been made by Oshima.[30] Oshima points out that when consideration is given to the relatively large urban overhead costs that are associated with industrial emphasis, or the technological possibilities in agriculture, it is clear that the analytical assumptions for improvements in the allocation problem must be a good deal more complex and sophisticated than the Mahalanobis model.

Problems such as national investment allocations are generally not well-structured and certainly are not adequately reflected by simple two-sector models. This is especially true when reliable data are in short supply, which is generally the case in the LDC's. Therefore, a cautious and qualified approach is required. With this as background, it seems clear that the dangers of overselling and overdoing operations research on broad planning problems in LDC's are sufficiently great that the cautionary admonitions of Hitch, Dorfman, and others should be kept prominently in mind. However, there are arguments which hopefully show that operations research can make a distinctly useful, although limited, contribution to important planning problems in LDC's. To show this, the general reasons for utilizing management sciences in LDC's is examined first. This is followed by a discussion of the

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[29] R. Komiya, "A Note on Professor Mahalanobis' Model of India Economic Planning," Review of Economics and Statistics 41 (February 1959): 29-35.

[30] Harry T. Oshima, "A Strategy for Asian Development," Economic Development and Cultural Change (April 1962): 314-315.

methodological aspects of operations research work in LDC's.

One of the most important reasons for promoting the use of management sciences in LDC's is that the general lack of resources, particularly qualified human and financial, imposes an urgent need for using them more efficiently. While a relatively rich country can afford some measure of waste in the use of its resources, more easily absorb planning errors in investment decisions, and tolerate duplication of efforts, this certainly is not the case for the poor countries. A single mistake can have catastrophic effects that are felt for many years. For example, Sagasti reported that an erroneous decision to locate a fertilizer plant in the Peruvian central highlands, which uses an expensive method for producing hydrogen, as of 1971 still had a negative impact on the national economy, even though the decision to construct the plant was made around 1959 and production began in the early 1960's.[31] From examples like this, Sagasti concluded that the larger the disparity that separates an LDC from the more developed countries, the greater the intensity with which the scientific principles should be applied to optimize decisions that involve the use of scarce resources. This reasoning is strongly supported by Wu when he stated that:

> If the economic gaps between the developing and industrially advanced countries is to be closed or even

[31] F. R. Sagasti, "Management Sciences in an Underdeveloped Country: The Case of Operations Research in Peru," Management Science 19 (October 1972): 121.

> narrowed, it is obvious that the former must grow more rapidly than the latter. This is not going to be easy. Apart from the availability of necessary physical and other inputs, rapid progress requires commitment, sense of urgency, and leadership. Assuming that all these factors for development are present, developing countries relatively will need greater administrative capabilities than were historically prevalent in the industrially advanced countries. The developing countries must be able to approach developmental problems with a sense of urgency required for solving emergency problems and crises. To create administrative capabilities commensurate with requirements, developing countries must be able, among other things, to use modern management techniques more effectively than is the case in the industrially advanced countries.[32]

The literature contains numerous examples of applied operations research, with varying degrees of success. Sagasti points out that to have a greater chance for success, the researcher must consider the methodological aspects of operations research in LDC's. He indicates that LDC's have many characteristics differentiating them sharply from the more advanced countries, where operations research has been most applied and where the majority of techniques have been developed. The mere transfer of OR techniques and approaches from developed countries to LDC's is likely to encounter many difficulties and produce results that may be largely irrelevant. Distinctive characteristics of LDC's tend to make it necessary to modify the types of OR work and customary methodological procedures prevailing in the more advanced countries. These modifications may take the form of shifts in emphasis

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[32]Chi-Yuen Wu, "Operations Research for Developing Countries," paper delivered at the 36th National Meeting of ORSA, Miami, Florida, November, 1969, p. 5.

in the variables considered, types of models to utilize or construct, and the criteria for deriving solutions.[33] As Ghosal pointed out:

> The most important thing about the application of OR is to bear in mind the environment under which the proposed solution is sought. Consequently, the approach of problems is likely to be different in different conditions. In other words, there cannot be any ready-made solution to any problem faced by the client because the solution to a similar problem faced in countries like the U.S.A., U.K., etc., may be completely unsuited for a country like India or any other developing country.[34]

Some specific environmental conditions in LDC's which require modifications in the methodology include an understanding of the behavioral aspects of the problem situation and of the social and psychological characteristics of individuals and groups related to them. Shakun, in his paper on OR in India, pointed out that a knowledge of the social sciences can be utilized by management scientists in the following ways: (1) learning how to incorporate behavioral variables in OR models and (2) considering explicitly the implementation of OR work as an integral part of the project.[35] Shakun's second aspect has also been suggested by Abrams who considers the implementation of

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[33] Sagasti, p. 128.

[34] A. Ghosal, "Poor Man's OR," Opsearch (Operational Research Society of India) 4 (1967): 45-47.

[35] Melvin F. Shakun, Operations Research in Developing Countries: Focus on India, 1970. (Mimeographed)

OR "a problem in sociology,"[36] and by Wu, who suggested that a close relation between the social sciences and operations research would lead to higher implementation of project results.[37]

Another observation which had methodological implications for OR work in LDC's refers to the lack of statistical data that would render the quantitative model inoperative. This should not represent, by itself,a serious limitation to management scientists. Sagasti reports that a recently developed financial model for the Peruvian Educational Reform is being put to such use by making a series of sensitivity tests and finding out which of the parameters and variables of the model have a major influence on the total costs of the Educational Reform.[38] Perhaps more importantly, with this information at hand, it will be possible to detect where data gathering efforts should be improved and refined.[39] In a general sense Salib has pointed out that:

> A great number of people think elaborate models cannot be worked out successfully because of a lack of statistics. This is a negative attitude that will leave our level of knowledge static; the field cannot develop at all if this objection is frequently raised. In fact, statistical

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[36] John Abrams, "Implementation of Operational Research: A Problem in Sociology," Journal of the Canadian OR Society 3 (1966): 152-60.

[37] Wu, pp. 1-6.

[38] Sagasti, p. 130.

[39] Sagasti, p. 131.

> machinery has never been thought of except as the tool to supply research workers with as many observations as they require.[40]

The last observation regarding the methodology of OR work in LDC's arises from the fact that the criteria used for constructing OR models for LDC's may be different from those customarily used in the developed ones, for example, the well-known differences in capital availability, investment risks, and profit margins between developed and under-developed nations. Since capital is relatively abundant in developed countries and, consequently, investment risks are small, profit margins also tend to be small. In LDC's, however, capital is relatively scarce, investment risks are high, and profit margins are also comparatively high. Therefore, the types of models to be constructed for capital investment decisions must reflect the conceptual and structural differences between the two situations. Finally, many of the available operations research techniques are more applicable to short- and medium-range tactical problems, whereas the problem of LDC's involve primarily strategic and long-range planning considerations.

In general, one must recognize the difficulties that arise in the application of OR techniques in LDC's. In addition, there must be a realization that the judgment of experienced decision-makers will not be replaced by analytic studies. It is essential to examine where both analysis and judgment can make the best contribution. Analysis

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[40]Salib cited by Mohamed I. Dessouky, Operations Research in National Planning, paper delivered at the 36th National Meeting of ORSA, Miami, Florida, November, 1969, p. 51.

is not the antithesis of judgment, but rather a tool for exercising that judgment. While judgment can often readily distinguish between "good" and "bad," it cannot readily determine the "best" in the complex problems of water and sewage treatment.[41]

The quantitative model is, then, a tool of the decision-maker and it supplements, not replaces, judgment. Although the problem of improving water and sewage treatments are, by their nature, complex and difficult, quantitative techniques can make a significant contribution by forcing planners to develop a better understanding of the development process itself. Attempts to use management science techniques are themselves motivating research on the fundamentals of development, thus, contributing to the needed understanding and serving as an effective tool for allocating development assistance.[42]

In summary, most types of applications of OR that have been made in developed countries are relevant to the LDC's, although some adaptation to local conditions is usually required. In many problem areas, OR professionals may not be able to find solutions, but they can both broaden the range of the alternatives considered and reduce the number of choices from which the decision-makers can make a choice. In other words, they can provide a better, even if incomplete, basis for choice. OR usually has to operate in LDC's with less and poorer quality data

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[41] J. Farmer, "Applying Analytic Methods to Problems of Development Assistance," paper presented at the Twenty-ninth National Meeting of the Operations Research Society of America, Santa Monica, California, 20 May 1966, p. 3.

[42] Ibid., p. 13.

than are available in the so-called advanced countries. But in spite of the poor quality of the data, even gross approximations can yield dramatic improvements in LDC conditions. Finally, too much effort has gone into developing sophisticated tactical and strategic planning models that are mathematically tractable by distorting reality or disguising ignorance in obscurely worded assumptions.

Traditional Planning Approaches to Water and Waste Water Treatment in the LDC's

The traditional planning of water and waste water treatment facilities in the LDC's can be classified into two methods: (1) the use of in-country design engineers and (2) the use of consultants.

Design engineers are the individuals who generally assume the responsibility for making preliminary engineering studies and reports, collecting and interpreting information necessary for project financing, guiding the preparation of plans and specification, supervising construction of water treatment and waste disposal facilities, and providing for the development of procedures and personnel to insure effective maintenance and operation of the completed facilities.

Most of the LDC's are not yet in a position to initiate and maintain educational programs tailored for the preparation of design engineers. Traditionally, those selected for this role are sent abroad for further study, many of them attending schools in the United States or Europe. In the United States, for example, most academic programs leading to MS or Ph.D. in sanitary engineering degrees are necessarily oriented to conditions prevailing in the United States, because most of the students originate and will practice there throughout their careers. Accordingly, much of the technology which is taught, especially in the design area, is appropriate primarily for application in the United States.

A student completing such a program and returning to his homeland usually is confronted with the task that much of his hard earned knowledge is impractical for direct application under local circumstances prevailing there. Perhaps the most obvious problem is the radical differences which may exist between sociological and technological situations in the student's home country and those in the country where the advanced education is undertaken. In some instances, the individual views this as a challenge and uses his formal education as a basic foundation upon which to build new technological viewpoints for developing solutions more appropriate under local conditions. In other instances, the reaction is much less favorable and leads to increased frustration at the incompatability between his educational background and needs of his country. Frequently, the end result may be selection of design alternatives with which the engineer has become familiar during his education, and for which technical information already is conveniently available to him.[43] Obviously this may result in serious design errors, waste of limited financial resources, and the installation of facilities

[43] For several specific examples in which water supply facilities in LDC's have been based too much on United States and European practices, with little or no attention to the utilization of local materials, personnel, and techniques see: J.C. Brown and D.A. Okun, "An International Program in Sanitary Engineering Design," Ingenieria Sanitaria 19 (October, 1965): 11-20.

which cannot be operated efficiently.

The second method of planning involves the use of outside consultants. They are a major technical resource available to LDC's. Some have long experience in the preparation of feasibility reports and the design of waterworks in LDC's. In other cases Okun and McJunkin found that many of the fundamental decisions were made by outside consultants or equipment manufacturers from other countries.[44] Frequently local engineers were not consulted or their opinions were disregarded. In some instances, the lack of local planners has permitted projects to be conceived and executed by equipment manufacturers from the developed countries through so-called "turn key" contracts, where the contractor is primarily interested in the sale of equipment. This equipment may be from a functional point of view, quite efficient. In the developed country of the equipment's origin, where wages are high, interest rates low, and full employment prevalent, such equipment may also be efficient in an economic sense. But its use in situations where labor costs are low, unemployment high, interest or capital high, and foreign exchange funds limited seems to be questionable.

Just as with imported equipment, the use of imported engineers has certain disadvantages. In designing a water supply system, it is necessary that load on the system be established. An outsider, parti-

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[44] D. A. Okun and F. E. McJunkin, "Planning and Developing Water Supply Programs in Developing Countries," International Conference on Water for Peace May 23-31, 1967 (Washington, D.C.: Government Printing Office), p. 4.

cularly one from another culture, labors under a handicap in this regard. How many people will use the water? What is per capita consumption? What is the population of the community? How is it changing from a rural to a city centered population? For all these data the outside engineer must depend on local information which the local engineer is better prepared to both gather and evaluate.

Another area in which outside consultants are at a disadvantage is in preparation of cost estimates. Outside consulting engineers are often very much in the dark as to the cost of local materials and labor, especially labor. These estimates are particularly important in estimating local currency requirements.

In order to cope with the problem of the traditional methods of planning, several programs to improve water and sewage treatment have been initiated by various groups. These programs for water supply development in the literature can be classified under three main types. The first type emphasizes fiscal soundness and the improvement of organizational capabilities. This type of program has been followed by the World Bank, where there is emphasis on communities or water usage units paying their own way and on improving their organizational capabilities. This has led to the financing of the larger urban projects.[45] The bank has not ruled out loans for rural development; however, the

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[45] World Bank, Water Supply and Sewerage, Sector Working Paper (Washington, D.C.: World Bank, 1971).

financial and institutional problems have hindered bank participation in the rural areas. Some of the questions regarding fiscal soundness versus the ability to pay for water have appeared in an article by Shipman. He noted the concern for providing water for those less able to pay for it, and concludes that the assignment of a uniform rate is more equitable than the setting of a minimum charge for a given amount of water. Shipman emphasized the need for a rate level which will provide fiscal soundness for the water company.[46]

The second approach focuses on building from simple schemes to larger ones, with emphasis on the larger rural villages. This approach has been described extensively for Latin America by Donaldson, where the rural program generally includes villages from 500-2,000 inhabitants. This is simply a building-block approach aimed at dispersed, semi-concentrated, and concentrated populations. On the simplest level, the well is used; the next level involves utilizing rudimentary aqueducts and later rural aqueducts. Donaldson advocated a mass approach with standardized techniques for these programs at various levels of population concentration. This distinction is not made by most authors.[47] Donaldson felt that the key points in this type of approach are the focus on the concentrated rural population, extensive use of trained

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[46]H. R. Shipman, "Water Rate Structure in Latin America," Journal of the American Waterworks Association 59 (January 1967): 3-12.

[47]D. Donaldson, Progress in the Rural Water.

technicians, and the promotion of intensive local community participation.[48] Warner describes a similar program for Ethiopia. He started with a study of water resources of the country then discussed the developing of supplies using cheap simple mechanisms (i.e., collecting rain water). This was accompanied by an educational program designed to stimulate demand for purer water.

Demonstration projects using simple technology suitable for small settlements represent the third type of program. Supporters of this approach hope that these projects will be copied elsewhere. A prominent example of this type of approach has been described by UNICEF-WHO. They felt that demonstration projects, coupled with training and educational programs, can serve as a catalyst for improved national programs. This emphasizes supply and equipment contributions to individual projects and the stimulation of parallel training and health education programs. Recommendations were made that health education needs be made more effective, that excreta disposal be included with water supply improvements if possible, and that studies should be made as to how to increase community participation in planning, construction, and use.[49] A similar approach has been carried out on an individual basis by a private organization called VITA (Volunteers for

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[48] D. Donaldson, "Rural Water Supplies in Developing Countries," Pan Sanitary Bureau, Washington, D.C., undated. (Mimeographed)

[49] UNICEF-WHO Joint Committee on Health Policy, Assessment of Environmental Sanitation and Rural Water Supply Programmes Assisted by the United Nations Children's Fund and the World Health Organization 1939-1968, JC16/UNICEF-WHO/69.2 (Geneva: World Health Organization, 1969).

International Technical Assitance, Inc.)[50] Their basic aim is to enable villages in different parts of the world to learn from each other's experience.

The above approaches have been evaluated by the agencies involved and various reviews have been undertaken regarding sanitary engineering facilities and services for LDC's. Wolman et al. in a 1972 article emphasized the key role of international organizations in stimulating training facilities and research, and in providing loans for improved water supply and waste water treatment programs. They described efforts made by the national governments to provide funds and facilities, such as the current training and research programs in Peru, Colombia, Brazil, Argentina, and selected Central American countries.[51] Efforts have been made to evaluate improvements in terms of the total impact on a community, with more of a systems approach.

Heijnen and Conyers set forth a number of hypotheses in need of testing by further studies.[52] There does not seem to be systematic attempts on a worldwide basis to determine which countries have had the

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[50] VITA, Village Technology Handbook (Schenectady, New York: Volunteers for International Technical Assistance, Inc., 1970).

[51] A. Wolman, M. Hollis, and C. S. Pineo, "A Generation of Progress in Sanitary Engineering Facilities and Services for Latin America and Caribbean Countries," Boletin de la Oficina Sanitaria Panamericana, English ed., no. 6 (1972): 9-25.

[52] J. D. Heijnen and D. Conyers, "Impact Studies of Rural Water Supply," Water Supply (June 1971): 53-63.

most success in bringing water to people and to assess just how this has been done, probably because the required information is difficult to obtain and assemble.

The general lack of resources, particularly human and financial, imposes an urgent need for using them more effectively. Progress up to this time has shown that a lot of money has been expended in an effort to improve water and waste treatment in less developed countries without tangible results. This waste of resources is something the LDC's can ill afford. The approach needed is one that seeks to optimize the use of scarce resources. To cope with this urgent need, the LDC's should consider the introduction and widespread utilization of modern management techniques, including operations research as one of the integral parts of their planning strategy to improve water and waste water treatment.

The results in other areas have shown that in many complex situations the intentions of the planners were inferior to the proposed solutions that management scientists provided by means of their models. The area of water treatment and waste water treatment in LDC's is no exception. As a result this study was initiated in an effort to provide a better way of planning water and waste water treatment projects. The study can be justified in two areas. First, in the advancement of theory, the planning model developed in this study represents the first attempt to evaluate the problem in terms of the systems approach. In short, this study represents the first attempt to "model" the decision making process for the selection of various processes for the treatment of water and waste water in less developed countries. Second, the model developed in the study was designed to provide a useable tool for planners involved with designing treatment systems on the community level.

The approach in this study was to adopt an attitude of pragmatic activism while recognizing the basically stochastic nature of the many variables in the water and waste treatment planning environment and hence, not attempting to behave as if the environment were deterministic and fully predictable. Thus, in the LDC environment, there has been an acknowledgment that information on the most vital variables can be generated only by water and sewage treatment development itself. Therefore, a perfectionist attitude can only perpetuate stagnation as a consequence of the operation of a number of vicous circles, such as scarcity of information, inadequate planning organization, and no development activity.

Conclusion

As the programs and studies discussed in this chapter suggest, numerous qualifications and reservations usually need to be attached to any serious attempts to apply OR to major environmental and development problems of the LDC's.

Moreover, the necessary reservations associated with plans that are designed to help alleviate environmental and developmental issues tend to be more serious when planners seek the optimal solution to the problem under examination. Nevertheless, if the current decision-making practices are considered with respect to these problems, it seems clear that quantitative techniques can make a number of important contributions to improved decision-making.

Management science techniques can provide a more rational way of uncovering and clarifying the alternative choices that are available. They focus conscious attention on the policy alternatives that are implicit in a particular decision process by making explicit (in quantitative terms) the benefits associated with the available alternatives.

Finally, it appears that the most challenging opportunity to improve environmental health lies in shaping the emphasis of development programs so that they can contribute more directly by enabling the people affected by the many hazards of the total environment to choose how much improvement they can achieve through their own efforts.

CHAPTER III

DEVELOPMENT OF THE RESOURCE PLANNING MODEL FOR THE SELECTION OF WATER AND SEWAGE TREATMENT PROCESSES

Introduction

The resource planning model developed in this study to aid LDC planners in selecting water and sewage treatment processes for their specefic areas is a heuristic simulation model. Although generally less accurate than a mathematical programming model, simulation was chosen because of an inability to reduce the varying and complex culture patterns in LDC's to sufficiently accurate numerical values. Heuristic techniques were used because the data required for programmed analyses is generally incomplete for LDC's and the environmental problems of these areas are not well structured.

The two major objectives of the planning model are to (1) identify the major areas of environmental capabilities of peoples and governments and (2) determine the measures required to respond effectively to those concerns. The approach taken was to perform an analysis of selected input variables to identify the perceptions of the scientific and political communities concerning environmental problems. The result is a planning action program which considers both the presently available manpower skills and implementation funds for given LDC areas.

Inherently, models have been the subject of much of this project. The concept developed mainly as the problem structure. As a structure or definition of the problem, the model includes the objectives and variables which can be used to express the problem and the way in which these variables are related to each other. The model is also used to guide computation, and this discussion emphasizes the predominatly mathematical methodology of interrelating sets of data to obtain the solution.

Most Operations Research (OR) models qualify as planning models. The most well-known and useful such OR technique is mathematical programming. Mathematical programming can be used both for formulating and stating problems and as a set of mathematical procedures for identifying the best course of action. Essentially, this technique specifies how to use limited resources to obtain a particular objective, such as least cost or highest margin, when those resources have alternate uses. It also systematizes, for certain conditions, the process of selecting the most desirable course of action from a number of available courses of action, thereby allowing planners to make more effective decisions about the resources under their control.[1]

There are several types of mathematical programming, one of the most popular being linear programming. Linear programming assumes that the criterion and the constraints in the problem can be represented by

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[1]R. O. Ferguson and L. F. Sargent, Linear Programming, (New York: McGraw-Hill Book Company, 1958), p. 3.

straight-line segments; that is, the slope is constant. Although the assumption of constant returns and costs is patently false in many situations, the linear assumption is the easiest to work and solve, and the results are generally valid because many important functions are linear or nearly linear over much of their range.

A number of techniques are available for solving linear programming problems once they have been expressed mathematically. Graphical solutions are possible when the number of variables is not more than three. But a more common, all-purpose method is the simplex algorithm. An algorithm is a systematic method for testing various solutions; it guarantees that each successive solution will represent an improvement until the best solution is reached.

Nonlinear programming is a problem formulation where either some constraint(s) or the effectiveness criterion, or both, are nonlinear. One example is quadratic programming, which uses a second-degree curve for some of the contraints or effectiveness criterion, or both.

Integer programming is a variant so named because the optimal solution is constrained to consist of whole numbers. Thus, integer programming is a way of avoiding the ambiguities of fractional answers.

Dynamic programming, the most complicated of the mathematical programming variants, is a technique dealing with the optimization of multistage decision processes. The technique was developed in the early 1950's by Richard Bellman, who also coined its name. In this technique, decisions regarding a certain problem are typically optimized at subsequent stages, rather than simultaneously. This generally signifies that the original decision problem is divided into small subproblems (stages) which can then be handled more efficiently from a computational viewpoint.

A stage in a dynamic programming problem may represent a period of time (i.e., one month) so that decisions are made periodically over time, or a portion of the decision is made at each stage. Decisions, for example, must be made throughout the year; today's decision must be made in terms of what it implies for the decision choices in the next month, which in turn will affect the decision choices in the following month, and so on.

In summary, mathematical programming models are applied to problems where there seem to be many different ways to allocate resources. Contraints (usually in the form of mathematical inequalities) are introduced to reduce the number of admissible solutions. Then a search is made for that solution among the feasible set which is optional in terms of some effectiveness criterion.

Network analysis is a technique which is particularly useful in planning and controlling large and complex projects. This technique is a useful tool in systems design because it assists the planner in recognizing and identifying the relationships which exist among the subsystems. First, each separate segment, or link, of the system is described in terms of other components or activities of the system. The flow of materials and/or information is measured in terms of volume, specifications, or time. This flow is generally illustrated by a flow chart or diagram. Network analysis allows the planner to reappraise the existing systems and identify examples of duplication and overlap which may detract from the systems efficiency. A change in type of output or a change in scheduling in a particular subsystem can be evaluated, and the effect can be determined in units of time, money, facilities, or other resources. By laying out the network of jobs, planners can obtain an explicit visual representation of the relationship between all the tasks involved.[2]

Despite the variety of available mathematical programming techniques, at times an operation under study is so complicated that it is impractical or impossible to describe the operation by use of those techniques. In such cases, planners may resort to the use of a simulation. Simulation consists of developing a simplified or different form (model) of the process or object that will simulate its functions in a manner that allows study or manipulation of the original phenomenon. There are a number of reasons for developing such models: (1) there is no other way to investigate the phenomenon (i.e., simulating an astronomical system such as the earth and its planets); (2) a commitment or unknown consequences would result from manipulating the end object itself (i.e., alternative programs for flood control of a river); (3) the cost of experimenting with the original would be excessive (i.e., rearrangement of a factory to manufacture a new product); (4) a basis for a more factual statement of a particular matter is needed (i.e., programming a complex project); and/or (5) the complexity of the real process necessitates a simplified expression of its functioning to begin analysis (i.e., simulation of the planning of water and waste water treatment in LDC's).

[2] For a detailed discussion of the mechanics of network model building see R. A. Johnson, F. E. Kast, and J. E. Rosenzweig, The Theory and Management of Systems, 2nd ed., (New York: McGraw-Hill Book Co., 1967), pp. 325-329.

Even though simulation models do not develop optimum operating strategies by themselves, they can be powerful tools for gaining further insight into operations.[3]

Heuristic techniques are used where a decision must be made but information needed for that decision in incomplete, the problems are not well structured, and mathematical analyses would be inappropriate (give dubious results). The term "heuristic" has been used by different people to include any or all of the following stages: (1) discover rules of thumb that help delineate the problems; (2) determine means of setting up the problems for solution; (3) identify the most promising methods to use in searching for a solution; (4) find ways to retrieve and interpret information on each experience; and (5) enumerate the methods for achieving a solution under all conditions. Obviously, heuristic thinking is tentative, plausible, not highly programmed, and generally cannot be supported by rigorous proof.[4]

Heuristic programming is simple the development of a search pattern which will lead, step by step, toward a "good" or highly feasible solution. The search pattern contains trial and error steps as well as mathematical techniques. This approach was used as a solution technique for water and sewage treatment planning problems in LDC countries.

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[3]N. J. Driebeek, "What is Operations Research," Systems and Procedures Journal 16 (November-December, 1965): 17.

[4]P. Gordon, "Heuristic Problem Solving," Business Horizons 5 (Spring, 1962): 52.

The procedure takes the form of a network of paths, similar to a maxe, that leads from the starting condition (present water or sewage treatment) through alternative paths to one of several possible decisions. Each selection between alternative paths is determined by using the appropriate decision rule at each junction (step) in the network. The outcome of a particular decision rule depends on the conditions existing at that junction.

The Basis of the Heuristic Planning Model

There are two major reasons for the selection of a heuristic planning model. The first is that some problems, although they can be reduced to numbers and equations, are too large to solve by analytical techniques, even with the aid of a computer. Linear programming, for instance, has been widely used to solve many problems of resource allocation (transportation, routing, machine scheduling, product mix, and oil refinery operation), but some problems are just too large for it. In job shop scheduling, for instance, linear programming could conceptually lead to an optimum assignment of start times for thousands of jobs to be scheduled in a large shop, given some criteria like "minimize idle machine time," but the number of steps necessary to reach the optimum solution -- though finite -- is so large it renders the method useless. Heuristic programming, on the other hand, attempts to short-cut computations. It is not concerned with finding the one best answer after a lengthy search but with rapidly finding a satisfactory one. In this case, it is willing to trade a guaranteed optimum solution for a "good" one if it can do so with considerably less computational effort.

The other reason for employing a heuristic model, which is the case in this research study, is that some problems are ill structured -- they cannot be expressed in mathematical terms. Judgment, intuition, creativity, and learning are important elements of the problem and its solution, and these variables are qualitative rather than numerical. Quantitative techniques are not available nor are they suitable for solving problems of water and waste water planning.[5] The object of a heuristic program is to develop a program that imitates certain human problem-solving processes.

As a result, most of the purely analytical tools are of only limited value because of limitations in insight and information. Therefore, a heuristic approach is required to serve planners in the initial stages of water and sewage treatment planning, since information requirements and problem structure are at their lowest level. As the development of water and sewage treatment projects unfolds, and as information feedbacks are created, planners will gain a better understanding of the planning environment and the planning methodology. Then, they will gradually be able to introduce more and more analytical tools. The design of the heuristic strategies in this study are aimed at guiding planners in the early phases of water and sewage treatment planning.

Central to the problem is science and technology. However, the simple transplant of a developed country's technology to sites in LDC

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[5] J. D. Wiest, "Heuristic Programs for Decision Making," Harvard Business Review 45 (September-October, 1966): 130-131.

communities is not the answer. Technology, size or scale of the facility, and development are all relevant, and must be defined.

One way of looking at this is to utilize a conceptual scheme developed by McGregor.[6] He indicated that scientific knowledge consists of (1) the identification of the factors, characteristics, or variables that are sufficient and necessary causes of a given set of phenomena; and (2) statements about the relationships among these factors that are associated with the changes in the phenomena. Relating this to water and sewage treatment method selection, the performance P of an individual installation is a function of certain characteristics of the methods of treatment M, the scale of operation S, and certain aspects of the environmental situation E.

$$P = f(M_{a,b,c,d,e} \quad S_{h,i,j,k} \quad E_{s,t,u,v})$$

The planning model developed in this study has quantified a number of variables relating the performance of a treatment method based on the above framework. $M_{a,b,c,d,e}$ represents the various treatment processes, each with its own sanitary, mechanical, and electronic capability criteria. $S_{h,i,j,k}$ represents the scale of the plants. The limitation of the study described earlier indicated that the plant scale will be limited to ones supplying populations from 500 to 100,000. The

[6]D. McGregor, The Professional Manager (New York: McGraw-Hill Book Company, 1967), p. 5.

$E_{s,t,u,v}$ represents the environmental capability which is defined by the manpower, demographic, socio-economic physical resources, and financial posture.

This is graphically shown in Figure 1. The development from the LDC to developed community is ordered; it is essentially from one of dominant agricultural activities to one of manufacturing and mass production. People activities of the communities in the LDC's are concerned with feeding themselves, and each technological advance brings about a reduced commitment to agriculture and a greater effort toward the production of consumer goods. In essential services such as water and sewage treatment, the sequence generally progreses from hydrant water to in-house plumbing. So as urbanization increases, and as scale increases, so does the life style and income. As this happens, more sophisticated technology can be utilized to provide low-cost solutions. What is proper for a rural or small community is not necessarily proper for a large one. From the processes and their definition and from the local resources and their capabilities, solutions can arise. However, these solutions are not static, but in a sense become cumulative over time.

Once it was determined that the model must be a heuristic simulation, the next step involved developing a set of variables by which the environment could be matched with one or more treatment processes. Of main concern in this work were the environmental variables (E). The scale (S) variables were defined by the limitations established at the beginning of the study, and the method or process (M) variables could

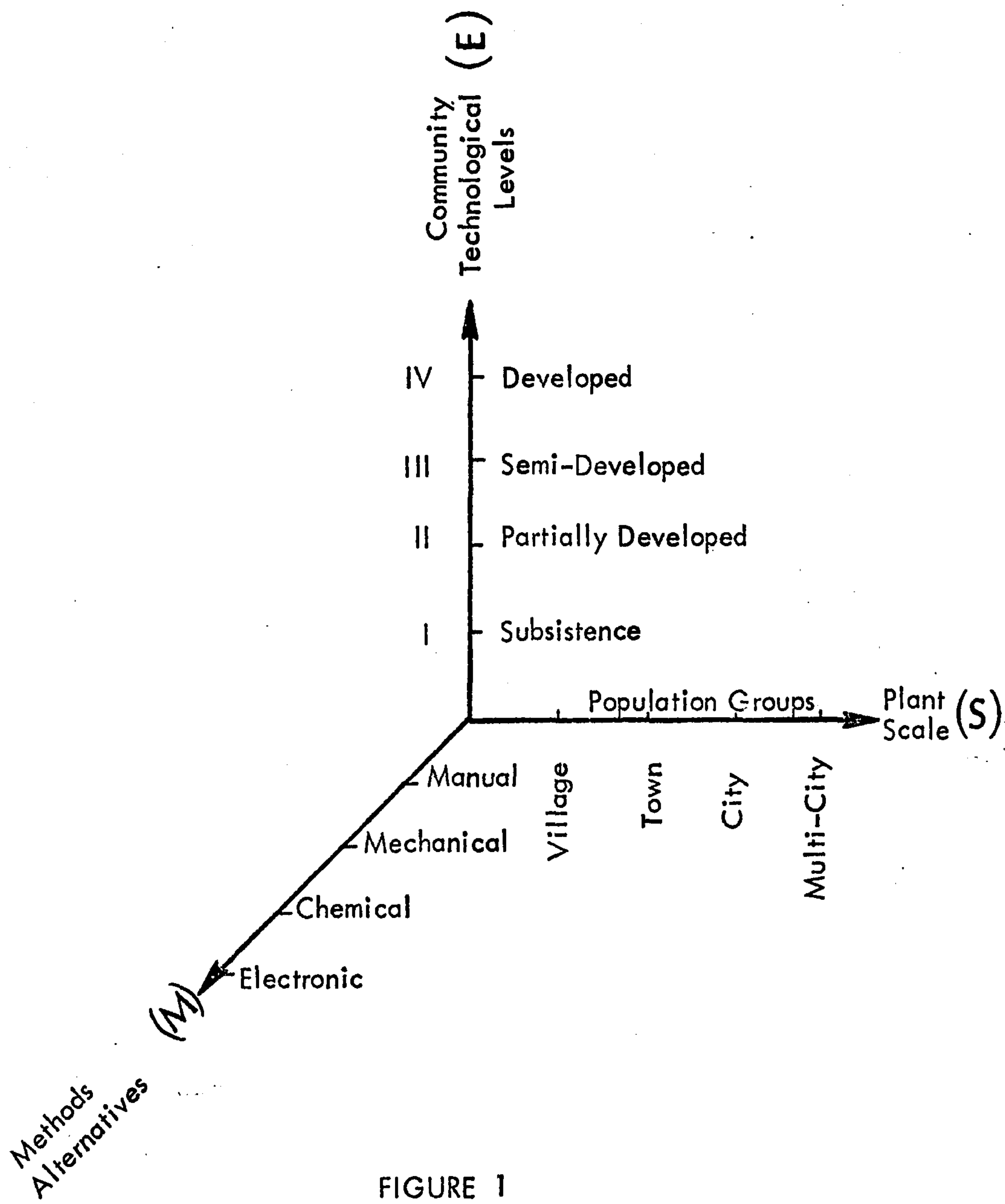

FIGURE 1

Graphical Presentation of the Performance Components be determined by evaluating the requirements needed for the various processes. The list of suitable processes and their characteristics was supplied by Professor George W. Reid, Director of the Bureau of Water and Environmental Resources Research, University of Oklahoma, Norman, Oklahoma.

The basic design goal of this study was to construct a model that conforms to the procedures, rules, and outcomes of the human decision-making process being examined. Models of human decision-making behavior must be based on the observation of that behavior, and this heuristic model could not be an exception. The technique used to observe this behavior consisted of unstructured interviews with experts in sanitary design, international demographic analysis, manpower evaluation, and financial analysis. The interviews were supplemented with a library research effort in all the above areas.

The unstructured interview approach was chosen for several reasons.[7]

1. It helped eliminate prejudgment on the part of the interviewer.
2. It allowed the problem to be reformulated as the research progressed, thus modifying investigatory categories.

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[7]The observations which follow were derived from the following sources: J.T. Doby, An Introduction to Social Research, 2nd ed. (New York: Appleton-Century-Crofts, 1967), pp. 274-304; F.N. Kerlinger, Foundations of Behavioral Research (New York: Holt, Rinehart and Winston, Inc., 1964), pp. 467-478; B.S. Phillips, Social Research - Strategy and Tactics, 2nd ed., (New York: The Macmillan Company, 1971), pp. 139-146; and C. Selltiz, et al., Research Methods in Social Relations, rev. ed. (New York: Holt, Rinehart and Winston, 1959), pp. 574-587.

3. It enabled the researcher to avoid misleading or meaningless questions that might have occurred had questionnaires been used.
4. It allowed a more accurate assessment of the respondents' knowledge of the problem and valued their information appropriately.
5. It allowed the investigator to ease himself into the problem at an appropriate pace and thereby avoid rebuff by blundering into delicate situations or subject matter.
6. It allowed the opportunity to input motives for the research study by contrasting stated ideals with actual behavior, supplemented by the informant's reactions with "feed-back." Here, the investigator was able, when necessary, to describe the informant's motives as they appeared to him for corroboration or modification.
7. It provided the opportunity to obtain material in greater depth than could be obtained from survey research.
8. It provided the opportunity to postpone immediate data gathering to cultivate the relationship and draw out depth material only when the informant was ready to give it.
9. It provided the opportunity to absorb much information that at the time seemed irrelevant. Later, when the perspective on the situation changed, the information in some cases proved extremely valuable.
10. It enabled the researcher to make use of selected informants'

skills and insights by giving these informants a free rein to describe the situation as they saw it.

11. It allowed informants to talk about what they wanted to talk about. The survey researcher has to limit respondents to his specific topics.

The selection of the respondents was based primarily on their availability and the nature of their expertise. In addition to meetings with local experts, the investigator made two interview trips to Washington, D.C. and contacted still others by telephone. A comprehensive list of individuals consulted is provided at the end of the bibliography. Generally, the informants were familiar with the problem being studied, and many were in advantageous positions to analyze and interpret on-going events. They often knew the local jargon and technical terms necessary to understand the problem. Some even understood the people (those in LDC's) well enough to know the meaning of their actions.

Generally the informants were relatively uninhibited and not inclined to slant their comments to protect themselves or others. The interviewing provided a quick and efficient means of collecting data. Key data or lack of it was generally at the forefront of consciousness of the informants and was easily within reach of the investigator.

The unstructured interview approach was generally able to provide an abundant source of information on all components of the model, except one. The lone exception was the socio-economic variables. These components required an extensive library research. The initial assumption was that communities in the LDC's are in different stages of development. Even Western societies, where the bulk of the world's economic wealth is found, have undergone and are undergoing a variety of revolutions. A review of the literature indicates that similar movements are underway in the LDC's.

Socio-Economic and Socio-Cultural Factors

The last twenty years have yielded a large body of experience and study on this process by researchers, assisting institutions, and governments themselves. However, the trend toward specialization of scholarship has yielded views of development which are placed in a dominantly economic or political framework rather than in an ecological perspective which includes all variables. For example, Paul Samuelson sees development in these terms:

> An underdeveloped nation is simply one with real per capita income that is low relative to present per capita incomes of wealthy nations such as United States, Canada, Great Britain, and Western Europe. Usually an underdeveloped nation is regarded as being capable of substantial improvement in its income level.[8]

There is a tendency to view the economic development on a country basis merely in terms of average per capita income. With the introduction and recent refinements of national accounts, it has become fashionable to use the per capita national income as if it were the last word in measuring the economic welfare of a people. Undoubtedly, this statistic has its uses if applied with a knowledge of its limitations, and these

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[8]Paul Samuelson, Economics, 5th ed., (New York: McGraw-Hill Book Company, 1961), p. 776.

are formidable. First, it expresses the "monetary value of the sum total of goods and services produced by a country divided by the population," and thus it is actually an index of production and not a direct measure of income received by consumers. Second, it should be noted that even in the most highly developed countries the absolute income figures obtained are liable to appreciable statistical errors, though measurement of year to year changes may show a considerable degree of accuracy.[9] Finally, in countries with limited statistical services, the amount of rough estimation involved in preparing the national accounts make all but large annual changes of doubtful statistical significance.

Particularly problematic is any attempt to compare the per capita income between countries. This is normally done by converting local currencies to U.S. dollars, but frequently no single exchange rate exists and even a free rate of exchange does not necessarily give a true indication of the real purchasing value of the respective currencies. Because of this, devices have been used in the past to arrive at a measure of relative incomes, such as hours of labor required to purchase one kilogram of milk or a pair of pants; however, none of these are sufficiently general in scope. Very valuable of course is knowledge of income distribution.

Any number of economists and others have postulated stages of economic growth. Karl Marx associated change in economic growth with

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[9]F. R. Van der Mehden, Politics of Developing Nations, 2nd ed., (Englewood Cliffs, N.J.: Prentice Hall, Inc., 1969), p. 135.

institutional changes from feudalism to capitalism to socialism. Harbison and Myers arrived at a level of human resource development for a country by using a composite index which included the percentage of those in the 15-19 year old population enrolled in secondary education, as well as the percentage of the 20-24 year old population enrolled in advanced, or third level education.[10] They weighted the advanced education figures, inasmuch as this group was believed to be a more sensitive indicator of the level of human resource development in a society. Another growth theorist is W. W. Rostow, who classified growth into five stages: (1) traditional society; (2) preconditions; (3) takeoff; (4) the drive to maturity; and (5) high mass production.[11] These approaches mainly rely on national statistics that have been gathered by the United Nations and several of its agencies concerned with development; namely, the International Bank for Reconstruction and Development, the International Development Association, the Inter-American Development Bank, the Asian Development Bank, and the Organization for Economic Cooperation and Development.

The above approaches were inadequate because both political and economic statistics for the developing world often lack accuracy, plus it is difficult to judge the merit of the variety of national statistical offices. Most United Nations statistics are provided by the nation concerned without warning to the unsuspecting reader as to their veracity.

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[10] Frederick H. Harbison and Charles A. Meyers, Education, Manpower and Economic Growth, (New York: McGraw-Hill Book Company, 1964), pp. 23-48.

[11] W. W. Rostow, The Stages of Economic Growth (Cambridge, Mass.: University Press, 1960).

While computerized systems for correlating data are to be found in many less developed countries, the collection of raw material at the local level remains of low quality and political factors often hinder an accurate or objective rendition of the results. Data are questionable for population, literacy, health standards, GNP, and agricultural production.[12] For example, Von der Mehden stated that one governmental official admitted to him that literacy rates in his country were lower than they had been during his country's colonial period; the government had given the United Nations artificially high figures, he explained, because of national pride.[13]

Finally, these analyses cannot be entirely accurate because they deal with situations in flux. Although the basic patterns appear to remain fairly constant, their elements may not be the same from one year to the next. The very instability that is under analysis must be taken into account when charts and examples are considered. These changes, however, often take place within what has become a general pattern, and change itself is a part of that pattern.

It takes years to develop a reliable statistical system and to accumulate the time series required for economic analysis and planning. At each stage of planning, various data inadequacies become apparent, and they tend to guide the planners in determining statistical priorities. Some countries attempt to construct complex secondary data systems without having first developed the necessary basic statistics. These systems

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[12] Von der Mehden, Politics, p. 135.

[13] Von der Mehden, Politics, p. 5.

are generally based on numerous assumptions and estimates that may mislead just as much as they guide planners.

Since the published data sources could not be used as a reliable source of data, the approach in this study was to develop the levels of technology at the community level utilizing data that could be obtained at the local level without tedious effort on the part of the planners.[14] The following section discusses the nature of the socio-cultural and socio-economic factors: the approach in this study was to select several variables that have been used by growth theorists[15] to determine their validity with this type of data to see if the variables could be obtained at the local or community level.

The first attempt at trying to measure development or levels of technology began with a list of 36 variables under four main categories.

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[14] Interviews with D. Donaldson, Pan American Health Organization, Washington, D.C. (September, 1973), A.P. Talboys, United States Public Health Service, Washington, D.C. (May, 1974), and A.D. Swisher, Agency for International Development, Washington, D.C. (May, 1974), confirmed that this approach would probably generate the most accurate and timely data at the community level in LDC's.

[15] The following sources were utilized for sources of the input variables. These sources also provided a basis for determining how the variables could be used to determine the level of development at the community level. A.S. Banks and R.B. Texler, A Cross-Polity Survey, (Cambridge: MIT Press, 1963); F.H. Harbison, J. Maruhnic, and J.R. Resnick, Quantitative Analysis of Modernization and Development, Princeton, N.J.: Industrial Relations Section (Princeton University, 1970); F.H. Harbison and C.A. Myers, Manpower and Education: Country Studies in Economic Development, (New York: McGraw-Hill Book Company, 1965); W.W. Rostow, The Process of Economic Growth, 2nd ed., (New York: Norton Press, Inc., 1960); W.W. Rostow, The Stages of Economic Growth, A Non-Communist Manifesto, 2nd ed., (Cambridge, England: University Press, 1971), United Nations Demographic Yearbook, 1971, (New York: Publishing Service -- United Nations, 1972).

These categories were: (1) socio-economic conditions; (2) levels of health; (3) health services; and (4) miscellaneous criteria. (The miscellaneous criteria contained such variables as irregular executive transfers, protest demonstrations, riots, and deaths from domestic violence.)

Ideally, indicators should permit comparison between different countries and also between different developmental stages within any one country. The measurements should be easily available and must have a reasonable degree of accuracy.

In practice, however, indicators generally lack those qualities. For example, Molina and Noam reported that Puerto Rico had undergone remarkable social and economic progress which was accompanied by impressive improvements in the levels of health of the population.[16] Between 1940 and 1960 life expectancy increased by 25 years; the crude death rate and infant mortality were reduced by one-third. At the same time, per capita national income, in constant dollars, doubled. The proportion of children in schools increased by more than 50%.

The coinciding improvements in health services and population health tempt researchers to postulate a close relationship between the two. However, the experience in Chile seems to contradict the Puerto Rico case. Beginning in 1953, a unified national Health Service in Chile extended hospital, clinic, and health services. The percentage

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[16] G. Molina and I.F. Noam, "Indicators of Health, Economy, and Culture in Puerto Rico and Latin America," American Journal of Public Health 54 (August 1964): 1191-1206.

of births occurring in hospitals increased from 37 in 1950 to 56 in 1958, visits of children to clinics more than doubled, and rates of hospitalization showed large increases. Yet such measures of health as Molina and Noam found available did not demonstrate any substantial improvement in the health status of the people of Chile. In an attempt to correlate changes in the standard of living and the changes in health services, these authors were confronted with a scarcity of reliable indicators capable of measuring these changes accurately.[17]

The above discussion briefly outlines some of the problems associated with the use of indicators. In spite of this, a number of variables were selected on the basis of their "availability" at the local level and how they reflected the level of development at the community level.[18]

These inputs are:

1. Distribution of labor force
2. Income characteristics
3. School operators
4. Highest grade offered by local schools
5. Nearest high school
6. Compulsory primary education

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[17] Ibid., p. 1193.

[18] The appropriateness on the use of these variables as indicators of development or technology was substantiated by discussions with Dr. George M. Ayoub, Associate Professor, American University of Beirut, Beirut, Lebanon and M. Ikua Muiga, Research Associate, Bureau of Water and Environmental Resources Research, University of Oklahoma, Norman, Oklahoma.

7. Availability of in-service training programs
8. Local college or university
9. Chemistry department in local college
10. Community fiscal level
11. Unemployment problem
12. Availability of extension services
13. Schools of local college students
14. Level of technology available
15. Government as a labor user
16. Availability of public employment services

These variables and their characteristics are briefly described below.

1. Distribution of the labor force is expressed in terms of the percentage of professional, skiled, and unskilled workers in the employed labor force. The employed labor force meaning those persons who are in some way connected with the market economy. In a subsistence economy, only a very small portion of the total population is engaged in market activities, whereas the advanced modern level of development has a large percentage of persons in market activities and these workers have expertise levels at the professional and skilled categories.

2. Income characteristics generally reflect the level of development. A larger per capita income generally denotes higher levels of development.

3-6. These variables relate to the investment that a community has in the education of its youth. When schools are operated by voluntary agencies or missionary organizations, the level of development tends to be at a low level. Increases in the standard of living tend to bring compulsory education to at least the primary level. The general accessibility of schools to a community indicates the level of development. Generally, the higher the grade offered, the higher the level of development.

7. The availability of in-service training programs reflects the level of development -- these programs are not generally available in lower developed areas. These programs often become more available as the need for higher skills and more expertise in technical areas is required in the community. These in-service programs may be offered through agricultural extension and community development programs.

8-9. These variables relate to the sophistication of the educational opportunities within the community itself. The availability of a chemistry department gives some indication of the technical expertise available in the community. It also provides a potential place for the testing of water quality characteristics. In short, the availability of higher education indicates a high level of development.

10. Community fiscal level relates to the ability of a community to meet the needs of improved water and sewage treatment by providing for some, if not all, of the funds required for these improvements.

11. Rampant unemployment is characteristic of communities at a low level of development. The bulk of those unemployed in an area of low development are unskilled workers. Generally the unemployment problem decreases as the level of development increases.

12. Agricultural extension services tend to improve as the level

of development increases. At low levels of development, agricultural extension services and demonstration projects are scarce. In addition, at low levels there is a tremendous need for advisory services to farmers, and other programs to upgrade the skills and enlist the participation of the rural masses. The main hurdle at low levels is that the appropriate organizational and institutional structures are lacking for implementation of and administration of extension services.

13. The university or collegiate schools that the local college students attend gives an indication of the level of development. If most or all of the students receive their higher (third) education in neighboring communities or abroad, then the community is at a low level of development.

14. Level of technology available is a generalized data variable that calls on the experience of the planner. It simply asks what level of development is available as signified by four general categories of technology. These categories are: (1) hand tools; (2) mechanical tools (i.e., gasoline powered equipment); (3) chemical products (i.e., use of fertilizers and/or chlorine); and (4) electronic technology.

15. The government's role in the labor market also gives an indication of the level of development. At low levels of development the government at the community level tends to be the major employer. As development increases, employment in the private or non-governmental related activities tend to increase.

16. The availability of public employment services indicates the level of development. These services are generally only available at high levels of development. Public employment services in lesser

developed countries tend to se-vice blue-collar workers rather than professionals.

Demographic Criteria

Demography is generally defined as the science of vital statistics, meaning deaths, births, marriages, and many other details influencing change in population. This science can be and is applied on global, national, and regional or local scales.

The model requires demographic criteria on a local scale or community level. The basic instrument concerned with the details describing the change in population is the national population census. Most nations take a census regularly every ten years, although a smaller number take a population census every five years.

Obtaining accurate statistics can be a serious problem. Even in areas with a long history of census-taking, some people are missed by enumerations, and demographers must adjust for undercounting and wrong answers in analyzing the results. The requirements of a census can be especially discouraging in LDC's where resources of money and trained personnel are limited, and the difficulties of gathering information are formidable. On a national level in 1972, the United Nations reported that about 30 nations, with a combined population of over 200 million, had never taken a census, while others did so only irregularly.[19]

It is not a simple matter to count each person. In many LDC communities, women tend not to list those children who did not survive the first weeks of infancy. If local custom decrees that only the head of a household can be interviewed, women or children may be undernumerated.

In cultures where people are not traditionally age-conscious, ingenious methods of determining age have been devised. For example, Kitiyu youths in Africa receive special names identifying them as members of groups which passed through the circumcision ritual together. The characteristic names permit enumerators to estimate ages for these people fairly accurately.

Another method involves the case where enumerators are provided with calendars of religious, national, or local events. Then they ask respondents what their ages were at the time of significant past events. However, this technique tends to result in a "heaping" of replies around the dates of the most easily remembered events. A similar phenomenon is seen for ages ending in the numerals 0 and 5, because many people spontaneously reply to questions about age in multiples of 5 -- the number of fingers on one hand. These heaping patterns tend to distort the true age distribution of the population.

In areas where there are few literate people, the enumerator is often an overworked schoolteacher or local official. The workload and

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[19]"Refining Census Capabilities," Population Dynamics Quarterly 2 (Winter, 1974): 7.

deadlines of census-interviewing can create pressures that may have an adverse effect on the data.

Finally, in analyzing the census returns, generally the earlier the stage of economic development of the country or community, the higher the degree of sophistication required to evaluate data and determine what is happening to the population. The dilemma for LDC's is that they often lack trained analysts familiar with demographic variables under different conditions, while experts from other countries cannot evaluate the data because they are unfamiliar with the local cultures.

With these limitations well understood, the demographic inputs to the model were designed to be those most readily available. Those selected were:[20]

Present population

Survival rate

Birth rate

% immigrants

% emmigrants

In utilizing the model, some cases may arise where the above demographic variables are not available on a local level. In this situation, estimates by knowledgeable individuals and groups should be sought. The evaluation of the labor force data is discussed in more detail in the manpower supply input data section.

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[20]These were considered the minimum essential number of variables for determining future population levels. See: G.W. Reid, A Multi-structured Population Forecasting Model (Norman, Oklahoma: Oklahoma Economic Development Foundation, 1969).

Manpower Supply

Probably the most difficult component of the model is measuring the manpower supply at the micro-planning level (community level). The first step involves becoming familiar with the current and probable future economics of the community to identify present and potential areas of manpower bottlenecks. However, this does not imply a listing of trained people required to provide basic services of water and sewage treatment to the population (such as engineers, chemists, and/or physicians) or those needed to speed expansion of the commercial sector (such as qualified managers, accountants, and marketing and production specialists). Such a listing would have little point since the specified manpower deficiencies would not necessarily be related to the ability of the community to employ such people if they could be trained. Communities in LDC's are poor cities, and they lack not only trained manpower but a great many other essentials to speed economic and social expansion, such as capital or infrastructure; in fact, the community is likely to be handicapped in varying degrees along each of these fronts.

Therefore, a manpower study in an LDC community must begin by sorting out and assessing the problems connected with the acquisition of skill and competence and the effective employment of trained people in water and sewage treatment projects. A common error in both LDC's and developed countries is to focus exclusively on matters of manpower supply and thus fail to give full consideration to manpower utilization. Since a trained person who is not used or who is poorly used is not really an asset, manpower analysis must pay particular attention to utilization. Improvement on this front offers one of the best prospects of securing a better balance between a limited supply of and an unmet demand for skill.

In dealing with a manpower profile, the first problem is the lack of precision in the concept of employment levels. Even in the developed countries of the West, a significant proportion of the labor force does not work for wages or salaries. They are not employees, but are self-employed. In most countries, self-employed persons are to be found in agriculture, small or cottage industries, repair and maintenance services, retail trade, and the professions. In the developed countries, agriculture and small industries of the one-man or familial character account for a rather small proportion of the labor force, while trade and repair and maintenance services are increasingly coming under the control of large organizations. Both of these trends result in a steady increase in the employee element in the total labor force. Professions, of course, continue to have a large element of the self-employed, though the tendency is toward an increase in the employee element, owing to increasing governmental responsibilities in the social field with the rise of the developed manpower and welfare state.

The labor market is a flexible area expanding or contracting with economic and labor force activities. However, while these changes may take place over time, at any one time the labor market area must have rigidly defined boundaries. This is necessary so that estimates of labor demand can be matched with a corresponding labor supply and related figures of population estimates and economic activity may be compared to the manpower data. Where possible, the labor market boundaries should be the same as a minor civil division. This will permit easier identification of the labor market and will allow comparisons to be made with other types of data which may be available at the local level.

Numerous published sources have data presented for the LDC's as a whole without regard to the local labor market areas it contains. The assumption exists that the nation in its entirety constitutes a homogeneous labor market; that is, a person can move from one place of employment to another without moving his place of residence. This can be the case where the land area is small; it can be true over time, though it might not be true for the short term; or it can be a valid assumption with respect to certain elements in the labor market situation or for the specific analytical purpose that the data compilation was designed to serve.

At this point, the question can be asked, is it worthwhile to pursue questions which cannot be analyzed in depth because there is no reliable data? The answer is simple: while statistics are important, they are not the only means of understanding complex issues such as manpower. In the absence of detailed statistical data, there are many ways in which pieces of information can be obtained to assess the availability of manpower for water and sewage treatment plants. To illustrate with the matter of manpower shortages, it is difficult to reach sound judgments about the magnitude and severity of various manpower shortages without reliable data about the supply of trained manpower in the various sectors of a society.

The following scheme, based on the levels of development presented earlier, helps a planner determine the relative availability of various types of manpower needed to operate a plant. The main emphasis of the scheme is operating personnel, as opposed to construction personnel. Investigation up to this point has indicated that failure of a project almost always occurs in the operation and maintenance rather than during construction. Therefore, skilled workers required in the construction stage are not included because they can easily be supplied where necessary by the international construction industry. The occupations required on water and sewage treatment programs in the post-construction stage fall into the following categories:

1. Unskilled-Semiskilled (Category C)
2. Skilled or Craftsmen (Category B)
3. Professional (Category A)

Category A and B occupations require a substantial amount of special formal training. Hence the sources, volume, and timing of their supply is relatively easy to identify. In category C, by contrast, most individuals master these skills by relatively non-formal means in the plant and on the job and do not undergo formal courses or pass through formal in-plant training schemes. This is true even in those craft occupations that for generations have been termed "apprenticeable." It is even more true in most of the new "industrial" skilled manual occupations, which have emerged since the industrial revolution. The skills cannot normally be gained away from or outside the employing institution because of the nature of the operation or the special machinery and equipment involved or the working environment itself.

The main supply of category B occupations, which require a secondary school education plus two to three years of vocational training, is produced by the training schools and schemes maintained by ministries of the government which operate them to meet their own specialized requirements. In many LDC's these facilities are generally well-established.

Decision rules or heuristics were developed from the research carried out in this study so that the treatment method selected can be maintained with workers selected from the local manpower supply. The heuristics are a result of discussions with experts from the International Office of the United States Department of Labor and others familiar with the labor situation on a community level in the LDC's.[21] The purpose of the heuristics is to avoid the manpower problems of many previous projects; that is, the installation of processes without regard to supply of local manpower to repair and maintain the treatment operation. These rules, translated into constraints, are:

1. In Level I communities only unskilled manpower is available. (Category C only).

2. Level II communities have only unskilled and semi-skilled labor available. (Categories A and B only).

3. Level III communities have only unskilled and semi-skilled labor available in populations under 50,000. In populations over 50,000 Level III and Level IV communities have all categories of manpower available.

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[21]Telephone interviews were conducted with (1) M.R. Sugg, (retired) Labor Statistician, Bureau of International Labor Affairs, U.S. Dept. of Labor, Washington, D.C., (2) E.C. McVoy, Director, The International Manpower Institute, Manpower Administration, U.S. Dept. of Labor, Washington, D.C., (3) H. Kuptzin, U.S. Employment Service, U.S. Dept. of Labor, Washington, D.C., February, 1974, for the purpose of validating the heuristics.

Local Resources and Available Materials

One of the primary objectives of the planning scheme being developed in this research effort is to suggest systems or processes which make use of local materials. This group of inputs supplies some basic data concerning the physical resources of a community and also specifies what processes are currently being utilized to treat water and sewage.

Throughout this study, water and sewage treatment have been mentioned together, because the two necessarily go together. The design of the water supply system is greatly influenced by the sanitation services proposed to be used. Sewage treatment is, therefore, the reverse side of the coin from water supply. This is seen clearly in the practice of disposing human bodily waste by means of a waterborne piped collection network. Such systems are, however, less than 200 years old. Among the first were those in Hamburg (1842), London (1855), and Paris (1860). Sewage systems became possible with the advent of abundant quantities of water supplies to the household and became fashionable with the invention of the water closet.[22]

Waterborne sewage systems have served admirably in cities with high density populations where abundant water is cheaply available, and where the level of wealth can support the high capital costs required. They are also appropriate where the natural environment has a capacity

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[22] G. M. Fair et al., Water and Wastewater Engineering, Vol. 1 (New York: John Wiley and Sons, Inc., 1966), pp. 1-9.

to absorb a concentrated flow of wastes in an untreated or semi-treated state. These conditions apply in some major metropolitan areas in LDC's but rarely do in smaller communities or rural areas.

In this study, the list of available processes for sewage treatment is for waterborne sewage systems; therefore, some communities, due to their size and their inability to provide the volumes of water required, are not considered for sewage treatment in this planning model. In areas of water shortage, such as arid and semi-arid regions, considerably higher costs would be entailed to provide the water required. The cost of sewage systems (as also with piped water supplies) increases as the density of population declines, and such systems are both inappropriate and unnecessary for low density, dispersed rural populations.

Therefore, some communities are not provided with a plausible sewage treatment method for the reasons discussed above.

Data about the local resources and the present technology available for a community is based on the variables in the following list. The list is made up of chemical supplies and mechanical equipment, need for the operation of a wide variety of water and waste water treatment systems. The availability of these items is matched, within the model, against the requirements of the various processes. Those processes which require materials or resources not locally available are eliminated from the plausible treatment alternatives suggested by the model. The data input variables on these local resources and materials include:

A. Present Level of Water Technology Development

1. Central village pump
2. Piped water supply to houses
3. Sewage collection system
4. Sewage treatment

B. Water Source

1. River or stream
2. Lake or impoundment
3. Wells (is groundwater available?)
4. Sea or brackish

C. Waste Water Quality

1. Is the central collection system in existence?
2. Number of people connected to the system.
3. Number of people to be connected within 10 years.
4. Are industrial or commercial concerns using the system?
5. Number of industrial or commercial concerns using within 10 years?

D. Equipment Available

1. Meters
2. Lawn mowers
3. Blowers
4. Recording devices
5. Laboratory equipment
6. Portable power plant
7. Motors
8. Pumps

E. Maintenance Supplies

1. Pipe (clay, steel, cement, plastic, copper, etc.)
2. Pipe fittings
3. Paint
4. Valves
5. Tanks
6. Gauges
7. Heat exchanges
8. Silica sand
9. Graded gravel
10. Clean water
11. Gasoline

F. Chemical Supplies

1. Al_2SO_4 (Aluminum Sulphate)
2. $FeCl_2$ (Ferric Chloride)
3. Activated charcoal
4. Lime
5. Soda ash
6. Chlorine
7. Ozone
8. Laboratory chemicals

Available Processes for Water and Waste Treatment

In order to transform raw water into potable water conforming with quality requirements, some treatment processes are required. Table 1 shows both water and sewage treatment processes and the manpower and materials requirements associated with each process on an operational basis. The processes begin at the elementary level and proceed to ones that require the technology of a very modern economy. The function of the planning model is to evaluate the inputs described earlier in this chapter against the requirements of the processes. Treatment is generally carried out for health reasons in order to remove harmful bacteria or dangerous substances and for aesthetic reasons. In some cases, treatment may be carried out for economic reasons, such as water softening, or for other special purposes. Water softening is designed to remove soluable minerals from water supplies. These minerals or "hardness" may prevent the water from being used for commercial reasons such as for bottling and for paper-making. The treatment

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[23] The number and the various types of processes described in this section were suggested by Professor George W. Reid, Professor of Civil Engineering, University of Oklahoma, Norman, Oklahoma and Dr. Kenneth C. Govaerts, Associate Professor, Oklahoma State University Technical Institute, Oklahoma City, Okla.

TABLE 1 WATER AND SEWAGE TREATMENT PROCESSES WITH ESSENTIAL COMPONENTS FOR OPERATION

	Basic Water and Wastewater Treatment Processes	Manpower Operation				Materials Operation					Equipment Operation						
		Unskilled	Skilled	Technical	Professional	Chemicals-Laboratory	Silica Sand	Chlorine	Chemicals-Coagulant	Chemicals-Oxidation	Pumps	Laboratory Equipment	Recording Devices	Air Diffusers	Meters	Valves	Heat Exchanger
Water Supply	Drilled Well	X									X					X	X
	Disinfection		X	X		X		X				X				X	
	Settling Tank	X														X	
	Slow Sand Filter	X					X									X	
	Rapid Sand Filter		X	X	X	X	X	X	X		X	X	X		X	X	
Waste Water	Oxidation Pond	X														X	
	Primary Sedimentation	X	X													X	
	Trickling Filter	X	X	X		X					X	X				X	
	Activated Sludge	X	X	X	X	X					X	X	X	X	X	X	

processes to be carried out for a water supply system depend on the raw water source and its quality, on the quality requirement for the treated water, and on local conditions and economic possibilities.

A brief description of the processes listed in Table II applicable to the LDC's follows.

Many communities rely heavily on ground water as a water source, and the water well is a facility which plays an important part in water system development. Water wells are classified basically according to the method used to build them. The four common types are: driven, dug, bored, and drilled. A driven well is constructed by driving a well point on the end of a pipe into the ground with a heavy weight. A dug well is simply dug and gravel is put into the bottom; it is often lined with bricks. A bored well is constructed with a hand-operated augering device. Drilled wells are constructed by machine-operated rig drills.

Not all wells are equally satisfactory as water facilities. Dug wells, in particular, are not acceptable as a safe, reliable, water supply because of their depth and design. A vast majority of such wells are vulnerable to contamination from local sources, such as privies, hen houses, pig pens, feedlots, private garbage dumps, and polluted streams. A relatively deep, well-designed, and well-constructed drilled well is the best type for developing a ground water supply capable of long-term, high capacity production.

Sedimentation (or the settling tank) is the process by which suspended particles settle by natural gravity, while water is retained in a natural or artificial basin. The settling tank is very efficient in reducing turbidity of surface water containing large amounts of suspended matter, mainly coarse materials such as sand and silt. The settling tank also reduces the total number of bacteria in water simply by storing water, because the bacteria die off faster than they multiply in a water environment. Other functions of the settling tank are that it improves the color of the water and that the settling basin can also serve as a storage reservoir. The most common tanks are rectangular; their simplest and cheapest construction is by excavation without lining or by an earth dam which forms an impounding basin.

Sand filtration is a process where the physical, chemical, and biological characteristics of water are improved by passing water through layers of sand. The process of sand filtration is very complex, involving straining, sedimentation, absorption, oxidation, electrical effects, and biological action. As a result, large particles together with small suspended particles are removed, mainly at the surface of the sand and in the upper layers. A thin gelatinous layer, referred to as schmulzdecke, is formed on the sand surface, and it is here that most biological and chemical processes occur. There are two types of sand filters--slow sand filters is one in which the water flows by gravity at a slow rate and the main pumping action is obtained by absorption on the surface layer; rapid sand filters are those which have been designed to operate at a much higher rate and are more suitable for water that may have already passed some pre-treatment. However, the pre-treatment is not a necessary requirement for effective use of rapid sand filters. The most common type of rapid sand filter consists of pressure filters which can filter pumped water up to a pressure of about 10 atmospheres without dissipating the pressure.

Disinfection is carried out mainly for bacteriological purification of water. Chlorination is the most common method. It is toxic, but it is used in such concentration that it kills most pathogenic bacteria in water without affecting man. The danger of chlorine overdosage which would be dangerous to man is controlled by the taste given to water. At dangerous concentrations the taste of chlorine is so strong that the water is unacceptable for drinking. Chlorine is very active and reacts with organic and inorganic matter found in water. Effective chlorination has to provide a dose of chlorine suitable for making the reactions possible in the specific water to be disinfected and to leave enough residual free chlorine for bacteriological purposes. A residual chlorine of 0.5 ppm (parts per million) after a period of 30 minutes is considered sufficient for disinfection purposes.

The lower part of Table 2 shows the various processes to treat sewage. Again the processes are listed in terms of their complexity, with the simplest being the oxidation ponds and the most complex process being activated sludge.

A lagoon or oxidation pond is essentially a shallow pond where the effluent is kept well mixed so that the aerobic processes can prevail. Algae participate in the biochemical breakdown of sewage in lagoons because of the exposure to sunlight. When mixing is poor and the lagoon is run anaerobically, the dead and decaying algae help to deplete the dissolved oxygen, and the result can be a foul-smelling open septic tank. In a facultative pond, the upper layers of water (the water can separate into thermal layers if there is little physical mixing) operate aerobically, while the lower layers are anaerobic.

Mechanical aerators can be floated atop the pond to keep the entire pond aerobic.

In waste water treatment, sedimentation is the removal, by gravitational settling, of suspended particles heavier than water. When the impurities are separated from the suspending fluid by gravitation and natural aggregation of the settling particles, the operation is called primary sedimentation. Wastewater enters at the center and travels outward toward effluent weirs located on the periphery of the tank. The inlet line usually terminates near the surface but the wastewater must travel down behind a stilling well before entering the actual settling zone. A stilling well reduces velocity and imparts a downward motion to the solids which drop to the tank floor.

Trickling filter systems involve the wastewater or effluent trickling more or less continuously in thin films over a bed of crushed rock or other media, coated with biological films. The biological slime layer consists of bacteria, protozoa, and fungi. Sludge worms, filter fly larvae, rotifers, and other higher animals frequently find the environment suitable for growth. The surface of the bed may support algal growth when the temperature and sunlight conditions are optimum. As the wastewater flows over the microbial film, the soluble organics are rapidly metabolized and the colloidal organics absorbed onto the surface.

The activated sludge process consists of feeding water continuously into an aerated tank where there are many types of microorganisms. The air is bubbled through the tank to provide oxygen required by the microorganisms (activated sludge) to consume the sewage. Because the gelatinous masses of microorganisms are heavier than water, they sink as sludge if not kept in suspension. From the aeration tank, partially treated sewage (called mixed liquor) flows into the clarifier, where clean water flows out the top and solids sink to the bottom as activated sludge. Part of the activated sludge is then returned to the aeration chamber where it is re-aerated and kept in suspension to help provide treatment for the incoming raw sewage, and the treatment cycle continues.

As indicated earlier, the remainder of Table II illustrates the types of manpower, materials, and equipment needed to build and maintain plants that employ the above processes. The determination of the manpower requirements for each process has followed these guidelines:

1. Examination of the numbers of personnel of each occupation employed in each activity on existing water and sewage treatment projects, especially those that have been implemented rapidly and successfully.

2. Evaluating the adequacy of the current manpower density by consulting individuals familiar with the various activities and by observing the divergence between the best practice and the common practice, etc.

3. Relating the manpower densities recommended on the basis of experience to other project parameters to determine the manpower coefficients. Usually the paucity of data does not warrant the use of sophisticated statistical methods, and only simple curve fitting is appropriate.

The use of these guidelines at the micro-planning level makes possible a fine dissegregation, the introduction of the planners' judgment, and a comparison among different projects and countries. The standards derived from this method seem to represent satisfactory manpower levels deduced from the experience of successful past projects, and, hence, reasonable figures to be used in the planning of water and sewage projects in the future.

Financial Criteria

Planning a water and sewage treatment project simply because an area is dry is a tempting exercise for those who wish to make the "desert bloom," but some shifting on the basis of cost in relation to overall benefits is required.[25] Ideally, the value added by the project should be equal to that added by similar investments elsewhere in the community. In view of the data deficiencies, it is nearly always necessary to use approximate figures backed with bold assumptions. However, this will force the asking of the correct questions at the appraisal stage, and it will be better than no evaluation at all.

Water and sewage treatment programs could be justified in the traditional manner by using the traditional Marshallian supply and demand analysis. A rate of return could then be calculated based on these revenues, and the economic cost of the project could be determined. Mainly for reasons of pricing policy and income distribution, the rate of return is often not a useful tool to justify water and sewage treatment projects. This is particularly true in LDC's for the following reasons. First, pricing schedules generally involve income redistribution rather than efficiency. Therefore, the revenues collected generally do not correctly express the benefits of a particular project. Second, incremental revenues and costs of the project and major programs can generally not be determined with accuracy. Third, projects selected on the basis of rate of return are not always the most economical; a project may appear attractive because it supplies large per capita volume of water to high income families rather than the minimum

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[25] J. D. Carruthers, Issues in Selection and Design of Rural Water Projects (Discussion Paper No. 88) Nairobi: Institute for Development Studies University College, December, 1969.

per capita volume to a larger number of low income families. A high return may demonstrate that the willingness to pay for water is high. However, this can be a reflection of an uneven income distribution rather than that water is perceived to be more valuable the higher the per capita consumption. On the contrary, without the income distribution effect, the marginal value of potable water is most likely to decrease with higher per capita consumption.

Therefore, the economic justification of a project is difficult because of problems in establishing the level of returns.[26] Water is both a producer and a consumer good. As a producer good is it possible in theory to estimate the producer's "willingness to pay" for the input rather than go without it by estimating the demand curve and price elasticity of demand. In its use as a consumer good, one is dealing with subjective units of utility.

At present, investment is usually justified by the intuition of the decision maker who knows the benefits of water and sewage treatment in other areas and who sees the potential benefits for the site under consideration. However, in many of the LDC's, the proposed scale of investment is now such that intuition is an insufficient basis for decisions. A more analytic approach is needed and is set forth in this section in terms of the model being constructed.

Community water and sewage treatment projects indirectly assist health improvements, cash crop production, tourist industry, and other activities. Emphasis is often placed according to the viewpoint of the advocate. However, planners should take a broad or balanced view of the proposed project because no project is exclusively a health

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[26] A. Wiener, The Role of Water in Development, (New York: McGraw-Hill Book Company, 1972), pp. 203-205.

project or a beef cattle production project. In an effort to provide a balanced view, the following classification, which agrees in principle with those set forth by Carruthers[27] and Davis[28] was incorporated into the planning model. Water and sewage treatment projects are classified into three categories:

1. Pure charity projects where the beneficiaries are poor and prospects for increased income and repayment are minimal.

2. Projects where beneficiaries are poor and payment prospects are not good, but, nevertheless, social benefits exceed social costs. For example, projects in areas to alleviate government famine relief expenditures or projects in or near game zones to keep herders and cattle from game viewing areas, thus safeguarding tourist revenue.

3. Projects in areas of high population density, generally with comparatively high incomes from cash crops or industrial capabilities. This also includes arable regions with potential for expansion of crop area or yields when labor becomes available. Also areas where absence of drinking water for the entire year prevents permanent settlement. In these areas repayment prospects are good, particularly if credit if provided for investment.

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[27] Carruther, Issues.

[28] R. Davis, Rural Water Supply Services: Community Financing. (Document No. REMSA/INF/12) Washington, D.C.: Pan American Health Organization, 1968.

Clearly there will be different financial and economic implications to the program according to the weight of these project types. For maximum economic growth, water and sewage treatment should be provided to select agricultural areas and to arable areas where the population density is not too great. For financial returns, again agricultural areas have priority but also the densely populated arable areas with comparatively high incomes should receive high consideration. For input into the planning model a more specific criteria has been established.

In categories (1) and (3) the lowest total cost will be used to determine the plausible type of water or sewage treatment system. However, in category (2) situations where the ability to repay is limited, then the lowest maintenance cost will be the overriding factor in determination of the most plausible system to implement.[29] Total cost in all cases is defined to be the following:[30]

$$\text{Total Cost} = \underset{\text{(Construction Cost)}}{\text{Capital Cost}} + \underset{\text{for 20 Years}}{\text{Maintenance Cost}}$$

[29]The validity of these assumptions was confirmed during discussions with Talboys and Swisher (May, 1974).

[30]The following formula was suggested by Dr. Kenneth Govarts, of the Bureau of Water and Environmental Resources Research, The University of Oklahoma, Norman, Oklahoma.

In most cases the plants were costed out for a twenty year life. In the other cases, where the equipment does not generally last twenty years, the total cost was adjusted so that all costs were on a twenty year basis.

In the LDC's on the national, state, and local level, no long-term final commitments can be made for water and sewage treatment projects for almost all cases. General targets are necessary, but flexibility has to be maintained so that changes can be made if overall financial resource priorities change and if experience reveals the program to be either too ambitious or too modest. Generally, a single financial year time horizon is too short in the planning environment and, if rigidly applied, can preclude the use of planning as a tool for the agencies involved. Therefore, governments often commit themselves to long-term arrangements even though no specific authorizations are made beyond one year. Loans and contracts are entered into that clearly bind the government to long-term programs.

Time is an important dimension to be considered in reaching a financial decision. It is likely that in many projects water and sewage treatment requirements will increase over time as a result of population growth, migrations, and the increasing awareness of the utility of water and sewage treatment. The problem is then to establish to what extent capital should be committed now to cope with future demands or whether investment should be deferred. It is certain that the total cost will be a lot higher if capacity has to be increased in ten years time for additional facilities and equipment. A case in point is the Kyeni water project in Kenya where it is anticipated in the early years of the project only 25% of the capacity will be used and that it will be 20 years before full capacity will be utilized.[31] In this situation, the alternative of putting in half the capacity and returning ten years later for expansion was rejected on the grounds that the savings would be small and that technical problems were envisioned. This dilemma can be resolved, in principle, by estimating the discounted costs for the two approaches and comparing these with the respective discounted benefits. Although major problems exist with respect to choice discount rate and cost estimation, the main obstacle for a water or sewage treatment project is the difficulty of identifying and quantifying the benefits. Therefore, intuitively it appears that the latter approach involving a larger number of projects with limited capacity is more appropriate. This approach has been incorporated into the planning model.

Evidence to support this view can be found by considering the question of the returns to varying amounts of water. What is the minimum amount of water required per family and what are the marginal returns to increasing supplies? These questions not only refer to the capacity of the system but also to the degree of sophistication. The amount of water people use is inversely related to the distance people have to walk.[32] White found no such association, though there

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[31] I. D. Carruthers, "Issues in Selection."

[32] Dennis Warner, "Rural Water Supply and Development--a Comparison of Nine Villages in Tanzania," paper for East African Agricultural Economics Conference, Nairobi, Kenya, 1969.

was a clear difference in volume used between people who carry water any distance and people who have water in their home.[33] White concludes: "In the promoting of economic development in low income countries through supply of clean water, even where urbanization is rapid, there appears to be special merit in a policy which favors heavy withdrawal by fewer consumers."

In the design of a system, one other financial aspect should be considered, that being the problem of operating costs and maintenance, When a water or sewage treatment project budget runs low, expenditures on water quality may be regarded as non-essential. Skilled and regular maintenance is necessary for successful operation of the plants. In capital scarce economies, substituting for capital costs by accepting increased maintenance expenditures should, in principle, prove the best policy because future espenditures are heavily discounted. In practice however, obtaining the resources for operation and maintenance costs is uncertain, especially for categories (1) and (2) discussed earlier. For this reason, economic efficiency is probably not as serious as in a Level IV environment.

To summarize, at this point in the chapter, the input variables for the planning model were described. Briefly, 16 socio-economic and socio-cultural variables were used. These variables are evaluated by the model so that the communities level of technology can be determined. Four levels of technology have been described, each possessing various technical

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[33] Gilbert White, "Change and Disease in Africa--Domestic Water Use and Cost," University of Chicago, 1968. (Mimeographed)

and human resource capabilities. Five demographic inputs were described and along with this the five order variables describing the manpower supply were presented. The local resources and available materials required by the treatment processes were grouped by operation equipment, process materials, maintenance supplies, and chemical supplies. The last input discussed dealt with fiscal soundness of the community so that in capital poor areas, consideration could be given to alternatives that were financially feasible. These inputs are summarized in Figure 2. Figure 2 also shows, conceptually, how the inputs are matched against the requirements of the processes. The outputs of the model are also shown in Figure 2. Both the nature of and structure of the model and the processes characteristics are described in the remainder of this chapter.

The Structure of the Resource Planning Model

The heuristic program was prepared in two forms, which is normally the case. The first is a schematic diagram depicting every possible step in the decision process and showing the route segments. The route segments connect the various steps in the decision process and form a network of paths leading to the final decision alternatives. Decision rules were specified for each junction to determine which route segments were to be selected and, hence, which path will be followed in solving a particular problem.

The second form is a computer program prepared by transcribing the schematic diagram into a form useable by the University of Oklahoma IBM 370 computer. The input information needed to apply the decision

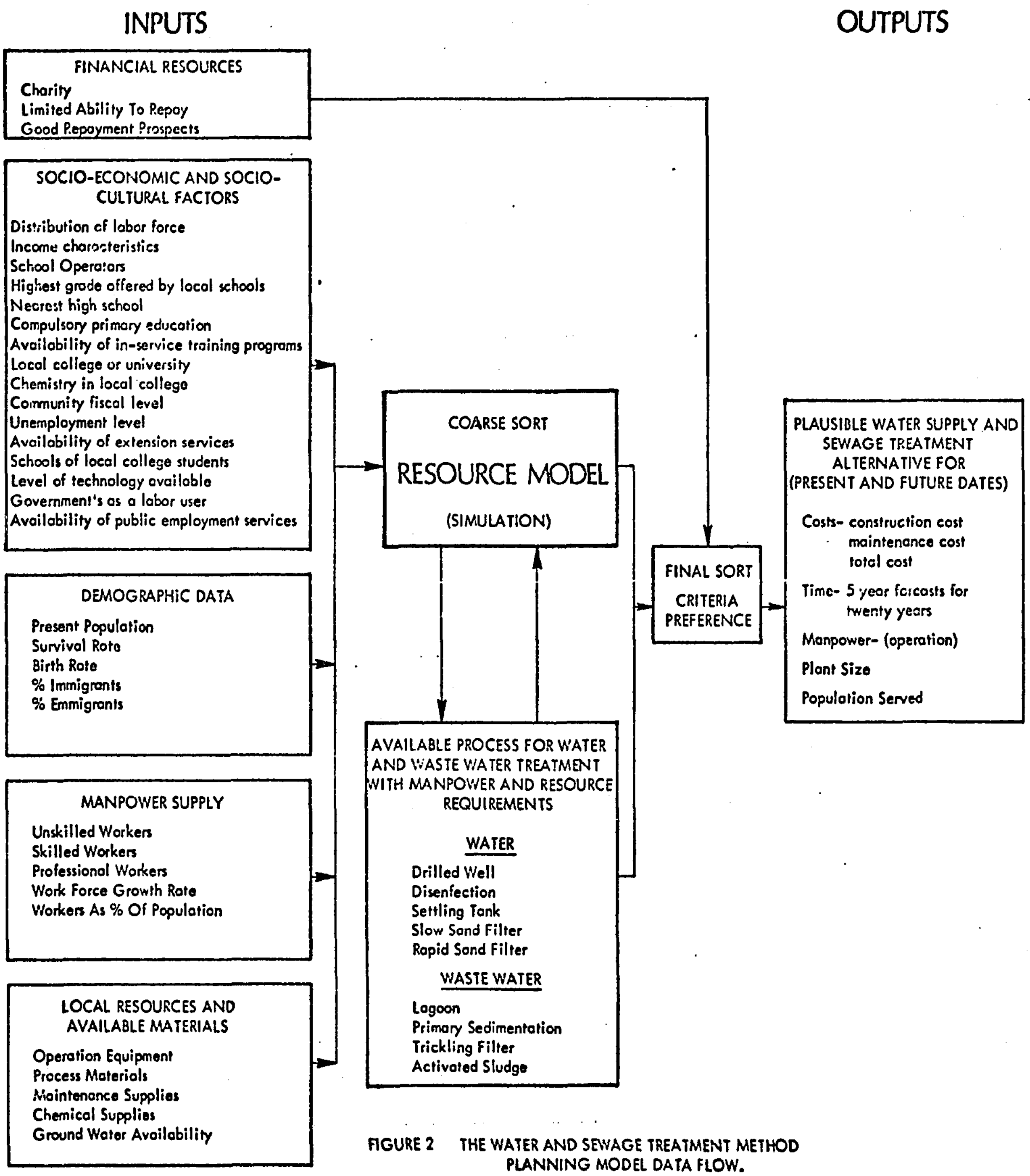

FIGURE 2 THE WATER AND SEWAGE TREATMENT METHOD PLANNING MODEL DATA FLOW.

rules must be all quantitative or can alternatively be assigned a numerical value. The result is a model.

The value of this heuristic model is primarily to show planners the implications of their judgments. If the model accurately describes the human decision process, it might be used as a first approximation to actual allocations. The human decision maker, of course, is at liberty to "override" the models results should special considerations arise which are not encompassed by the model. However, if the model is an adequate description of the planning process, departures from the model serve as a check on the human decision making consistency and, thus, forces planners to explicate the reasons for their departures.

The basic design objective of this heuristic program was to construct a model that confromed to the procedure, rules, and outcomes of the human decision process being examined. Models of human decision making behavior must be based on observation of that behavior, and this heuristic model is no exception. This investigation included interviews with a number of participants involved in the decision process, and observations of the process in motion, and has traced the planning process from start to finish.

The resource planning model developed for selecting water and sewage treatment processes consists of two parts. The main program, or the course sort, examines the socioeconomic--socio-cultural, demographic manpower profile, and local resources. These variables are "matched" against the requirements of the process available to treat water and sewage. The final sort, entered after processing in the main program is complete, attempts to modify the solutions arrived at in the main program by evaluating the financial implications of the communities under consideration. These two parts were illustrated earlier in Figure 1 which is the flow diagram of the entire program.

The upshop of this interplay of variables is shown in Figure 3, which gives the water treatment portion of the model. Figure 4 gives the sewage treatment portion of the model. The decision tree (called a "tree" because of its physical appearance) is used to describe, in a formal manner, the alternatives present in the planning situation. It is essentially a bookkeeping device which helps keep track of the various alternatives and their relationships to each other. The branches shown in Figures 3 and 4 are "action" or "decision" branches. The action or alternative chosen by the model is a direct result of the data inputs. By tracing through the tree diagram one can easily see how the program works. For example, the selection of water treatment process begins with the calculation of the demographic data for the particular community under consideration (shown on the left side of Figure 3).

The basic ingredient of any plan is people. One must not only know how many, but also their needs, characteristics, and spatial distribution. Population is the model's driving force, along with its environment or technological level. Population forecasting is a matter of the decisions a planning agency makes as to the type of water users and sewage producers (both public and private) and the development and environmental controls that the

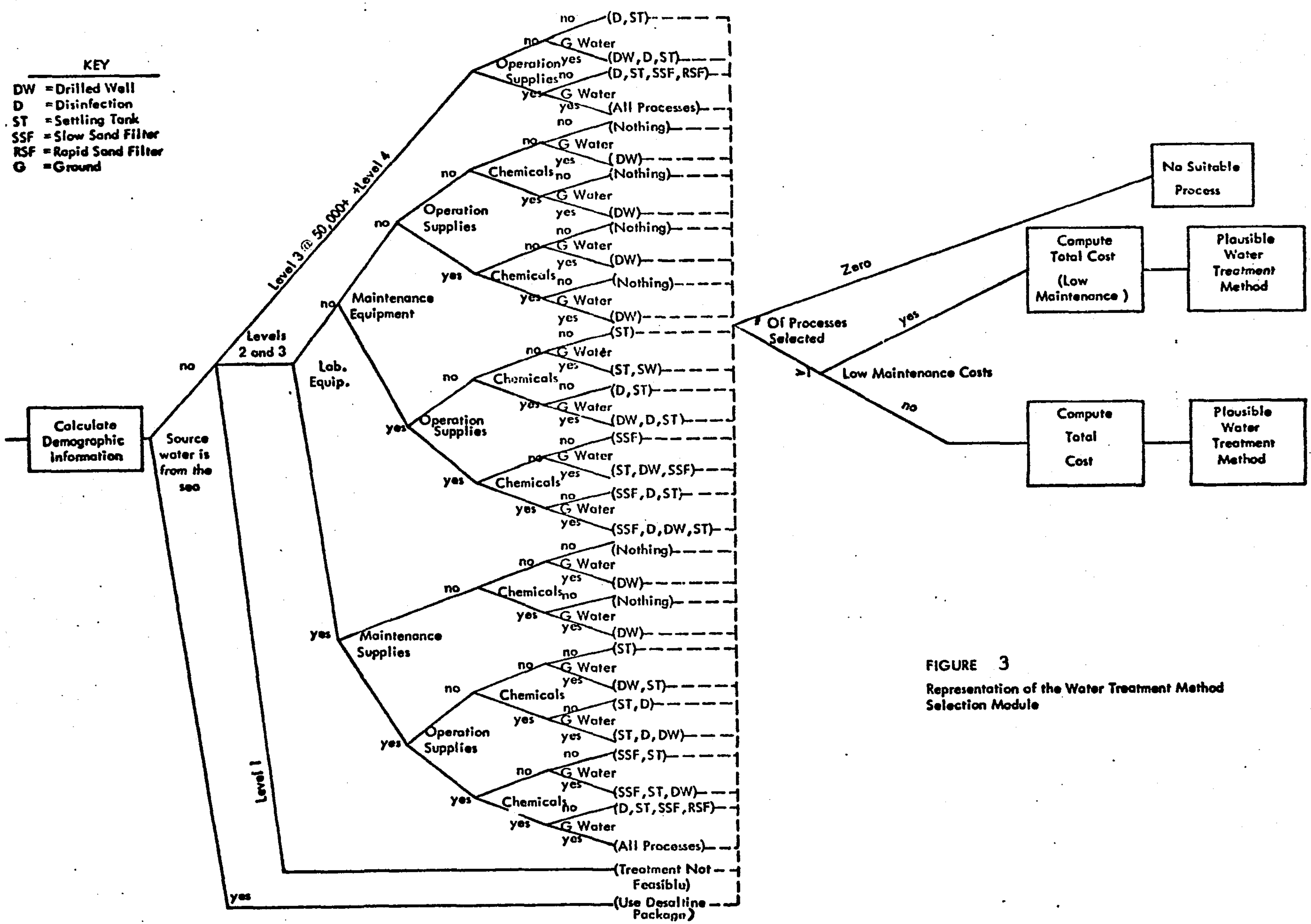

FIGURE 3

Representation of the Water Treatment Method Selection Module

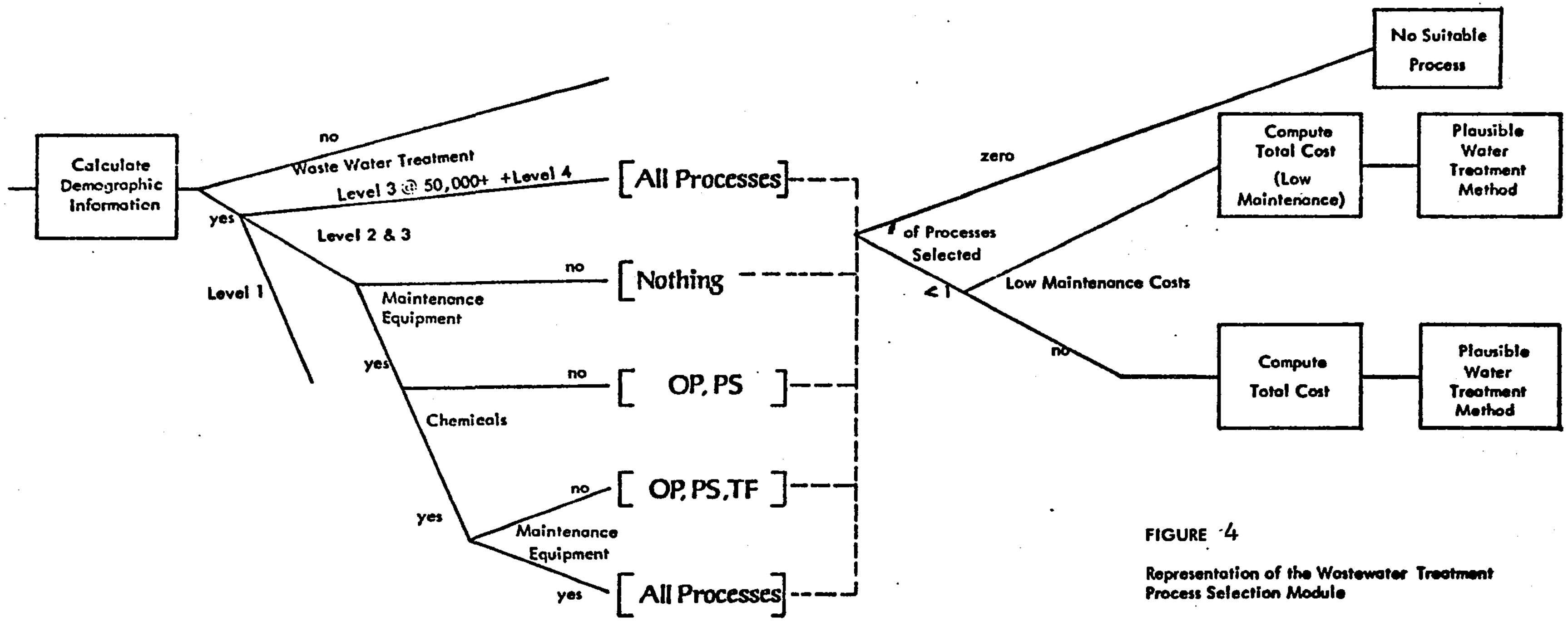

FIGURE 4

Representation of the Wastewater Treatment Process Selection Module

KEY

OP = Oxidation Pond
PS = Primary Sedimentation
TF = Trickling Filter
AS = Activated Sludge

area must attract to support the projected numbers and life style. In modeling, this is controlled through the choice of data inputs. Therefore, these forecasts are possible worlds, worlds responsive to the needs of the people.

The first portion of the model makes forecasts for the total population of the community under study for each five-year interval. The routine used is in a loop so that it is repeatedly used. An important input into the model is migration. This migration data is modified for each future time interval and added to a growing base population to give the net population for the next time interval.

Where: Base population at time = t

(+) Births

(-) Deaths

<u>(±) Migration</u> During time = t to t + 5.

Population at time = t + 5

The migration during each time interval is calculated. This is done by placing the population minus the migration for the base year in file. Although this does not completely explain changes in migration, it does give a close approximation of migration. This is highly contingent on the rates of change in the industrial and commercial institutions of a community. If the input percentages of change are not expected to vary appreciably during this time period, the method will give a good approximation of the so-called "norm" of the community. This "norm" will be what the area would look like if "nobody tinkered with the works."

The next portion of the population model computes the population utilizing survival rates and birth rates. Each category in the occupation groups are forecast on the basis of a constant percentage growth rate per five-year period. There are three occupational categories. First, the percentage of each category is computed from the base year data. Second, the new percentages are calculated by adding the growth percentage to the base year percentage. In short, the population model approaches the problem of determining the future population by utilizing a projected population. These projections are useful only if one is satisfied with saying that a community will grow in the future as it has in the past.

The next decision point in the model looks at the source of water. If the water source is from the sea, the model is not applicable since a desalinization package plant will be required to treat such water. In other cases the model is applicable, and it proceeds to the decision rule on the determination of the technological level of a community. From the technological level the process selected depends on the availability of selected maintenance and operating materials. These groups are laboratory equipment, valves, silica sand, chemicals, and ground water. This completes the course sort. The final sort evaluates the process or processes selected in the course sort on the basis of total cost for the life of the process or on the basis of yearly maintenance costs.

Since U.S. data are readily available, the method used in calculating costs of treatment facilities in LDC's is based on U.S. cost. This was accomplished by breaking the cost of operation and maintenance and the construction costs down into basic components (i.e., labor, material, etc.) for each category of scale (population) and each technology level. Coefficients for a cost transfer equation are produced from socio-economic data collected for the site under study. The equation, when multiplied by U.S. cost, produces total operation and maintenance, and capital costs, for each treatment process for an individual site based on local conditions.[34]

The procedure is as follows:

Step 1. Determine for each treatment process the percentage of the total cost involving labor and materials. As an example suppose construction of a conventional sedimentation-trickling filter installation cost analysis showed 50% labor and 50% material. Operational costs might break down as 80% labor and 20% material.

Step 2. Labor costs are further divided into skilled and unskilled. Materials are divided into the percent that can be purchased in-country and the percent that must be imported.

Steps 1 and 2 are shown in Table 2 with typical percentages for the trickling filter process. These values differ with population size and from country to country, depending on technology level.

TABLE 2

AN EXAMPLE OF THE PERCENTAGE LABOR AND MATERIAL FOR THE CONSTRUCTION AND THE OPERATION AND MAINTENANCE OF THE TRICKLING FILTER PROCESS

A. Construction Cost

Process	Percent Labor	Unskilled	Skilled	Percent Material	In-country	Imported
Trickling filter	50%	30%	20%	50%	40%	10%

B. Operation and Maintenance Yearly Costs

Process	Percent Labor	Unskilled	Skilled	Percent Material	In-country	Imported
Trickling filter	80%	60%	20%	20%	5%	15%

[34] This technique was developed and the data were compiled by Professor George W. Reid, Dr. Kenneth Govaerts, and Mr. Michael Muija, all of the Bureau of Water and Environmental Resources Research, The University of Oklahoma, Norman, Oklahoma.

The total cost of a treatment facility is the sum of labor and material (excluding land, legal, and engineering); by multiplying the percent labor by total cost, the labor portion of the cost may be obtained. As in our example, if the entire facility cost was \$30 per capita, then labor would be \$30(50%) = \$15.00 per capita for construction. If total yearly operating costs are \$6 per capita, then labor amounts to \$6(80%) - \$4.80. Unskilled labor would cost \$4.80(60%) = \$2.88 and so forth.

However, the \$30 and \$6 are U.S. figures and are based on U.S. wages and materials costs. If unskilled laborers in an LDC are only paid \$1.00 per hour as compared with \$3.00 for U.S. laborers, the cost of operation of the treatment facility in the LDC will be reduced to \$2.88(1/3) = \$.96 per capita per year. However, this same location may be required to pay skilled craftsmen, who are in short supply and must be imported, at a cost of \$9.00 per hour. This would increase the cost of the facility operation per capita per year to: (4.80) (20%) (9/6) = \$1.44. Further development of this reasoning reveals that for a particular LDC, materials manufactured in country sell for 1/3 as much as the same materials manufactured in the U.S. Likewise, if materials must be imported, the price goes up significantly.

Using these hypothetical values for a total LDC capital cost based on the \$30 per capita results in:

$$C_{LDC} = C_{U.S.} \left(L_{unskilled} \times \frac{LDC}{U.S.}\right) + \left(L_{skilled} \times \frac{LDC}{U.S.}\right) + \left(M_{in\ country} \times \frac{LDC}{U.S.}\right) + \left(M_{imported} \times \frac{LDC}{U.S.}\right)$$

where: C = cost

L = labor percent of cost

M = materials percent of cost

Therefore, from the above values:

$$C_{LDC} = \$.30\ (50\%)(30\%\ X\ 1/3 + 20\%\ X\ 9/6)$$
$$+ (50\%(40\%\ X\ 1/3 + 10\%\ X\ 2/1)$$
$$= \$1.50 + \$4.50 + \$2.00 + \$3.00.$$

C_{LDC} = \$11.00 per capita construction cost.

The actual values for cost of labor and materials were collected for the resource matrix as described earlier. From this data the cost transfer coefficients will be calculated, and total per capita cost for construction and operation and maintenance will be available for evaluation in the selection of the most appropriate (least cost) treatment process. Tables 3 through 14 show typical values for a number of possible applications. The actual data input format and a listing of the cards used in the computerized version of the model are shown in Appendix A.

The determination of the total cost for the water and sewage treatment process is as follows:

(construction) $$C_2 = C_1(P)((\frac{Q_1}{Q_2})(X_{11})(\frac{X_{21}}{X_{22}}) + (X_{12})(\frac{X_{31}}{X_{32}}) + (X_{41})(X_{51}) + (X_{42})(X_{52}))$$

(maintenance) $$C_3 = C_1(P)(((X_{11})\frac{X_{21}}{X_{21}}) + (X_{12})(\frac{X_{31}}{X_{32}}) + (X_{41})(X_{51}) + (X_{42})(X_{52}))$$

Consequently the total cost over a twenty year period is:

$$C_4 = C_2 + C_3(20)$$

TABLE 3

WATER TREATMENT COST TRANSFER CONSTRUCTION MATRIX FOR
LABOR AND MATERIAL ON SELECTED PROCESSES
FOR TECHNOLOGY LEVEL - I

TREATMENT PROCESSES	LABOR AS PERCENT OF LDC OPERATING COST	PERCENT UNSKILLED LABOR - LDC X_{11}	PERCENT SKILLED LABOR - LDC X_{12}	HOURLY WAGE UN-SKILLED LABOR-LDC X_{21}	HOURLY WAGE UN-SKILLED LABOR-DC X_{22}	HOURLY WAGE SKILLED LABOR - LDC X_{31}	HOURLY WAGE SKILLED LABOR - DC X_{32}	MATERIALS AS PERCENT LDC OPERATING COST	PERCENT IN COUNTRY MATERIALS X_{41}	PERCENT OUT OF COUNTRY MATERIALS X_{42}	COST IN COUNTRY MATERIALS LDC/DC X_{51}	COST OUT OF COUNTRY MATERIALS LDC/DC X_{52}	TOTAL OPERATION COST PER CAPITA DC - US $ C_1	POPULATION GROUP P
Drilled Well	50	10	40	.25	3.00	9.00	6.00	50	10	40	1/3	2/1	75.00 20.00 12.00 10.00	1 2 3 4
Chlorination	30	20	10	.25	3.00	9.00	6.00	70	10	50	1/3	2/1	4.00 0.80 1.50 1.20	1 2 3 4
Sedimentation Filtration	70	50	20	.25	3.00	9.00	6.00	30	20	10	1/3	2/1	9.00 0.70 0.80 0.50	1 2 3 4
Slow Sand Filter	60	40	20	.25	3.00	9.00	6.00	40	30	10	1/3	2/1	101.0 7.40 9.10 5.90	1 2 3 4
Rapid Sand Filter	40	5	35	.25	3.00	9.00	6.00	60	20	40	1/3	2/1	11.20 8.80 5.00 2.65	1 2 3 4

TABLE 4

WATER TREATMENT COST TRANSFER CONSTRUCTION MATRIX FOR LABOR AND MATERIAL ON SELECTED PROCESSES FOR TECHNOLOGY LEVEL - II

TREATMENT PROCESSES	LABOR AS PERCENT OF LDC OPERATING COST	PERCENT UNSKILLED LABOR - LDC	PERCENT SKILLED LABOR - LDC	HOURLY WAGE UN-SKILLED LABOR-LDC	HOURLY WAGE UN-SKILLED LABOR-DC	HOURLY WAGE SKILLED LABOR - LDC	HOURLY WAGE SKILLED LABOR - DC	MATERIALS AS PERCENT LDC OPERATING COST	PERCENT IN COUNTRY MATERIALS	PERCENT OUT OF COUNTRY MATERIALS	COST IN COUNTRY MATERIALS LDC/DC	COST OUT OF COUNTRY MATERIALS LDC/DC	TOTAL OPERATION COST PER CAPITA DC - US $	POPULATION GROUP
		X_{11}	X_{12}	X_{21}	X_{22}	X_{31}	X_{32}		X_{41}	X_{42}	X_{51}	X_{52}	C_1	P
Drilled Well	50	10	40	.25	3.00	9.00 9.00 8.00 8.00	6.00	50	30	20	1/2 1/2 1/1.5 1/1.5	1.5/1	75.00 20.00 12.00 10.00	1 2 3 4
Chlorination	20	10	15	.75 .75 1.00 1.00	3.00	9.00 9.00 8.00 8.00	6.00	75	5	70	1/2 1/2 1/1.5 1/1.5	1.5/1	4.00 0.80 1.50 1.50	1 2 3 4
Sedimentation Filtration	60	35	25	.75 .75 1.00 1.00	3.00	9.00 9.00 8.00 8.00	6.00	40	20	20	1/2 1/2 1/1.5 1/1.5	1.5/1	9.00 0.70 0.80 0.50	1 2 3 4
Slow Sand Filter	50	30	20	.75 .75 1.00 1.00	3.00	9.00 9.00 8.00 8.00	6.00	50	30	20	1/2 1/2 1/1.5 1/1.5	1.5/1	101.00 7.40 9.10 5.90	1 2 3 4
Rapid Sand Filter	50	30	20	.75 .75 1.00 1.00	3.00	9.00 9.00 8.00 8.00	6.00	50	30	20	1/2 1/2 1/1.5 1/1.5	1.5/1	11.20 8.80 5.00 2.65	1 2 3 4

TABLE 5

WATER TREATMENT COST TRANSFER CONSTRUCTION MATRIX FOR LABOR AND MATERIAL ON SELECTED PROCESSES FOR TECHNOLOGY LEVEL - III

TREATMENT PROCESSES	LABOR AS PERCENT OF LDC OPERATING COST	PERCENT UNSKILLED LABOR - LDC X_{11}	PERCENT SKILLED LABOR - LDC X_{12}	HOURLY WAGE UN-SKILLED LABOR-LDC X_{21}	HOURLY WAGE UN-SKILLED LABOR-DC X_{22}	HOURLY WAGE SKILLED LABOR - LDC X_{31}	HOURLY WAGE SKILLED LABOR - DC X_{32}	MATERIALS AS PERCENT LDC OPERATING COST	PERCENT IN COUNTRY MATERIALS X_{41}	PERCENT OUT OF COUNTRY MATERIALS X_{42}	COST IN COUNTRY MATERIALS LDC/DC X_{51}	COST OUT OF COUNTRY MATERIALS LDC/DC X_{52}	TOTAL OPERATION COST PER CAPITA DC - US $ C_1	POPULATION GROUP P
Drilled Well		10	40	1.00 1.00 1.50 1.50	3.00	8.00 8.00 7.00 7.00	6.00	50	40	10	1/2 1/1.5 1/1.5 1	1.5/1 1.5/1 1. 1.	75.00 20.00 12.00 10.00	1 2 3 4
Chlorination	25	5	20	1.00 1.00 1.50 1.50	3.00	8.00 8.00 7.00 7.00	6.00	50	40	10	1/2 1/1.5 1/1.5 1	1.5/1 1.5/1 1. 1.	4.00 .80 1.50 1.20	1 2 3 4
Sedimentation Filtration	60	30	30	1.00 1.00 1.50 1.50	3.00	8.00 8.00 7.00 7.00	6.00	40	30	10	1/2 1/1.5 1/1.5 1	1.5/1 1.5/1 1. 1.	9.00 .70 .80 .50	1 2 3 4
Slow Sand Filter	60	40	20	1.00 1.00 1.50 1.50	3.00	8.00 8.00 7.00 7.00	6.00	40	20	20	1/2 1/1.5 1/1.5 1	1.5/1 1.5/1 1 1	101.0 7.40 9.10 5.90	1 2 3 4
Rapid Sand Filter	60	5	55	1.00 1.00 1.50 1.50	3.00	8.00 8.00 7.00 7.00	6.00	40	5	35	1/2 1/1.5 1/1.5 1	1.5/1 1.5/1 1 1	11.20 8.80 5.00 2.65	1 2 3 4

TABLE 6

WATER TREATMENT OPERATION COST TRANSFER FOR
LABOR AND MATERIALS ON SELECTED PROCESS
FOR TECHNOLOGY LEVEL-I

TREATMENT PROCESSES	LABOR AS PERCENT OF LDC OPERATING COST	PERCENT UNSKILLED LABOR - LDC	PERCENT SKILLED LABOR - LDC	HOURLY WAGE UN-SKILLED LABOR-LDC	HOURLY WAGE UN-SKILLED LABOR-DC	HOURLY WAGE SKILLED LABOR - LDC	HOURLY WAGE SKILLED LABOR - DC	MATERIALS AS PERCENT LDC OPERATING COST	PERCENT IN COUNTRY MATERIALS	PERCENT OUT OF COUNTRY MATERIALS	COST IN COUNTRY MATERIALS LDC/DC	COST OUT OF COUNTRY MATERIALS LDC/DC	TOTAL OPERATION COST PER CAPITA DC - US $	POPULATION GROUP	MANPOWER REQUIRED Unsk	Skil	Pro.
		X_{11}	X_{12}	X_{21}	X_{22}	X_{31}	X_{32}		X_{41}	X_{42}	X_{51}	X_{52}	C_1	P	M_1	M_2	M_3
Slow sand filter	90	80	10	.25	3.00	9.00	6.00	10	10	0	1/2	3/1	2.00 0.50 0.25 0.20	1 2 3 4	1 2 5 8	 1	
Rapid sand filter	80	60	20	.25	3.00	9.00	6.00	20	20	0	1/2	3/1	4.00 2.00 1.75 1.5	1 2 3 4	1 1 8 10	1 1 2 3	 1 1 1
Sedimentation filtration	95	90	5	.25	3.00	9.00	6.00	5	5	0	1/2	3/1	6.00 3.50 2.75 2.5	1 2 3 4	1 1 4 6	 1 2	
Chlorination	50	10	40	.25	3.00	9.00	6	50	10	40	1/2	3/1	5.00 2.30 1.75 1.50	1 2 3 4	1 1 2 4	 1 1 1	 1 1
Drilled well	95	90	5	.25	3.00	9.00	6.0	5	2	3	1/2	3/1	2.50 2.00 1.50 1.00	1 2 3 4	1 2 4 8		

TABLE 7

WATER TREATMENT OPERATION COST TRANSFER MATRIX FOR LABOR AND MATERIALS ON SELECTED PROCESSES FOR TECHNOLOGY LEVEL - II

TREATMENT PROCESSES	LABOR AS PERCENT OF LDC OPERATING COST	PERCENT UNSKILLED LABOR - LDC X_{11}	PERCENT SKILLED LABOR - LDC X_{12}	HOURLY WAGE UN-SKILLED LABOR-LDC X_{21}	HOURLY WAGE UN-SKILLED LABOR-DC X_{22}	HOURLY WAGE SKILLED LABOR - LDC X_{31}	HOURLY WAGE SKILLED LABOR - DC X_{32}	MATERIALS AS PERCENT LDC OPERATING COST	PERCENT IN COUNTRY MATERIALS X_{41}	PERCENT OUT OF COUNTRY MATERIALS X_{42}	COST IN COUNTRY MATERIALS LDC/DC X_{51}	COST OUT OF COUNTRY MATERIALS LDC/DC X_{52}	TOTAL OPERATION COST PER CAPITA DC - US $ C_1	POPULATION GROUP P	MANPOWER REQUIRED Unsk M_1	MANPOWER REQUIRED Skil M_2	MANPOWER REQUIRED Pro M_3
Slow sand filter	90	80	10	0.75	3.00	9.00	6.00	10	10	0	1/2	1.5/1	2.00	1	1		
				0.75		9.00					1/2		0.50	2	2		
				1.00		8.00					1/1.5		0.25	3	5		
				1.00		8.00					1/1.5		0.20	4	8	1	
Rapid sand filter	80	60	20	0.75	3.00	9.00	6.00	20	20	0	1/2	1.5/1	4.00	1	1	1	
				0.75		9.00					1/2		2.00	2	1	1	1
				1.00		8.00					1/1.5		1.75	3	8	2	1
				1.00		8.00					1/1.5		1.5	4	10	3	1
Sedimentation filteration	95	75	0	0.75	3.00	9.00	6.00	5	5	0	1/2	1.5/1	6.00	1	1		
				0.75		9.00					1/2		3.50	2	1		
				1.00		8.00					1/1.5		2.75	3	4	1	
				1.00		8.00					1/1.5		2.5	4	6	2	
Chlorination	50	10	40	0.75	3.00	9.00	6.00	50	10	40	1/2	1.5/1	5.00	1	1		
				0.75		9.00					1/2		2.30	2	1	1	
				1.00		8.00					1/1.5		1.75	3	2	1	1
				1.00		8.00					1/1.5		1.50	4	4	1	1
Drilled well	90	80	10	.75	3.00	9.00	6.00	10	5	5	1/2	1.5/1	2.50	1	1		
				.75		9.00					1/2		2.00	2	2		
				1.00		8.00					1/1.5		1.50	3	4		
				1.00		8.00					1/1.5		1.00	4	8		

TABLE 8

WATER TREATMENT OPERATION COST TRANSFER MATRIX FOR LABOR AND MATERIALS ON SELECTED PROCESSES FOR TECHNOLOGY LEVEL-III

TREATMENT PROCESSES	LABOR AS PERCENT OF LDC OPERATING COST	PERCENT UNSKILLED LABOR - LDC	PERCENT SKILLED LABOR - LDC	HOURLY WAGE UN-SKILLED LABOR-LDC	HOURLY WAGE UN-SKILLED LABOR-DC	HOURLY WAGE SKILLED LABOR - LDC	HOURLY WAGE SKILLED LABOR - DC	MATERIALS AS PERCENT LDC OPERATING COST	PERCENT IN COUNTRY MATERIALS	PERCENT OUT OF COUNTRY MATERIALS	COST IN COUNTRY MATERIALS LDC/DC	COST OUT OF COUNTRY MATERIALS LDC/DC	TOTAL OPERATION COST PER CAPITA DC - US $	POPULATION GROUP	MANPOWER REQUIRED Unsk	Skil	Pro
		X_{11}	X_{12}	X_{21}	X_{22}	X_{31}	X_{32}		X_{41}	X_{42}	X_{51}	X_{52}	C_1	P	M_1	M_2	M_3
Slow sand filter	90	80	10	1 1 1.5 1.5	3.00	8.00 8.00 7.00 7.00	6.00	10	10	0	1/1.5	1.5/1	2. .5 .25 15.2	1 2 3 4	1 2 5 8	 1	
Rapid sand filter	80	70	10	1 1 1.5 1.5	3.00	8.00 8.00 7.00 7.00	6.00	20	15	5	1/1.5	1.5/1	4 2 1.75 .5	1 2 3 4	1 1 8 10	1 1 2 3	 1 1 1
Sedimentation filtration	80	85	5	1 1 1.5 1.5	3.00	8.00 8.00 7.00 7.00	6.00	10	5	5	1/1.5	1.5/1	6 3.5 2.75 2.5	1 2 3 4	1 1 4 6	 1 2	
Chlorination	40	10	30	1 1 1.5 1.5	3.00	8.00 8.00 7.00 7.00	6.00	60	40	20	1/1.5	1.5/1	5. 2.3 1.75 1.5	1 2 3 4	1 1 2 4	 1 1 1	 1 1
Drilled well	90	80	10	1 1 1.5 1.5	3.00	8.00 8.00 7.00 7.00	6.00	10	5	5	1/1.5	1.5/1	2.5 2 1.5 1	1 2 3 4	1 2 4 8		

TABLE 9

WASTEWATER COST TRANSFER CONSTRUCTION-MATRIX FOR LABOR AND MATERIAL ON SELECTED TREATMENT PROCESSES FOR TECHNOLOGY LEVEL - I

TREATMENT PROCESSES	LABOR AS PERCENT OF LDC OPERATING COST	PERCENT UNSKILLED LABOR - LDC	PERCENT SKILLED LABOR - LDC	HOURLY WAGE UN-SKILLED LABOR-LDC	HOURLY WAGE UN-SKILLED LABOR-DC	HOURLY WAGE SKILLED LABOR - LDC	HOURLY WAGE SKILLED LABOR - DC	MATERIALS AS PERCENT LDC OPERATING COST	PERCENT IN COUNTRY MATERIALS	PERCENT OUT OF COUNTRY MATERIALS	COST IN COUNTRY MATERIALS LDC/DC	COST OUT OF COUNTRY MATERIALS LDC/DC	TOTAL OPERATION COST PER CAPITA DC - US $	POPULATION GROUP
		X_{11}	X_{12}	X_{21}	X_{22}	X_{31}	X_{32}		X_{41}	X_{42}	X_{51}	X_{52}	C_1	P
Lagoon	90	70	20	.25	3.00	9.00	6.00	10	8	2	1/3	2/1	67 6 4 22.7	0.5 25 50 100
Primary sedimentation sludge die	60	40	20	.25	3.00	9.00	6.00	40	20	20	1/3	2/1	88 24 19.5 15.5	0.5 25 50 100
Trickling filter	50	30	20	.25	3.00	9.00	6.00	50	30	20	1/3	2/1	137 40.5 33 26.5	0.5 25 50 100
Activated sludge	40	30	10	.25	3.00	9.00	6.00	60	50	10	1/3	2/1	134 40 32 2.6	0.5 25 50 100

TABLE 10

WASTEWATER COST TRANSFER CONSTRUCTION MATRIX FOR LABOR AND MATERIAL ON SELECTED TREATMENT PROCESSES FOR TECHNOLOGY LEVEL - II

TREATMENT PROCESSES	LABOR AS PERCENT OF LDC OPERATING COST	PERCENT UNSKILLED LABOR - LDC	PERCENT SKILLED LABOR - LDC	HOURLY WAGE UN-SKILLED LABOR-LDC	HOURLY WAGE UN-SKILLED LABOR-DC	HOURLY WAGE SKILLED LABOR - LDC	HOURLY WAGE SKILLED LABOR - DC	MATERIALS AS PERCENT LDC OPERATING COST	PERCENT IN COUNTRY MATERIALS	PERCENT OUT OF COUNTRY MATERIALS	COST IN COUNTRY MATERIALS LDC/DC	COST OUT OF COUNTRY MATERIALS LDC/DC	TOTAL OPERATION COST PER CAPITA DC - US $	POPULATION GROUP
		X_{11}	X_{12}	X_{21}	X_{22}	X_{31}	X_{32}		X_{41}	X_{42}	X_{51}	X_{52}	C_1	P
Lagoon	80	60	.20	.75 .75 1.00 1.00	3.00	9.00 9.00 8.00 8.00	6.00	20	10	10	1/2 1/2 1/1.5 1/1.5	1.5/1	.67 6 4 22.7	0.5 25 50 100
Primary sedimentation sludge die	60	35	25	.75 .75 1.00 1.00	3.00	9.00 9.00 8.00 8.00	6.00	40	15	25	1/2 1/2 1/1.5 1/1.5	1.5/1	88 24 19.5 15.5	0.5 25 50 100
Trickling filter	40	25	15	.75 .75 1.00 1.00	3.00	9.00 9.00 8.00 8.00	6.00	60	30	30	1/2 1/2 1/1.5 1/1.5	1.5/1	137 40.5 32 26.5	0.5 25 50 100
Activated sludge	30	15	15	.75 .75 1.00 1.00	3.00	9.00 9.00 8.00 8.00	6.00	70	10	60	1/2 1/2 1/1.5 1/1.5	1.5/1	134 40 32 2.6	0.5 25 50 100

TABLE 11

WASTEWATER COST TRANSFER CONSTRUCTION MATRIX FOR LABOR AND MATERIAL ON SELECTED TREATMENT PROCESSES FOR·TECHNOLOGY LEVEL - III

TREATMENT PROCESSES	LABOR AS PERCENT OF LDC OPERATING COST	PERCENT UNSKILLED LABOR - LDC X_{11}	PERCENT SKILLED LABOR - LDC X_{12}	HOURLY WAGE UN-SKILLED LABOR-LDC X_{21}	HOURLY WAGE UN-SKILLED LABOR-DC X_{22}	HOURLY WAGE SKILLED LABOR - LDC X_{31}	HOURLY WAGE SKILLED LABOR - DC X_{32}	MATERIALS AS PERCENT LDC OPERATING COST	PERCENT IN COUNTRY MATERIALS X_{41}	PERCENT OUT OF COUNTRY MATERIALS X_{42}	COST IN COUNTRY MATERIALS LDC/DC X_{51}	COST OUT OF COUNTRY MATERIALS LDC/DC X_{52}	TOTAL OPERATION COST PER CAPITA DC - US $ C_1	POPULATION GROUP P
Lagoon	75	45	30	1.00 1.00 1.5 1.5	3.00	8.00 8.00 7.00 6.00	6.00	25	10	15	1/2 1/1.5 1/1.5 1	1.5/1 1.5/1 1 1	67 6 4 227	0.5 25 50 100
Primary sedimen-tation sludge die	60	30	30	1.00 1.00 1.5 1.5	3.00	8.00 8.00 7.00 6.00	6.00	40	10	30	1/2 1/1.5 1/1.5 1	1.5/1 1.5/1 1 1	88 24 19.5 15.5	0.5 25 50 100
Trickling filter	40	20	20	1.00 1.00 1.5 1.5	3.00	8.00 8.00 7.00 6.00	6.00	60	20	40	1/2 1/1.5 1/1.5 1	1.5/1 1.5/1 1 1	137 40.5 33 26.5	0.5 25 50 100
Activated sludge	25	5	20	1.00 1.00 1.5 1.5	3.00	8.00 8.00 7.00 6.00	6.00	75	5	70	1/2 1/1.5 1/1.5 1	1.5/1 1.5/1 1 1	134 40 32 26	0.5 25 50 100

TABLE 12

WASTEWATER OPERATION COST TRANSFER MATRIX FOR LABOR AND MATERIALS ON SELECTED TREATMENT PROCESSES FOR TECHNOLOGY LEVEL I

TREATMENT PROCESSES	LABOR AS PERCENT OF LDC OPERATING COST	PERCENT UNSKILLED LABOR - LDC	PERCENT SKILLED LABOR - LDC	HOURLY WAGE UN-SKILLED LABOR-LDC	HOURLY WAGE UN-SKILLED LABOR-DC	HOURLY WAGE SKILLED LABOR - LDC	HOURLY WAGE SKILLED LABOR - DC	MATERIALS AS PERCENT LDC OPERATING COST	PERCENT IN COUNTRY MATERIALS	PERCENT OUT OF COUNTRY MATERIALS	COST IN COUNTRY MATERIALS LDC/DC	COST OUT OF COUNTRY MATERIALS LDC/DC	TOTAL OPERATION COST PER CAPITA DC - US $	POPULATION GROUP	MANPOWER REQUIRED		
															Unsk	Skil	Pro
		X_{11}	X_{12}	X_{21}	X_{22}	X_{31}	X_{32}		X_{41}	X_{42}	X_{51}	X_{52}	C_1	P	M_1	M_2	M_3
Lagoon	95	95	0	.25	3.00	9.00	6.00	5	5	0	1/3	2/1	1.7	1	1		
													1.34	2	2		
													1.24	3	4		
													2.5	4	6		
Primary sedimen-tation sludge die	90	85.	5	.25	3.00	9.00	6.00	10	5	5	1/3	2/1	2.56	1	1		
													1.94	2	1		
													1.71	3	2	1	
													1.52	4	6	2	
Trickling filter	85	80	5	.25	3.00	9.00	6.00	15	5	10	1/3	2/1	3.92	1	1		
													2.27	2	1	1	
													1.79	3	4	1	1
													1.42	4	6	2	1
Activated sludge	75	70	5	.25	3.00	9.00	6.00	25	5	20	1/3	2/1	5.2	1	1	1	
													2.27	2	2	1	
													1.79	3	4	1	1
													1.42	4	8	2	2

TABLE 13

WASTEWATER OPERATION COST TRANSFER MATRIX FOR LABOR AND MATERIALS ON SELECTED TREATMENT PROCESSES FOR TECHNOLOGY LEVEL-II

TREATMENT PROCESSES	LABOR AS PERCENT OF LDC OPERATING COST	PERCENT UNSKILLED LABOR - LDC	PERCENT SKILLED LABOR - LDC	HOURLY WAGE UN-SKILLED LABOR-LDC	HOURLY WAGE UN-SKILLED LABOR-DC	HOURLY WAGE SKILLED LABOR - LDC	HOURLY WAGE SKILLED LABOR - DC	MATERIALS AS PERCENT LDC OPERATING COST	PERCENT IN COUNTRY MATERIALS	PERCENT OUT OF COUNTRY MATERIALS	COST IN COUNTRY MATERIALS LDC/DC	COST OUT OF COUNTRY MATERIALS LDC/DC	TOTAL OPERATION COST PER CAPITA DC - US $	POPULATION GROUP	MANPOWER REQUIRED Unsk	MANPOWER REQUIRED Skil	MANPOWER REQUIRED Pro
		X_{11}	X_{12}	X_{21}	X_{22}	X_{31}	X_{32}		X_{41}	X_{42}	X_{51}	X_{52}	C_1	P	M_1	M_2	M_3
Lagoon	95	95	0	.75 .75 1.00 1.00	3.00	9 9 8 8	6.00	5	5	0	1/2 1/2 1/1.5 1/1.5	1.5/1	1.7 1.34 1.26 2.5	1 2 3 4	1 2 4 6		
Primary sedimen-tation sludge die	90	85	5	.75 .75 1.00 1.00	3.00	9 9 8 8	6.00	10	5	5	1/2 1/2 1/1.5 1/1.5	1.5/1	2.56 1.94 1.71 1.51	1 2 3 4	1 1 2 4	1 2	
Trickling filter	85	75	10	.75 .75 1.00 1.00	3.00	9 9 8 8	6.00	15	10	5	1/2 1/2 1/1.5 1/1.5	1.5/1	3.92 2.27 1.79 1.42	1 2 3 4	1 1 4 6	1 1 2	1 1
Activated sludge	75	60	15	.75 .75 1.00 1.00	3.00	9 9 8 8	6.00	25	15	10	1/2 1/2 1/1.5 1/1.5	1.5/1	5.2 3.52 2.98 2.52	1 2 3 4	1 2 4 8	1 1 1 2	1 2

TABLE 14

WASTEWATER OPERATION COST TRANSFER MATRIX FOR LABOR AND MATERIALS ON SELECTED TREATMENT PROCESSES FOR TECHNOLOGY LEVEL-III

TREATMENT PROCESSES	LABOR AS PERCENT OF LDC OPERATING COST	PERCENT UNSKILLED LABOR - LDC	PERCENT SKILLED LABOR - LDC	HOURLY WAGE UN-SKILLED LABOR-LDC	HOURLY WAGE UN-SKILLED LABOR-DC	HOURLY WAGE SKILLED LABOR - LDC	HOURLY WAGE SKILLED LABOR - DC	MATERIALS AS PERCENT LDC OPERATING COST	PERCENT IN COUNTRY MATERIALS	PERCENT OUT OF COUNTRY MATERIALS	COST IN COUNTRY MATERIALS LDC/DC	COST OUT OF COUNTRY MATERIALS LDC/DC	TOTAL OPERATION COST PER CAPITA DC - US $	POPULATION GROUP	MANPOWER REQUIRED Unsk	MANPOWER REQUIRED Skil	MANPOWER REQUIRED Pro
		X_{11}	X_{12}	X_{21}	X_{22}	X_{31}	X_{32}		X_{41}	X_{42}	X_{51}	X_{52}	C_1	P	M_1	M_2	M_3
Lagoon	95	95	0	1.00	3.00	8.00 8.00 7.00 6.00	6.00	5	5	0	1/1.5	1.5/1	1.7 1.34 1.26 2.59	1 2 3 4	1 2 4 6		
Primary sedimentation sludge die	90	85	5	1.00	3.00	8.00 8.00 7.00 6.00	6.00	10	5	5	1/1.5	1.5/1	2.56 1.94 1.71 1.52	1 2 3 4	1 1 2 4	 1 2	
Trickling filter	85	75	10	1.00	3.00	8.00 8.00 7.00 6.00	6.00	15	10	5	1/1.5	1.5/1	3.92 2.27 1.79 1.42	1 2 3 4	1 1 4 6	 1 1 2	 1 1
Activated sludge	80	60	20	1.00	3.00	8.00 8.00 7.00 6.00	6.00	20	15	5	1/1.5	1.5/1	5.2 3.52 2.98 2.52	1 2 3 4	1 2 4 8	1 1 1	 1 2

where:

C_1 = Total construction cost per capita in U.S.,

C_2 = Total construction cost for the process,

C_3 = Total maintenance cost for the process for one year,

C_4 = Total cost for the process for 20 years,

P = Population served,

Q_1 = Consumption Rate (Gal/Cap)LDC,

Q_2 = Consumption Rate (Gal/Cap)DC,

X_{11} = Percent Unskilled Labor--LDC,

X_{12} = Percent Skilled Labor--LDC,

X_{21} = Hourly Wage Unskilled Labor--DC,

X_{31} = Hourly Wage Skilled Labor--LDC,

X_{32} = Hourly Wage Skilled Labor--DC,

X_{41} = Percent on-site materials manufactured,

X_{42} = Percent off-site materials manufactured,

X_{51} = Cost on-site materials manufactured--LDC/DC, and

X_{52} = Cost off-site materials manufactured--LDC/DC.

The above variables will differ depending on the technological or development level of the community under consideration. Variations will also occur because of the size of the population served. For example, larger populations generally have a lower per capita cost for water and sewage treatment. For the purposes of figuring the costs on a per capita basis, communities were broken down into four population groups:

1. 500 - 2,499
2. 2,500 - 14,999

3. 15,000 - 49,999

4. 50,000 - 100,000

An assumption was made that the costs per capita within each of the above population groups are sufficiently uniform for the purposes of this planning study.

The model was computerized by transcribing the schematic diagram and cost formulas into a FORTRAN computer program. Figures 3 and 4 represent the water and sewage treatment method selecting process for a community. The output of both modules provides a seemingly plausible water supply and sewerage treatment alternative for a specified community in five-year increments for twenty years. The details provided include:

1. Total cost over a twenty year period which includes both the capital or construction cost and the maintenance cost.

2. Manpower needed for the effective maintenance and operation of the plant or plants.

3. The output of both treated water and/or the amount of sewage influent that the suggested methods are capable of handling.

4. The population served under the proposed system.

Summary

The objective of this section was to describe the methodology and procedures used in the development of the heuristic model for the selection of water and sewage treatment projects in less developed communities. Initially, the model concept was presented to show how the problem was defined. This led to the discussion of the variables that were identified for close attention. The proposed heuristic program was discussed next. In this instance, the decision process consisted of selecting a plausible treatment process to characterize the decision process which planners appear to follow. Pertinent variables and relationships were developed from interviews with planners and engineers who actually make these kinds of decisions. The above discussion of the problems gives a static view of the model. The following chapter gives the use and value of the model when it is simulated according to some specified future data. Included in this are the specified data requirements of the model and the output of a sample run of the computerized version of the planning model.

CHAPTER IV

MODEL CHARACTERISTICS AND RESULTS

The purpose of this chapter is to provide a usable guide for effective use of the water and sewage treatment method planning model as it was developed in Chapter III. Initially, the input data formats are discussed in enough detail so that the reader can acquire a card deck and begin using the model. This is followed by the computerized model itself. A general flowchart is provided to show how the various data inputs are analyzed using the logic of the FORTRAN programming language. A FORTRAN listing is provided and with this listing is a copy of the cards used to run a simulation test of the program. Finally, the models descriptive power and the usefulness of the models output is discussed.

Data Input Formats

Based on certain views, conditioned by actual experience in dealing with several planning agencies, groups, individuals, and modified by a literature search, a conceptual data input format was established. Of prime importance was that an ordinary, everyday planner would have a usable tool- -usability being assessed by the extent of user involvement, minimization of built-in decision routines, ample invitations to intercept flexible variety and detail of data required, and the minimization of involvement by computer specialists.

All the following cards must be presented in the order shown. The formats of the various cards used in this model are described in Table 15.

TABLE 15

DEMOGRAPHIC INPUT DATA PUNCHED CARD LAYOUT (CARD 1)

Variable Name	Card Column	FORTRAN Format	Item Description
K_7	1- 2	I2	Transaction code
BACKYR	3- 6	I4	Background year
BASYR	7-10	I4	Base year
PROJYR	11-14	I4	Projected year
CONYR	15-18	I4	Control year
PØP	19-24	I6	Present population
SURV	25-27	F3.1	Survival rate
BIRTH	28-30	F3.1	Birth rate
PIM	31-34	F4.2	% Immigrants
PEM	35-38	F4.2	% Emmigrants
WORK(1)	39-44	I6	Unskilled workers
WORK(2)	45-50	I6	Skilled workers
WORK(3)	51-56	I6	Professional workers
WFGR	57-59	F3.1	Work force growth rate
WFP	60-63	F4.2	Worker factor (% of population in the work force)

Variable names are included in Table 15 so that the reader can refer to the computer listing itself for a more detailed inquiry of how the data is manipulated within the computer program. Some of the population inputs require a brief explanation. A transaction code has been placed on each card for ease of identifying the sequence with which they are compiled into the card deck. The background year is a previous year for which there is data. This should be some year that is 5 to 10 years prior to the base. A previous census year can be used as a background year. The base year is the year that is closest to time equal zero in which good data is available. The project year is the year for which the data are to be projected. The model is set to predict on five-year increments. The project year is equal to base year plus some increment times five years. This year is used to help control the parameters that compile the intermediate data points.

The last two input data cards contain information that was extracted from a data form. The function of the data form is to provide an aid in obtaining the necessary information on the location of the community and the technology level of the community. The data form is illustrated in Appendix B.

Questions 1 and 2 of the data sheet supply the information necessary for Card 2. The structure of card two is shown in Table 16.

After questions 2 and 3, the data form contains information on the technology level of the community. This information is coded on card 3 and the format is shown in Table 17. The data form is structured in the multiple choice design. That is, most of the questions can be completed by selecting one of the choices following it. The choices range from two to thirteen. The major exception to this occurs in

TABLE 16

LOCATION DATA PUNCHED CARD LAYOUT (CARD 2)

Variable Name	Card Column	Format	Item
K8	1- 2	I2	Transaction code
CN	3-22	5A4	Community name
ST	23-42	5A4	State or province
COM	43-62	5A4	County
AG	63	4A4	Planning group or agency

TABLE 17

SITE CHARACTERISTICS AND COMMUNITY TECHNOLOGY LEVEL
PUNCHED CARD LAYOUT (CARD 3)

Variable Name	Card Column	Question No.	Format	Item
K9	1- 2	3	I2	Transaction code
LL(1)	3	3	I1	Level of education
LL(2)	4	4	I1	Distribution of the labor force
LL(3)	5	5	I1	Income characteristics
LL(4)	6	6	I1	% of high level manpower
LL(5)	7	7	I1	Schools operated by missionary groups
L2	8- 9	8	I2	Highest grade offered by schools
LL(7)	10	9	I1	Nearest high school
LL(8)	11	10	I1	Technical or vocational schools
LL(9)	12	11	I1	Compulsory education
LL(10)	13	12	I1	In-service training programs
LL(11)	14	13	I1	Local college or university
LL(12)	15	14	I1	Chemistry dept. in the university
LL(13)	16	15	I1	Communities ability to finance improvements
LL(14)	17	16	I1	Is unemployment widespread
LL(15)	18	17	I1	Availability of advisory services
LL(16)	19	18	I1	Education of college students
LL(17)	20	19	I1	Technology level
LL(18)	21	20	I1	Government dominance in labor market
LL(19)	22	21	I1	Public employment services
LL(20)-LL(27)	23-30	22	8I1	Operation

TABLE 17 (Continued)

Variable Name	Card Column	Question No.	Format	Item
LL(28)-LL(34)	31-37	23	7I1	Process equipment
LL(35)-LL(38)	38-41	24	4I1	Operation and maintenance
LL(39)-LL(46)	42-49	25	8I1	Chemicals
LL(47)	50	26	I1	Water source
LL(48)-LL(49)	51-56	27	2I3	Per capita water demand
LL(50)	57	28	I1	Ground water availability
LL(51)	58	29	I1	Drilled wells
LL(52)	59	30	I1	Central wastewater collection
LL(53)-LL(55)	60-68	31	3I3	Wastewater connections
LL(56)-LL(58)	69-80	32	3I4	Industrial & commercial usage

questions 22, 23, 24, and 25. These questions contain groups of materials and the individual filling out the data form is asked to circle the items that are never available on a local basis. If the majority of the items are circled, then the particular materials group is considered not available. These groups determine which branches of the tree diagram of the model discussed in the previous chapter are feasible. The program or model has the ability to tally the various items in each materials group. By using the materials grouped, as described in questions 22-25 of the data form (see appendix B), the planning model assumes that if the majority of the items are present, others in the group may be available without extensive costs or substitutes may be found.

A few questions toward the end of the data form ask for specific figures relating to the demand for water and sewage treatment. This can be termed helpful information for special circumstances. If it is not available when utilizing the data sheet for input into the model, it can be left blank. This will not cause an error in the system.

Figure 5 shows the data deck structure. Immediately following this in Figure 6 are examples of these cards with the data punched into them. These cards are representations of the actual ones used in the test of the model.

Table 18 gives the data sheet weighting factors for each of the appropriate questions relating to the technology level of the community. The choice selected is coded into card 3 and the model examines the choice and assigns an indexing factor to each of the questions answered. Those questions unanswered, of course, do not receive any technology index points. In short, the level of a community's technology level as

FIGURE 5

Data Deck Structure

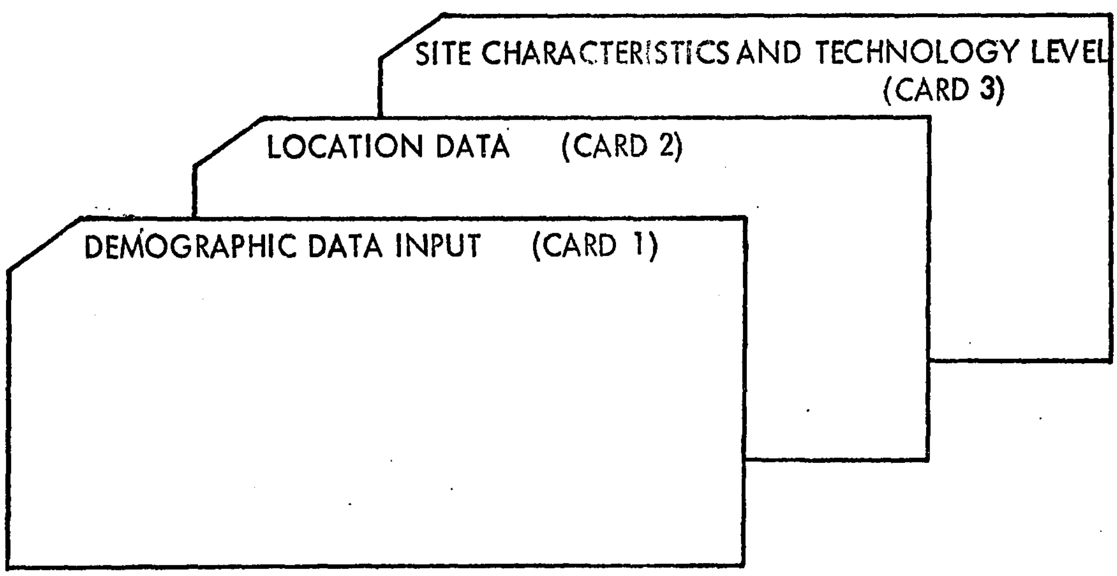

FIGURE 6

EXAMPLES OF DATA INPUT CARDS FOR THE KENYA TEST RUN

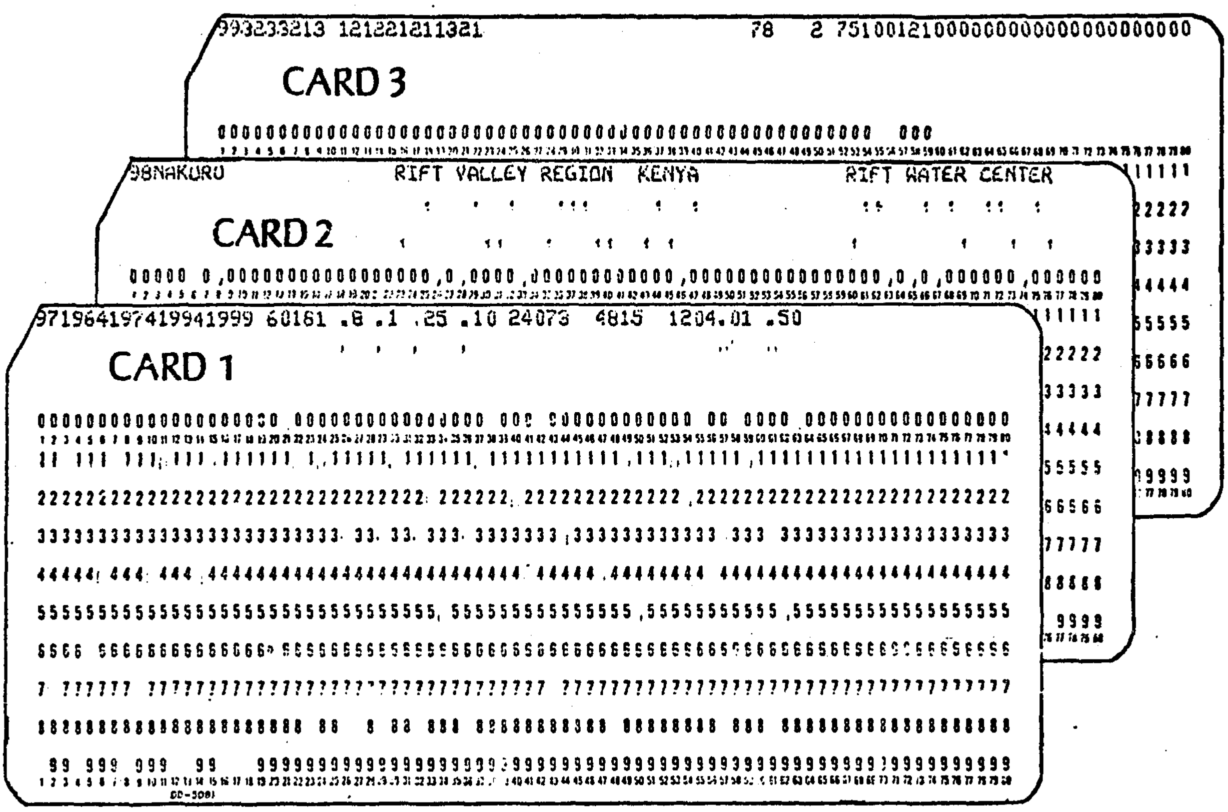

TABLE 18

DATA SHEET WEIGHTING FACTORS FOR TECHNOLOGY LEVEL DETERMINATION FOR COMMUNITIES IN LESS DEVELOPED COUNTRIES

Question Number	Possible Choices	Index Factor
3.	1	0
	2	5
	3	10
	4	15
4.	1	0
	2	5
	3	10
	4	15
5.	1	0
	2	5
	3	10
	4	15
6.	1	4
	2	3
	3	2
	4	1
	5	0
7.	1	0
	2	5
8.	0	0
	1- 6	2
	7-10	4
	11-12	7
	12+	10
9.	1	3
	2	2
	3	1
	4	0
10.	1	5
	2	0
11.	1	10
	2	0
12.	1	5
	2	0

TABLE 18 (Continued)

Question Number	Possible Choices	Index Factor
13.	1	10
	2	0
14.	1	3
	2	0
16.	1	0
	2	5
17.	1	3
	2	0
18.	1	0
	2	3
19.	1	0
	2	5
	3	10
	4	15
20.	1	0
	2	5
21.	1	5
	2	0

described in Chapter III is determined by the choices selected from the questions on the data sheets.

The Computerized Model

The flow chart illustrated in Appendix C shows the basic logic of the computerized model. The model was set up so that the main module is very small. The main module essentially reads the population data and computes the population parameters. Then control is shifted to the model subroutine, which actually determines the technology level, the feasible processes, computes the cost information, and prints the results.

Appendix D contains a listing of the card deck of the entire model. The model was set up so that an unlimited number of communities can be run sequentially during the execution of one job. All that is necessary is that the cards be in the order as shown earlier in Figure 5 and that they are placed in the proper location. Figure 7 shows the location of all the various types of cards used to execute the computerized model, including the job control language (JCL) cards. Each community requires three data dards. All communities must be placed in the Data Deck section of the card deck as shown in Figure 7.

A Simulation Test of the Model

To demonstrate the usefulness of the model, a test was executed for the community of Nakuru, which is located in the Rift Valley Region of Kenya. The data input cards for the run were illustrated earlier in Figure 6. The first page of output for the model is contained in Table 19. For each community evaluated, the computer program generates five pages of output. The first output page is generated for the base year,

FIGURE 7

COMPLETE CARD DECK STRUCTURE FOR THE WATER AND SEWAGE TREATMENT METHOD SELECTION MODEL

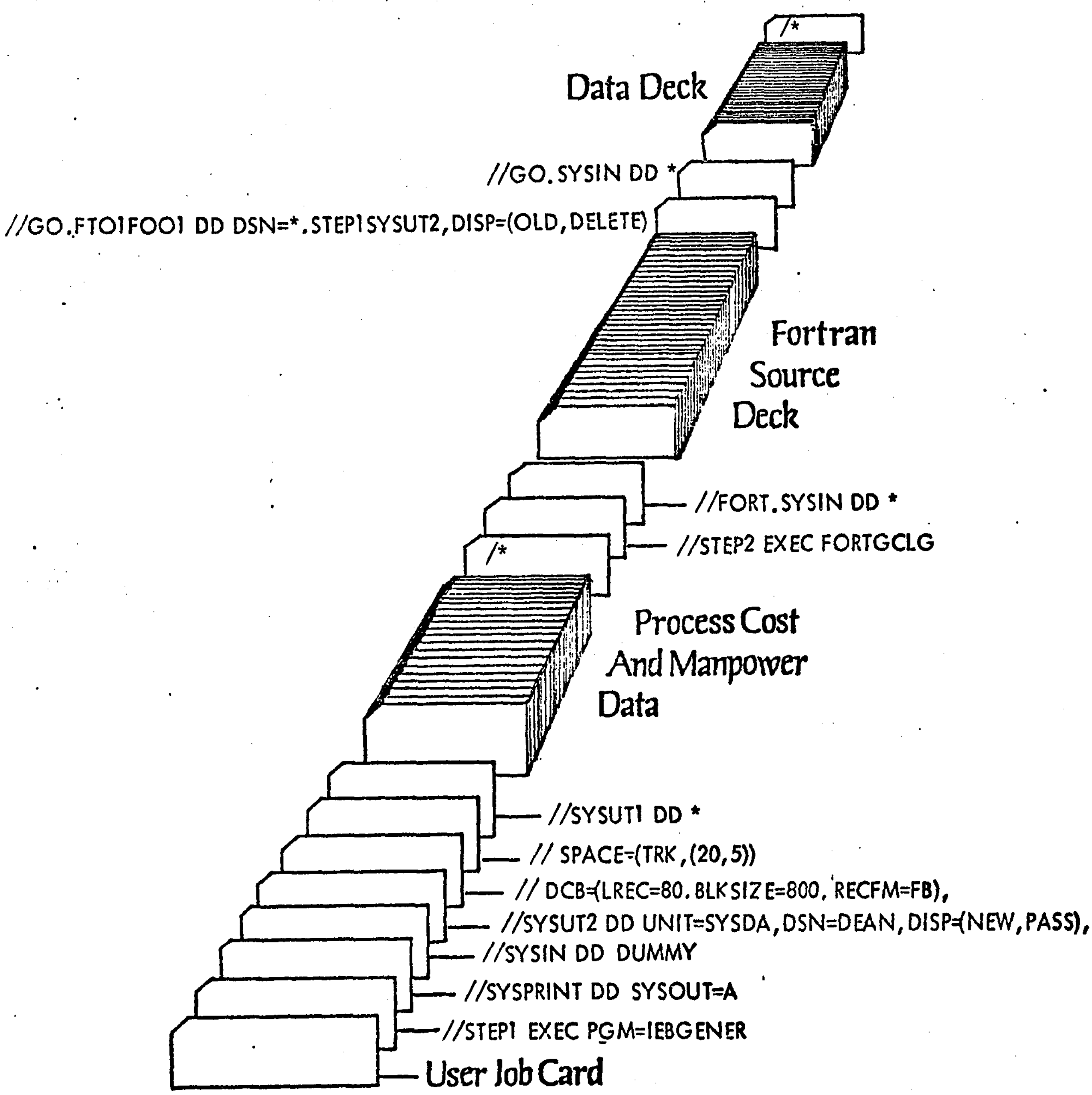

TABLE 19

THE PLANNING MODEL OUTPUT FOR THE BASE YEAR SHOWING THE SELECTED PROCESSES AND THE RELATED COSTS AND MANPOWER

THE LDC WATER AND SEWAGE TREATMENT PLANNING MODEL

FOR THE COMMUNITY NAKURU

IN THE STATE OR PROVINCE OF RIFT VALLEY REGION

IN THE COUNTRY OF KENYA

FOR THE PLANNING GROUP RIFT WATER CENTER BASE YEAR = 1974

****** SUITABLE WATER TREATMENT PROCESSES FOR IMPLEMENTATION IN...1974******

PROCESS NAME	INITIAL CONSTRUCTION COST(U.S.$)	YEARLY MAINTENANCE COST(U.S.$)	TOTAL COST 20 YEARS	REQUIRED MANPOWER USKIL	SKIL	PROF	POPULATION SERVED	PLANT SCALE U.S.GALLONS
CW	479160.88	42326.01	1325681.11	4	0	0		
CHO	67150.63	76459.88	1596348.13	2	1	1		
SEC	28922.96	73460.25	1498127.96	4	1	0		
SSF	315170.63	6586.05	446891.64	5	0	0		
RSF	237000.13	50723.14	1251462.94	8	2	1		

THE LOWEST TOTAL COST WATER TREATMENT PROCESS IS THE FOLLOWING

SLOW SAND FILTER	$ 315170.63	$ 6586.05	$ 446891.64	5	0	0	60181.	4513575.

****** SUITABLE WASTE WATER TREATMENT PROCESSES FOR IMPLEMENTATION IN...1974 ******

LAG	142989.94	19914.32	541276.34	4	0	0
SSC	763087.06	34744.77	1457932.45	2	1	0
TF	12918747.00	41096.65	13740680.05	4	1	1
AS	1432547.00	81890.75	3070362.00	4	1	1

THE LOWEST TOTAL COST WATER TREATMENT PROCESS IS THE FOLLOWING

OXIDATION POND	$ 142989.94	$ 19914.32	$ 541276.34	4	0	0	60181.	4513575.

which in the case of Nakura was 1974. The processes listed on the left side of the output sheet are those suitable for Nakura. On the same line, along with each of the processes, are the initial construction cost of the project, the yearly maintenance cost, the total cost over the life of the project, and the manpower required by three categories of skill level. From the processes listed, the program determines the one with the lowest total cost, and this process is printed again with a heading indicating that this is the lowest total cost process. This output line also contains the population of the community and the approximate plant scale. The plant scale is the approximate daily capacity in U.S. gallons for the proposed treatment plant.

The output for Nakuru contains all the processes possible. In other situations, this may not happen. For example, if the community under study did not have groundwater available, then the drilled well (DW) process would not be listed on the computer printout. Other processes may be eliminated by the lack of silica sand, valves, chemicals, or laboratory equipment. In the case where all the processes have been eliminated, a message will be printed to indicate this.

The waste water treatment processes are treated in essentially the same manner as the water treatment processes. All the suitable processes are listed along with their costs and manpower. The lowest total cost process is printed again with the costs and manpower, plus the projected or present population and the approximate plant scale in gallons per day. For the base year, the default population is the same as that used for the water treatment. Different population parameters can be specified in Card 3 of the input data.

If the low maintenance option is desired, it can be specified by selecting alternative 2 in question 15 of the data sheet. When this choice is selected, the lowest maintenance cost process is selected by the model and is printed below the list of acceptable processes with a heading to indicate that it is the lowest maintenance process available. In the Nakuru example, an examination of the results shows that the lowest total cost processes selected are also those which have the lowest yearly maintenance. However, testing other examples did not always give these same results. In cases where there is not a central waste water collection system, the model does not investigate for suitable waste water treatment process.

Table 20 gives the output of the second page of the Nakuru printed output. At this point, the population was projected for five years to 1979. The water and waste water treatment costs were again computed for the various processes selected and in each case the lowest total cost treatment method was repeated with the population and plant scale data added. In this particular example, the slow sand filter and the oxidation sand continue to be the lowest total cost alternatives. Table 21 gives the results for 1984, and these show again that the slow sand filter and the oxidation pond continue to be the lowest total cost processes. In 1989, as shown in Table 22, with the population almost seventy thousand the lowest total cost water treatment process is the rapid sand filter; for waste water treatment, the process is primarily sedimentation. These lowest total cost processes do not change for the final five-year period shown in Table 23.

TABLE 20

THE PLANNING MODEL OUTPUT FOR THE BASE YEAR +5 SHOWING THE SELECTED PROCESSES AND THE RELATED COSTS AND MANPOWER

THE LDC WATER AND SEWAGE TREATMENT PLANNING MODEL

FOR THE COMMUNITY NAKURU

IN THE STATE OR PROVINCE OF RIFT VALLEY REGION

IN THE COUNTRY OF KENYA

FOR THE PLANNING GROUP RIFT WATER CENTER BASE YEAR = 1974

****** SUITABLE WATER TREATMENT PROCESSES FOR IMPLEMENTATION IN...1979******

PROCESS NAME	INITIAL CONSTRUCTION COST(U.S.$)	YEARLY MAINTENANCE COST(U.S.$)	TOTAL COST 20 YEARS	REQUIRED MANPOWER USKIL	SKIL	PROF	POPULATION SERVED	PLANT SCALE U.S.GALLONS
CW	503118.75	44442.28	1391964.30	4	0	0		
CFC	70508.13	80282.81	1676164.38	2	1	1		
SED	30369.10	77133.19	1573032.85	4	1	0		
SSF	330929.06	6915.35	469236.09	5	0	0		
RSF	248850.00	53259.25	1314035.08	8	2	1		

THE LOWEST TOTAL COST WATER TREATMENT PROCESS IS THE FOLLOWING

SLOW SAND FILTER	$ 330929.06	$ 6915.35	$ 469236.09	5	0	0	63190.	4739251.

****** SUITABLE WASTE WATER TREATMENT PROCESSES FOR IMPLEMENTATION IN...1979 ******

LAG	150139.38	20910.03	568339.92	4	0	0		
SSD	801241.06	36481.99	1530880.83	2	1	0		
TF	13564679.00	43151.47	14427708.45	4	1	1		
AS	1504174.00	85985.19	3223877.75	4	1	1		

THE LOWEST TOTAL COST WATER TREATMENT PROCESS IS THE FOLLOWING

OXIDATION POND	$ 150139.38	$ 20910.03	$ 568339.92	4	0	0	63190.	4739251.

TABLE 21

THE PLANNING MODEL OUTPUT FOR THE BASE YEAR +10 SHOWING THE SELECTED PROCESSES AND THE RELATED COSTS AND MANPOWER

THE LDC WATER AND SEWAGE TREATMENT PLANNING MODEL

FOR THE COMMUNITY NAKURU

IN THE STATE OR PROVINCE OF RIFT VALLEY REGION

IN THE COUNTRY OF KENYA

FOR THE PLANNING GROUP RIFT WATER CENTER BASE YEAR = 1974

****** SUITABLE WATER TREATMENT PROCESSES FOR IMPLEMENTATION IN...1984******

PROCESS NAME	INITIAL CONSTRUCTION COST(U.S.$)	YEARLY MAINTENANCE COST(U.S.$)	TOTAL COST 20 YEARS	REQUIRED MANPOWER USKIL	SKIL	PROF	POPULATION SERVED	PLANT SCALE U.S.GALLONS
DW	528274.50	46664.39	1461562.31	4	0	0		
CHC	74033.56	84296.94	1759972.31	2	1	1		
SED	31867.54	80989.81	1651683.79	4	1	0		
SSF	347475.31	7261.11	492697.58	5	0	0		
RSF	261292.44	55922.20	1379736.42	8	2	1		

THE LOWEST TOTAL COST WATER TREATMENT PROCESS IS THE FOLLOWING

SLOW SAND FILTER	$ 347475.31	$ 7261.11	$ 492697.58	5	0	0	66350.	4976212.

****** SUITABLE WASTE WATER TREATMENT PROCESSES FOR IMPLEMENTATION IN...1984 ******

LAG	157646.25	21955.52	596756.64	4	0	0
SSD	841302.81	38306.09	1607424.69	2	1	0
TF	14242907.00	45309.04	15149087.86	4	1	1
AS	1579382.00	90284.44	3385070.75	4	1	1

THE LOWEST TOTAL COST WATER TREATMENT PROCESS IS THE FOLLOWING

OXIDATION POND	$ 157646.25	$ 21955.52	$ 596756.64	4	0	0	66350.	4976212.

TABLE 22

THE PLANNING MODEL OUTPUT FOR THE BASE YEAR +15 SHOWING THE SELECTED PROCESSES AND THE RELATED COSTS AND MANPOWER

THE LDC WATER AND SEWAGE TREATMENT PLANNING MODEL

FOR THE COMMUNITY NAKURU

IN THE STATE OR PROVINCE OF RIFT VALLEY REGION

IN THE COUNTRY OF KENYA

FOR THE PLANNING GROUP RIFT WATER CENTER BASE YEAR = 1974

****** SUITABLE WATER TREATMENT PROCESSES FOR IMPLEMENTATION IN...1989******

PROCESS NAME	INITIAL CONSTRUCTION COST(U.S.$)	YEARLY MAINTENANCE COST(U.S.$)	TOTAL COST 20 YEARS	REQUIRED MANPOWER USKIL	SKIL	PROF	POPULATION SERVED	PLANT SCALE U.S.GALLONS
CH	531209.25	32665.03	1184509.80	8	0	0		
CHC	63222.61	75867.13	1580565.11	4	1	1		
SED	23512.55	77308.38	1569680.05	6	2	0		
SSF	256896.38	45744.94	1171795.20	8	0	0		
RSF	147693.56	46411.14	1075916.30	10	3	1		

THE LOWEST TOTAL COST WATER TREATMENT PROCESS IS THE FOLLOWING

RAPID SAND FILTER	$ 147693.56	$ 46411.14	$ 1075916.30	10	3	1	69667.	5225015.

****** SUITABLE WASTE WATER TREATMENT PROCESSES FOR IMPLEMENTATION IN...1989 ******

LAG	919209.94	47387.27	1866955.25	6	0	0		
SSC	688395.44	35090.46	1390204.73	4	2	0		
TF	1246165.00	36503.98	1976244.61	6	2	1		
AS	1324540.00	75776.19	2840063.75	8	2	2		

THE LOWEST TOTAL COST WATER TREATMENT PROCESS IS THE FOLLOWING

PRIMARY SEDIMENTATONS	688395.44	$ 35090.46	$ 1390204.73	4	2	0	69667.	5225015.

TABLE 23

THE PLANNING MODEL OUTPUT FOR THE BASE YEAR +20 SHOWING THE SELECTED PROCESSES AND THE RELATED COSTS AND MANPOWER

THE LCC WATER AND SEWAGE TREATMENT PLANNING MODEL

FOR THE COMMUNITY NAKURU

IN THE STATE OR PROVINCE OF RIFT VALLEY REGION

IN THE COUNTRY OF KENYA

FOR THE PLANNING GROUP RIFT WATER CENTER BASE YEAR = 1974

****** SUITABLE WATER TREATMENT PROCESSES FOR IMPLEMENTATION IN...1994******

PROCESS NAME	INITIAL CONSTRUCTION COST(U.S.$)	YEARLY MAINTENANCE COST(U.S.$)	TOTAL COST 20 YEARS	REQUIRED MANPOWER USKIL	SKIL	PROF	POPULATION SERVED	PLANT SCALE U.S.GALLONS
CM	557769.44	34298.26	1243734.67	8	0	0		
CMC	66383.63	79660.44	1659592.38	4	1	1		
SEC	24688.17	81173.75	1648163.17	6	2	0		
SSF	269741.06	48032.18	1230334.73	8	0	0		
RSF	155078.13	48731.69	1129711.95	10	3	1		

THE LOWEST TOTAL COST WATER TREATMENT PROCESS IS THE FOLLOWING

RAPID SAND FILTER	$ 155078.13	$ 48731.69	$ 1129711.95	10	3	1	73150.	5486264.

****** SUITABLE WASTE WATER TREATMENT PROCESSES FOR IMPLEMENTATION IN...1994 ******

LAG	965169.75	49756.62	1960302.17	6	0	0
SSD	722814.88	36844.96	1459714.02	4	2	0
TF	1308472.00	38329.18	2075055.52	6	2	1
AS	1390766.00	79565.00	2982066.00	8	2	2

THE LOWEST TOTAL COST WATER TREATMENT PROCESS IS THE FOLLOWING

PRIMARY SEDIMENTATON$	722814.88	$ 36844.96	$ 1459714.02	4	2	0	73150.	5486264.

The Descriptive Power of the Model

The model has the ability of bringing together a number of critical inputs relating to the effective installation and use of various water and waste water treatment methods. These inputs are manipulated within the model, and the output provides a simple setup for listing the plausible alternatives for water treatment and/or waste water treatment in communities in less developed countries. The output allows the planners to look at all the plausible processes and their related costs, plus the manpower requirements associated with each of the variable processes.

The key elements of this approach were: (1) the systematic evaluation of the importance and interrelationships of all relevant aspects of the problem, such as technical, economic, social, political, and cultural factors; (2) the assessment of alternative courses of action; and (3) an analysis of benefits and costs as the basis on which policies can be determined and decisions made. Emphasis, then, has been on obtaining a grasp of the total picture and putting the pieces together in a practical, usable way so that international health organizations, lending agencies, and regional institutes will have a viable planning tool.

The transplanting of water and waste water treatment technology from developed to developing countries has not led to satisfactory utilization of either foreign or domestic resources. To overcome this, the approach in this study was to use known techniques, to arrive at the simplest, cheapest treatment methods possible which actually take advantage of local conditions, including manpower, materials, and socio-economic goals.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS FOR FURTHER RESEARCH

Summary of the Problem

The unprecedented urban population increases in less developed countries during the past 20 years, which more than doubled the size of many cities, have resulted in corresponding increases in serious water resource and waste water treatment problems. In an attempt to expand and upgrade water treatment facilities for these areas, and thus guard public health, efforts have been made to transfer modern equipment, standards, techniques, and engineering methodology *in toto* to the LDC's.

However, these attempts to transplant water and waste water treatment technology have generally not led to satisfactory utilization of either foreign or domestic resources. Modern methods, developed in and for industrialized nations, are often so costly that available funds are insufficient for meeting the burgeoning needs of the LDC's. Also, they are generally too intricate and automated to be maintained by local technicians.

The problem then was the lack of a methodology for the selection and use of known techniques that will arrive at the simplest, cheapest water treatment methods considering local socio-economic goals, skilled manpower, and available materials. The primary objectives of this project were to develop that methodology and then construct a decision-making model which would match treatment methods with local conditions and recommend the most feasible courses of action.

This methodology is provided to assist those who are charged with responsibility of developing and managing the water and waste water treatment for communities in LDC's. Planning models of this nature, when used with caution, can be very useful tools for design engineers, consulting engineers, municipal officials, developers, urban planners, and the other agencies involved in improving water and waste treatment.

Summary of the Research Results

The methodology developed in this research study is a computerized, heuristic, simulation model. The model was developed after exhaustive interviews and consultations with numerous international experts in sanitary systems design and in other environmental fields, including anthropology, manpower analysis, economic development, demography, and model design. The interviews were supplemented, when necessary, with an extensive literature search to help evaluate and justify the information derived from the interview.

The inputs of the model, which are designed to be collected at the local level, consists of demographic information, data relating to the level of the communities development, and inputs relating to the present water and waste water treatment, types of maintenance supplies, chemicals available, water operation supplies, and process equipment. Special emphasis was placed on the ease of obtaining the above information.

The model evaluates potential processes for a community on the basis of the level of technology available in the community, the manpower available to operate and maintain the processing plants, and the availability of local materials and supplies required by the processes for satisfactory operation. The output of the model is a list of suitable processes, including their associated costs and manpower requirements for a projected period of 20 years (in five-year increments). The model recommends the lowest total cost approach or the lowest annual maintenance cost process, depending on the criteria selected by the planner.

The key elements of this approach were: (1) the systematic evaluation of the importance and interrelationships of all relevant measurable aspects of the problem, such as technical, economic, social, political, and cultural factors; (2) the assessment of alternative courses of action; and (3) an analysis of benefits and costs as the basis on which policies can be determined and decisions made. Emphasis was on obtaining a grasp of the total picture and putting the pieces together in a practical, usable way so that international health organizations, lending agencies, LDC government planning groups, and regional institutes will have a viable planning tool.

Interpretation of the Research Results

The study concludes that although LDC water supply and sanitation problems are not highly complex in technical terms, there is a complex relationship between technology, society, and environment which makes specific local situations both complicated and delicate. The model deals with the technological and environmental factors; the planner(s) can then add the sociological factor to choose between feasible alternatives.

Perhaps the outstanding conceptual (theoretical) and structual distinction of the planning model is that it facilitates both aggregation and disaggregation. Thus, the effects of differences of local resources and manpower availability are reflected in terms of the communities' ability (effectiveness) to provide clean water and adequate waste water treatment while, at the same time, the implications of the level of technology are reflected in the various levels of treatment that should be utilized.

The practical value of the planning model was assessed in several ways. For example, some of the ease or difficulty of application was foreseen. Also, comparison to alternative decision-making methods at a conceptual and structual level were possible. In addition, certain tests were performed on the model to assess what is sometimes called "validity" but will be referred to here as "reasonableness". (Reasonableness is used in preference to validity because the latter term generally implies a quantitative comparison with real world data. This step has not yet been reached with the proposed planning model.) Although final evaluation of the planning model will depend on its application to a real planning situation, these preliminary evaluations were helpful in deciding whether or not to recommend a move to the application stage.

The reasonableness of the planning model was tested by checking for logical error and consistency of output. This required an examination of each variable in relation to other variables and the examination of actual values of variables as the model was simulated. Also, individuals were consulted to determine if there were unreasonable patterns of process selection. However, the ultimate test is the extent to which the planning model specification is consistent with empirical studies, and potential users must form their own opinions in this area on how well the model meets that test. However, the planning model proposed in this study differs in one main respect. Previous attempts to provide communities in the LDC's with improved treatment facilities has resulted in a large expenditure of manpower and funds. This has not worked. The planning model sets forth a methodology which selects treatment methods which generally cost less and they are required to take advantage of local resources.

A detailed comparison of the water and waste water treatment planning model to other planning models is not possible at this time because alternative models have not yet been developed or at least have not been reported.

Suggestions for Additional Research

A great deal has been learned about the problems of measuring the stages and processes of development and modernization of the community level. In this area, the major limitation on the use of quantitative indicators is the lack of data for measurement. The economic indicators, such as per capita GNP, conceal the disparities in wealth between both individuals and areas. Data series on income distribution and some measure of the modern versus subsistence sectors in developing countries are needed to provide a realistic picture of a community's economic development.

Cultural indicators are also far from perfect. Data on literacy can be misleading because of questionable criteria used in its determination.

The human resources data are far from ideal. First, indicators of the development of human resources (i.e., the generation of skills, knowledge, and capacities of the present and future labor force) are incomplete. Generally, only statistics on enrollment in formal education are available. (The development of human resources through non-formal education, in-service training, and access to productive working environments is just as important as development through formal education, but quantitative measures for these are unavailable as yet in any country, much less on a community level.) Even more critical is the absence of comparable data on utilization of human resources.

Another deficiency in the human resource area is inadequate comparable data on stocks of manpower with various categories of skill and knowledge. Figures on educational attainment, for example, are available only for the advanced countries and a small number of the LDC's.

In short, adequate resource indicators would include data on both the stock and the flow (generating capacity) of human skills and knowledge, as well as some kind of index of effectiveness of utilization. For the most part, such data are not yet available.

In relation to the model itself, the study ends by stating: "This is only the beginning." Much remains to be done in terms of empirical testing of the model and calibrating the cost input data, although the test runs executed to date have shown a relatively good relationship between the costs generated by the model and those reported in the published material. Since the model has been designed to plan water and sewage treatment under a wide variety of human resources, materials, and water supplies, more thorough testing will make useful tool in the planning process.

The model's usefulness could be greatly expanded by the addition of several more processes for both water and waste water treatment and the combination of presently incorporated processes. For example, in water treatment, the slow sand filter and disinfection are commonly used together. The treatment involves passing the water through the sand filter and then treating it with chlorine to further purify the water.

A further refinement of the model would be the addition of some data regarding the input quality of the water to be treated. This data could be analyzed by the model so that only those processes that are efficient in treating the local water quality problem are suggested by the model.

The amount of testing needed is not known at this point. However, at least 9 or 10 sites should be examined, with local planners assisting in the data gathering. After these initial tests, the model should be examined by planners to test its usefulness. A favorable response from planners will determine whether this planning model has made a contribution in the form of an improved planning methodology. If the planners are encouraged by these preliminary results, then work should proceed on both expanding the list of processes for both water and waste water treatment, and on incorporating the additional feature of adding water quality input data to determine which water and waste treatment methods would be best for treating the specific local water supply.

Model testing should probably occur in communities that have recognized the need for improved water and sanitary services. Improvements in water and waste treatment should not be foisted on communities at a premature stage in their development because this generally leads to waste and inefficient allocation of resources. The most obvious indication of the priority accorded to water by the community is the offer of self-help in the form of either material, cash, or labor. Other indications of priority might be effective user group formation and lobbying of their political representatives.

It is unlikely that precise data regarding the nature of the water and waste water treatment will already be available in documentary form. Instead, field work will be required; planners must be sent to communities in the LDC's to gather information required for the operation of the planning model. For optimum results, these efforts must be on an organized basis. Successful field work demands the proper approach.

A number of points should be kept in mind when gathering data on water and waste water treatment. Field work involves selling. Many of the people who need water or improved waste treatment may not think they need it. They may feel that their present treatment methods are adequate or that an alternative method would be either impossible or too expensive. The health aspects in inadequate water (a big selling point with government agencies) should not be stressed with residents; they have learned to live with impure water. A better approach is in terms of the improved quantity and quality of the water itself. Although residents in some areas may want improved water so desperately that little selling is required, residents in most areas require some persuasion.

The fieldwork personnel must have the full support of the sponsoring agency. If the planning team is beset with internal squabbles over power and prerogatives, the field work (and thus the entire project) will suffer.

The most important criteria for survey workers is that they know the community well and are able to work comfortably with the residents. Knowledge of the area not only contributes to more successful data gathering but also may save time and money. Thus, local residents generally make the best survey workers. They know which residents can only be contacted at certain times or places, and they are familiar with local geography.

In addition, survey workers probably should share areal characteristics in terms of age and race. In rural areas, for example, the residents will tend to be somewhat older persons; hence, data gatherers should be in this older age group. Black persons will probably be able to work better in black areas, white persons in white areas. Naturally, there will be many exceptions to these age-race rules, and the planners utilizing the model should not hesitate to make them.

In relation to implementation in general, the field of management science has long been shadowed by the contrast between the technical advances it has achieved and the limited success it has had in obtaining successful implementation. There has been an emphasis on techniques rather than problem definition. As a result, sound approaches are often discarded because of unforeseen implementation difficulties and, all too often, proposed techniques prove to be elegant solutions to irrelevant problems. What can be done about this?

Planners who don't understand and don't have confidence in models tailored to help them make decisions may prefer to live with a familiar problem rather than accept a solution that is unfamiliar and suspicious. In part, the planner is often threatened by the new technique and may respond by keeping it in the impractical window-dressing stage indefinitely. This can be accomplished by avoiding an accurate definition of the decision problem or by the failure to discourage the model building from drifting from the real problem. The solution lies in getting the planners involved as early and as deeply as possible so they will tend to view the model as part of their own decision process. This has been a major drawback of this present study. If the study were initiated again, closer cooperation should be sought between the researcher and the planners. Clearly, the nature of the relationship between the planner and the researcher lies at the heart of the implementation problem. The approach suggested here is one that involves a close working relationship in an atmosphere of trust and respect.

Another barrier to successful implementation lies in organization considerations. A good solution can be found to the right problem and decision makers' support achieved, yet the project somehow still gets mysteriously sabotaged. The reason usually lies in organizational factors which are particularly insidious, for there is no overt reason to include them in the problem. Further, they involve the informal organization and power structure which, to say the least, presents delicate areas for the planner to be involved in. There certainly needs to be more research done on organizational considerations.

The heuristic model developed in this research study represents the first effort to quantify the decision-making process of selecting water and waste treatment methods. A model of this nature is still exploratory. After being tested, several of the input variables may be discarded in favor of others which appear more appropriate. The present variables appear to be the "best" ones, but in fact, no one knows at this point the critical variables that determine the successful implementation of a water or waste treatment method. When this point has been reached, then other methods of management science, such as linear programming, can be considered for evaluating plans. This will result in a model that can truly provide the optimal solution. Presently, however, the heuristic approach offers the best method for helping to solve the problem.

The most important item that this model has to offer is that it represents a move into an area that has traditionally avoided any kind of quantitative approach. The model presents an organized way of looking at the problem. Each of the input categories represents a step in the process of making the decision for a treatment method. The model merely takes the inputs and provides an orderly way for evaluating them. Improvements over time may suggest additional inputs or eliminations of those already incorporated into the model, but the procedure will probably remain essentially the same.

The procedure developed in this research study also suggests uses in other areas. One area that immediately comes to mind is health care. Improved water and waste treatment are generally seen as a major weapon against disease. Another area which helps reduce the incidence of disease is health care, in the form of improved hospitals and outpatient medical care. It seems reasonable to apply the approach of utilizing the local resources, manpower, and level of development as important considerations for the implementation of health care programs.

Large scale use of this planning model would not provide any guarantee that the present unhappy situation would be radically altered; however, such use should significantly enhance prospects for worthwhile change. If the planning model or something similar were to be used as a major effect, more effective tactics and operating methods would very likely be devised than those suggested here. Even so, it might fall short of its objectives. Amid considerable uncertainty it remains unclear whether technical skills, administrative decisions, and political motivation can be harmoniously developed together in recognition of the single principle of a healthy environment as a basic human right. If the analysis offered here is substantially accurate, there are grounds for hope that a significant advance can be made for the provision of better water supplies and sanitation for the well-being of the people in less developed countries.

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APPENDIX A

PUNCHED CARD LAYOUT AND PUNCHED CARD LISTING FOR TABLES 4-15 SHOWING THE VARIOUS TREATMENT PROCESSES AND THEIR RELATED COSTS AND MANPOWER FOR CONSTRUCTION AND OPERATION

APPENDIX A

THE PUNCHED CARD LAYOUT FOR TABLES 4-15 SHOWING THE VARIOUS TREATMENT PROCESSES AND THEIR RELATED COSTS AND MANPOWER FOR CONSTRUCTION AND OPERATION

Variable Name	Card Column	Format	Item
K9	1- 2	I2	Transaction code
LX	3	I1	Level
P	3- 6	A3	Process
X11	7- 9	F3.0	% Unskilled labor LDC
X12	10-12	F3.0	% Skilled labor
X21	13-17	F5.2	Hourly wage unskilled labor
X22	18-22	F5.2	Hr. wage unskilled DC
X31	23-27	F5.2	Hr. wage unskilled LDC
X32	28-32	F5.2	Hr. wage skilled DC
X41	33-35	F3.0	% On site materials manuf.
X42	36-38	F3.0	% Off site materials manuf.
X51	39-43	F5.2	Cost on site LDC/DC
X52	44-48	F5.2	Cost off site LDC/DC
C	49-54	F6.2	Total Const. Cost Per Capita DC U.S. $
PC	55	I	Population Category
M1	56-57	I2	Minimum number of unskilled personnel
M2	58-59	I2	Minimum number of skilled personnel
M3	60-61	I2	Minimum number of Professional

APPENDIX A (Cont'd)

Punched Card Listing For Tables 4-15

11DW	10	40	0.25	3.00	9.00	6.00	10	40	0.33	2.00	75.001			
21DW	90	5	0.25	3.00	9.00	6.00	2	3	0.50	3.00	2.501	1	0	0
11DW	10	40	0.25	3.00	9.00	6.00	10	40	0.33	2.00	20.002			
21DW	0	5	0.25	3.00	9.00	6.00	2	3	0.50	3.00	2.002	2	0	0
11DW	10	40	0.25	3.00	9.00	6.00	10	40	0.33	2.00	12.003			
21DW	90	5	0.25	3.00	9.00	6.00	2	3	0.50	3.00	1.503	4	0	0
11DW	10	40	0.25	3.00	9.00	6.00	10	40	0.33	2.00	10.004			
21DW	90	5	0.25	3.00	9.00	6.00	2	3	0.50	3.00	1.004	8	0	0
11CHO	20	10	0.25	3.00	9.00	6.00	10	50	0.33	2.00	4.001			
21CHO	10	40	0.25	3.00	9.00	6.00	10	40	0.50	3.00	5.001	1	0	0
11CHO	20	10	0.25	3.00	9.00	6.00	10	50	0.33	2.00	0.802			
21CHO	10	40	0.25	3.00	9.00	6.00	10	40	0.50	3.00	2.302	1	1	0
11CHO	20	10	0.25	3.00	9.00	6.00	10	50	0.33	2.00	1.503			
21CHO	10	40	0.25	3.00	9.00	6.00	10	40	0.50	3.00	1.753	2	1	1
11CHO	20	10	0.25	3.00	9.00	6.00	10	50	0.33	2.00	1.204			
21CHO	10	40	0.25	3.00	9.00	6.00	10	40	0.50	3.00	1.504	4	1	1
11SED	50	20	0.25	3.00	9.00	6.00	20	10	0.33	2.00	9.001			
21SED	90	5	0.25	3.00	9.00	6.00	5	0	0.50	3.00	6.001	1	0	0
11SED	50	20	0.25	3.00	9.00	6.00	20	10	0.33	2.00	0.702			
21SED	90	5	0.25	3.00	9.00	6.00	5	0	0.50	3.00	3.502	1	0	0
11SED	50	20	0.25	3.00	9.00	6.00	20	10	0.33	2.00	0.803			
21SED	90	5	0.25	3.00	9.00	6.00	5	0	0.50	3.00	2.753	4	1	0
11SED	50	20	0.25	3.00	9.00	6.00	20	10	0.33	2.00	0.504			
21SED	90	5	0.25	3.00	9.00	6.00	5	0	0.50	3.00	2.504	6	2	0
11SSF	40	20	0.25	3.00	9.00	6.00	30	10	0.33	2.00	101.001			
21SSF	80	10	0.25	3.00	9.00	6.00	10	0	0.50	3.00	2.001	1	0	0
11SSF	40	20	0.25	3.00	9.00	6.00	30	10	0.33	2.00	67.402			
21SSF	80	10	0.25	3.00	9.00	6.00	10	0	0.50	3.00	0.502	2	0	0
11SSF	40	20	0.25	3.00	9.00	6.00	30	10	0.33	2.00	9.103			
21SSF	80	10	0.25	3.00	9.00	6.00	10	0	0.50	3.00	0.253	5	0	0
11SSF	40	20	0.25	3.00	9.00	6.00	30	10	0.33	2.00	5.904			
21SSF	80	10	0.25	3.00	9.00	6.00	10	0	0.50	3.00	0.204	8	0	0
11RSF	20	20	0.25	3.00	9.00	6.00	40	20	0.33	2.00	11.201			
21RSF	60	20	0.25	3.00	9.00	6.00	20	0	0.50	3.00	4.001	1	1	0
11RSF	20	20	0.25	3.00	9.00	6.00	40	20	0.33	2.00	8.802			
21RSF	60	20	0.25	3.00	9.00	6.00	20	0	0.50	3.00	2.002	1	1	1
11RSF	20	20	0.25	3.00	9.00	6.00	40	20	0.33	2.00	5.003			
21RSF	60	20	0.25	3.00	9.00	6.00	20	0	0.50	3.00	1.753	8	2	1
11RSF	20	20	0.25	3.00	9.00	6.00	40	20	0.33	2.00	2.654			
21RSF	60	20	0.25	3.00	9.00	6.00	20	0	0.50	3.00	1.504	10	3	1
12DW	10	40	0.75	3.00	9.00	6.00	30	20	0.50	1.50	75.001			
22DW	80	10	0.75	3.00	9.00	6.00	5	5	0.50	1.50	2.501	1	0	0
12DW	10	40	0.75	3.00	9.00	6.00	30	20	0.50	1.50	20.002			
22DW	80	1	0.75	3.00	9.00	6.00	5	5	0.50	1.50	2.002	2	0	0
12DW	10	40	1.00	3.00	8.00	6.00	30	20	0.67	1.50	12.003			
22DW	60	10	1.00	3.00	8.00	6.00	5	5	0.67	1.50	1.503	4	0	0
12DW	10	40	1.00	3.00	8.00	6.00	30	20	0.67	1.50	10.004			
22DW	60	10	1.00	3.00	8.00	6.00	5	5	0.67	1.50	1.504	8	0	0
12CHO	10	15	0.75	3.00	9.00	6.00	5	70	0.50	1.50	4.001			
22CHO	10	40	0.75	3.00	9.00	6.00	10	40	0.50	1.50	5.001	1	0	0
12CHO	10	15	0.75	3.00	9.00	6.00	5	70	0.50	1.50	0.802			

APPENDIX A (Cont'd)

22CHO	10	40	0.75	3.00	9.00	6.00	10	40	0.50	1.50	2.302	1	1	0
12CHO	10	15	1.00	3.00	8.00	6.00	5	70	1.50	1.50	1.503			
22CHO	10	40	1.00	3.00	8.00	6.00	10	40	0.67	1.50	1.753	2	1	1
12CHO	10	15	1.00	3.00	8.00	6.00	5	70	1.50	1.50	1.204			
22CHO	10	40	1.00	3.00	8.00	6.00	10	40	0.67	1.50	1.504	4	1	1
12SED	35	25	0.75	3.00	9.00	6.00	20	20	0.50	1.50	9.001			
22SED	95	0	0.75	3.00	9.00	6.00	5	0	0.50	1.50	6.001	1	0	0
12SED	35	25	0.75	3.00	9.00	6.00	20	20	0.50	1.50	0.702			
22SED	95	0	0.75	3.00	9.00	6.00	5	0	0.50	1.50	3.502	1	0	0
12SED	35	25	1.00	3.00	8.00	6.00	20	20	1.50	1.50	0.803			
22SED	95	0	1.00	3.00	8.00	6.00	5	0	0.67	1.50	2.753	4	1	0
12SED	35	25	1.00	3.00	8.00	6.00	20	20	1.50	1.50	0.504			
22SED	95	0	1.00	3.00	8.00	6.00	5	0	0.67	1.50	2.504	6	2	0
12SSF	30	20	0.75	3.00	9.00	6.00	30	20	0.50	1.50	101.001			
22SSF	80	10	0.75	3.00	9.00	6.00	10	0	0.50	1.50	2.001	1	0	0
12SSF	30	20	0.75	3.00	9.00	6.00	30	20	0.50	1.50	67.402			
22SSF	80	10	0.75	3.00	9.00	6.00	10	0	0.50	1.50	0.502	2	0	0
12SSF	30	20	1.00	3.00	8.00	6.00	30	20	1.50	1.50	9.103			
22SSF	80	10	1.00	3.00	8.00	6.00	10	0	0.67	1.50	0.253	5	0	0
12SSF	30	20	1.00	3.00	8.00	6.00	30	20	1.50	1.50	5.904			
22SSF	80	10	1.00	3.00	8.00	6.00	10	0	0.67	1.50	0.204	8	0	0
12RSF	30	20	0.75	3.00	9.00	6.00	30	20	0.50	1.50	11.201			
22RSF	60	20	0.75	3.00	9.00	6.00	20	0	0.50	1.50	4.001	1	1	0
12RSF	30	20	0.75	3.00	9.00	6.00	30	20	0.50	1.50	8.802			
22RSF	60	20	0.75	3.00	9.00	6.00	20	0	0.50	1.50	2.002	1	1	1
12RSF	30	20	1.00	3.00	8.00	6.00	30	20	1.50	1.50	5.003			
22RSF	60	20	1.00	3.00	8.00	6.00	20	0	0.67	1.50	1.753	8	2	1
12RSF	30	20	1.00	3.00	8.00	6.00	30	20	1.50	1.50	2.654			
22RSF	60	20	1.00	3.00	8.00	6.00	20	0	0.67	1.50	1.504	10	3	1
13DW	10	40	1.00	3.00	8.00	6.00	40	10	0.50	1.50	75.001			
23DW	80	10	1.00	3.00	8.00	6.00	5	5	0.67	1.50	2.501	1	0	0
13DW	10	40	1.00	3.00	8.00	6.00	40	10	0.67	1.50	20.002			
23DW	60	10	1.00	3.00	8.00	6.00	5	5	0.67	1.50	2.002	2	0	0
13DW	10	40	1.50	3.00	7.00	6.00	40	10	0.67	1.00	12.003			
23DW	80	10	1.50	3.00	7.00	6.00	5	5	0.67	1.50	1.503	4	0	0
13DW	10	40	1.50	3.00	7.00	6.00	40	10	1.00	1.00	10.004			
23DW	80	10	1.50	3.00	7.00	6.00	5	5	0.67	1.50	1.004	8	0	0
13CHO	5	20	1.00	3.00	8.00	6.00	5	70	0.50	1.50	4.001			
23CHO	10	30	1.00	3.00	8.00	6.00	40	20	0.67	1.50	5.001	1	0	0
13CHO	5	20	1.00	3.00	8.00	6.00	5	70	0.67	1.50	0.802			
23CHO	10	30	1.00	3.00	8.00	6.00	40	20	0.67	1.50	2.302	1	1	0
13CHO	5	20	1.50	3.00	7.00	6.00	5	70	0.67	1.00	1.503			
23CHO	10	30	1.50	3.00	7.00	6.00	40	20	0.67	1.50	1.753	2	1	1
13CHO	5	20	1.50	3.00	7.00	6.00	5	70	1.00	1.00	1.204			
23CHO	10	30	1.50	3.00	7.00	6.00	40	20	0.67	1.50	1.504	4	1	1
13SED	30	30	1.00	3.00	8.00	6.00	30	10	0.50	1.50	9.001			
23SED	85	5	1.00	3.00	8.00	6.00	5	5	0.67	1.50	6.001	1	0	0
13SED	30	30	1.00	3.00	8.00	6.00	30	10	6.70	1.50	0.702			
23SED	85	5	1.00	3.00	8.00	6.00	5	5	0.67	1.50	3.502	1	0	0
13SED	30	30	1.50	3.00	7.00	6.00	30	10	0.67	1.00	0.803			
23SED	85	5	1.50	3.00	7.00	6.00	5	5	0.67	1.50	2.753	4	1	0

APPENDIX A (Cont'd)

13SED	30	30	1.50	3.00	7.00	6.00	30	10	1.00	1.00	0.504			
23SED	85	5	1.50	3.00	7.00	6.00	5	5	0.67	1.50	2.504	6	2	0
13SSF	40	20	1.00	3.00	8.00	6.00	20	20	0.50	1.50	101.001			
23SSF	80	10	1.00	3.00	8.00	6.00	10	0	0.67	1.50	2.001	1	0	0
13SSF	40	20	1.00	3.00	8.00	6.00	20	20	0.67	1.50	67.402			
23SSF	80	10	1.00	3.00	8.00	6.00	10	0	0.67	1.50	0.502	2	0	0
13SSF	40	20	1.50	3.00	7.00	6.00	20	20	0.67	1.00	9.103			
23SSF	80	10	1.50	3.00	7.00	6.00	10	0	0.67	1.50	0.253	5	0	0
13SSF	40	20	1.50	3.00	7.00	6.00	20	20	1.00	1.00	5.904			
23SSF	80	10	1.50	3.00	7.00	6.00	10	0	0.67	1.50	1.504	8	0	0
13RSF	5	55	1.00	3.00	8.00	6.00	5	35	0.50	1.50	11.201			
23RSF	70	10	1.00	3.00	8.00	6.00	15	5	0.67	1.50	4.001	1	1	0
13RSF	5	55	1.00	3.00	8.00	6.00	5	35	0.67	1.50	8.802			
23RSF	70	10	1.00	3.00	8.00	6.00	15	5	0.67	1.50	2.002	1	1	1
13RSF	5	55	1.50	3.00	7.00	6.00	5	35	0.67	1.00	5.003			
23RSF	70	10	1.50	3.00	7.00	6.00	15	5	0.67	1.50	1.753	8	2	1
13RSF	5	55	1.50	3.00	7.00	6.00	5	35	1.00	1.00	2.654			
23RSF	70	10	1.50	3.00	7.00	6.00	15	5	0.67	0.50	1.504	10	3	1
31LAG	70	20	0.25	3.00	9.00	6.00	8	2	0.33	2.00	67.001			
41LAG	95	0	0.25	3.00	9.00	6.00	5	0	0.33	2.00	1.701	1	0	0
31LAG	70	20	0.25	3.00	9.00	6.00	8	2	0.33	2.00	6.002			
41LAG	95	0	0.25	3.00	9.00	6.00	5	0	0.33	2.00	1.342	2	0	0
31LAG	70	20	0.25	3.00	9.00	6.00	8	2	0.33	2.00	4.003			
41LAG	95	0	0.25	3.00	9.00	6.00	5	0	0.33	2.00	1.263	4	0	0
31LAG	70	20	0.25	3.00	9.00	6.00	8	2	0.33	2.00	22.704			
41LAG	95	0	0.25	3.00	9.00	6.00	5	0	0.33	2.00	2.594	6	0	0
31SSD	40	20	0.25	3.00	9.00	6.00	20	20	0.33	2.00	88.001			
41SSD	85	5	0.25	3.00	9.00	6.00	5	0	0.33	2.00	2.561	1	0	0
31SSD	40	20	0.25	3.00	9.00	6.00	20	20	0.33	2.00	24.002			
41SSD	85	5	0.25	3.00	9.00	6.00	5	0	0.33	2.00	1.942	1	0	0
31SSD	40	20	0.25	3.00	9.00	6.00	20	20	0.33	2.00	19.503			
41SSD	85	5	0.25	3.00	9.00	6.00	5	0	0.33	2.00	1.713	2	1	0
31SSD	40	20	0.25	3.00	9.00	6.00	20	20	0.33	2.00	15.504			
41SSD	85	5	0.25	3.00	9.00	6.00	5	0	0.33	2.00	1.524	4	2	0
31TF	30	20	0.25	3.00	9.00	6.00	30	20	0.33	2.00	137.001			
41TF	80	5	0.25	3.00	9.00	6.00	5	0	0.33	2.00	3.921	1	0	0
31TF	30	20	0.25	3.00	9.00	6.00	30	20	0.33	2.00	40.502			
41TF	80	5	0.25	3.00	9.00	6.00	5	0	0.33	2.00	2.272	1	1	0
31TF	30	20	0.25	3.00	9.00	6.00	30	20	0.33	2.00	33.003			
41TF	80	5	0.25	3.00	9.00	6.00	5	0	0.33	2.00	1.793	4	1	1
31TF	30	20	0.25	3.00	9.00	6.00	30	20	0.33	2.00	26.504			
41TF	80	5	0.25	3.00	9.00	6.00	5	0	0.33	2.00	1.424	6	2	1
31AS	30	20	0.25	3.00	9.00	6.00	50	10	0.33	2.00	134.001			
41AS	70	5	0.25	3.00	9.00	6.00	5	0	0.33	2.00	5.201	1	1	0
31AS	30	20	0.25	3.00	9.00	6.00	50	10	0.33	2.00	40.002			
41AS	70	5	0.25	3.00	9.00	6.00	5	0	0.33	2.00	3.522	2	1	0
31AS	30	20	0.25	3.00	9.00	6.00	50	10	0.33	2.00	32.003			
41AS	70	5	0.25	3.00	9.00	6.00	5	0	0.33	2.00	2.983	4	1	1
31AS	30	20	0.25	3.00	9.00	6.00	50	10	0.33	2.00	26.004			
41AS	70	5	0.25	3.00	9.00	6.00	5	0	0.33	2.00	2.524	8	2	2
32LAG	60	20	0.75	3.00	9.00	6.00	10	10	0.50	1.50	67.001			

APPENDIX A (Cont'd)

42LAG	95	0	0.75	3.00	9.00	6.00	5	0	0.50	1.50	1.701	1	0	0
32LAG	60	20	0.75	3.00	9.00	6.00	10	10	0.50	1.50	6.002			
42LAG	95	0	0.75	3.00	9.00	6.00	5	0	0.50	1.50	1.342	2	0	0
32LAG	60	20	1.00	3.00	8.00	6.00	10	10	0.67	1.50	4.003			
42LAG	95	0	1.00	3.00	8.00	6.00	5	0	0.67	1.50	1.263	4	0	0
32LAG	60	20	1.00	3.00	8.00	6.00	10	10	0.67	1.50	22.704			
42LAG	95	0	1.00	3.00	8.00	6.00	5	0	0.67	1.50	2.594	6	0	0
32SSD	35	25	0.75	3.00	9.00	6.00	15	25	0.50	1.50	88.001			
42SSD	85	5	0.75	3.00	9.00	6.00	5	5	0.50	1.50	2.561	1	0	0
32SSD	35	25	0.75	3.00	9.00	6.00	15	25	0.50	1.50	24.002			
42SSD	85	5	0.75	3.00	9.00	6.00	5	5	0.50	1.50	1.942	1	0	0
32SSD	35	25	1.00	3.00	8.00	6.00	15	25	0.67	1.50	19.503			
42SSD	85	5	1.00	3.00	8.00	6.00	5	5	0.67	1.50	1.713	2	1	0
32SSD	35	25	1.00	3.00	8.00	6.00	15	25	0.67	1.50	15.504			
42SSD	85	5	1.00	3.00	8.00	6.00	5	5	0.67	1.50	1.514	4	2	0
32TF	25	15	0.75	3.00	9.00	6.00	30	30	0.50	1.50	137.001			
42TF	75	10	0.75	3.00	9.00	6.00	10	5	0.50	1.50	3.921	1	0	0
32TF	25	15	0.75	3.00	9.00	6.00	30	30	0.50	1.50	40.502			
42TF	75	10	0.75	3.00	9.00	6.00	10	5	0.50	1.50	2.272	1	1	0
32TF	25	15	1.00	3.00	8.00	6.00	30	30	0.67	1.50	33.003			
42TF	75	10	1.00	3.00	8.00	6.00	10	5	0.67	1.50	1.793	4	1	1
32TF	25	15	1.00	3.00	8.00	6.00	30	30	0.67	1.50	26.504			
42TF	75	10	1.00	3.00	8.00	6.00	10	5	0.67	1.50	1.424	6	2	1
32AS	15	15	0.75	3.00	9.00	6.00	10	60	0.50	1.50	134.001			
42AS	60	15	0.75	3.00	9.00	6.00	15	10	0.50	1.50	5.201	1	1	0
32AS	15	15	0.75	3.00	9.00	6.00	10	60	0.50	1.50	40.202			
42AS	60	15	0.75	3.00	9.00	6.00	15	10	0.50	1.50	3.522	2	1	0
32AS	15	15	1.00	3.00	8.00	6.00	10	60	0.67	1.50	32.003			
42AS	60	15	1.00	3.00	8.00	6.00	15	10	0.67	1.50	2.983	4	1	1
32AS	15	15	1.00	3.00	8.00	6.00	10	60	0.67	1.50	26.004			
42AS	60	15	1.00	3.00	8.00	6.00	15	10	0.67	1.50	2.524	8	2	2
33LAG	45	30	1.00	3.00	8.00	6.00	10	15	0.50	1.50	67.001			
43LAG	95	0	1.00	3.00	8.00	6.00	5	0	0.67	1.50	1.701	1	0	0
33LAG	45	30	1.00	3.00	8.00	6.00	10	15	0.67	1.50	6.002			
43LAG	95	0	1.00	3.00	8.00	6.00	5	0	0.67	1.50	1.342	2	0	0
33LAG	45	30	1.50	3.00	7.00	6.00	10	15	0.67	1.00	4.003			
43LAG	95	0	1.00	3.00	7.00	6.00	5	0	0.67	1.50	1.263	4	0	0
33LAG	45	30	1.50	3.00	6.00	6.00	10	15	1.00	1.00	22.704			
43LAG	95	0	1.00	3.00	6.00	6.00	5	0	0.67	1.50	2.594	6	0	0
33SSD	30	30	1.00	3.00	8.00	6.00	10	30	0.50	1.50	88.001			
43SSD	85	5	1.00	3.00	8.00	6.00	5	5	0.67	1.50	2.561	1	0	0
33SSD	30	30	1.00	3.00	8.00	6.00	10	30	0.67	1.50	24.002			
43SSD	85	5	1.00	3.00	8.00	6.00	5	5	0.67	1.50	1.942	1	0	0
33SSD	30	30	1.50	3.00	7.00	6.00	10	30	0.67	1.00	19.503			
43SSD	85	5	1.00	3.00	7.00	6.00	5	5	0.67	1.50	1.713	2	1	0
33SSD	30	30	1.50	3.00	6.00	6.00	10	30	1.00	1.00	15.504			
43SSD	85	5	1.00	3.00	6.00	6.00	5	5	0.67	1.50	1.524	4	2	0
33TF	20	20	1.00	3.00	8.00	6.00	20	40	0.50	1.50	137.001			
43TF	75	10	1.00	3.00	8.00	6.00	10	5	0.67	1.50	3.921	1	0	0
33TF	20	20	1.00	3.00	8.00	6.00	20	40	0.67	1.50	40.502			
43TF	75	10	1.00	3.00	8.00	6.00	10	5	0.67	1.50	2.272	1	1	0

APPENDIX A (Cont'd)

33TF	20	20	1.50	3.00	7.00	6.00	20	40	0.67	1.00	330.003			
43TF	75	10	1.00	3.00	7.00	6.00	10	5	0.67	1.50	1.793	4	1	1
33TF	20	20	1.50	3.00	6.00	6.00	20	40	1.00	1.00	26.504			
43TF	75	10	1.00	3.00	6.00	6.00	10	5	0.67	1.50	1.424	6	2	1
33AS	5	20	1.00	3.00	8.00	6.00	5	70	0.50	1.50	134.001			
43AS	60	20	1.00	3.00	8.00	6.00	15	5	0.67	1.50	5.201	1	1	0
33AS	5	20	1.00	3.00	8.00	6.00	5	70	0.67	1.50	40.002			
43AS	60	20	1.00	3.00	8.00	6.00	15	5	0.67	1.50	3.522	2	1	0
33AS	5	20	1.50	3.00	7.00	6.00	5	70	0.67	1.00	32.003			
43AS	60	20	1.00	3.00	7.00	6.00	15	5	0.67	1.50	2.983	4	1	1
33AS	5	20	1.50	3.00	6.00	6.00	5	70	1.00	1.00	26.004			
43AS	60	20	1.00	3.00	6.00	6.00	15	5	0.67	1.50	2.524	8	2	2

APPENDIX B

THE LDC WATER AND SEWAGE TREATMENT PLANNING DATA FORM

APPENDIX B The LDC water and sewage treatment planning data form

1. Location of Community

City Name ______________________________

State ______________________________

County ______________________________

2. Planning Group or Agency ______________________________________

3. Level of Education Obtained (Circle most appropriate level)

Level	None	Primary	High School	Technical Institute	College
1	95%	4%	1%	0%	0%
2	70%	19%	7%	3%	1%
3	55%	22%	14%	6%	3%
4	9%	34%	42%	8%	7%

4. Distribution of Labor Force (Circle most appropriate level)

Level	Unskilled	Semi-Skilled	Professional
1	97%	2%	1%
2	80%	16%	4%
3	61%	27%	12%
4	45%	30%	25%

5. Income Characteristics--Annual Average in U.S. dollars per Family (If Available)

   (Circle one)

   1. Less than $100 2. $100-$1,000 3. $1,000-$3,000

   4. Greater than $3,000

6. Percent of high-level manpower in both industry and government composed of non-indigenious workers

   1 Less than 10%
   2 10% - 25%
   3 25% - 50%
   4 50% - 75%
   5 75% - 100%

7. Are the primary and secondary schools operated by voluntary or missionary organizations?

   1 Yes 2 No

APPENDIX B (Cont'd)

8. What is the highest grade offered by local schools on a reguiar basis? (Circle one)

   1 2 3 4 5 6 7 8 9 10 11 12 12+

9. If the number selected in #8 above is less than 12, how far away is the nearest high school ofering the 12th grade?

   1. Less than 10 miles
   2. 10-30 miles
   3. 30-50 miles
   4. Greater than 50 miles.

10. Are there any technical or vocational schools in the community?

    1 Yes 2 No

11. Has the community achieved compulsory primary education of at least six years?

    1 Yes 2 No

12. Are there any formal in-service training programs by either the government or local industry for their employees?

    1 Yes 2 No

13. Is there a college or university in the community?

    1 Yes 2 No

14. Does the university have a chemistry department or laboratory?

    1 Yes 2 No

15. How do you rate the ability of the community to finance a water and sewage treatment project:

    1 Unable to repay--the project is a pure charity scheme because the beneficiaries are poor.

    2 Limited ability to repay--however, the social benefits exceed the social costs.

    3 Repayment prospects are good--the beneficiaries have comparatively high incomes.

16. Is unemployment widespread?

    1 Yes 2 No

APPENDIX B (Cont'd)

17. Are advisory services widely available to farmers for community development or for other programs designed to upgrade the skills and enlist the participation of the masses?

1 Yes 2 No

18. Do most college or university students of the community receive their education abroad or in neighboring communities?

1 Yes 2 No

19. The level of technology available can generally be classified as

1 Hand tools only
2 Mechanical tools (i.e., gasoline powered equipment)
3 Chemical Products (fertilizers, chlorine)
4 Electronic Technology

20. Does the government dominate the labor market?

1 Yes 2 No

21. Are public employment services readily available?

1 Yes 2 No

Questions 22-25 relate to the availability of materials and equipment. Circle those items that are never available in the Community.

22. Operation

1 Meters
2 Lawn mowers
3 Blowers
4 Recording devices
5 Laboratory equipment
6 Portable power plant
7 Motors
8 Pumps

23. Process

1 Pipe (clay, steel, cement, plastic, copper, etc.)
2 Pipe fittings
3 Paint
4 Valves
5 Tanks
6 Gauges
7 Heat exchangers

24. Operation and Maintenance

1 Silica sand
2 Graded gravel
3 Clean water
4 Gasoline

APPENDIX B (Cont'd)

25. Chemicals

1	Al_2SO_4 (aluminum sulfate)	5	Soda ash
2	$FeCl_2$ (ferric chloride)	6	Chlorine
3	Activated Charcoal	7	Ozone
4	Lime	8	Laboratory chemicals

26. Major Water Source: (Circle appropriate category)

1 River or stream
2 Lake or impoundment
3 Wells
4 Sea or brackish

27. Approximate per capita water demand (daily)

1 Current ____________________
2 10 year projection ____________________ __________ units

28. Is groundwater available?

1 Yes 2 No

29. Are wells already drilled?

1 Yes 2 No

30. Is a central wastewater collection system in existence?

1 Yes 2 No

31. Is the following wastewater data available?

Percent of people in the community:

1 Currently connected to the system ____________________

2 To be connected within 5 years of the start of the project ____________________

3 To be connected within 10 years ____________________

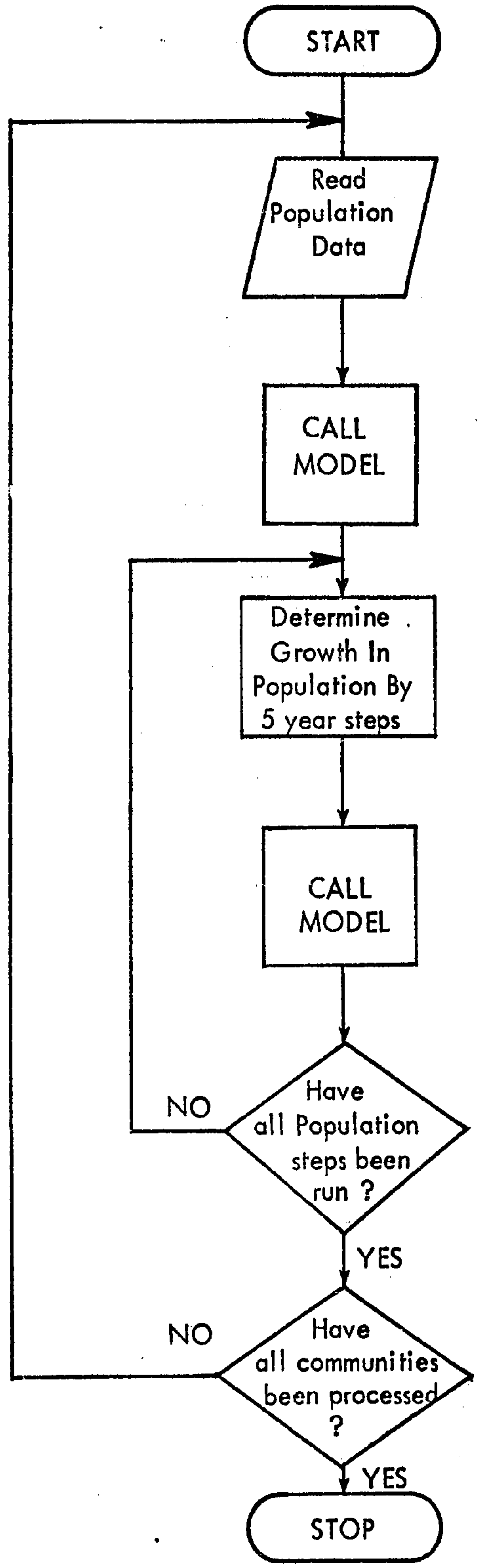
32. Are industrial and commercial conerns using the waste water system: (Thousands of gallons)

1 Currently ____________________
2 Within 5 years ____________________
3 Within 10 years ____________________

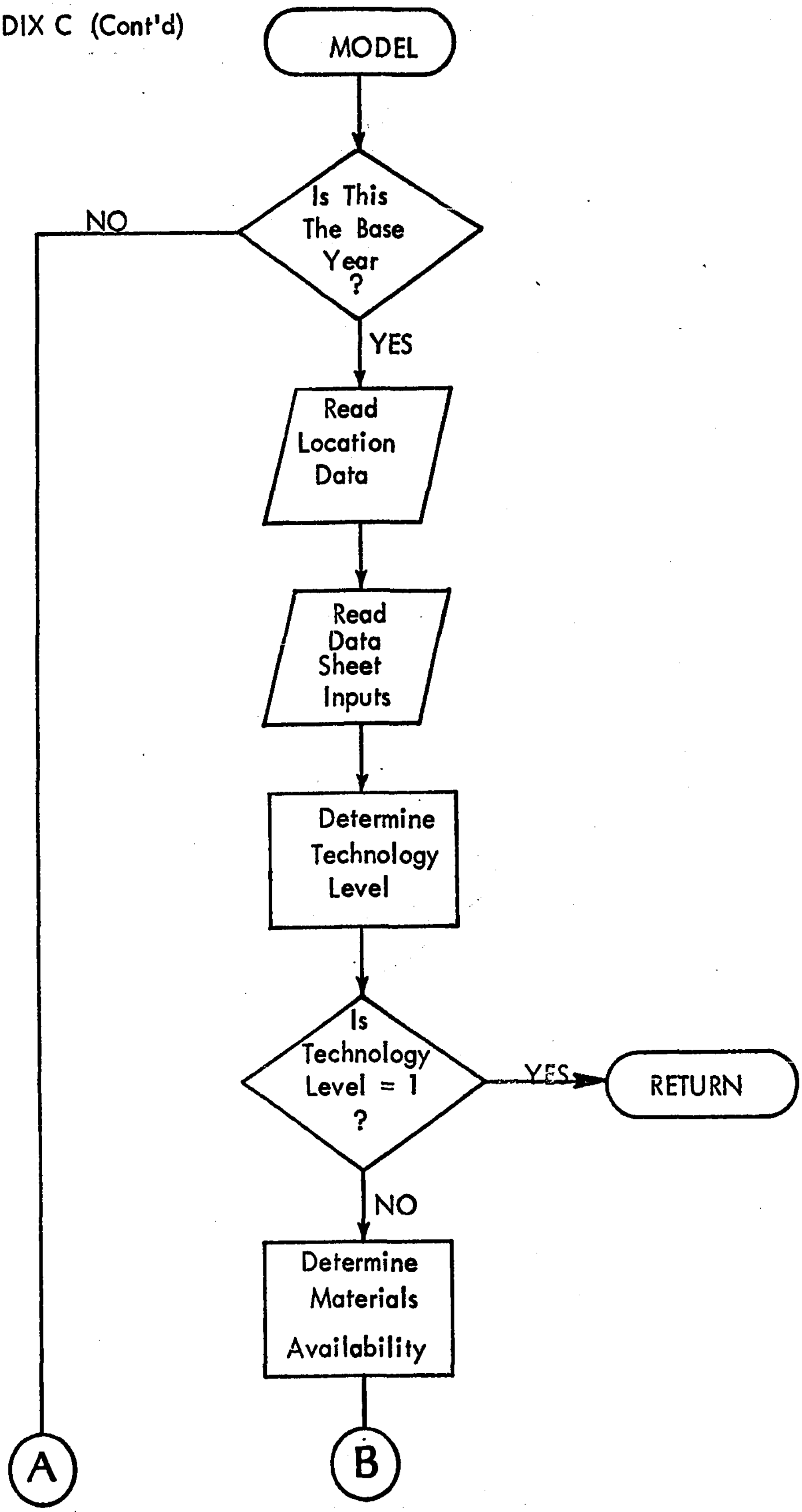
APPENDIX C

GENERAL FLOW CHART FOR THE WATER AND SEWAGE TREATMENT SELECTION MODEL

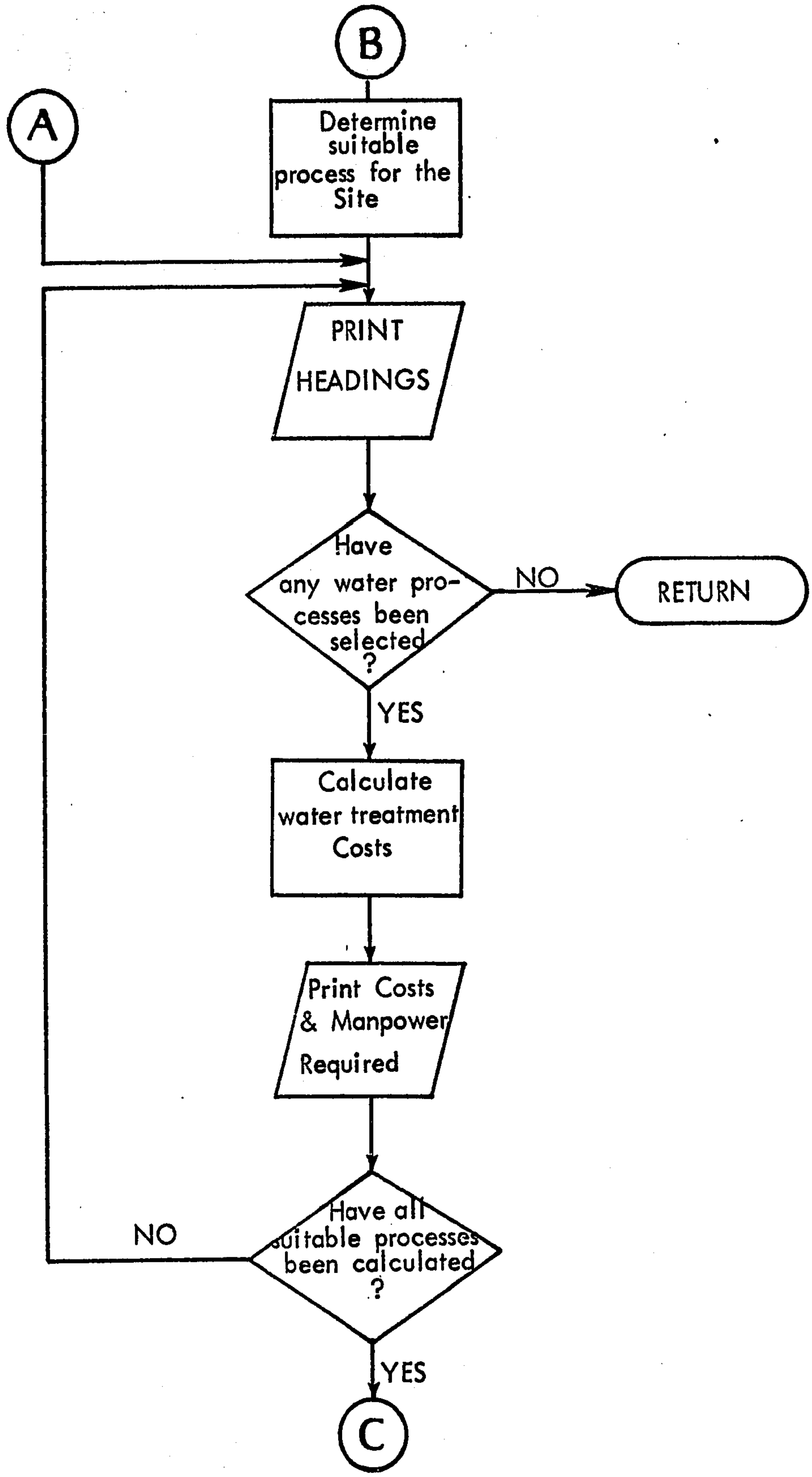
APPENDIX C General Flow Chart for the Water and Sewage Treatment Method Selection Model



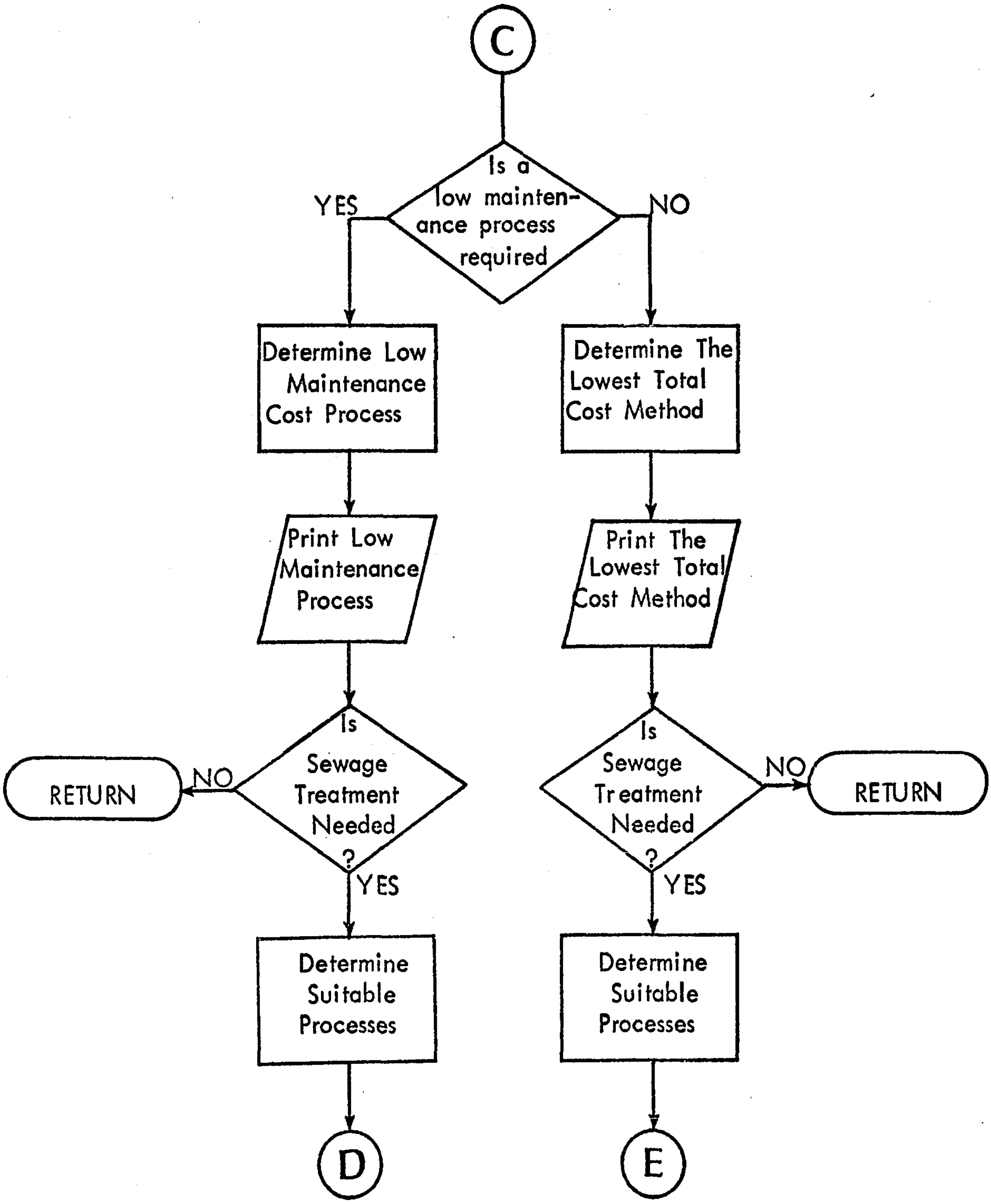
APPENDIX C (Cont'd)



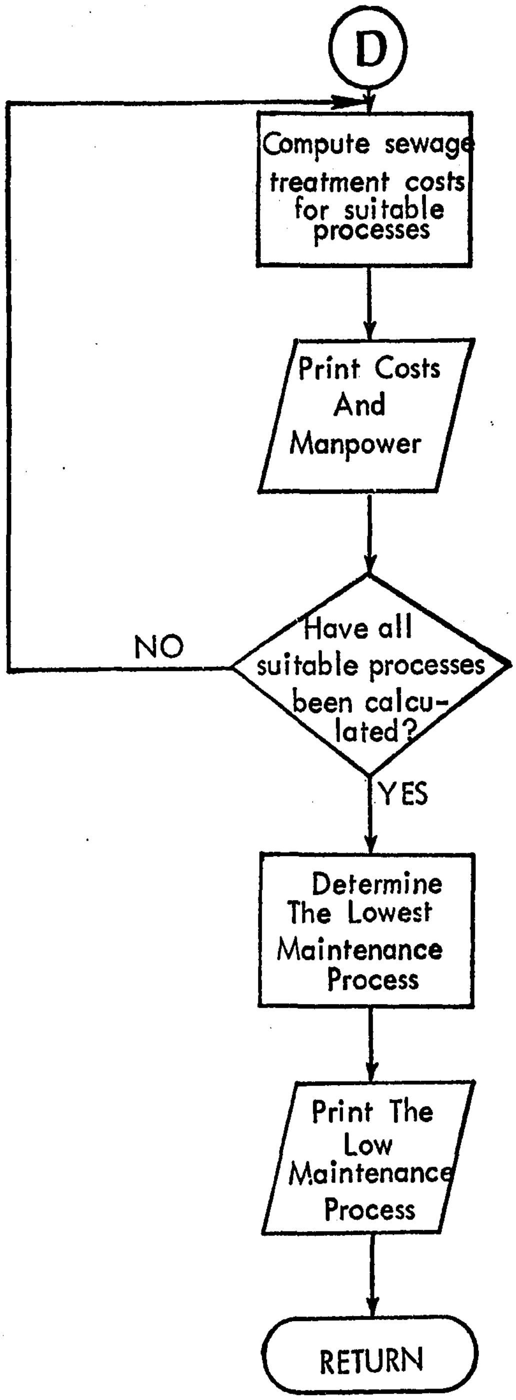
APPENDIX C (Cont'd)



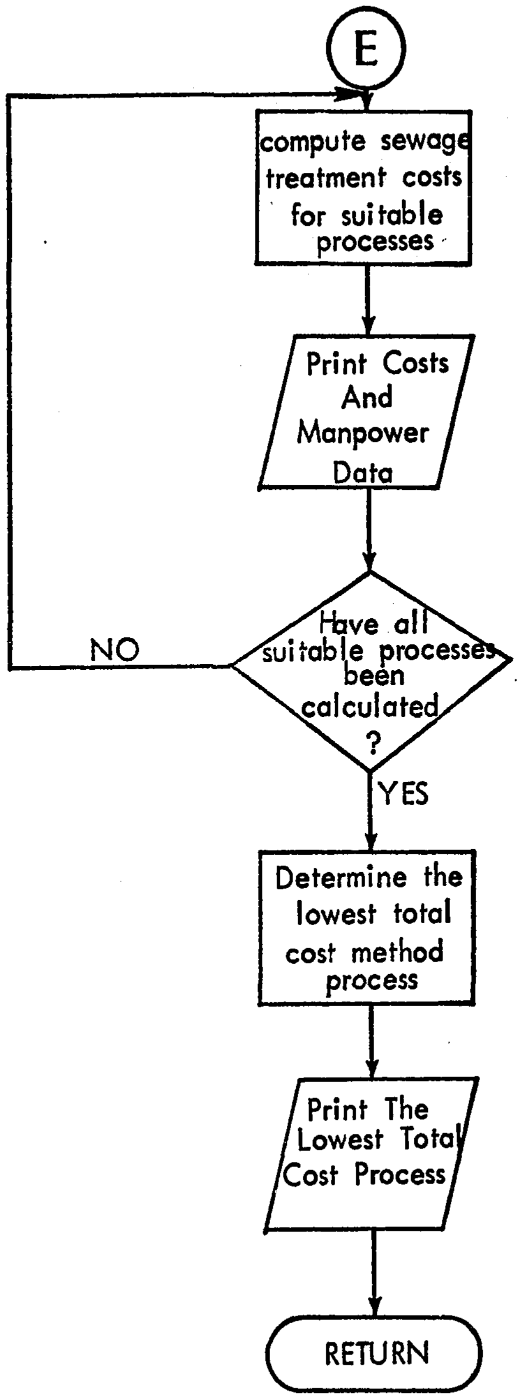
APPENDIX C (Cont'd)



APPENDIX C (Cont'd)



APPENDIX C (Cont'd)



APPENDIX D

FORTRAN SOURCE LISTING OF THE WATER AND WASTE WATER TREATMENT PROCESS SELECTION PLANNING MODEL

APPENDIX D

FORTRAN Source Listing of the Water and Waste Water Treatment Process Selection Planning Model

```
FORTRAN IV G LEVEL  21                    MAIN                DATE = 74175

                C      PROGRAM AIDMAIN
                C      WRITTEN BY RICHARD DISCENZA   MAY, 1974
                C      THIS PROGRAM SIMULATES THE DECISION MAKING PROCESS FOR THE
                C        SELECTION OF WATER AND SEWAGE TREATMENT METHODS FOR
                C        COMMUNITIES IN LESS DEVELOPED COUNTRIES
                C      THIS VERSION IS FOR THE IBM 370/OS FORTRAN IV  LEVEL G
 0001                  DIMENSION WORK(3)
 0002                  COMMON IYEAR,PP1,BASYR,LFT,JA
 0003                  INTEGER BACKYR,BASYR,PROJYR,CONYR
 0004               10 READ(5,200,END=999)K8,BACKYR,BASYR,PROJYR,CONYR,POP,
                      *SURV,BIRTH,PIM,PEM,(WORK(J),J=1,3),WFGR,WFP
 0005              200 FORMAT(I2,4I4,F6.0,2F3.1,2F4.2,3F6.0,F3.2,F4.2)
 0006                  JA = 0
 0007                  TOT=0.0
 0008                  DO 20 I=1,3
 0009            20    TOT=TOT+WORK(I)
 0010                  IYEAR=BASYR
 0011                  PP1 = POP
 0012                  LFT = 0
 0013                  CALL MODEL
 0014                  IP=PROJYR-5
 0015                  DO 40 I=BASYR,IP,5
 0016                  XKIDS=POP*BIRTH
 0017                  SVIV=SURV*POP
 0018                  XIM=PIM*POP
 0019                  XEM=PEM*POP
 0020                  POP=SVIV + XKIDS + XIM - XEM
 0021                  IYEAR=I+5
 0022                  ZZ=FLOAT(PROJYR-BASYR)
 0023                  XX=FLOAT(IYEAR-BASYR)
 0024                  RR=XX/ZZ
 0025                  TTT=0.0
 0026                  DO 35 J=1,3
 0027            35    TTT=TTT+WORK(J)
 0028                  WFP = WFP + WFGR
 0029                  DO 37 J=1,3
 0030            37    WORK(J)=WORK(J)*((POP * WFP)/TTT)
 0031                  PP1 = POP
 0032                  LFT = 1
 0033                  JA = JA + 5
 0034            40    CALL MODEL
 0035                  GO TO 10
 0036           999    STOP
 0037                  END
```

APPENDIX D (Cont'd)

FORTRAN IV G LEVEL 21 MODEL DATE = 74175

```
      SUBROUTINE MODEL
      COMMON IYEAR,PP1,BASYR,LFT,JA
      INTEGER PC,PS
      DOUBLE PRECISION X,R1,R2,R3,R4,R5,CT(5),C3,C1,C2,CS(5)
      DIMENSION CC(5),JW(5),M11(5),M22(5),M33(5)
      DIMENSION LL(60),LB(10),JP(10),CN(5),ST(5),COM(4),AG(5),
     *CW(4),PS(5)
      DATA RSF/3HRSF/,BK/1H /
      DATA LL/55*0/
      LOGICAL LA(10)
      LA(3) = .TRUE.
      LA(4) = .TRUE.
      LA(5) = .TRUE.
      LA(6) = .TRUE.
      LA(7) = .TRUE.
      JB = 0
      POP = 0.
      IF(LFT.EQ.1)GO TO 51
      READ(5,201)K7,CN,ST,COM,AG
  201 FORMAT(I2,5A4,5A4,4A4,5A4)
      READ(5,202)K8,   (LL(J),J=1,5),L2,(LL(J),J=7,47), L3,L4,LL(50),
     *LL(51),LL(52),L5,L6,L7,L8,L9,L10
  202 FORMAT(I2,5I1,I2,41I1.2I3.3I1.3I3.3I4)
C     LOC LEVEL OF TECHNOLOGY INDEX DETERMINATION
      IF(LL(1).EQ.0)GO TO 13
      IF(LL(1)-3)10,11,12
   10 JA=JA+5
      GO TO 13
   11 JA = JA + 10
      GO TO 13
   12 JA=JA+15
   13 IF (LL(2).EQ.0)GO TO 17
      IF(LL(2)-3)14,15,16
   14 JA=JA+5
      GO TO 17
   15 JA=JA+10
      GO TO 17
   16 JA=JA+15
   17 IF(LL(3).EQ.0)GO TO 21
      IF(LL(3)-3)18,19,20
   18 JA = JA + 5
      GO TO 21
   19 JA = JA + 10
      GO TO 21
   20 JA = JA + 15
C   QUESTION   6
   21 IF(LL(4).EQ.5)GO TO 27
      IF(LL(4)-2)22,23,24
   22 JA = JA + 4
      GO TO 27
   23 JA = JA + 3
      GO TO 27
```

APPENDIX D (Cont'd)

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```
      24 IF(LL(4)-4)26,25,27
      25 JA = JA + 1
         GO TO 27
      26 JA = JA + 2
C     QUESTION   7
      27 IF (LL(5).EQ.1)GO TO 28
         JA = JA + 5
      28 IF(L2.EQ.0)GO TO 33
         IF(L2.LE.6.AND.L2.GE.1) GO TO 30
         IF(L2.LE.10.AND.L2.GE.7)GO TO 31
         IF(L2.LE.12.AND.L2.GE.11)GO TO 32
         JA = JA + 10
         GO TO 33
      30 JA = JA + 2
         GO TO 33
      31 JA = JA + 4
         GO TO 33
      32 JA = JA + 7
C       QUESTION   9
      33 IF(LL(7).EQ.4.OR.LL(7).EQ.BK)GO TO 37
         IF(LL(7)-2)34,35,36
      34 JA = JA + 3
         GO TO 37
      35 JA = JA + 2
         GO TO 37
      36 JA = JA + 1
C      QUESTION   10
      37 IF(LL(8).EQ.2)GO TO 38
         JA = JA + 5
      38 IF(LL(9).EQ.2)GO TO 39
         JA = JA + 10
C      QUESTION   12
      39 IF(LL(10).EQ.2)GO TO 40
         JA = JA + 5
      40 IF(LL(11).EQ.2)GO TO 41
         JA = JA + 10
      41 IF(LL(12).EQ.2)GO TO 42
         JA = JA + 3
C      QUESTION   16
      42 IF(LL(14).EQ.1)GO TO 43
         JA = JA + 5
C     QUESTION   17
      43 IF(LL(15).EQ.1)GO TO 44
         JA = JA + 3
      44 IF (LL(16).EQ.1)GO TO 45
         JA = JA + 3
C     QUESTION   19
      45 IF(LL(17).EQ.1)GO TO 49
         IF(LL(17)-3)46,47,48
      46 JA = JA + 5
         GO TO 49
      47 JA = JA + 10
```

APPENDIX D (Cont'd)

```
FORTRAN IV G LEVEL  21                    MODEL                DATE = 74175

              GO TO 49
           48 JA = JA + 15
           49 IF(LL(18).EQ.1)GO TO 50
              JA = JA + 10
C  QUESTION   21
           50 IF(LL(19).EQ.2)GO TO 51
              JA = JA + 5
              IF(LL(47).EQ.4)GO TO 100
C  COMPUTE THE LEVEL OF TECHNOLOGY FOR THE COMMUNITY
           51 WRITE(6,251)CN,ST,COM,AG,BASYR
          251 FORMAT(1H1/,25X,'THE LDC WATER AND SEWAGE TREATMENT PLANNING MODEL
             2   '////,25X,'FOR THE COMMUNITY ',20X,5A4,//,25X,'IN THE STATE OR
             *PROVINCE OF',10X,5A4,//,25X,'IN THE COUNTRY OF',20X,4A4,//,25X,'FO
             *R THE PLANNING GROUP',20X,5A4,5X,'BASE YEAR = ',I4)
              IF(JA.GT.93)GO TO 52
              IF(JA.GT.51)GO TO 53
              IF(JA.GT.23)GO TO 54
              LB(2) = 1
              GO TO 103
           52 LB(2) = 3
              GO TO 56
           53 LB(2) = 3
              GO TO 55
           54 LB(2) = 2
              GO TO 64
C  LEVEL 3 WITH 50,000+ POPULATION AND LEVEL 4
           55 IF(PP1.LT.50000)GO TO 64
           56 JB = 0
              DO 57 J = 28,34
              IF(LL(J).EQ.0)GO TO 57
              JB = JB + 1
           57 CONTINUE
              IF(JB.GE.3)GO TO 58
              GO TO 60
           58 IF(LL(50).EQ.1)GO TO 59
C    NO SAND AND NO GROUNDWATER
              JP(2) = 9
              JP(3) = 9
              GO TO 100
           59 JP(1) = 9
              JP(2) = 9
              JP(3) = 9
              GO TO 100
C    SAND AND NO GROUNDWATER        LEVEL 4
           60 IF(LL(50).EQ.1)GO TO 62
              DO 61 J = 2,5
              JP(J) = 9
           61 CONTINUE
              GO TO 100
C   SAND AND GROUNDWATER     LEVEL 4
           62 DO 63 J = 1,5
              JP(J) = 9
```

APPENDIX D (Cont'd)

```
FORTRAN IV G LEVEL  21                    MODEL               DATE = 74175

      63 CONTINUE
         GO TO 100
C     LEVEL 2 AND LEVEL 3 UNDER 50,000 POPULATION
C       COMPUTE LAB. EQUIPMENT AVAILABILITY
      64 JB = 0
         DO 65 J = 20,27
         IF(LL(J).EQ.0)GO TO 65
         JB = JB + 1
      65 CONTINUE
         IF(JB.GE.4)GO TO 70
C     COMPUTE VALVES AVAILABILITY
      71 JB = 0
         DO 66 J = 28,34
         IF(LL(J).EQ.0)GO TO 66
         JB = JB + 1
      66 CONTINUE
         IF(JB.GE.3)GO TO 72
C        COMPUTE SAND AVAILABILITY
      73 JB = 0
         DO 67 J = 28,34
         IF(LL(J).EQ.0)GO TO 67
          JB = JB + 1
      67 CONTINUE
         IF(JB.GE.3)GO TO 74
C       COMPUTE CHEMICALS AVAILABILITY
      75 JB = 0
         DO 68 J = 39,46
         IF(LL(J).EQ.0)GO TO 68
         JB = JB + 1
      68 CONTINUE
         IF(JB.GE.4)GO TO 76
C     CHECK FOR GROUNDWATER AVAILABILITY
      77 IF(LL(50).EQ.2)GO TO 78
         GO TO 69
C     MATERIALS AVAILABILITY REGISTER
      70 LA(3) = .FALSE.
         GO TO 71
      72 LA(4) = .FALSE.
         GO TO 73
      74 LA(5) =.FALSE.
         GO TO 75
      76 LA(6) = .FALSE.
         GO TO 77
      78 LA(7) = .FALSE.
C THE DETERMINATION OF SUITABLE PROCESSES
      69 IF(LA(3).AND.LA(4).AND.LA(5).AND.LA(6).AND.LA(7))GO TO 62
         IF(LA(3).AND.LA(4).AND.LA(5).AND.LA(6).AND..NOT.LA(7))GO TO 79
         IF(LA(3).AND.LA(4).AND.LA(5).AND..NOT.LA(6).AND.LA(7))GO TO 81
         IF(LA(3).AND.LA(4).AND.LA(5).AND..NOT.LA(6).AND..NOT.LA(7))GO TO
        *82
         IF(LA(3).AND.LA(4).AND..NOT.LA(5).AND.LA(6).AND.LA(7))GO TO 83
         IF(LA(3).AND.LA(4).AND..NOT.LA(5).AND.LA(6).AND..NOT.LA(7))GO TO
```

APPENDIX D (Cont'd)


```
     *84
      IF(LA(3).AND.LA(4).AND..NOT.LA(5).AND..NOT.LA(6).AND.LA(7))GO TO
     *85
      IF(LA(3).AND.LA(4).AND..NOT.LA(5).AND..NOT.LA(6).AND..NOT.LA(7))GO
     * TO 86
      IF(LA(3).AND..NOT.LA(4).AND.LA(6).AND.LA(7))GO TO 87
      IF(LA(3).AND..NOT.LA(4).AND.LA(6).AND..NOT.LA(7))GO TO 100
      IF(LA(3).AND..NOT.LA(4).AND..NOT.LA(6).AND.LA(7))GO TO 87
      IF(LA(3).AND..NOT.LA(4).AND..NOT.LA(6).AND..NOT.LA(7))GO TO 100
      IF(.NOT.LA(3).AND.LA(4).AND.LA(5).AND.LA(6).AND.LA(7))GO TO 88
      IF(.NOT.LA(3).AND.LA(4).AND.LA(5).AND.LA(6).AND..NOT.LA(7))GO TO
     *89
      IF(.NOT.LA(3).AND.LA(4).AND.LA(5).AND..NOT.LA(6).AND.LA(7))GO TO
     *81
      IF(.NOT.LA(3).AND.LA(4).AND.LA(5).AND..NOT.LA(6).AND..NOT.LA(7))GO
     * TO 88
      IF(.NOT.LA(3).AND.LA(4).AND..NOT.LA(5).AND.LA(6).AND.LA(7))GO TO
     183
      IF(.NOT.LA(3).AND.LA(4).AND..NOT.LA(5).AND..NOT.LA(6).AND..NOT.LA(
     *7))GO TO 84
      IF(.NOT.LA(3).AND.LA(4).AND..NOT.LA(5).AND..NOT.LA(6).AND.LA(7))GO
     * TO 85
      IF(.NOT.LA(3).AND.LA(4).AND..NOT.LA(5).AND..NOT.LA(8).AND..NOT.LA(
     $7))GO TO 86
      IF(.NOT.LA(3).AND..NOT.LA(4).AND.LA(5).AND.LA(6).AND.LA(7))GO TO 8
     *7
      IF(.NOT.LA(3).AND..NOT.LA(4).AND.LA(5).AND.LA(6).AND..NOT.LA(7))GO
     * TO 100
      IF(.NOT.LA(3).AND..NOT.LA(4).AND.LA(5).AND..NOT.LA(6).AND.LA(7))GO
     * TO 87
      IF(.NOT.LA(3).AND..NOT.LA(4).AND.LA(5).AND..NOT.LA(6).AND..NOT.LA(
     *7))GO TO 100
      IF(.NOT.LA(3).AND..NOT.LA(4).AND..NOT.LA(5).AND.LA(6).AND.LA(7))GO
     1 TO 87
      IF(.NOT.LA(3).AND..NOT. LA(4).AND..NOT.LA(5).AND.LA(6).AND..NOT.LA
     1(7))GO TO 100
      IF(LA(7))GO TO 87
   79 DO 80 J = 2,5
      JP(J) = 9
   80 CONTINUE
      GO TO 100
   81 JP(4) = 9
   85 JP(3) = 9
      JP(1) = 9
       GO TO 100
   82 JP(4) = 9
   86 JP(3) = 9
      GO TO 100
   83 JP(3) = 9
      JP(2) = 9
   87 JP(1) = 9
      GO TO 100
```

APPENDIX D (Cont'd)

```
FORTRAN IV G LEVEL  21                  MODEL              DATE = 74175

            84 JP(3) = 9
               JP(2) = 9
               GO TO 100
            88 JP(4) = 9
               GO TO 83
            89 JP(2) = 9
               GO TO 82
C COMPUTE THE TOTAL COST OF THE VARIOUS PROCESSES
   100 WRITE(6,400)IYEAR
   400 FORMAT('-','****** SUITABLE WATER TREATMENT PROCESSES FOR ',
      *' IMPLEMENTATION IN...',I4,'******')
       WRITE(6,401)
   401 FORMAT(' ',25X,'INITIAL',9X,'YEARLY',9X'TOTAL',8X,'REQUIRED',
      *24X,'PLANT')
       WRITE(6,402)
   402 FORMAT(6X,'PROCESS',8X,'CONSTRUCTION',6X,'MAINTENANCE',7X,
      *'COST',9X,'MANPOWER',6X,'POPULATION',10X,'SCALE')
       WRITE(6,403)
   403 FORMAT(8X,'NAME',10X,'COST(U.S.$)',5X,'COST(U.S.$)',6X,
      *'20 YEARS',2X,' USKIL SKIL PROF ',4X,'SERVED',9X,'U.S.GALLONS')
       JZ = 0
       DO 101 J = 1,5
       IF (JP(J).NE.9)GO TO 101
       JZ = JZ + 1
   101 CONTINUE
       IF(JZ.EQ.0)GO TO 103
C  SCALE CONVERSION FACTORS
C NOTE THAT THE SCALE FACTOR IS THE SAME AS THE POP BECAUSE 100 GALLONS
       LH = LB(2)
       GO TO(90,91,92,109),LH
    90 POP =.25  * PP1
       GO TO 109
    91 POP = .50 * PP1
       GO TO  109
    92 POP = .75 * PP1
C POPULATION GROUP DETERMINATION STORED IN LD
   109 IF(POP.GE.125.AND.POP.LT.2500)GO TO 110
       IF(POP.GE.2500.AND.POP.LT.15000)GO TO 111
       IF(POP.GE.15000.AND.POP.LT.50000)GO TO 112
       IF(POP.GE.50000.AND.POP.LT.100001)GO TO 113
       WRITE (6,207)
   207 FORMAT(1H-,20X, '  THE POPULATION PARAMETERS GIVEN DO NOT FIT THE
      * MODEL')
       GO TO 998
   103  WRITE(6,208)
   208 FORMAT(1H-,'NO WATER TREATMENT PROCESSES HAVE BEEN SELECTED')
       GO TO 998
   104 WRITE(6,307)
   307 FORMAT(1H-,10X,'NO WASTE TREATMENT PROCESSES HAVE BEEN SELECTED')
       GO TO 998
   110 LD = 1
       GO TO 114
```

APPENDIX D (Cont'd)

```
FORTRAN IV G LEVEL  21                    MODEL                DATE = 74175

0259          111 LC = 3
0260              GO TO 114
0261          112 LD = 5
0262              GO TO 114
0263          113 LD = 7
0264          114 IF(LB(2).EQ.1)GO TO 118
0265              LE = 40* (LB(2)-1)
            C THIS DO LOOP BRINGS US TO THE APPROPRIATE LEVEL
0266              DO 115 M = 1,LE
            C AT THIS POINT WE KNOW BOTH POP AND TECH LEVEL
0267              READ(1,203)K9,LX,P,X11,X12,X21,X22,X31,X32,X41,X42,X51,X52,C,PC,
                 *M1,M2,M3
0268          203 FORMAT(I2,I1,A3,2F3.0,4F5.2,2F3.0,2F5.2,F6.2,I1,3I2)
0269          115 CONTINUE
0270          118 DO 123 K = 1,5
0271              IF(JP(K).EQ.9)GO TO 120
0272              DO 119 J1 = 1,8
0273              READ(1,203)K9,LX,P,X11,X12,X21,X22,X31,X32,X41,X42,X51,X52,C,PC,
                 *M1,M2,M3
0274          119 CONTINUE
0275              CT(K) = 10.0**20
0276              CS(K) = 10.0**20
0277              GO TO 123
0278          120 DO 121 J = 1, LD
0279              READ(1,203)K9,LX,P,X11,X12,X21,X22,X31,X32,X41,X42,X51,X52,C,PC,
                 *M1,M2,M3
0280          121 CONTINUE
            C NOW AT THE CORRECT POPULATION AND TECHNOLOGY LEVELS
            C    CALCULATION OF THE CONSTRUCTION COST FOR THE SELECTED PROCESSES
0281              X11 = X11 * .01
0282              X12 = X12 * .01
0283              X41 = X41 * .01
0284              X42 = X42 * .01
0285              C = C * POP
0286              C1 = C*((X11*X21/X22) + (X12* X31/X32) + (X41*X51) + (X42*X52))
            C    NEXT MAINTENANCE COSTS ON  YEARLY BASIS
0287              READ(1,203)K9,LX,P,X11,X12,X21,X22,X31,X32,X41,X42,X51,X52,C,PC,
                 *M1,M2,M3
0288              X11 = X11 * .01
0289              X12 = X12 * .01
0290              X41 = X41 * .01
0291              X42 = X42 * .01
0292              C = C * POP
0293              C2 = C*((X11*X21/X22) + (X12* X31/X32) + (X41*X51) + (X42*X52))
0294              C3 = C1 + (C2*20.)
0295              CC(K) = C1
0296              CS(K) = C2
0297              M11(K) = M1
0298              M22(K) = M2
0299              M33(K) = M3
0300              CT(K) = C3
0301              PS(K) =  P
```

APPENDIX D (Cont'd)

```
FORTRAN IV G LEVEL  21                    MODEL               DATE = 74175

0302              WRITE(6,261)P,C1,C2,C3,M1,M2,M3
0303          261 FORMAT(1H0, 3X,A3,10X,F15.2, 1X,F13.2, 3X,F15.2,2X,I2,3X,I2,3X,I2)
0304              IF (LD.EQ.7)GO TO 122
0305              LZ = 7 - LD
0306              DO 122 J = 1,LZ
0307              READ(1,203)K9,LX,P,X11,X12,X21,X22,X31,X32,X41,X42,X51,X52,C,PC,
                 *M1,M2,M3
0308          122 CONTINUE
0309          123 CONTINUE
            C CHECK FOR LOW MAINTENANCE REQUIREMENT
0310              IF(LL(13).EQ.2)GO TO 130
            C  CALCULATION OF THE LOWEST TOTAL COST METHOD
0311              WRITE(6,204)
0312          204 FORMAT(1H-,10X,'THE LOWEST TOTAL COST WATER TREATMENT'
                 *' PROCESS IS THE FOLLOWING')
            C  DETERMINATION OF THE LOWEST TOTAL COST PROCESS
0313              R1 = CT(1)
0314              R2 = CT(2)
0315              R3 = CT(3)
0316              R4 = CT(4)
0317              R5 = CT(5)
0318              GAL = POP * 100.
0319              X = DMIN1(R1, R2, R3, R4, R5)
0320              IF(R1.EQ.X) GO TO 125
0321              IF(R2.EQ.X) GO TO 126
0322              IF(R3.EQ.X) GO TO 127
0323              IF(R4.EQ.X) GO TO 128
0324              IF(R5.EQ.X) GO TO 129
0325          125 WRITE(6,211)CC(1),CS(1),CT(1),M11(1),M22(1),M33(1),PP1,GAL
0326          211 FORMAT(1H-,'DRILLED WELL         ','$',F12.2,'  $',F10.2,'  $',
                 *F15.2,3X,I2,3X,I2,3X,I2,5X,F9.0,5X,F16.0)
0327              GO TO 140
0328          126 WRITE(6,212)CC(2),CS(2),CT(2),M11(2),M22(2),M33(2),PP1,GAL
0329          212 FORMAT(1H-,'DISINFECTION         ','$',F12.2,'  $',F10.2,'  $',
                 *F15.2,3X,I2,3X,I2,3X,I2,5X,F9.0,5X,F16.0)
0330              GO TO 140
0331          127 WRITE(6,213)CC(3),CS(3),CT(3),M11(3),M22(3),M33(3),PP1,GAL
0332          213 FORMAT(1H-,'SETTLING TANK        ','$',F12.2,'  $',F10.2,'  $',
                 *F15.2,3X,I2,3X,I2,3X,I2,5X,F9.0,5X,F16.0)
0333              GO TO 140
0334          128 WRITE(6,214)CC(4),CS(4),CT(4),M11(4),M22(4),M33(4),PP1,GAL
0335          214 FORMAT(1H-,'SLOW SAND FILTER     ','$',F12.2,'  $',F10.2,'  $',
                 *F15.2,3X,I2,3X,I2,3X,I2,5X,F9.0,2X,F16.0)
0336              GO TO 140
0337          129 WRITE(6,215)CC(5),CS(5),CT(5),M11(5),M22(5),M33(5),PP1,GAL
0338          215 FORMAT(1H-,'RAPID SAND FILTER    ','$',F12.2,'  $',F10.2,'  $',
                 *F15.2,3X,I2,3X,I2,3X,I2,5X,F9.0,5X,F16.0)
0339              GO TO 140
0340          130 WRITE(6,205)
0341          205 FORMAT(1H0,20X,'THE LOWEST MAINTENANCE COST PROCESS IS THE FOLLOWI
                 *NG')
            C  LOW MAINTENANCE REQUIREMENT CALCULATIONS
```

APPENDIX D (Cont'd)

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FORTRAN IV G LEVEL  21                    MODEL                DATE = 74175

0342              R1 = CS(1)
0343              R2 = CS(2)
0344              R3 = CS(3)
0345              R4 = CS (4)
0346              R5 = CS (5)
0347              X = DMIN1(R1, R2, R3, R4, R5)
0348              IF(R1.EQ.X) GO TO 125
0349              IF(R2.EQ.X) GO TO 126
0350              IF(R3.EQ.X) GO TO 127
0351              IF(R4.EQ.X) GO TO 128
0352              IF(R5.EQ.X) GO TO 129
           C  NOW THE MODEL CONSIDERS  WASTE WATER TREATMENT
           C   A CHECK FOR A CENTRAL WASTE WATER COLLECTION SYSTEM
0353          140 IF(LL(52).EQ.2)GO TO 998
           C  READ THE REMAINDER OF THE WATER TREATMENT INPUT DATA
0354          146 IF(K9.EQ.02.AND.P.EQ.RSF.AND.PC.EQ.4)GO TO 147
0355              READ(1,203)K9,LX,P,X11,X12,X21,X22,X31,X32,X41,X42,X51,X52,C,PC,
                 *M1,M2,M3
0356              GO TO 146
           C THE DETERMINATION OF THE SUITABLE PROCESSES
0357          147 GO TO(148,153,150,151),LH
0358          148 WRITE(6,220)
0359          220 FORMAT(1H0,10X,'WASTE WATER TREATMENT NOT RECOMMENDED BECAUSE OF
                 *THE TECHNOLOGY LEVEL')
0360              GO TO 998
0361          150 IF(PP1.LT.50000)GO TO 153
           C COMPUTE ALL PROCESSES
0362          151 DO 152 J = 1,4
0363              JW(J) = 9
0364          152 CONTINUE
0365              GO TO 156
           C  LEVEL 2 AND LEVEL 3 UNDER 50,000 POPULATION
0366          153 IF(.NOT.LA(4))GO TO 104
0367              IF(LA(4).AND..NOT.LA(6))GO TO 154
0368              IF(LA(4).AND.LA(6).AND..NOT.LA(3))GO TO 155
0369              GO TO 151
0370          154 JW(1) = 9
0371              JW(2) = 9
0372              GO TO 156
0373          155 JW(3) = 9
0374              GO TO 154
           C  COMPUTE THE TOTAL COST FOR THE WASTE WATER PROCESSES
           C  ASSUMES AT LEAST 1 PROCESS HAS BEEN SELECTED
0375          156 WRITE(6,221)IYEAR
0376          221 FORMAT(1H-,'****** SUITABLE WASTE WATER TREATMENT PROCESSES',
                 *' FOR IMPLEMENTATION IN...',I4,' ******')
0377              IF (LB(2).EQ.1)GO TO 318
0378              LE = 32 * (LB(2) -1)
           C THIS DO LOOP BRINGS US TO THE APPROPRIATE LEVEL
0379              DO 315 M = 1,LE
           C AT THIS POINT WE KNOW BOTH POP AND TECH LEVEL
0380              READ(1,203)K9,LX,P,X11,X12,X21,X22,X31,X32,X41,X42,X51,X52,C,PC,
```

APPENDIX D (Cont'd)


```
           *M1,M2,M3
     315 CONTINUE
     318 DO 323 K = 1,4
         IF(JW(K).EQ.9)GO TO 320
         DO 319 J1 = 1,8
         READ(1,203)K9,LX,P,X11,X12,X21,X22,X31,X32,X41,X42,X51,X52,C,PC,
        *M1,M2,M3
     319 CONTINUE
         CS(K) = 10.0**20
         CT(K) = 10.0**20
         GO TO 323
     320 DO 321 J = 1, LD
         READ(1,203)K9,LX,P,X11,X12,X21,X22,X31,X32,X41,X42,X51,X52,C,PC,
        *M1,M2,M3
     321 CONTINUE
C NOW AT THE CORRECT POPULATION AND TECHNOLOGY LEVELS
C      CALCULATION OF THE CONSTRUCTION COST FOR THE SELECTED PROCESSES
         X11 = X11 * .01
         X12 = X12 * .01
         X41 = X41 * .01
         X42 = X42 * .01
         C = C * POP
         C1 = C*((X11*X21/X22) + (X12* X31/X32) + (X41*X51) + (X42*X52))
C      NEXT MAINTENANCE COSTS ON  YEARLY BASIS
         READ(1,203)K9,LX,P,X11,X12,X21,X22,X31,X32,X41,X42,X51,X52,C,PC,
        *M1,M2,M3
         X11 = X11 * .01
         X12 = X12 * .01
         X41 = X41 * .01
         X42 = X42 * .01
         C = C * POP
         C2 = C*((X11*X21/X22) + (X12* X31/X32) + (X41*X51) + (X42*X52))
         C3 = C1 + (C2*20.)
         CC(K) = C1
         CS(K) = C2
         M11(K) = M1
         M22(K) = M2
         M33(K) = M3
         CT(K) = C3
         PS(K) =  P
         WRITE(6,261)P,C1,C2,C3,M1,M2,M3
         IF (LD.EQ.7)GO TO 322
         LZ = 7 - LD
         DO 322 J = 1,LZ
         READ(1,203)K9,LX,P,X11,X12,X21,X22,X31,X32,X41,X42,X51,X52,C,PC,
        *M1,M2,M3
     322 CONTINUE
     323 CONTINUE
C CHECK FOR LOW MAINTENANCE REQUIREMENT
         IF(LL(13).EQ.2)GO TO 330
C  CALCULATION OF THE LOWEST TOTAL COST METHOD
         WRITE(6,204)
```

APPENDIX D (Cont'd)

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FORTRAN IV G LEVEL  21                MODEL               DATE = 74175

C  DETERMINATION OF THE LOWEST TOTAL COST PROCESS
      R1 = CT(1)
      R2 = CT(2)
      R3 = CT(3)
      R4 = CT(4)
      X = CMIN1(R1,R2,R3,R4)
      IF(R1.EQ.X) GO TO 325
      IF(R2.EQ.X) GO TO 326
      IF(R3.EQ.X) GO TO 327
      IF(R4.EQ.X) GO TO 328
  325 WRITE(6,216)CC(1),CS(1),CT(1),M11(1),M22(1),M33(1),PP1,GAL
  216 FORMAT(1H-,'OXIDATION POND      ','$',F12.2,'  $',F10.2,'   $',
     *F15.2,3X,I2,3X,I2,3X,I2,5X,F9.0,5X,F16.0)
      GO TO 340
  326 WRITE(6,217)CC(2),CS(2),CT(2),M11(2),M22(2),M33(2),PP1,GAL
  217 FORMAT(1H-,'PRIMARY SEDIMENTATON','$',F12.2,'  $',F10.2,'   $',
     *F15.2,3X,I2,3X,I2,3X,I2,5X,F9.0,5X,F16.0)
      GO TO 340
  327 WRITE(6,218)CC(3),CS(3),CT(3),M11(3),M22(3),M33(3),PP1,GAL
  218 FORMAT(1H-,'TRICKLING FILTER    ','$',F12.2,'  $',F10.2,'   $',
     *F15.2,3X,I2,3X,I2,3X,I2,5X,F9.0,5X,F16.0)
      GO TO 340
  328 WRITE(6,219)CC(4),CS(4),CT(4),M11(4),M22(4),M33(4),PP1,GAL
  219 FORMAT(1H-,'ACTIVATED SLUDGE    ','$',F12.2,'  $',F10.2,'   $',
     *F15.2,3X,I2,3X,I2,3X,I2,5X,F9.0,5X,F16.0)
      GO TO 340
  330 WRITE(6,305)
  305 FORMAT(1H0,20X,'THE LOWEST MAINTENANCE COST PROCESS IS THE FOLLOWI
     *NG')
C  LOW MAINTENANCE REQUIREMENT CALCULATIONS
      R1 = CS(1)
      R2 = CS(2)
      R3 = CS(3)
      R4 = CS (4)
      X = CMIN1(R1,R2,R3,R4)
      IF(R1.EQ.X) GO TO 325
      IF(R2.EQ.X) GO TO 326
      IF(R3.EQ.X) GO TO 327
      IF(R4.EQ.X) GO TO 328
  340 CONTINUE
  998 CONTINUE
      REWIND 1
      RETURN
      END
```