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LOWER COST METHODS OF WATER AND WASTE TREATMENT IN LESS DEVELOPED COUNTRIES

FIRST ANNUAL REPORT

Submitted to

Office of Health
Agency for International Development
Department of State
Washington, D.C. 70523

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From

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May 31, 1974

REPORT SUMMARY

A. 1. Project Title: LOWER COST METHODS OF WATER AND WASTE TREATMENT IN LESS DEVELOPED COUNTRIES

Contract Number: AID/CM/TA-C-73-13

2. Principal Investigator: Professor George W. Reid

Contractor: Office of Research Administration, University of Oklahoma
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3. Contract Period: from 3/1/73 to 12/31/75

4. Period covered by Report: 3/1/73 to 5/31/74

5. Total AID Funding of contract to date: $148,000

6. Total expenditures and obligations through previous contract year: $59,339

7. Total expenditures and obligations for current year: $59,339

8. Estimated expenditures for next contract year: $160,000

B. Narrative Summary of Accomplishments and Utilization

In relation to the research objectives, the following accomplishments have been made during the report period and life of the project:

1. The detailed site matrices are complete and operational
2. The resources model is complete, computerized and operational
3. The process and cost matrices are complete
4. The data formatting is complete and arrangements have been made with the IRC to locate unpublished and innovative material relevant to LDC water and wastewater treatment
5. Initial field trips to Latin America, Europe, the Near East, Africa, and the Far East have been completed. The global study of sites representative of appropriate water and sewage treatment processes is underway. A subcontract with CEPIS has been made and tentative contracts in Turkey, Lebanon and Africa have been drawn up. Site selections are being determined in the Far East.
6. The basic field kit is ready for field tests

In summary, the initial steps as detailed in the original objectives, have been accomplished and a firm foundation for the continuance of the research has been established. Arrangements are being made to produce various "States of the Art" papers. These, combined with the on-site global studies and the other work products, will be documented and presented in three global conferences. WHO and UNEP are cooperating with the documentation and conferences.

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ANNUAL RESEARCH REPORT

A. General Background

For many years less developed countries (LDC) have been using developed countries' technology without modification and sometimes to their detriment. A significant example has been the use of water and waste water treatment devices or processes that simply have not been compatible with in-country man-power and natural resources. The basic rationale that led to initiation of this project was to see if it would be possible to forecast which of the many water and waste treatment processes that could be looked at in the frame of reference of in-country resources. There is ample field evidence that such transplanted technology, although effective for developed countries, when placed in underdeveloped countries simply became inoperable after a short period of time. In effect too often all of the resources that have gone into their development have been for nothing.

It is important to note, that the development of LDC's in many ways hinges on the development of water and waste water disposal processes and their incorporation into the culture. Clean and plentiful water and proper disposal o human waste would go far to insure the development of industry and the maintenance of health. Each failure of a high technology not only wasted valuable resources but also discouraged continued development of pure water resources, inasmuch as public funds were normally invested for such developments it deprived the particular country of other public services and in some instances could lead to default on the loans used to develop water resources a treat waste water. The situations usually reflect a complete lack of organizec water delivery systems and sewage disposal in addition to high incidence of w

borne diseases. These problems are generally indicative of small (500) to large (100,000) organized communities but not so prominent within the major metropolitan areas.

B. Statement of Project Objectives as Stated in the Contract.

The primary objective as stated in the contract was to develop a system of matrices dealing with processes and in-country resources, that could be brought together in such a fashion as to identify processes that would be optimal in terms of resource conservation in LDC's. These processes need not be high technology. Specifically it would be technology appropriate to the ability of a country to supply the resources to build and operate it. The secondary objective, once the matrices were developed was to do a global study of sites representative of appropriate water and sewage treatment processes to see if the conceptional approach was sound. The tasks as outlined were to develop first process matrices and then resource matrices, these to be followed by a system which might be called a translation matrice. In other words once the methodology was developed and tested in the field, the final order of business would be to document it and find what is necessary to bring it to the useful attention of those involved in this activity.

Although the contractual objectives have not been modified the scope and purpose of the project have grown. This growth includes an attempt to identify sites where approporate technologies can be tested, identify a data management system, and prepare 'State of the Art' documents on the various processes. All of this will

include interests and certain aspects of the problem area that were found in WHO, UNEP, and several other National groups such as Intermediate Technology.

C. Continued Relevance of Objectives

As indicated in Part B the objectives continue to be relevant. Any savings in the development of water resources and waste disposal systems that can be implemented by this project, certainly could be looked at as an expansion of the ability to bring pure and adequate water to more people. An indication of increased relevance that occurred after the project was awarded and research undertaken, was the interest of UNEP in similar activities. Low cost water and waste water treatment technology for developing countries, has been stated as one of their prime objectives. After meeting with professionals of the International Reference Center (IRC) and various faculty of many countries and presentation of the project at several international meetings, it became increasingly apparent that interest in the objectives of this project was world wide. Few seem to share the overall objectives, however, since there appear to be a greater interest in providing information on low cost technology (process model). On the other hand there are groups such as the Club of Rome, and WHO whose activities in systems dynamics and other modeling, strongly show the increasing interest in models such as the project's resource model. The project remains unique, in that it is attempting to put the two models (process and resource) together.

As part of the overall objective the question still arises as to the types of activities necessary to get the LDC's to accept the appropriate technology. In other words, will they be willing to go 'second class' or 'third class' simply because it is more in keeping with their resources. Can they be made to understand that 'first class'

is normally not the answer for the current time frame. The second and third class types of treatment historically were adequate for DC's and within their rising affluence were quite satisfactory. The DC's have been able to use higher technology as their economy escalates. Because of this concern the project director suggested to both WHO and UNEP since they by charter are interested in this particular area, that they publish and disseminate the project material once it is documented and verified by the global studies. WHO through its IRC's would publish it and UNEP would assist in the development of regional workshops to bring it to the attention of the appropriate recipients. To this extent then the objectives are modified. An additional enhancement of the scope of work is the development of the classifications of tests that will insure the adequacy of any given process and a kit to go along with this. Another elaboration will be the identification of manpower requirements and perhaps, educational remedies such as relevant short courses.

D. Accomplishments to Date

1. Findings:

In reference to Section B of this report the operational significant findings of the current year's research are that the initial steps have been undertaken and a firm foundation for the continuance of the research has been established. The research (almost completed) in a broad sense could be divided into the work that is done in the accumulation and management of data in the development of the process and resource matrices. These matrices will be refined as the work in the field progresses. The field work is just starting since it could not start until the technology to be tested in the

field was developed. The sites selection matrices, which was developed initially to assure that all different types of innovative, adaptive and translative technology could be looked at, are included. Our literature search to date of published sources has uncovered many bits and pieces of data/information to fit into the whole. In addition we've also found unpublished information of a significance to various facets of the project. The significant findings and other accomplishments for this reporting period are on schedule as proposed. Sites have been selected after initial trips to Europe, Central and South America, The Caribbean, the Middle East, Africa, and the Far East were completed. A subcontract has been completed with the Latin American group and contracts have been drafted for the Middle Eastern/Africa groups. The basic data manipulation format has been established as the basis of a proposal made to the International Reference Center to detect the innovative and unusual techniques that are being done around the world through the International Reference Center, through the some 900 participants in the system.

Documentation for the contracts with the global sites has been completed and instructions for the collection and codification of all kinds of relevant data undertaken. The basic field kit is complete and ready for shipment. The process matrices have been developed although not in the detail that would ultimately be available but certainly in the detail that was envisioned in the proposal. The resource model and the various indices that will go into this effort have been developed and computerized.

The main finding that suggests possible complications was the fact that many others have worked on various facets of the project as we envision it. Some of these individuals and organizations have made some progress whereas others have made little or no progress. All initially were quite jealous of their territorial posture. Finally we feel that we have made some head way in answering the important question of in-country acceptance by working with WHO, UNEP, and the Peace Corps. They have all shown strong interest in helping us develop an in-country acceptance of the rational as a development.

2. Interpretation of Data and Supporting Evidence:

As the project has developed a series of reports were produced during the year. In addition, we have included additional material in the appendix of this annual report. At this writting it can be said that the detailed site matrices are complete and operational; the resources model is complete, computerized and operational; the process matrices and cost matrices that go with it are complete; the data formating is complete and has been communicated to the International Reference Center for incorporation into the activities of locating innovative and unpublished or undiscovered published information. In addition we've attempted to develop information on the needs for water and waste water generation in terms of the demographic and soci-economic parameters of LDC's. This has been coupled with a survey of costs of different process of construction under different LDC's to compare with the costs of our process matrices system.

3. Research Design:

As was stated earlier, the research has taken two broad divisions. One is on the overall literature search, documentation and the various matrices, mostly on campus studies and the other is the testing of these matrices under actual global conditions (e.g. field studies). The global tests are highly important. It was envisioned initially in the proposal, that as global sites were selected there might only be three: one in the Latin American countries; one in Africa; and one in Asia. This approach has been modified since its become apparent that we need several sites in Latin America (coordinated through CEPIS) and perhaps two smaller ones in the Caribbean. It also became apparent that we needed a site in the Middle East as well as in Africa. The division there has been between the dry arid and sea contiguous or fringe Middle Eastern Arabic countries and those that are basically in the East and West Africa domain. In addition potential sites have been selected in Taiwan, Thailand, Indonesia and the Philippines. Figure 1, the projected work schedule attached at the end of this report indicates the site coverage.

We plan to select three or four experts and have them visit the sites in addition to taking the collating and evaluating information brought into our data bank on all the different treatment processes and develop a State of the Art on each Treatment Process. These statements will then be used in the global conferences workshops presented by WHO. At this time some of these experts have been identified: Dr. Pasveer, of Delf (Waste Treatment); Dr. Ives, with the University of London (Water Treatment); Dr. Cleaseby from Iowa State University (Water Treatment); and Dr. Meadows, from Dartmouth (Systems Dynamics, Resources and Population Projections).

The five Appendixes discuss in detail the following:

1. The Second Generation Field Kit: A final version has been developed for actual test by field contractors. As field results are fed back, the kit will be modified.

2. The Process Matrices: Further development of the process matrix has been accomplished during the past six months and in particular the Cost Transfer Matrix. This technique will be used to assist in the selection process. The matrix will be expanded to include other processes as they are evaluated. In addition, demand and cost studies have been initiated and will include field data studies that will lead to forecastive equations.

3. Resource Model: This is the model that will provide the match with the Process Matrix. This match will be used for global field confirmations. This model is complete and ready for testing. Initial tests on Indian (Nagpur) data are being initiated.

4. Innovative and Historic Technology: These studies are being made to uncover as many unpublished examples of successful technology that may be appropriate as possible in addition to evaluating those historic techniques used by developed countries. This is just in the formative state.

5. Data Management: This appendix includes the basic subject classification to be used for bibliographic products as well as the data formatting process for use in data bank building. Also included is a suggested Minicomputer budget for an IRC.

The problems of data availability are beginning to resolve themselves in sampling and data processing: new techniques have been developed in the management of the model; and the research findings have revealed that the present methods we are using should be adequate. We do not envision at the present time any new approaches, but of course, this will rest entirely on the verification in the field of the modeling processes.

E. Dissemination and Utilization of Research Results

1. The major effort to eventually disseminate the project work products will be made through WHO, UNEP, the World and Asian Banks, and other such agencies. The arrangements to do this are being made through appropriate individuals and offices. A brochure describing the program was developed and given to most possible project participants and was presented at the Bilthoven Conference (1973) of the International Reference Center and collaborating institutions. "Lower Cost Methods of Water and Waste Treatment in Less Developed Countries," by the principal investigator, and Dr. Albert Talboys and Mr. Dale Swisher was presented at the International Meeting of the International Water Resources Associates in Chicago in October, 1973. This will be published in their minutes. Another paper entitled "The Importance of Low Cost Technologies in Water and Waste Water Treatment in Developing Countries," authored by the principal investigator was presented at the Conference for Environmental Health in Arab Cities in Baghdad, April 20th, 1974. A paper, similar to that at Baghdad, has been prepared and is on the agenda of the IADIS conference in Mexico City for the first week of August, entitled, "On Compatible Country Capabilities and Water and Waste Water Treatment Process Selection." Another paper by

Talboys and Reid is scheduled for the June 17 meeting of the Association Fronterize Mexicana, Estadocinidense de Salabridad, " Lower Cost Water and Waste Treatment--A Global Research Project." This will be presented in Monterrey, Mexico.

2. At this time it is not possible to site evidence of cases where the application of the findings have been applied because the finding are preliminary and the project is only finishing its first year phases.

3. The experience that has been gathered the past year has been significant enough to indicate that there must be more effective ways developed to expand the use of potential results of this research. As indicated in earlier reports, we envision as an expansion of the workload of the contract to develop a translation technology, and that most of this will be done through the State of the Art Papers and the global workshops.

4. The extent and nature of considerations involving LDC personnel and institutions has been considerable. Figure 1, attached to this report indicates the various processes, devices, and selected institutions to date. The institutional involvement is in testing the theoretical development of the process and the resource matrices under actual field conditions. The actual contractual arrangements being developed are varied but they are more of the nature of catalyzing efforts, in the sense that the monetary amounts are rather small with the funds paying for graduate assistance at the Universities as well as providing special materials. Of real importance to the recipients is that being involved with the global effort and having access to a wide array of expertise.

F. Statement of Expenditures and Obligations and Contractor Research

Expenditures to Date

Category	Amount
Salaries & Wages	$19,844
Fringe Benefits	1,830
Travel & Transportation	11,486
Consultants	10,977
Equipment & Supplies	2,202
Subcontracts	-0-
Other Direct Costs	1,872
Overhead	11,146
TOTAL	$59,357

Significant Problems and Effects

The expenditure rate has been slower than anticipated, primarily because of a reluctance to undertake the field studies without adequate preparation. All of the initial field visitations are now complete, and the lag or waiting was warrented in view of the accomplishments. One facet of the expenditure rate has been the subcontracts, most of which have been agreed upon in principle although consumation has been delayed because of the problems dealing with a variety of entities from various countries In most instances, AID, WHO, a particular country and a particular university all are being kept informed, if not actually involved. The complexities in doing this are inherently delaying, but hopefully it will provide greater support in the long run. For example, the Turkey contract will be with the University in Ankara, but it will be coordinated through AID/Turkey and the Turkish National Science Council, etc. Ther has been no significant changes in management, except that we have found a surprising number of devoted people around the globe who are interested in being involved with us.

It does appear from site visits, etc., that we will need a longer period for the subcontracts. Now they are for 12-15 months, but most will probably require an extension. It also appears that significant offshoot studies will materialize from this study, an example is "The Feasibility of Alternates to Sewerage vs Sewage Treatment for LDC's." On suggestion is individual toilets, publically maintained and managed. Studies like this will require additional funds.

G. Work Plan and Budget Forecast for the Coming Period

1. The anticipated accomplishments for the remaining period are indicated in the attached Figure 1. The first important step will be the consumation of the various global sites studies in Middle East, Africa and the Far East. Each of these studies will require site visits. The site visits are indicated for the AUB and Turkish contracts, in October. The site visit on the African contracts will be in November and those of the Far East will be in March, 1975. The purpose of these site visits in addition to assisting in the research, will be the formation of a group of consultants for the preparations of State of the Art Papers on Water and Sewage. Once the State of the Art Documents have been developed, they will be published by WHO for use in the global workshops.

We also plan to complete the various global contracts which will be more or less field tests of the modeling process. These will be sumarized so the same people that are used in the State of the Art groupings will also get together in July of the following year to develop the total program. This group will test the program including the completed field kit, the resource model, and the global cost and demand studies. Following the assimilation of the State of the Art papers, the literature surveys, the direct mailings, the cost demand studies, the historic practices studies, the on-site global studies will be put together and documented and presented in three global conferences. The report of the global conferences will constitute the project's final report. One other important aspect will be some studies on the problems associated with getting acceptance of recommended technology by the LDC's.

2. There are no marked departures from the procedures and activities underway at the present time. One slight departure from the original proposal is rather than assign an expert at any particular site for a long tour, is to assign him for a shorter tour and have him function in a two-fold manner. One will be in the development of the State of the Art Paper and two will be in the professional or consultation group which will bring together all aspects of the total program. The global contracts will function under AID contractual requirements and with definitive instructions as to the work to be performed as well as a uniform approach to use of personnel and data arrangements. Because low cost methods are not necessarily low technology the process matrices will be further developed to include all relevant treatment of water and waste. Because of the credibility of acceptance, we plan to study the problems that must be coped with in getting LDC's to use more suitable or appropriate technology.

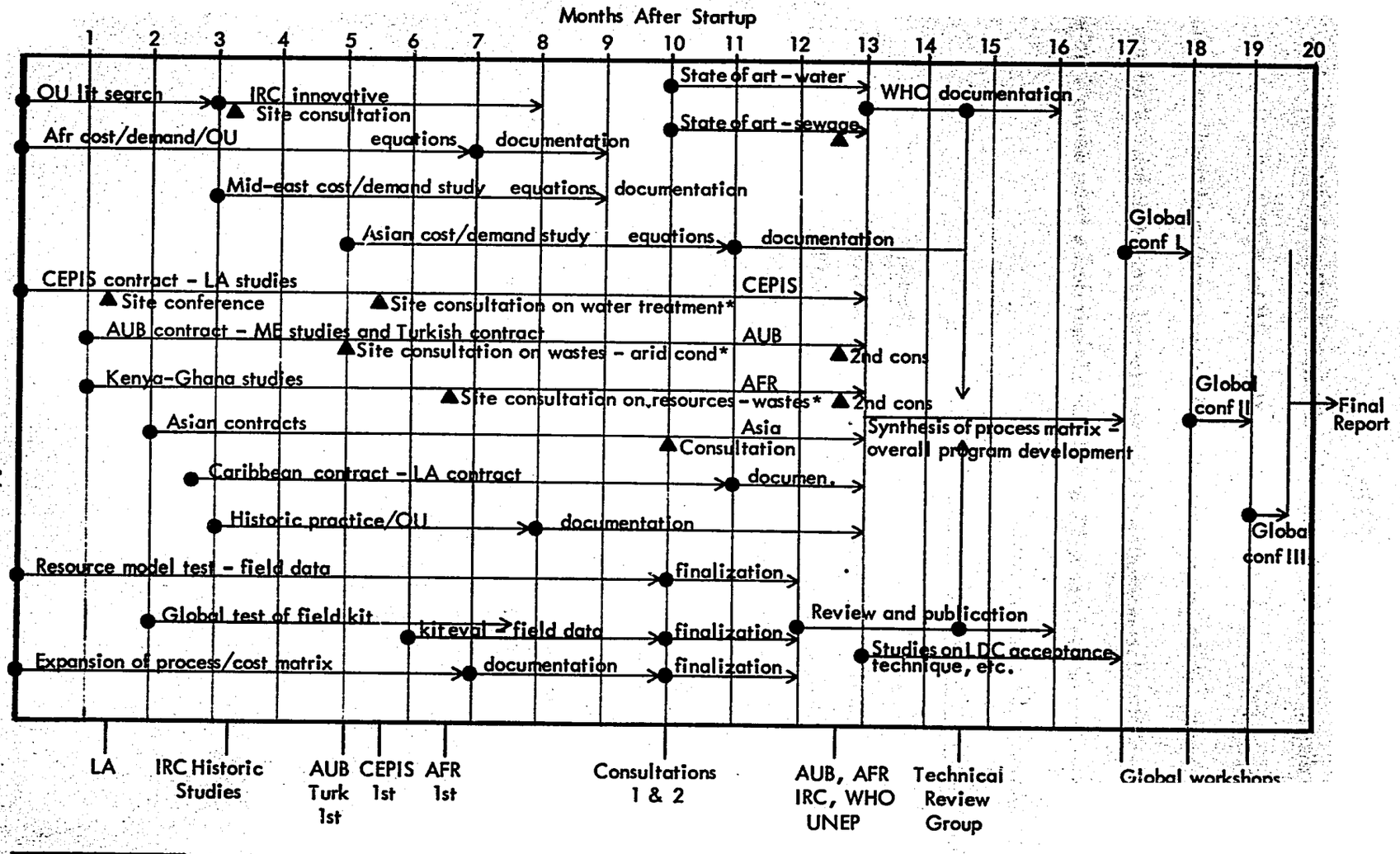
3. The factors that perhaps significantly promote or accelerate the accomplishments are really associated with the concepts of momentum. There is a broad interest around the world in this kind of activity, albeit its in pieces here and there. The project itself is having a catalytic action and if this continues it will be an exponential effect. There are two things that might impede the rate of accomplishment. One is reluctance on the part of the staff to proceed faster than we feel we're capable of doing. This has been evidenced in that we refused to visit foreign installations until we were sure we knew who we were visiting and why. The second thing that might impede these activities to some extent is establishing the Institutional arrangements and the inertia associated with any

global or international program.

4. The dissemination plan for the research results is illustrated in Figure 1 as a series of three global conferences. These will be held the last three or four months of the program as well as the documentation of the State of the Art, and the documentation of the resource and process models. We have verbal assurances from WHO and UNEP of their desire to be deeply involved in these global conferences.

5. Budget Statement for the Coming Year

Category	Amount
Salaries and Wages	$30,000
Fringe Benefits	4,050
Travel and Transportation	15,000
Consultants	12,000
Equipment and Supplies	20,000
Subcontracts	50,000
Other Direct Costs	12,150
Overhead	16,800
TOTAL	$160,000



*See AID/OU global matrix.

FIGURE 1--University of Oklahoma/AID Global Program

APPENDICES

APPENDIX I--Second Generation Field Kit

APPENDIX II--Further Development of PROCESS MATRIX:

A. Methods of Estimating Costs of Wastewater Treatment Systems in the United States

B. A Mathematical Model for Estimating Cost of Water and Wastewater Treatment Systems for Less Developed Countries

C. Cost Transfer Matrix

APPENDIX III--Resources Model

APPENDIX IV--Historic and Innovative Technology of Water and Wastewater Processes

APPENDIX V--Data Management

APPENDIX I

The Second Generation Field Kit: This is the final description of the kit to be furnished initially to the field test sites. Field experience with the kit will be incorporated into the final version of the kit for general distribution.

FIELD KIT

The field kit is designed to provide quality checks on the water and sewage facilities developed in this project. Six test were defined as being appropriate to provide an adequate health index of the water in question, these test are; Ph, chlorine residual, turbidity, coliform, biochemical oxygen demand, and dissolved oxygen.

Objectives of the kit were that it be: economical and rugged; responsive to data needs; available for mass distribution; usable by in country skills; and that expendables be replacable in country. Development of the kit was to be in stages beginning with a sophisticated kit for highly accurate analytical measurements where manpower and supplies were available, to a simple kit with adequate results where unskilled manpower and few chemicals if any were available.

The initial kit consisted of commerically available test kits such as La Motte or Hach. These were accurate, and required knowledgeable operators. The chemicals had to be ordered out of the country and the cost was over $250. We have developed a kit which consist of materials available locally and can be made fresh each day before going into the field. Results are adequate and require no skills or special knowledge. There are seven different pieces of equipment, including the thermometer and the cost is under $100 for the entire kit.

The kit includes a manual that will provide photographs of all operations plus pictures of the equipment needed for each test. The attachment provides alternative methods for performing each test, along with information on references, sterilization and distilling and conversion tables. Measurements in the manual are given in grams and milliliters along with tablespoons and ounces (in case scales are not available).

The kit is self-contained in a plastic cooler approximately 30" x 14" x 12". Following are the tests and their present form in the kit:

1) pH determination - presently involves pH papers, wide and narrow range. We are working on simple methods using more available materials i.e., litmus. The attachment includes a listing of liquid indicators including instructions for mixing universal indicators.

2) Turbidity - a sample bottle is provided for collection of a water sample. This is then compared to standards in the kit. Instructions will be included for making new standards, along with references to other methods i.e., turbidity rod, Jackson candle.

3) Chlorine Residual - a sample is taken and potassium iodide and starch are added. If no chlorine is present there is no color development, if chlorine is present a blue color is formed. The color being proportional to the amount of chlorine. Reference to the O-tolidine method is made in the attachment.

4) Coliform - Most probable number - a series of culture tubes are prepared using powdered milk and beef bullion media. Dilutions of the water are put into the tubes and incubated, either by conventional methods or a cloth holder which can be worn. Brom cresol purple is placed in the tubes, upon a drop in pH the purple color changes to yellow. No color change after 48 hours indicates a negative test. MPN table is included and reference is made in the attachment for alternate media. We are presently working on utilizing a simpler method eliminating the brom cresol purple, since this may not be available locally.

5) Biological Oxygen Demand - we have replaced this test with the relative stability test. In this test, a water sample is taken in a sample bottle, methylene blue is added (oxidation-reduction indicator) and when all the oxygen is used in the sample the color turns from blue to clear. By comparing the number of days it took to turn clear and using a K rate of .17/day we can tell approximately how much oxygen was available in the water. This test was introduced because it is far simpler than the standard BOD test, which increases the probability that the test will be run at all. Also the results we get does give a good idea of whether or not the water contains adequate oxygen. Reference is made in the attachment to the standard BOD determination.

6) Dissolved Oxygen - a ferrous sulfate method is being introduced into the kit, final test are being completed to ensure it will provide consistent results. Commercially available ferrous sulfate capsules (iron anemia) are dissolved in warm water. Ten, 10 ml. water samples are set up. In each tube, methylene blue and sodium hydroxide are put. Various amounts of the ferrous solution are put in each tube. The tubes in which all of the oxygen is consumed will give us a yellow color, where oxygen is present, the color remains blue, this has yielded results within $\pm$ 1ppm.

Equipment for the kit consist of:

1) Glass BOD or baby bottles
2) 150 mm x 16 mm test tubes
3) Dropper bottle
4) Plastic water sample bottles
5) Plastic disposable syringes (instead of pipettes)
6) Centigrade thermometer
7) Potassium iodide
8) Starch
9) Brom cresol purple
10) Powdered milk
11) Beef bullion
12) Ferrous sulphate capsules
13) Methylene blue
14) Sodium hydroxide
15) Mineral oil

There may be some difficulties in obtaining Biom cresol purple, sodium hydroxide, and methylene blue. By on-going tests and correspondence with people in the developing areas, we hope to eliminate these problems.

ATTACHMENT TO FIELD KIT APPENDIX

There will be a drawing of the kit that will show where everything belongs and what is in the kit. Stress will be made on those replenishable items. Such items need to be prepared fresh or set up each time a field test will be made. These include:

1. Chlorine Residual; starch. Make up starch solution before going into the field dropper bottle provided.

2. Coliform; milk, bullion, brom cresol purple. Make up milk and bullion solution. Add media and brom cresol purple to tubes and sterilize before going into the field. Brom cresol purple doesn't need to be made up each time but it should be added before sterilizing to avoid contamination.

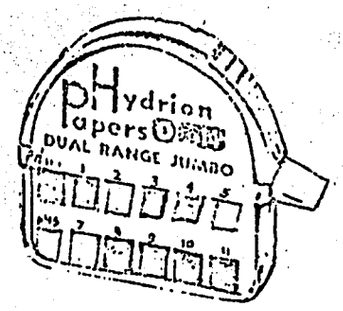
3. Dissolved Oxygen; ferrous sulphate capsules. Ferrous solution needs to be made up before going into the field. Mineral oil and covered with mineral oil, just a thin layer.

The following pages is the draft mannual to be used with the Field Kit.

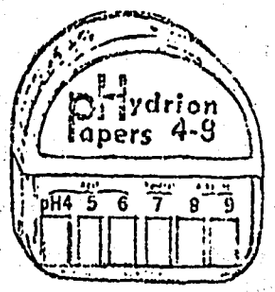
I. pH determination

1. Needed in the field:

A. pH papers



wide range

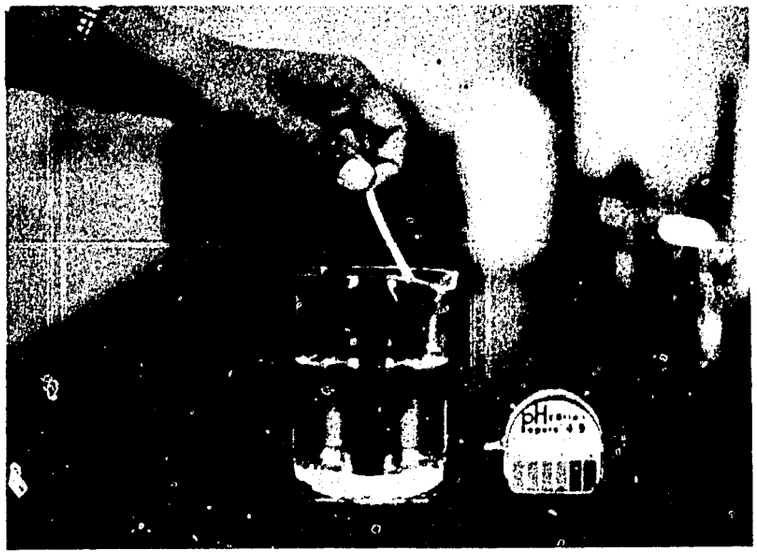


narrow range

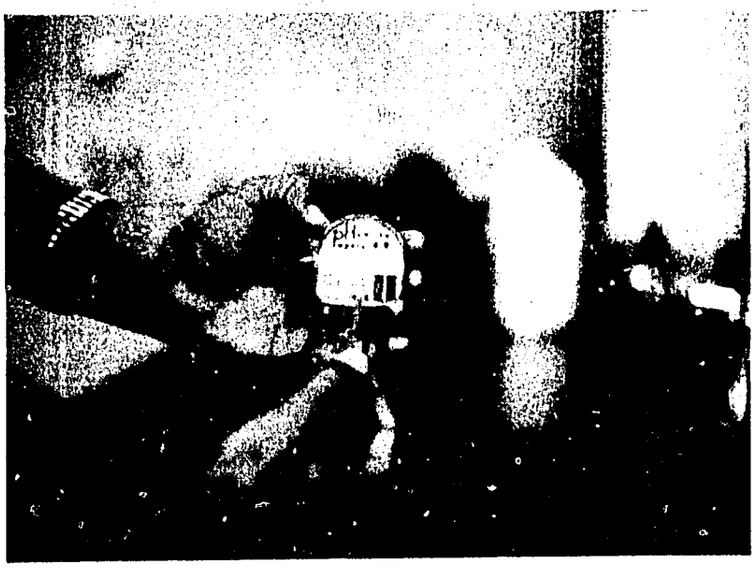
2. Need to do before going to field:

A. Check to make sure there is pH paper left, and that it isn't damp

3. Procedure



A. Take a piece of wide range paper, dip it in the water to be tested.



B. Compare the color of the paper to the chart on the dispenser.

C. If the wide range paper indicates the pH is between 7-10 take the narrow range paper and follow above procedure to obtain a more accurate pH reading.

D. If the pH is above 10 or below 7 then the pH of the water needs to be adjusted. After treatment the effluent pH should be within the 7-10 range.

4. Replacement reagents.

A. pH paper, narrow (7-10) and wide (1-11) range.

B. Refer to appendix for alternate indicators.

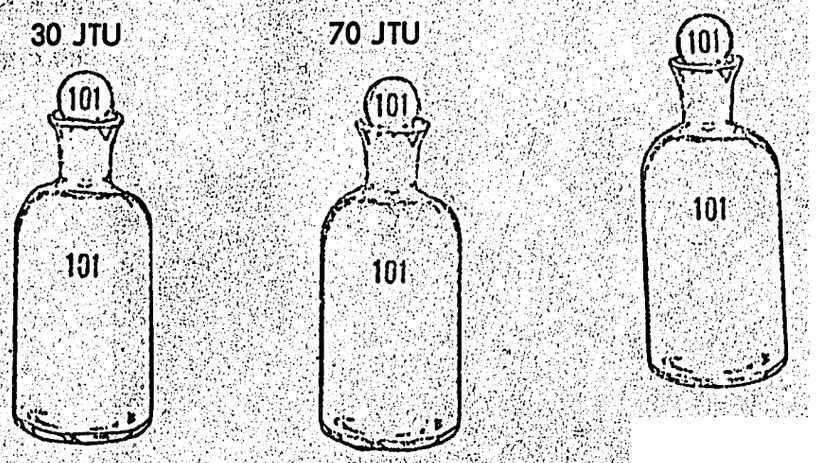
Note: keep the pH papers sealed in their container to avoid excessive moisture, which may interfere with results.

II. Turbidity

1. Needed in the field:

A. Standards

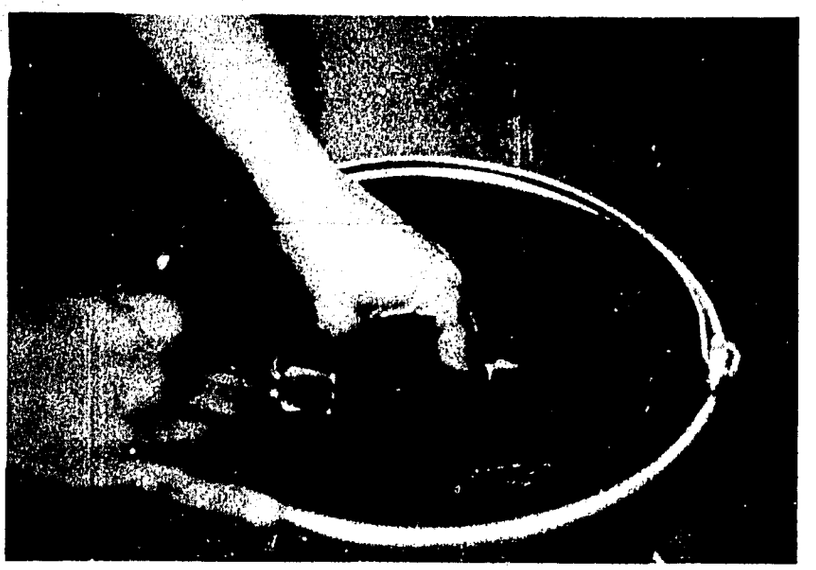
B. Sample bottle



2. Need to do before going to field:

A. Make sure standards are sealed and not leaking.

3. Procedure



A. Fill the sample completely full with the water to be tested.

B. Compare the sample with the two standards, using the white top of the kit, as a background.

C. Determine whether the sample is less than 30, less than 70 or greater than 70.

D. Effluent water should have a turbidity of less than 30.

4. Replacement reagents

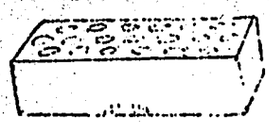
A. Standards can be ordered from a supply house or make using one of the alternate methods, refer to appendix.

III. Chlorine Residual

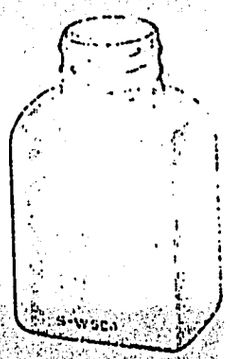
1. Needed in the field:

A. Two screw capped tubes

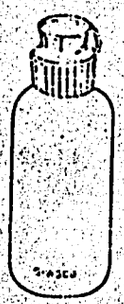
B. Tube rack



C. Potassium iodide crystals



D. Starch solution in dropper bottle



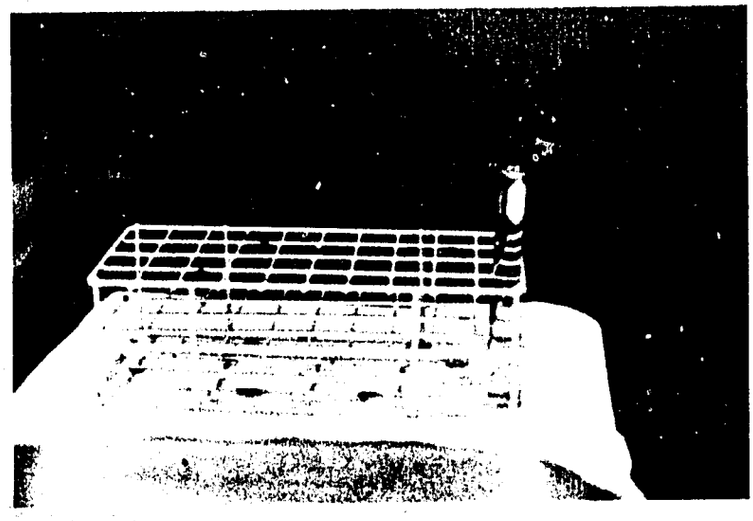
2. Need to do before going to field:

A. Make up starch solution and put in dropper bottle. Can be made up the night before.

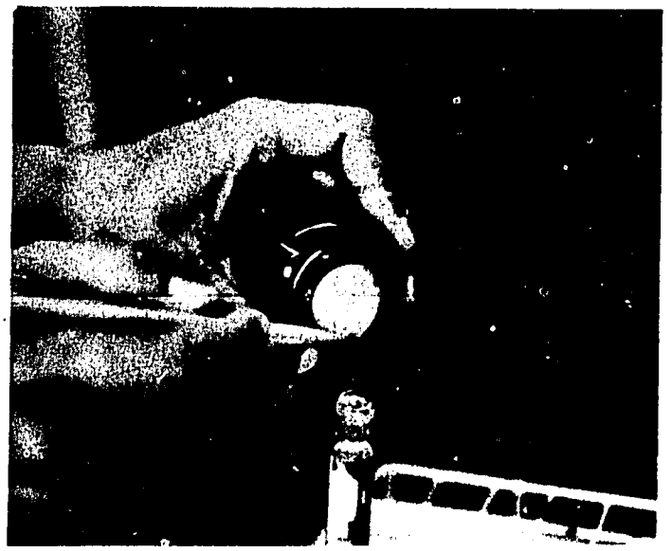
B. Make sure there are potassium iodide crystals.

3. Procedure

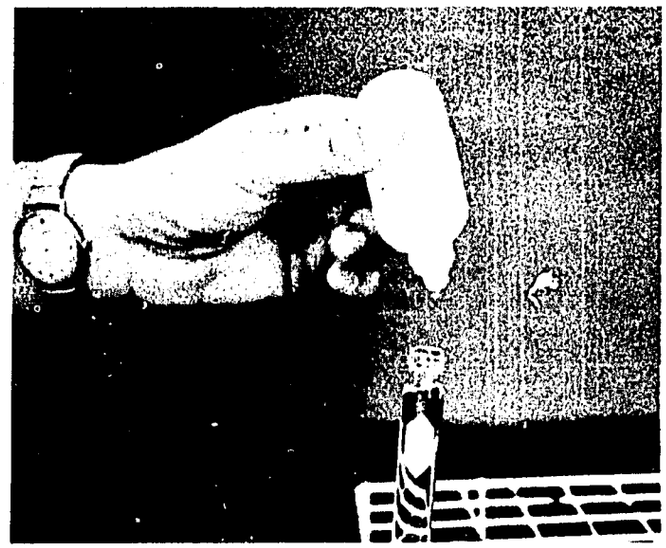
A. Fill the empty tube (to the neck) with effluent sample



B. Allow the sample of chlorinated water to stand 10 minutes after collection



C. Add one or two crystals of potassium iodide.

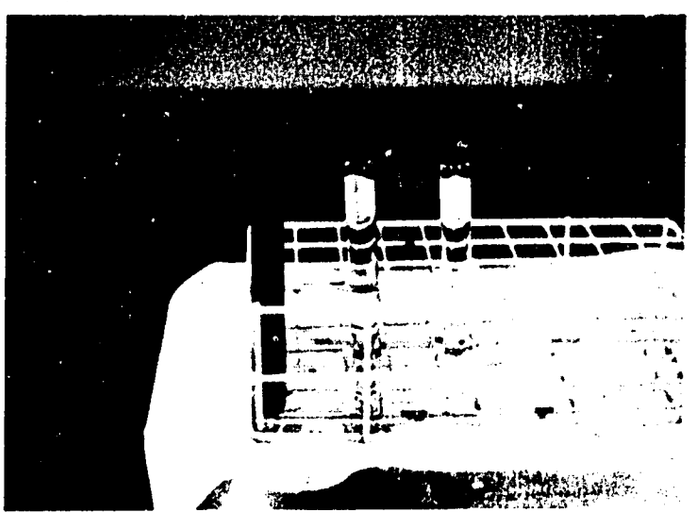


D. Add five to ten drops of starch solution.

E. Shake the sample thoroughly after adding the above chemicals.

F. Allow the mixture to stand for five minutes.

G. The color observed five minutes after the reagents are added should be recorded. Any increase of color intensity upon longer standing should be disregarded.



H. A faint blue color indicates the proper amount of chlorine. No color indicates absence of chlorine and dark blue indicates too much chlorine.

1. If there is natural color or turbidity in the water fill the second test tube with the effluent sample and add the starch solution. Don't add the potassium iodide crystals. Compare the two tubes for detection of blue color.

4. Replacement

A. Potassium iodide

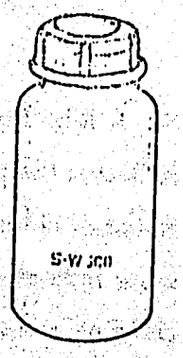
1. Starch solution; Mix 1 gram of clean starch (preferably arrowroot) with enough cold water to produce a thin paste. Pour about 200 ml. (7 oz.) of boiling water into this paste and stir. Boil for a few minutes. This solution may be preserved by adding a few drops of chloroform, but a fresh solution should be made at least every two weeks or more frequently to give the best results. If scales are not available 1 teaspoon of starch to 4 cups of water will give approximately the same results.

C. Refer to appendix for alternate methods.

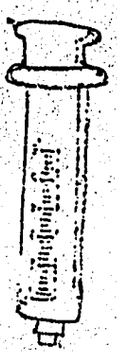
IV. Coliform

1. Needed in field:

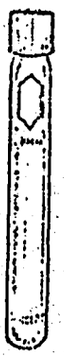
A. Sample bottle



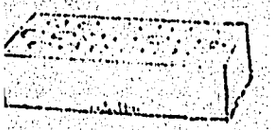
B. 10cc syringe does not require needle



C. 15-sterilized tubes containing media and brom cresol purple.



D. tube rack

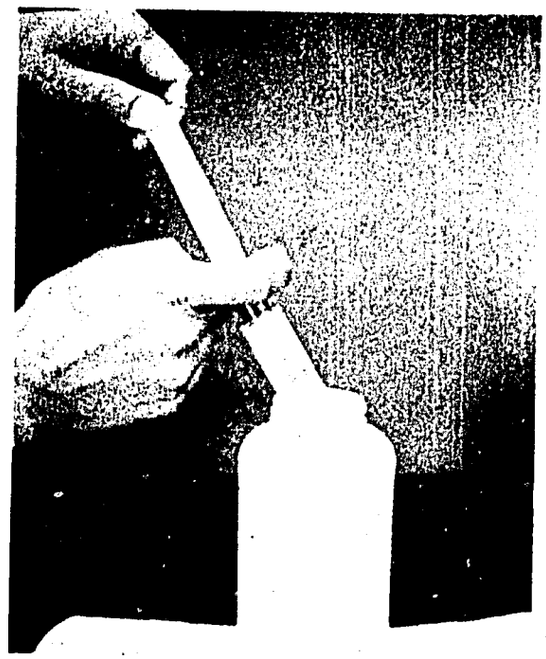


2. Need to do before going to field:

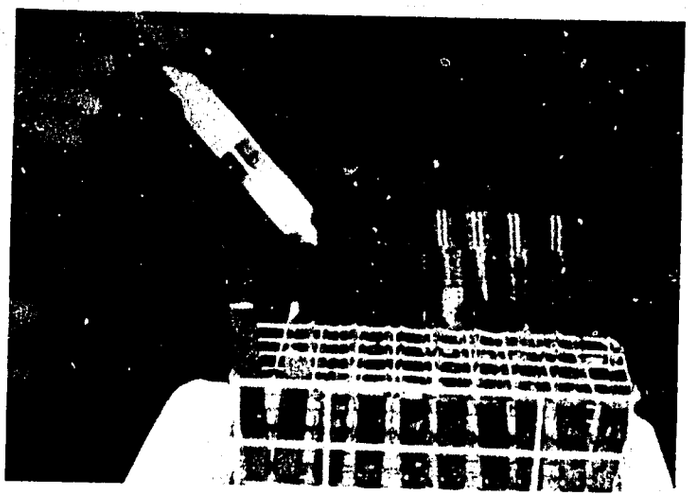
A. Mix up media, bullion and milk. Add 10cc. of media and 3-5 drops of brom cresol purple to each of the 15 tubes. Loosen caps and sterilize. Screw caps on tight and leave covered until in the field.

B. Make sure the syringe has been cleaned thoroughly with soap and water and rinsed with disinfectant (bleach), making sure to rinse with water to rinse out all the disinfectant. If glass syringes are available, sterilize. Refer to appendix for sterilization.

3. Procedure

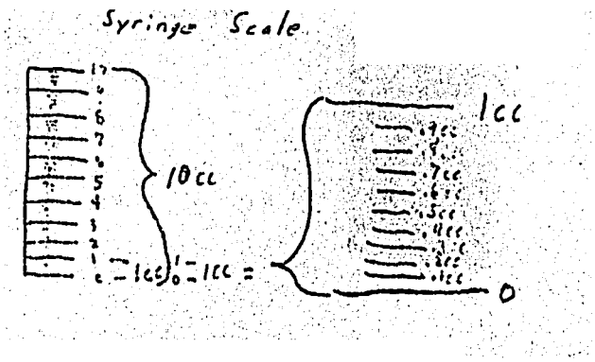


A. Fill the syringe with the water sample to be tested.



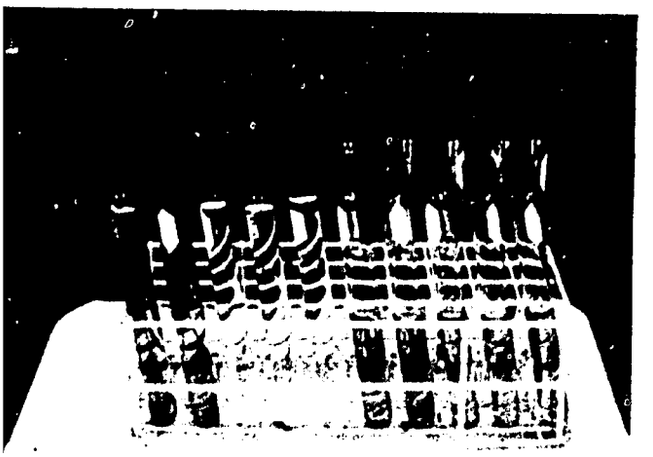
B. Take the 15 screw capped tubes, each containing 10cc. of broth, and 3-5 drops of cresol purple and using the syringe put 10cc. of sample into the first 5 tubes.

C. Put 1cc. of sample into the next five tubes.



D. Put 0.1cc of sample into the last five tubes.

E. Incubate the tubes for 48 hours at 35°C. If outdoor temperature is not this high and incubator is not available, the test tubes can be held close to ones body in shell holder (provided).



F. After 48 hours, tubes that have changed from purple to yellow show a positive test. Record the number of tubes in each group that show positive results.

G. Obtain MPN (Most Probable Number)

Number of tubes giving positive reaction out of:

5 tubes of 10cc. each	5 tubes of 1cc. each	5 tubes of .1cc. each	MPN Index per 100 ml
0	0	0	<2
0	0	1	2
0	1	0	2
0	2	0	>2
1	0	0	2
1	0	1	>2
1	1	0	>2
1	1	1	>2

Other combinations indicate value greater than 2

H. If coliforms are found in numbers higher than 2, then possible contamination could be taking place. Rerun test to check. If positive again the water treatment system should be checked.

4. Reagents

A. Brom cresol purple

B. Lactose Broth

Bullion - 5 grams
Powdered milk - 5 grams

Mix both in one liter of distilled water, heat to dissolve components. If scales are unavailable 3 1/2 teaspoons of bullion and 2 1/2 teaspoons of powdered milk can be mixed with 4 cups of water.

C. Remember to mix media and fill tubes before going to the field.

V. Dissolved Oxygen

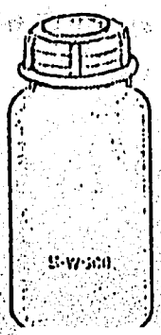
1. Needed in the field:

A. 3-30cc. syringes, 2 for the iron (ferrous) solution and should be used with the needles, to get under the oil cover. 1 is for the sample water and does not require a needle. This is the only test where the needles are used.

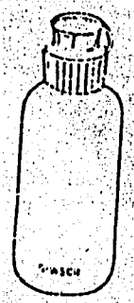
B. 10-capped tubes

C. Sample bottle 250 ml.

D. Bottle to mix iron solution in. 500 ml.



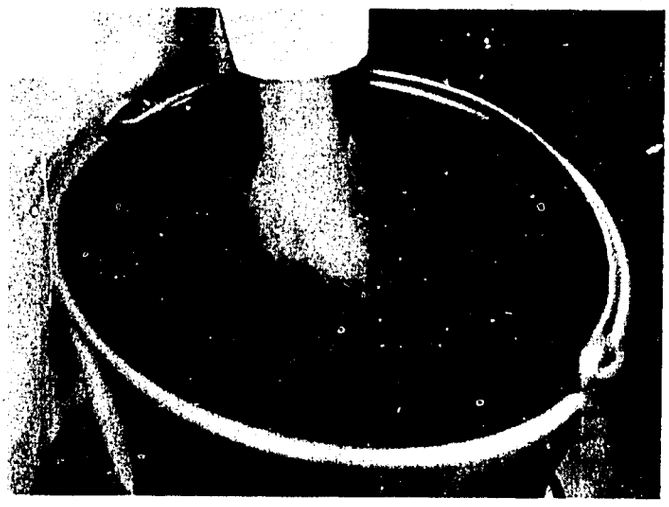
E. 2 dropper bottles
1 for NaOH
1 for methylene blue



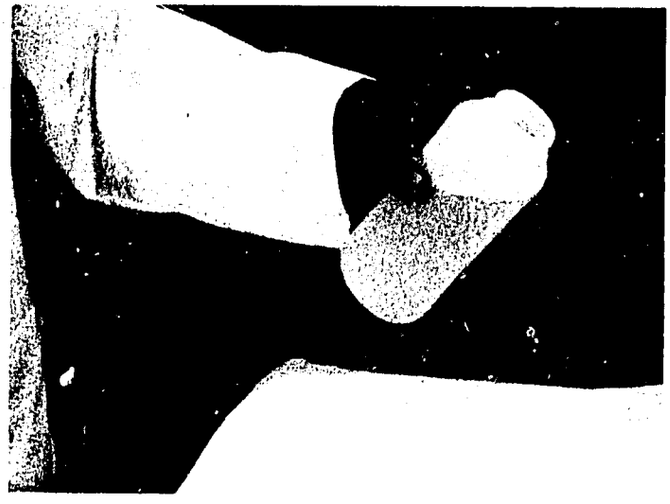
2. Need to do before going into field:

A. Make up Ferrous solution, and cover with a thin layer of mineral oil.

3. Procedure

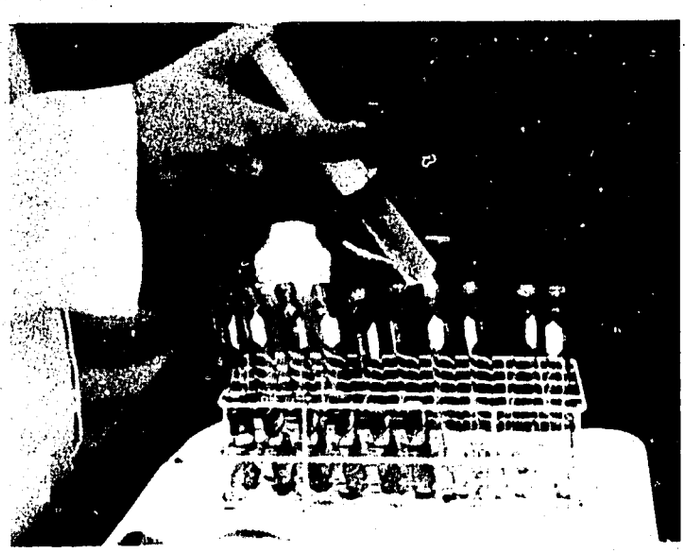


A. Fill the sample bottle with water to be tested. Making sure the bottle is submerged when filling, and tapping the bottle to make sure there are no trapped air bubbles.

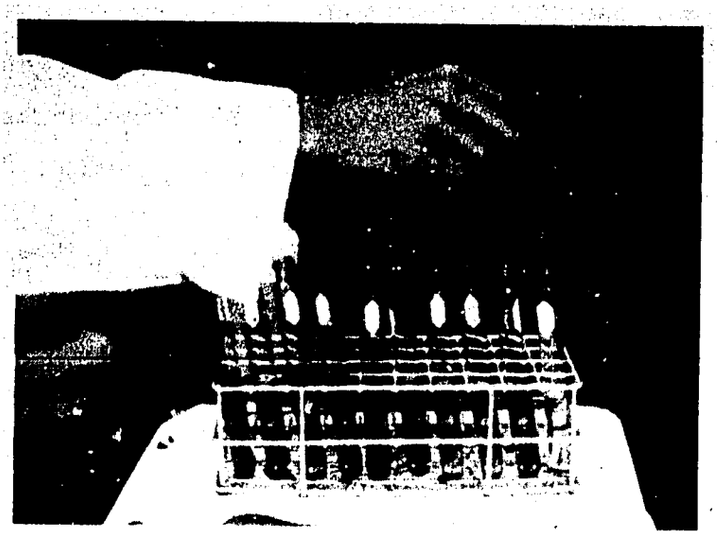


B. Mix the iron solution gently by swirling it to evenly distribute the mixture.

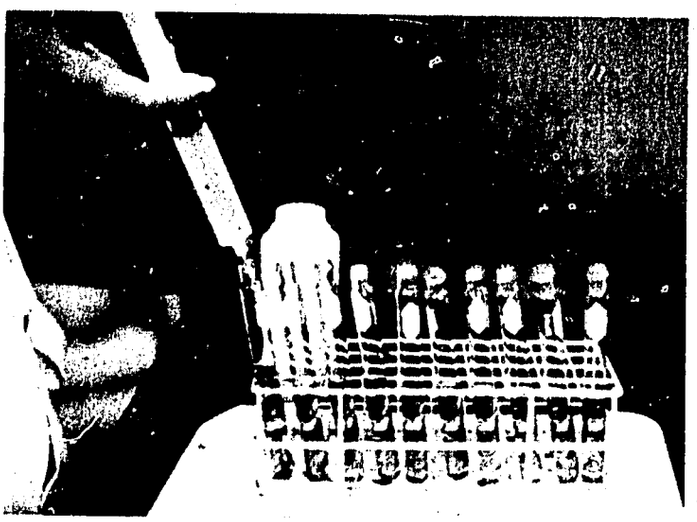
C. Fill the two syringes marked iron with the iron (ferrous) solution. Be sure to place the needle under the oil and tap gently to dislodge any oil droplets from the needle tip.



D. Fill the syringe marked sample from the sample bottle and put 10cc. of sample into each tube. Letting the sample run down the sides of the tube to avoid getting oxygen into the water.



E. In each test tube add 5 drops of methylene blue and 5 drops of NaOH.

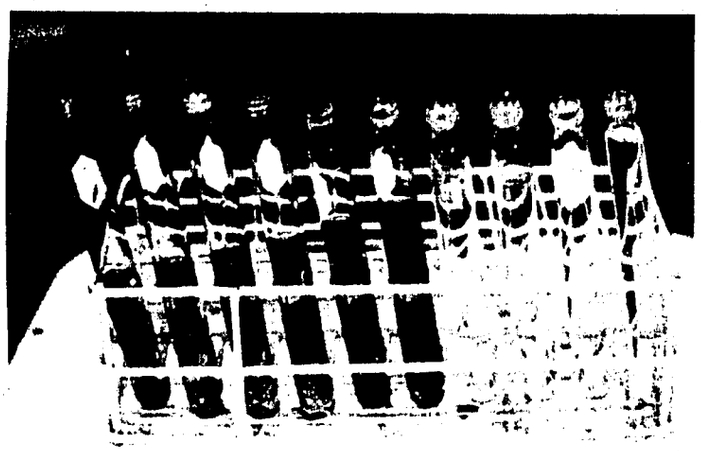


F. Using the syringes containing the iron solution place;

10cc. of the solution in tube #10
9cc. in tube #9
8cc. in tube #8
7cc. in tube #7
6cc. in tube #6
5cc. in tube #5
4cc. in tube #4
3cc. in tube #3
2cc. in tube #2
1cc. in tube #1

Add the solution carefully down the side of the tube so as not to introduce added oxygen.

G. Placing your finger over the end of the tube invert each tube gently to mix the solution.



H. After two minutes note the color formation.

I. Going from tube 1-10, the first tube in which the solution is clear or straw-colored is the break-point.

J. Refer to chart for approximate DO (dissolved oxygen reading)

Break between blue and straw	DO
all clear	0-1ppm
between 1 & 2	0-1ppm
2 & 3	0-2
3 & 4	1-3
4 & 5	2-4
5 & 6	3-5
6 & 7	4-6
7 & 8	5-7
8 & 9	6-8
9 - 10	8-9
all blue	8 or greater

K. Effluent value should be 4 ppm or greater. Break should be between 5 & 6 or higher.

4. Reagents

A. Ferrous sulphate capsules are used, trade name Feosol, Spansule (capsules contain 150mg of dried Ferrous sulphate). Dissolve 2 capsules in 500ml. (or 2 cups) of distilled water. The water should be 45-50°C at the time the capsules are put into the solution. The capsules are pulled apart and the pellets dropped into the water. The solution is covered with mineral oil. The solution should be made at least 5 hours before use, it can however, be made up the day before.

B. Methylene blue- dissolve 0.5 grams of U.S.P. methylene blue in distilled water to make 1 liter (4 cups). Same as Relative Stability.

C. NaOH - U.S.P. Sodium Hydroxide pellets are used. 1 gram is dissolved in 100ml. of distilled water, or 10 pellets in 3 1/2 ounces.

D. Mineral oil - commercially available mineral oil, used to cover solution.

E. Syringes - syringes are plastic and include 30cc. syringes. Glass or plastic can be used, and of any size. Also pipettes can be used in place of syringes

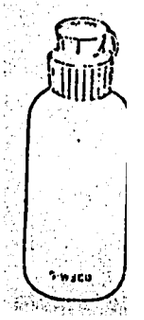
F. Alternate method in appendix.

VI. Relative Stability

1. Needed in field

A. Sample bottle

B. Dropper bottle for methylene blue

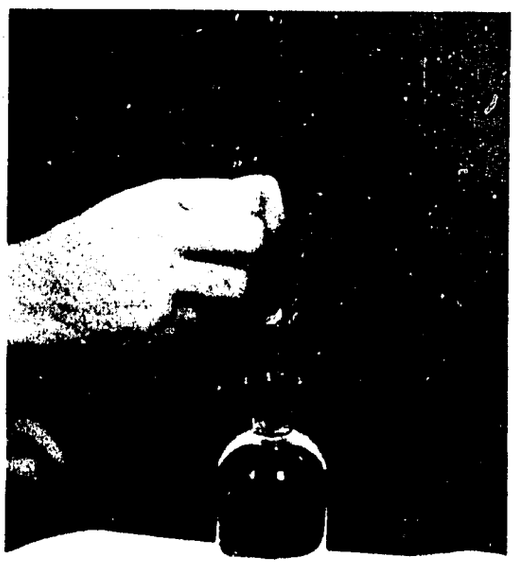


2. Needed before going into field

A. Make sure sample bottle is clean

3. Procedure

A. Fill the 300ml. glass stoppered bottle with sample, avoiding trapped air as with the dissolved oxygen measurement.



B. Add 16 drops of methylene blue indicator solution and mix by inverting the bottle.

C. Put water around the stopper to make sure no oxygen enters and incubate at 20°C plus or minus 2°.

D. Observe sample twice a day (morning and evening) until there is no blue color.

E. Record the number of days required for decolorization or the relative stability percentage shown in table. It is rarely necessary to incubate longer than 10 days.

F. A relative stability of 75% signifies that the sample contains a supply of oxygen equal to 75% of the amount needed.

G. The ice chest (kit) can be used to provide fairly constant temperatures. The temperature needs to be checked about every 6 hours. Cool temperatures as in a cellar can also be utilized.

Days	Relative Stability percentage
0.5	17.56
1.0	32.40
1.5	44.40
2.0	54.30
2.5	62.40
3.0	69.10
3.5	74.60
4.0	79.10
4.5	82.80
5.0	85.90
5.5	88.40
6.0	90.50
6.5	92.15
7.0	93.50
7.5	94.69
8.0	95.60
8.5	96.40
9.0	97.0
9.5	97.57
10.0	98.0
11.0	98.7
12.0	99+

4. Replacement

A. Methylene blue. Dissolve 0.5 grams of U.S.P. methylene blue in distilled water to make 1 liter.

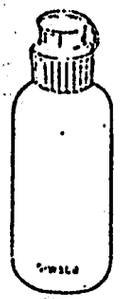
APPENDIX

I. Equipment and chemicals

A. Glass stoppered BOD bottles, 300ml.

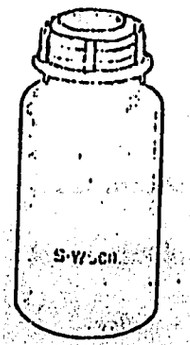
B. Screw capped culture tubes 150mm + 16mm

C. Dropper bottles 125ml. capacity

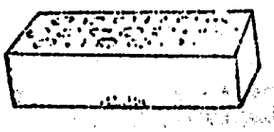


D. Plastic water sample bottles, wide mouth, 250ml.

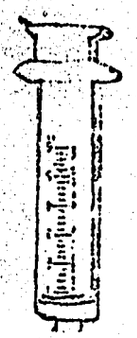
E. Plastic bottles iron solution wide mouth, 500ml.



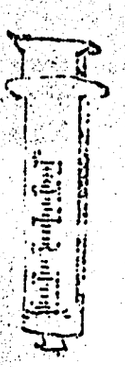
F. Tube rack



G. 10cc. syringe coliform test



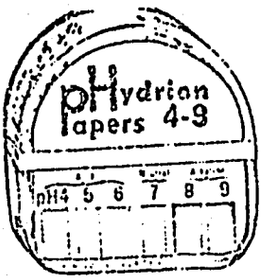
H. 30cc syringe

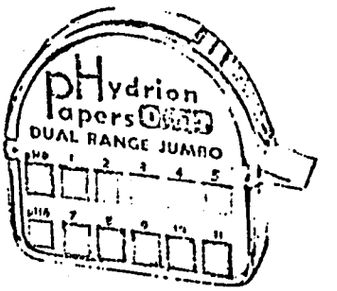


I. 18 gauge disposable needles

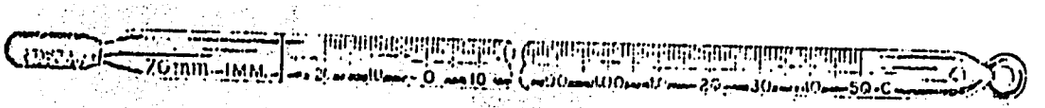
J. Thermometer -10 to 260°C

K. PH paper, pH 1-11 and pH 3-8





Centigrade Thermometers



L. Potassium iodide - obtain local

M. Arrowroot starch - obtain local

N. Brom cresol purple - order

O. Powdered milk - obtain local

P. Beef bullion - obtain local

Q. Ferrous sulphate capsules - obtain local

R. Methylene blue - order

S. Sodium Hydroxide (NaOH) - order

T. Mineral oil - obtain local

II. Companies where equipment and chemicals can be obtained

A. HACH Chemical Company PO Box 907
Ames, Iowa 50010
U. S. A.

B. Sargent Welch International Division
7300 North Linder Ave.
Skokie, Illinois 60076
U. S. A.

C. Curtin Scientific Company PO Box 1546
4220 Jefferson Avenue
Houston, Texas 77001
U. S. A.

OR

Curtin De Mexico, S.A. de C.V.
Mexico 13. D.F., Mexico
Apartado Postal 13265
Antonion Maura 29
Colonia Moderna

D. Fisher Scientific International Division
52 Faden Road
Springfield, New Jersey 07081
U. S. A.

OR

Fischer Scientific de Mexico, S. A.
Medellin 43-1402
Mexico 7, D.F. Mexico

III. Many tests are standardized throughout the world. A reference to precise and standardized test is:

Standard Methods for the Examination of Water and Wastewater

Prepared and published by: American Public Health Association
American Water Works Association
Water Pollution Control Federation

publication office: American Public Health Association
1015 Eighteenth Street, N.W.
Washington, D.C. 20036
U.S.A.

A good general book on lab procedures and equipment is:

Chemical Technicians' Ready Reference Handbook

written by: Shugar, Shugar, Bauman

published by: McGraw-Hill Book Company
Manchester Road
Manchester, Missouri 63011
U.S.A.

ALTERNATIVE METHODS

A. pH

1. pH meter

2. Indicators

a. Liquid indicators can be used to tell whether a solution is basic or acidic. For example; Thymol blue has a transformation interval of 1.2-2.8, at 1.2 and below it is red as the pH goes above 2.8 the indicator turns yellow. The fact that a liquid reacts acid to phenolphtalein means simply that its pH is less than 8, and when a medium is alkaline towards dimethyl yellow, we know merely that its pH exceeds 4.2.

INDICATORS

Name	Transformation Interval	Color change Acid - Alkaline
Thymol Blue	1.2-2.8	red-yellow
Dimethyl yellow	2.9-4.1	red-yellow
Methyl Red	4.4-6.3	red-yellow
Brom cresol purple	5.2-6.8	yellow-purple
Bromthymol blue	6.0-7.6	yellow-blue
Phenoi red	6.4-8.2	yellow-red
Neutral red	6.8-8.0	red-brown yellow
α Naptholphthalein	7.8-9.0	rose brown-blue green
Phenolphthalein	8.0-9.8	colorless-red violet
Thymolphthalein	9.3-10.5	colorless-blue
Tropeolin	11.1-12.7	yellow-orange brown

b. T. Milobedzski and S. Jajti studied the alcoholic blue cabbage extract named "cop". This extract exhibits the following colors; red at pH 2,

rose at 4-5, blue at 7, green at 8, yellow at 11. The solution is obtained by extracting blue cabbage with 50-60% alcohol. Solutions should be stored in orange colored bottle. Other extracts are generally unstable and cannot be used in alkaline solutions because they decompose rapidly.

c. Universal Indicators

1) methyl red, α-naphtolphthalein, phenolphthalein, bromthymol blue and thymolphthalein. Mix equal volumes of 0.1% solutions of the above five. This solution is red at pH of 4.0, yellow at 6, green-yellow at 7, green at 8, blue-violet at 10.

2) 100 mg phenolphthalein, 200 mg of methyl red, 300 mg of dimethyl yellow, 400 mg bromthymol blue, 500 mg of thymol blue in 500 ml. of alcohol, (methyl or ethyl), with sufficient 0.1N alkali added to produce a yellow color (pH=6); orange-red at pH 4, yellow at 6, yellow-green at 7, green at 8, blue at 10.

B. Turbidity

1. Jackson candle (refer to Standard Methods)

2. St. Louis or Baylis Turbidimeter (refer to Standard Methods)

3. Turbidity Rod: A calibrated rod, attached to one end is a fine plantinum wire of 1mm in diameter which is at right angles to the rod. 1.2 meters from this wire, is attached a wire ring through which the fine wire is observed when the rod is lowered into the water. To obtain the turbidity of a water with this instrument, the rod is lowered vertically into the water being tested. The observer places an eye immediately above the ring and watches the platinum wire as the rod is being lowered into the water. When the wire disappears from sight the position of the surface of the water is read on the calibrated scale of the rod, this is read in parts per million. The rod shall be graduated as follows; mark of 100 shall be placed on the rod at a distance of 100mm. from the center of the wire, and other gradations made so that:

Turbidity (ppm)	Vanishing depth of wire (mm)
10	794
20	426
40	228
60	158
80	122
100	100
150	72
200	57.4
300	43.2
400	35.4
500	30.9
1,000	20.9
2,000	14.8

C. Chlorine Residual

1. Orthotolidine method (Standard Methods)

D. Coliform

The technique is the same however certain materials can be substituted:

a. using durham tubes (inverted vials) to detect gas production instead of brom cresol purple.

b. using pH paper instead of brom cresol purple, should end up with a pH of about 5.

c. instead of plastic syrine, can use glass syringes or glass pipettes.

d. instead of powdered milk and bullion, can use regular media:
   8 grams of peptone and beef extract (nutrient broth)
   5 grams of Lactose

To be more accurate you can use the confirmed test or selective media, refer to Standard Methods.

E. Dissolved Oxygen

1. Winkler method or various modifications refer to Standard Methods.

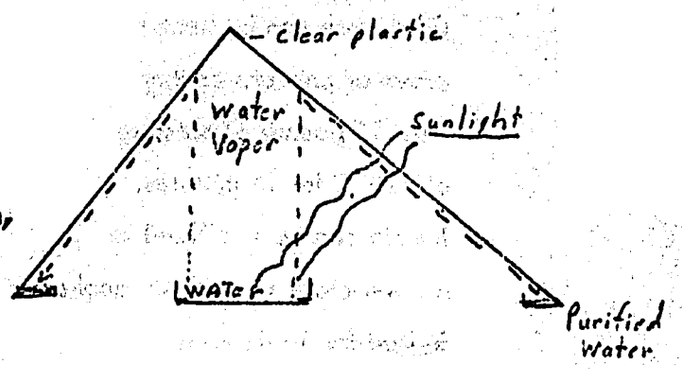
F. Relative Stability

1. BOD test, refer to Standard Methods or information on water analysis.

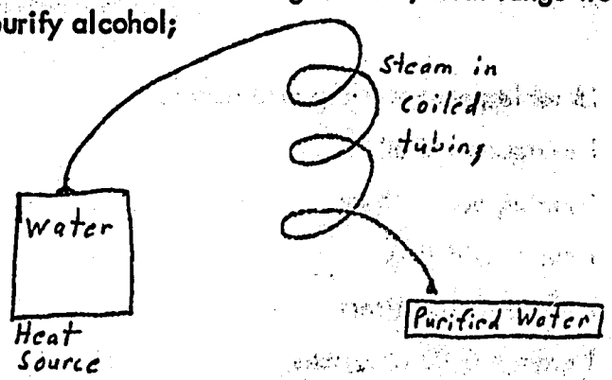
V. Distilling and Autoclaving

A. Distilling – the basic idea is to produce water in the gaseous state (thus leaving behind the impurities). This can be done in a number of ways:

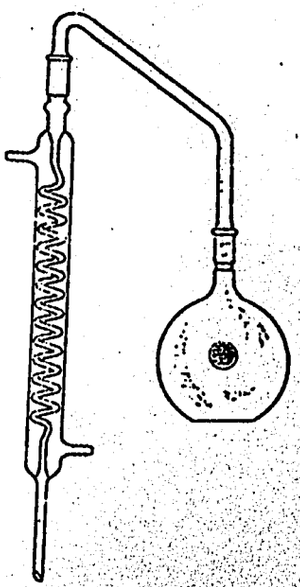
1. evaporation and collection, as in a greenhouse.



2. by heating the water to produce steam and then cooling the steam to obtain purified water. The method for distilling water by heat range from a simple still used to purify alcohol;



to more complex types that can be purchased from supply houses. These range from simple glass apparatuses



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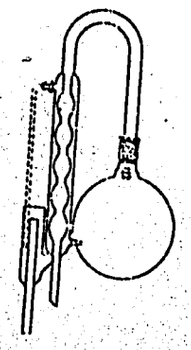

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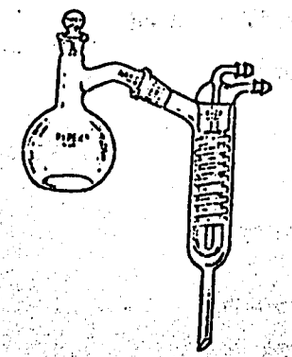
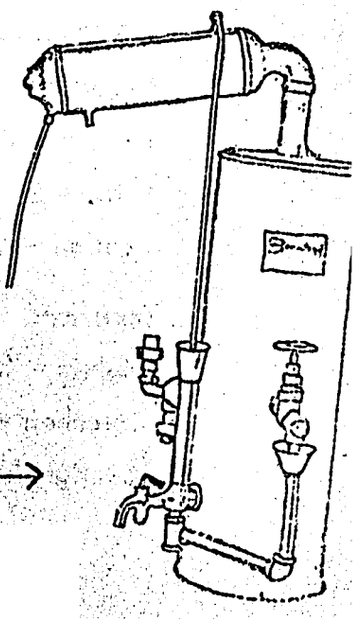
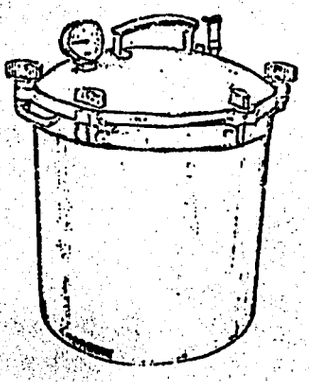


to elaborate electric or gas models. →



B. Autoclaving or sterilization – the idea here is to heat the material to a high enough temperature (using wet or dry heat) to kill or inactivate the micro-organisms.

Glassware can be heated in an oven at 170°C for 60 minutes, or put in an autoclave or pressure cooker (shown) with 15 pounds of pressure at 120°C for 15 minutes.



Media can be sterilized in an autoclave or pressure cooker as above or it can be boiled for 15 minutes.

CONVERSION TABLES

16 tablespoons = 1 cup or 8 ounces

1 teaspoon = 5 ml.

1 tablespoon = 15 ml.

1 cup = 1/4 liter

1 pint = .4732 liters

1 gram = 0.0352 ounces

1 ounce (avoir) = 28.35 grams

1 kilogram = 2.2046 pounds

1 pound = 453.6 grams

1 fluid ounce = 29.57 cc or ml.

1 quart = 946 milliliters

1 liter = 1.06 quarts

1 liter = 2.113 pints

1 gallon – 3.785 liters

Temperature Conversion

°Kelvin = °C + 273

°Farenheit = 9/5 °C + 32

°Centigrade = 5/9 (°F – 32)

1) pH paper wide range - (2.50)
narrow range - (2.50)

2) BOD bottles (4) - (2.37 each)
(9.48 total)

3) waterproof container
for pH paper - (0.50)

4) 150mm + 16mm (27)
culture tubes - (.24 each)
(6.48 total)

5) 125ml. dropper bottles - (.44 each)(5)
(2.20 total)

Sargent Welch
6) 2 wide mouth plastic bottles - (.65 each)
(1.30 total)

Sargent Welch
7) 1 wide mouth plastic bottle - (.90)

8) 4- 30cc syringes (disposable) - (.23 each)
(.92 total)

9) 1- 10cc syringe
(marked in tenths) - (.17)

10) 10-18 gauge needles - (.50)

11) thermometer
-10 to 260°C - (3.10)

12) ice chest - (15.00)

13) tube holders (3) - (1.75 each)
(5.25 total)

Total Equipment $50.80

Chemicals

1) potassium iodide, A.C.S. granular, 1/4 lb.	3.35
2) arrowroot starch	2.75/lb
3) Brom cresol purple, solution - 1 pint	4.00
4) powdered non-fat dry milk, 9.6 oz.	.70
5) beef bullion, 3 oz.	.27
6) Ferrous sulphate, 30 capsules	1.69
7) methylene blue, U.S.P., 1/4 lb.	4.37
8) Sodium Hydroxide, U.S.P., 1 lb.	
9) Mineral oil, 8 oz.	.66
Total chemicals	$ 19.87
Total equipment	$ 50.80
Kit total	$ 70.67

APPENDIX II

FURTHER DEVELOPMENT OF THE PROCESS MATRIX

A. Methods of Estimating Costs of Wastewater Treatment Systems in the United States

B. A Mathematical Model for Estimating Cost of Water and Wastewater Treatment Systems for Less Developed Countries

C. Cost Transfer Matrix

A. METHODS OF ESTIMATING COSTS OF WASTEWATER TREATMENT SYSTEMS IN THE UNITED STATES

Capital, operation and maintenance costs should be estimated before any choice of the process to be used is selected. It is not enough to estimate construction, engineering and legal fee costs because the operation and maintenance of some systems may go very high due to power consumption.

Land requirements play a significant part in stabilization lagoon design and expenditure. However, for conventional plants, land costs are usually smaller in comparison with overall costs. They may be considered as a separate entity for engineering estimates.

In some cases, especially in urban areas, the land required for building the plant may not be available or may be very small. In such situations, the stabilization lagoons and oxidation ponds should be eliminated from the process to be selected. Table 1 shows various wastewater treatment processes.

In the past, comprehensive assessment of the cost of wastewater collection and treatment in the United States has been made by various individuals or agencies. Smith and Eiler[3] have developed a log-log regression equation for predicting capital, operation and maintenance costs of wastewater treatment plants. Their analysis assumed cost was a function of flow and population and did not take into the consideration high BOD's produced by industries.

Their equation is in the form

$$Y = ax^b$$

where

Y = Capital costs or per capita operation and maintenance costs

X = population

a and b are constants

The estimating relationship of Smith and Eiler has been adjusted upward to 1973 dollars on the basis of an assumed 6.25% annual inflation rate[5]. Table 2 shows a computer

TABLE 1

	Land*	Power**
Stabilization Lagoon	vs	
Oxidation pond	vs	
Aeration Lagoon	s	x
Primary Sedimentation	s	x
Activated Sludge	ns	x
	ns	x

*vs very significant **power required
s significant
ns not significant

TABLE 2

COST OF WASTEWATER TREATMENT

POPULATION	WASTE STAB. Const.	WASTE STAB. O&M	PRIM. SED. Const.	PRIM. SED. O&M	ACT. SLUD. Const.	ACT. SLUD. O&M	TRICKLING FILTER Const.	TRICKLING FILTER O&M
5000	22.35	0.67	59.39	2.57	87.74	5.10	72.05	3.03
7500	17.49	0.57	52.74	2.39	[illegible]	[illegible]	71.97	3.42
10000	14.70	0.50	49.54	2.27	75.86	4.39	67.05	3.19
12500	12.84	0.46	45.59	2.19	72.39	4.16	64.99	2.87
15000	11.50	0.42	43.17	2.12	69.67	3.99	62.66	2.70
17500	10.47	0.40	41.29	2.06	67.45	3.84	60.75	2.56
20000	9.66	0.38	39.72	2.01	65.59	3.72	59.15	2.45
22500	9.00	0.36	38.40	1.97	63.98	3.61	57.78	2.35
25000	8.44	0.34	37.24	1.94	62.59	3.52	56.57	2.27
27500	7.97	0.33	36.23	1.90	61.36	3.44	55.50	2.20
30000	7.56	0.32	35.33	1.88	60.23	3.37	54.55	2.13
32500	7.20	0.31	34.52	1.85	59.23	3.31	53.68	2.08
35000	6.89	0.30	33.79	1.83	58.31	3.25	52.89	2.03
37500	6.61	0.29	33.13	1.80	57.47	3.20	52.16	1.98
40000	6.35	0.28	32.51	1.78	56.70	3.15	51.50	1.94
42500	6.12	0.28	31.95	1.76	55.98	3.10	50.88	1.90
45000	5.92	0.27	31.43	1.75	55.31	3.06	50.30	1.86
47500	5.73	0.26	30.94	1.73	54.69	3.02	49.76	1.83
50000	5.55	0.26	30.48	1.71	54.10	2.99	49.25	1.79
52500	5.39	0.25	30.06	1.70	53.55	2.95	48.77	1.76
55000	5.24	0.25	29.65	1.68	53.03	2.92	48.32	1.74
57500	5.10	0.24	29.28	1.67	52.54	2.89	47.90	1.71
60000	4.97	0.24	28.92	1.66	52.07	2.86	47.48	1.69
62500	4.85	0.23	28.58	1.65	51.63	2.83	47.10	1.66
65000	4.74	0.23	28.26	1.64	51.20	2.80	46.73	1.64
67500	4.63	0.23	27.95	1.63	50.80	2.78	46.39	1.62
70000	4.53	0.22	27.66	1.62	50.41	2.75	46.06	1.60
72500	4.43	0.22	27.38	1.61	50.04	2.73	45.72	1.58
75000	4.34	0.22	27.11	1.60	49.69	2.71	45.41	1.56
77500	4.26	0.21	26.86	1.59	49.35	2.69	45.12	1.55
80000	4.18	0.21	26.61	1.58	49.02	2.67	44.83	1.53
82500	4.10	0.21	26.38	1.57	48.72	2.65	44.55	1.51
85000	4.03	0.21	26.15	1.56	48.40	2.63	44.29	1.50
87500	3.96	0.20	25.93	1.55	48.10	2.61	44.03	1.48
90000	3.89	0.20	25.72	1.55	47.82	2.59	43.78	1.47
92500	3.83	0.20	25.52	1.54	47.55	2.57	43.55	1.46
95000	3.76	0.20	25.32	1.53	47.28	2.56	43.32	1.44
97500	3.71	0.19	25.13	1.53	47.02	2.54	43.09	1.43
100000	3.65	0.19	24.95	1.52	46.77	2.53	42.87	1.42

print-out of costs at various population level. Construction is given in dollars per capita and operation and maintenance in dollars per capita per year.

Table 2 shows that the cost of construction, operating, and maintaining stabilization lagoon at lower population is considerably lower than those required for building and maintaining conventional wastewater treatment systems.

Thus stabilization lagoons, compared to conventional disposal systems seem to be economical at small communities of less than 10,000 population. However, in view of the necessity of a large track of the land, especially with high populations, conventional treatment plants will be far more economical.

Studies have been done of municipal sewage treatment construction costs for 291 projects built in Illinois between 1957 and 1968[1]. These studies used least square regression analysis to relate design population equivalent to construction costs.

A regression equation was also developed for estimating lagoon land costs, plant operating costs, and FWPA construction indexes. The equations for estimating construction, operating, and land costs were developed in the general geometric form:

$$C = KP^n$$

where:

C = either construction, operating or land costs

K = regression constant

P = Sewage treatment capacity or average annual load treated

n = slope of the least square regression line.

A new equation was also developed to account of future expansion of the plant in the form:

$$C = KP^nS^m$$

where:

C = cost of new addition to old

K = a regression constant

P = capacity of new addition

S = capacity of existing plant

n, m = slope constants.

Following are the summary of equations developed for Illinois.

Stab. lagoon	$C_1 = 349P^{-.690}$
Primary digester	$C = 4290P^{-.506}$
Primary vacuum	$C = 634P^{-.362}$
Trickling filter digester	$C = 1069P^{-.362}$
Trickling filter imoff	$C = 738P^{-.328}$
Activated Sludge (in place build) P.E. $\geq$ 10,000	$C = 3746P^{-.493}$
Activated Sludge (in place built) P.E. $\leq$ 10,000	$C = 91P^{-.09}$
Activated Sludge (factory build)	$C = 1298P^{-.877}$
Lagoon land cost	$C_2 = 22.1P^{.877}$
Conventional plant operating cost	$C_0 = 23.3Pn^{.213}$

Table 3 gives Illinois construction costs. Other cost estimate studies have been done by Vebr[9], Diachishim[11], Rowan[12], and Assenso[4]. Only Assenso used population equivalent to develop the equation. However, he developed only one equation for all the processes.

Shah and Reid[2] developed separate equations for each process. In their study they included a dummy variable to account for different types of secondary treatment plants. Summary of their equations are given below:

$$\ln y = bo + \Sigma b_i \ln X_i \qquad a$$

$$\ln y = bo + \Sigma b_i \ln X_i + D_1 + D_2 \qquad b$$

$$\frac{1}{\ln y} = bo + \Sigma b_i \ln X_i \qquad c$$

$$\frac{1}{y} = bo + \Sigma b_i X_i \qquad d$$

where

Equation a is for primary and secondary plants

D_1 and D_2 are dummy variables

TABLE 3

Construction Cost Comparisons of Illinois Sewage Treatment Plants for 1957-1959 Base

Type of treatment plant	Total cost for design *PE*'s of 500	1000	2000	5000	10,000	30,000	Cost ratio * for design *PE*'s of 500	1000	2000	5000	10,000	30,000
Primary -- digester			183,000	287,800	403,700	696,900			1.50	1.27	1.12	0.92
Primary -- vacuum filter			80,900	145,300	226,000	456,000			0.66	0.64	0.63	0.61
Trickling filter-digester		95,100	149,900	272,000	426,900	872,400		1.24	1.23	1.20	1.19	1.16
Trickling filter-Imhoff	48,000	76,600	122,100	226,100	360,200	753,900	1.00	1.00	1.00	1.00	1.00	1.00
Activated sludge, constructed in place		124,900	176,000	293,200	397,800	1,081,000		1.63	1.44	1.30	1.10	1.43
Activated sludge, factory built	53,500	81,000	122,600	212,200	321,200		1.11	1.06	1.00	0.94	0.89	
Trickling filter additions	63,250	96,200	146,400	254,900	387,700	753,900	1.32	1.26	1.19	1.13	1.08	1.00
Activated sludge additions	77,500	119,500	184,300	326,850	504,000	1,002,000	1.61	1.56	1.50	1.45	1.40	1.33
Oxidation lagoon without land cost	25,400	41,000	66,200	124,000	201,000		0.53	0.54	0.54	0.55	0.56	
Oxidation lagoon with land cost	30,600	50,500	83,600	162,800	272,300		0.64	0.66	0.68	0.72	0.76	

* *Ratio of construction costs to trickling filter-Imhoff costs*

T.A. Butts and R.L. Evans, Cost of Municipal Sewage Treatment, Illinois State Water Survey, Urbana, 1970, pp. 36.

TABLE 4

K.L. Shah, Techniques of Estimating Construction Costs of Waste Treatment Plants, Ph.D. Dissertation, Univ. of Okla. 1969, p. 128.

ESTIMATED MEAN CONSTRUCTION COSTS PER DESIGN PE FOR SELECTED CAPACITIES

Type of Plant	PE Designed	Flow in MGD Designed	Estimate of Mean Cost
Standard-Rate Trickling Filter	100	0.01	$ 222.91
	1,000	0.1	77.98
	10,000	1.0	27.28
	100,000	10.0	9.54
	500,000	50.0	4.58
	1,000,000	100.0.	3.33
High-Rate Trickling Filter	100	0.01	120.14
	1,000	0.1	61.81
	10,000	1.0	31.80
	100,000	10.0	16.36
	500,000	50.0	10.28
	1,000,000	100.0	8.41
Activated Sludge	100	0.01	127.62
	1,000	0.1	67.52
	10,000	1.0	35.72
	100,000	10.0	18.89
	500,000	50.0	12.11
	1,000,000	100.0	9.99
All Secondary Treatment Plants Combined*	100	0.01	146.93
	1,000	0.1	71.27
	10,000	1.0	34.57
	100,000	10.0	16.76
	500,000	50.0	10.11
	1,000,000	100.0	8.13

*Using dummy variables.

Equation b is for secondary municipal and primary and secondary industrial wastes.

Equation c and d are for stabilization ponds

Table 4 shows construction costs, applying Shah and Reids equations a, b, c, d.

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13. Logan, J.A., et.al., Analysis of the Economics of Wastewater Treatment, Jour. Water Poll. Control Fed., 34, 860, 1962.

B. A MATHEMATICAL MODEL FOR ESTIMATING COST OF WATER AND WASTEWATER TREATMENT SYSTEM FOR LESS DEVELOPED COUNTRIES

With increases in population, urbanization and industrialization, the demand of water is likely to go up in Less Developed Countries. More and more wastewater will be discharged into rivers, lakes, and oceans causing health hazards, not only to human beings, but to wildlife. The problem of this part of study, therefore, arises from the need of a cost estimate of construction, operation, and maintenance of water and wastewater systems in Less Developed Countries. At the present the LDC's apply a rule of thumb or cost estimates from industrial countries. These estimates may not give actual estimate in Less Developed Countries since most of the materials, equipment, and technical manpower have to be imported. For example, Table 1 shows per capita construction, operation, and maintenance costs in U.S. and LDC (India).

In this example, construction, operation, and maintenance costs are much lower in the LDC (India) than those of the U.S. This is because land is cheaper in LDC and construction materials and labor for constructing lagoons are locally available. However, in the case of conventional water and wastewater systems, LDC costs will be much higher. Table 2 shows the cost of wastewater treatment in Thailand.

It is possible to develop mathematical equations for construction, operation, and maintenance costs for various processes with environmental parameters which can be applied in LDC's before construction is undertaken. With this model it should be possible to optimize the least costly process with the environment conditions such as climate, soil type, lifestyle, precipitation, source of water and size of the city. Field data will be obtained from various LDC's in order to produce a representative value from the model.

The purpose of the model will be:

1. To provide administrators, engineers, public officials in LDC's concerned with particular future water and wastewater systems with information which would allow them to assess the general level of construction costs to be anticipated prior to a detailed engineering determination of an estimated cost.

TABLE 1

U.S. WASTEWATER TREATMENT COST vs. LDC COST

		U.S.A.[1]		LDC (INDIA)[2]	
PROCESS	POPULATION	CONSTRUCTION dollars/capita	Oper. & Maint. dollars/yr. capita	CONSTRUCTION[3] dollars/capita	Oper. & Maint. dollars/yr. capita
Waste Stabilization Lagoon	5,000	16.56	0.50	2.09	0.32
	10,000	10.89	0.39	1.84	0.25
	50,000	4.11	0.20	1.29	0.17
	100,000	2.70	0.14	1.25	0.14
	200,000	1.78	0.11	1.17	0.12

[1] Cost to Consumer for Collection and Treatment of Wastewater U.S., EPA. July, 1970

[2] Low Cost Waste Treatment, CPHERI, Nagpur, India, 1972

[3] Includes Land Cost

TABLE 2

COST OF EXISTING WASTE TREATMENT PLANTS IN BANGKOK, THAILAND*

PROCESS	SOURCE OF WASTE	POPULATION EQ. (P.E.)	COST IN U.S. DOLLARS
Activated sludge	Beverage	20,000	150,000
Activated sludge	Beverage	20,000	350,000
Mechanical batch areation	Reconstituted milk	5,000	25,000
Activated sludge (Biosorption)	Reconstituted milk	5,000	50,000
Spray pond	Ice cream	4,000	150,000

*Low Cost Waste Treatment, CPHERI, Nagpur, India, 1972.

2. To provide financial guidance in making preliminary decisions concerning future water and wastewater process in Less Developed Countries.

3. To provide the least costly operation and maintenance processes in LDC.

4. To establish costs using environmental parameters of LDC.

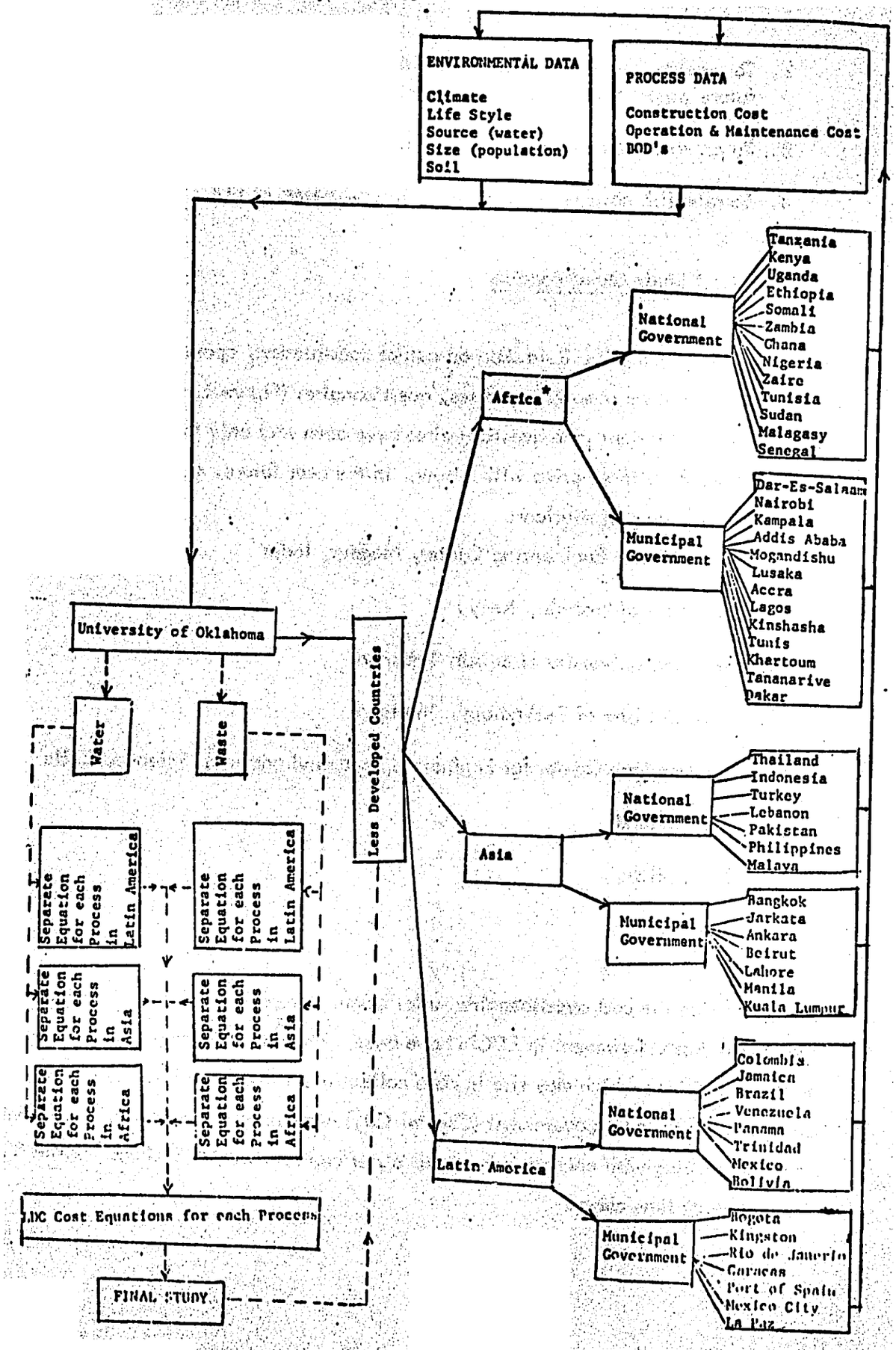
OU/LDC Cost Study Questionnaire

To obtain a representative field data on actual construction, operation, and maintenance costs of water and wastewater processes, questionnaires (Figure 1) have been sent directly to LDC. At the present time questionnaires have been sent only to Africa. The Far East, Middle East and Latin America will follow. In the near future, questionnaires will be sent to the following institutions:

1. Public Health Engineering Center, Nagpur, India
2. University of Nairobi, Kenya
3. American University of Beirut, Lebanon
4. Asian Institute of Technology, Thailand
5. Pan American Center for Engineering and Environmental Science, Chile
6. IRC/Holland
7. IRC/Zurich
8. UNEP

Accompanying the cost questionnaire, a letter and summary of the Low Cost Methods of Water and Waste Treatment in LDC's have been included. Due to problems of handling mail and problems which may rise in data collection, it has been necessary to send one questionnaire to local government (Capital City) and the other one to national government agencies dealing with construction of the Water and Wastewater Systems. Table 3 shows the cost study flow chart.

Table 3 Cost Study Flow Chart



NOTE: This is only a few of the total countries. In Africa alone a total of 45 countries have been mailed the questionnaires directly to the ministries of health, water, and municipal governments.

Figure 1

QUESTIONNAIRE 1

WATER AND WASTE CONSTRUCTION COST STUDIES

FOR DEVELOPING COUNTRIES

BUREAU OF WATER RESOURCES AND ENVIRONMENTAL SCIENCES RESEARCH

UNIVERSITY OF OKLAHOMA

NORMAN, OKLAHOMA 73069

U.S.A.

FEBRUARY, 1974

Please supply flowing data as shown in the tables for water and wastewater treatment processes. Indicate if the flow is in metric system or English (MGD), and if the cost is in local currency or in U.S. equivalent dollars.

Have you ever had any problem with operational and maintenance of your plants?

Yes_____

No_____

If Yes, which one and how did you overcome it?_____

_____

_____

Please do not hesitate to send any information on water and waste treatment in your country which you feel might be of help in our studies.

Would you like to have a final report of the study

Yes_____

No_____

Name and Title of individual completing questionnaire_____

_____

Address_____

Date_____

Figure 1a

WATER TREATMENT PROCESSES
(AID-UNIVERSITY OF OKLAHOMA LDC PROJECT)

Name of the Country_____

Name of the Town or City	Year Construction Completed	Type of Treatment Plant (e.g. slow sand filter or rapid sand filter)	Population Served	Design Capacity Million Gallons per Day (MGD)*	Construction Cost (in local currency or U.S. Dollars)**	Operation + Maintenance Cost/Year (in local currency or U.S. Dollars)**

* If design capacity is in metric system, please indicate.

** Please indicate currency.

Figure 1b

WASTEWATER TREATMENT PROCESSES
(AID-UNIVERSITY OF OKLAHOMA LDC PROJECT)

Name of the Country

ame of the own or City	Year Construction Completed	Type of Treatment Plant (e.g. Lagoon, Activated Sludge, etc.)	Population Served	Flow Into Treatment Plant MGD*	5 Days BOD of Effluent	5 Days BOD of Inffluent	Construction Cost (in local currency or U.S. Dollars)**	Operati and Mainte-nance Cost pe Year (i local currenc or U.S. Dollars

* If design capacity is in metric system, please indicate.

** Please indicate currency.

Methodology

Upon the return of OU/LDC/COST questionnaire, multiple regression and correlation methods will be used to formulate construction, operation, and maintenance mathematica equations for each process in LDC's. The model will be subdivided into two parts:

1. Deterministic Cost Model

   In this part the cost will be assumed to be function of flow in water and wastewater will be function of population equivalent.
   Thus:

   $C = f\,(\text{flow})$ for water -- (1)

   $C = f\,(P.E.)$ for waste -- (2)

   $C = a \times b$ -- (3)

   Where

   a = regression constant

   b = slope of least square regression line

   X = flow in mgd for water

   X = population equivalent (P.E.) for waste water

   Where

   $$P.E. = \frac{mgd \times BOD \times 8.3}{.2} \quad \text{-- (4)}$$

   Summary of such equations shall be shown as on Tables 4,5,6,7.

2. Probabilistic Cost Model

   Because per capita cost of water and wastewater processes may be influenced by the environmental parameters of the country, city or village, such as lifestyle, climate, source of water, precipitation, etc., an equation could be developed using the environmental index.

   $$\text{Per Capita/Cost} = f\,(L_1, L_2, L_3, L_4, L_5, L_6) \quad \text{-- (5)}$$

Table 4

Construction Cost Matrix

Water Treatment Systems	Africa	Asia	Latin America	Less Dev. Countries
Slow Sand Filter	$C_{AF} = ax^b$	$C_{AS} = ax^b$	$C_{LA} = ax^b$	$C_{LDC} = ax^b$
Rapid Sand Filter				
⋮				
Si				

Table 5

Construction Cost Matrix

Waste Water Treatment Systems	Africa	Asia	Latin America	Less Dev. Countries
Stabilization Pond	$C_A = ax^b$	$C_{AS} = ax^b$	$C_{LA} = ax^b$	$C_{LDC} = ax^b$
Activate Sludge				
Slow-Rate Trickling Filter				
High-Rate Trickling Filter				
⋮				
Si				

Table 6

Operation and Maintenance Cost Matrix

Water Treatment Systems	Africa	Asia	Latin America	Less Dev. Countries
Slow Sand Filter	$C_{AF} = ax^b$	$C_{AS} = ax^b$	$C_{LA} = ax^b$	$C_{LDC} = ax^b$
Rapid Sand Filter				
⋮				
Si				

Table 7

Operation and Maintenance Cost Matrix

Waste Water Treatment Systems	Africa	Asia	Latin America	Dev. Countries. Less Dev. Countries
Stabilization Pond	$C_A = ax^b$	$C_{AS} = ax^b$	$C_{LA} = ax^b$	$C_{LDC} = ax^b$
Activate Sludge				
Slow-Rate Trickling Filter				
High-Rate Trickling Filter				
⋮				
Si				

Where

$$L_1 = f(U_1, U_2, U_3, U_4) \quad \text{-- (6)}$$

$$L_2 = f(E_1, E_2, E_3, E_4) \quad \text{-- (7)}$$

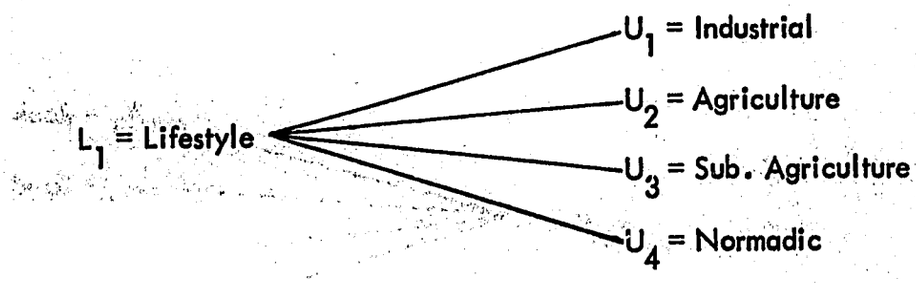
$$L_3 = f(K_1, K_2, K_3, K_4) \quad \text{-- (8)}$$

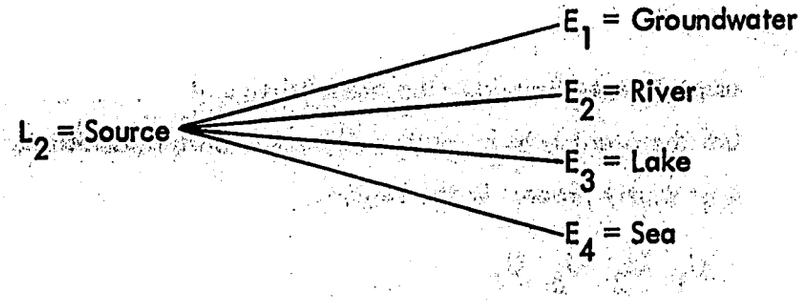
$$L_4 = f(P_1, P_2, P_3, P_4) \quad \text{-- (9)}$$

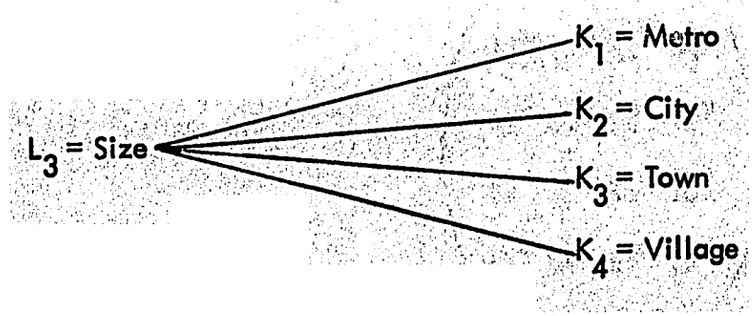
$$L_5 = f(F_1, F_2, F_3, F_4) \quad \text{-- (10)}$$

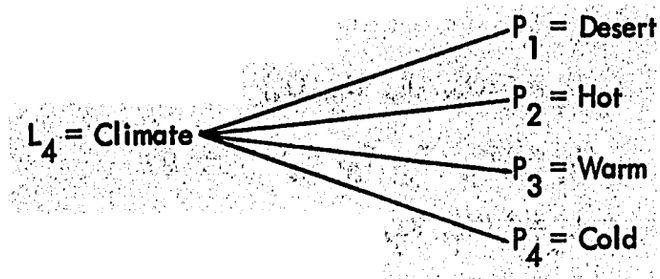
$$L_6 = f(A_1, A_2, A_3, A_4) \quad \text{-- (11)}$$

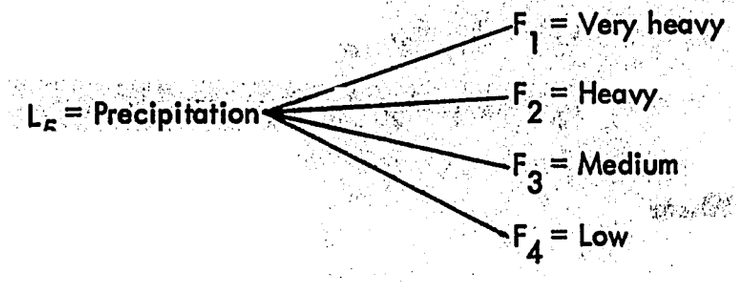
Where

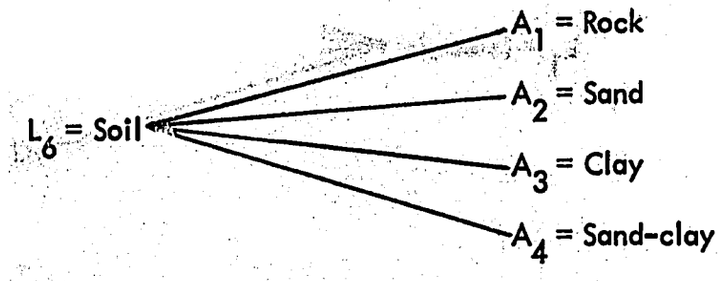












With previous parameters in mind, the probabilities of finding various parameters in any location where the plant is to be built will be formulated as follows and shall be used to locate the least costly process in the region.

$$P = \begin{array}{c} \\ U_1 \\ U_2 \\ U_3 \\ U_4 \end{array} \begin{array}{c} \begin{array}{cccc} U_1 & U_2 & U_3 & U_4 \end{array} \\ \begin{pmatrix} u_{11} & u_{12} & u_{13} & u_{14} \\ u_{21} & u_{22} & u_{23} & u_{24} \\ u_{31} & u_{32} & u_{33} & u_{34} \\ u_{41} & u_{42} & u_{43} & u_{44} \end{pmatrix} \end{array}$$

For L_1

$$P = \begin{pmatrix} e_{11} & e_{12} & e_{13} & e_{14} \\ e_{21} & e_{22} & e_{23} & e_{24} \\ e_{31} & e_{32} & e_{33} & e_{34} \\ e_{41} & e_{42} & e_{43} & e_{44} \end{pmatrix} \quad \text{For } L_2$$

$$P = \begin{pmatrix} k_{11} & k_{12} & k_{13} & k_{14} \\ k_{21} & k_{22} & k_{23} & k_{24} \\ k_{31} & k_{32} & k_{33} & k_{34} \\ k_{41} & k_{42} & k_{43} & k_{44} \end{pmatrix} \quad \text{For } L_3$$

$$P = \begin{pmatrix} p_{11} & p_{12} & p_{13} & p_{14} \\ p_{21} & p_{22} & p_{23} & p_{24} \\ p_{31} & p_{32} & p_{33} & p_{34} \\ p_{41} & p_{42} & p_{43} & p_{44} \end{pmatrix} \quad \text{For } L_4$$

$$P = \begin{pmatrix} f_{11} & f_{12} & f_{13} & f_{14} \\ f_{21} & f_{22} & f_{23} & f_{24} \\ f_{31} & f_{32} & f_{33} & f_{34} \\ f_{41} & f_{42} & f_{43} & f_{44} \end{pmatrix} \quad \text{For } L_5$$

$$P = \begin{pmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \\ a_{31} & a_{32} & a_{33} & a_{34} \\ a_{41} & a_{42} & a_{43} & a_{44} \end{pmatrix} \quad \text{For } L_6$$

Finally a computer print out will then be developed which can establish the least costly process, given the environmental types of the region. See Table 8.

TABLE 8

PROPOSED COMPUTER PRINT OUT FOR LEAST COSTLY PROCESS

Process	Env. Condition of the Region	Flow in MGD	COST
P_1	$U_1\ E_1\ K_1\ P_1\ F_1\ A_1$		
P_2			
P_3			
P_4			
P_i			
P_1			
P_2			
P_3			
P_i			
P_1			
P_2			

Let:

Chlorination = P_1 Settling = P_3 Lagoon = P_1 Activated Sludge = P_3

Slow Sand Filter = P_2 Rapid Sand Filter = P_4 Prim. Sed. = P_2 Trickling Filter = P_4

C. COST TRANSFER MATRIX

Numerous studies have been published regarding cost data for water and waste treatment facilities in the United States. 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 is accomplished by breaking cost of operation and maintenance, and construction costs down into basic components (i. e., labor, material, etc.) for each catagory 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 is multiplied by U.S. cost products, total operation and maintenance, and capital costs for each treatment process for an individual site based on local conditions.

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 1 with typical percentages for the trickling filter process. These values will differ with population size and from country to country, depending on technology level.

TABLE 1

Percentage Labor and Material

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%

The total cost of a treatment facility is the sum of labor and material (excluding land, legal and engineering) and 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 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. This same location may be required to pay skilled craftsmen, who are in short supply and must be imported, $9.00 per hour.

This would increase the cost of the facility operation to $4.80 (20%) 9/6 = $1.44 per capita per year. 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:

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

Where:

C = cost

L = labor percent of cost

M = materials percent of cos

Therefore, from the above values:

$$C_{LDC} = \$.30\ [(50\%)(30\% \times 1/3 + 20\% \times 9/6)$$

$$+ (50\%)(40\% \times 1/3 + 10\% \times 2/1)]$$

$$= \$1.50 + \$4.50 + \$2.00 + \$3.00$$

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

The actual values for cost of labor and materials will be 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 2 through 13 show typical values for a number of possible applications.

TABLE 2

WATER-OPERATION COST TRANSI MATRIX

TECHNOLOGY LEVEL - I

OPERATIONAL COSTS FOR SELECTED TREATMENT PROCESSES

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 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 SERVERED DC - X 1000 P	TOTAL OPERATION PER CAPITA COST LDC - US C
Slow sand filter	90	80	10	.25	3	9	6	10	10	0	1/2	3/1	2 .5 .25 .2	0.5 25 50 100	
Rapid sand filter	80	60	20	.25	3	9	6	20	20	0	1/2	3/1	4 2 1.75 1.5	0.5 25 50 100	
Sedimen-tation filtration	95	90	5	.25	3	9	6	5	5	0	1/2	3/1	6 3.5 2.75 2.5	0.5 25 50 100	
Chlor-ination	50	10	40	.25	3	9	6	50	10	40	1/2	3/1	5 2.3 1.75 1.5	0.5 25 50 100	

$$C = (C_1)\ (X_{11} * X_{21}/X_{22}) + (X_{12} * X_{31}/X_{32}) + (X_{41} * X_{51}) + (X_{42} * X_{52})$$

TABLE 3

WASTE WATER COST TRANSFER MATRIX

TECHNOLOGY LEVEL - I

OPERATIONAL COSTS FOR SELECTED TREATMENT PROCESSES

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 COUNTRY MATERIALS	COST IN COUNTRY MATERIALS LDC/DC	COST OUT OF COUNTRY MATERIALS LDC/DC	TOTAL OPERATION COST PER CAPITA DC - US $	POPULATION SERVERED DC - X 1000	TOTAL OPERATION PER CAPITA COST LDC - US
		X_{11}	X_{12}	X_{21}	X_{22}	X_{31}	X_{32}		X_{41}	X_{42}	X_{51}	X_{52}	C_1	P	C
Lagoon	95	95	0	.25	3	9	6	5	5	0	1/3	2/1	.34 .26 .19	.5 25 50 100	
Primary sedimen-tation sludge dig	90	85	5	.25	3	9	6	10	5	5	1/3	2/1	1.94 1.71 1.52	.5 25 50 100	
Trickling filter	85	80	5	.25	3	9	6	15	5	10	1/3	2/1	3.52 2.98 2.52	.5 25 50 100	
Activated sludge	75	70	5	.25	3	9	6	25	5	20	1/3	2/1	2.27 1.79 1.42	.5 25 50 100	

$$C = (C_1)\ (X_{11} * X_{21}/X_{22}) + (X_{12} * X_{31}/X_{32}) + (X_{41} * X_{51}) + (X_{42} * X_{52})$$

TABLE 4

WATER-OPERATION COST TRANSFER MATRIX

TECHNOLOGY LEVEL - II

OPERATIONAL COSTS FOR SELECTED TREATMENT PROCESSES

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 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 SERVERED DC - X 1000 P	TOTAL OPERATION PER CAPITA COST LDC - US C
Slow sand filter	90	80	10	.75 .75 1. 1.	3	9 9 8 8	6	10	10	0	1/2 1/2 1/1.5 1/1.5	1.5/1	2. .5 .25 .2	.05 25 50 100	
Rapid sand filter	80	60	20	.75 .75 1. 1.	3	9 9 8 8	6	20	20	0	1/2 1/2 1/1.5 1/1.5	1.5/1	4 2 1.75 1.5	.05 25 50 100	
Sedimen-tation filtration	95	5	0	.75 .75 1. 1.	3	9 9 8 8	6	5	5	0	1/2 1/2 1/1.5 1/1.5	1.5/1	6 3.5 2.75 2.5	.05 25 50 100	
Chlor-ination	50	10	40	.75 .75 1. 1.	3	9 9 8 8	6	50	10	40	1/2 1/2 1/1.5 1/1.5	1.5/1	5 2.3 1.75 1.5	.05 25 50 100	

$$C = (C_1)\ (X_{11} * X_{21}/X_{22}) + (X_{12} * X_{31}/X_{32}) + (X_{41} * X_{51}) + (X_{42} * X_{52})$$

TABLE 5

WASTE WATER COST TRANSFER MATRIX

TECHNOLOGY LEVEL - II

OPERATIONAL COSTS FOR SELECTED TREATMENT PROCESSES

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 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 SERVERED DC - X 1000 P	TOTAL OPERATIONAL PER CAPITA COST LDC - US C
Lagoon	95	95	0	.75 .75 1 1	3	9 9 8 8	6	5	5	0	1/2 1/2 1/1.5 1/1.5	1.5/1	.34 .26 .19	.5 25 50 100	
Primary sedimen-tation sludge die	90	85	5	.75 .75 1 1	3	9 9 8 8	6	10	5	5	1/2 1/2 1/1.5 1/1.5	1.5/1	1.94 1.71 1.51	.5 25 50 100	
Trick-ling filter	85	75	10	.75 .75 1 1	3	9 9 8 8	6	15	10	5	1/2 1/2 1/1.5 1/1.5	1.5/1	3.52 2.98 2.52	.5 25 50 100	
Activated sludge	75	60	15	.75 .75 1 1	3	9 9 8 8	6	20	10	10	1/2 1/2 1/1.5 1/1.5	1.5/1	2.27 1.79 1.42	.5 25 50 100	

$$C = (C_1)\ (X_{11} * X_{21}/X_{22}) + (X_{12} * X_{31}/X_{32}) + (X_{41} * X_{51}) + (X_{42} * X_{52})$$

TABLE 6

WATER-OPERATION COST TRANSFER MATRIX

TECHNOLOGY LEVEL - III

OPERATIONAL COSTS FOR SELECTED TREATMENT PROCESSES

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 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 SERVERED DC - X 1000 P	TOTAL OPERATIONAL PER CAPITA COST LDC - US C
Slow sand filter	90	10	0	1 1 1.5 1.5	3	8 8 7 7	6	10	10	0	1/1.5	1.5/1	2 .5 .25 .2	.05 25 50 100	
Rapid sand filter	80	10	10	1 1 1.5 1.5	3	8 8 7 7	6	20	15	5	1/1.5	1.5/1	4 2 1.75 1.5	.05 25 50 100	
Sedimen-tation filtration	90	5	5	1 1 1.5 1.5	3	8 8 7 7	6	10	5	0	1/1.5	1.5/1	6 3.5 2.75 2.5	.05 25 50 100	
Chlor-ination	40	10	30	1 1 1.5 1.5	3	8 8 7 7	6	60	40	20	1/1.5	1.5/1	5 2.3 1.75 1.5	.05 25 50 100	

$$C = (C_1)\ (X_{11} * X_{21}/X_{22}) + (X_{12} * X_{31}/X_{32}) + (X_{41} * X_{51}) + (X_{42} * X_{52})$$

TABLE 7

WASTE WATER COST TRANSFER MATRIX

TECHNOLOGY LEVEL - III

OPERATIONAL COSTS FOR SELECTED TREATMENT PROCESSES

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 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 SERVERED DC - X 1000 P	TOTAL OPERATION PER CAPITA COST LDC - US C
Lagoon	95	95	0	1	3	8 8 7 6	6	5	5	0	1/1.5	1.5/1	.34 .26 .19	.5 25 50 100	
Primary sedimen-tation sludge	90	85	5	1	3	8 8 7 6	6	10	5	5	1/1.5	1.5/1	1.94 1.71 1.52	.5 25 50 100	
Trickling filter	85	75	10	1	3	8 8 7 6	6	15	10	5	1/1.5	1.5/1	3.52 2.98 2.52	.5 25 50 100	
Activated sludge	75	55	20	1	3	8 8 7 6	6	20	15	5	1/1.5	1.5/1	2.27 1.79 1.42	.5 25 50 100	

$$C = (C_1)\ (X_{11} * X_{21}/X_{22}) + (X_{12} * X_{31}/X_{32}) + (X_{41} * X_{51}) + (X_{42} * X_{52})$$

TABLE 8

WATER TREATMENT COST TRANSFER CONSTRUCTION MATRIX

LABOR AND MATERIAL FOR SELECTED TREATMENT PROCESSES

TECHNOLOGY LEVEL - I

TREATMENT PROCESSES	LABOR AS PERCENT OF LDC CONSTRUCTION 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}	MATERIAL AS PERCENT OF LDC CONSTRUCTION COST	PERCENT ON-SITE MATERIALS MANUFAC. X_{41}	PERCENT OFF-SITE MATERIALS MANUFAC. X_{42}	COST ON-SITE MATERIALS MANUFAC. LDC/DC X_{51}	COST OFF-SITE MATERIALS MANUFAC. LDC/DC X_{52}	TOTAL CONSTRUCTION COST PER CAPITA DC - US $ C_1	POPULATION SERVERED DC - X 1000 P	TOTAL CONSTRUCTION COST LDC - US $ C
Slow sand filter	60	40	10	.25	3	9	6	40	30	10	1/3	2/1	67 6 4 2.7	0.5 25 50 100	
Rapid sand filter	40	20	20	.25	3	9	6	60	40	20	1/3	2/1	88 24 19.5 15.5	0.5 25 50 100	
Sedimen-tation filtration	70	50	20	.25	3	9	6	30	20	10	1/3	2/1	137 40.5 33 26.5	0.5 25 50 100	
Chlor-ination	30	20	10	.25	3	9	6	70	10	50	1/3	2/1	134 40 32 26	0.5 25 50 100	

$$C = (C_1)(X_{11} \times {}_{21}/X_{22}) + (X_{12} * X_{31}/X_{32}) + (X_{41} * X_{51}) + (X_{42} * X_{52})$$

TABLE 9

WASTEWATER COST TRANSFER CONSTRUCTION-MATRIX

LABOR AND MATERIAL FOR SELECTED TREATMENT PROCESSES

TECHNOLOGY LEVEL - I

TREATMENT PROCESSES	LABOR AS PERCENT OF LDC CONSTRUCTION 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}	MATERIAL AS PERCENT OF LDC CONSTRUCTION COST	PERCENT ON-SITE MATERIALS MANUFAC. X_{41}	PERCENT OFF-SITE MATERIALS MANUFAC. X_{42}	COST ON-SITE MATERIALS MANUFAC. LDC/DC X_{51}	COST OFF-SITE MATERIALS MANUFAC. LDC/DC X_{52}	TOTAL CONSTRUCTION COST PER CAPITA DC - US $ C_1	POPULATION SERVERED DC - X 1000 P	TOTAL CONSTRUCTION COST LDC - US $ C
Lagoon	90	70	20	.25	3	9	6	10	8	2	1/3	2/1	67	0.5	
		70	20	.25	3	9	6		8	2	1/3	2/1	6	25	
		70	20	.25	3	9	6		8	2	1/3	2/1	4	50	
		70	20	.25	3	9	6		8	2	1/3	2/1	2.7	100	
Sedi-mentation filter sludge-dis	60	40	20	.25	3	9	6	40	20	20	1/3	2/1	88	0.5	
		40	20	.25	3	9	6		20	20	1/3	2/1	24	25	
		40	20	.25	3	9	6		20	20	1/3	2/1	19.5	50	
		40	20	.25	3	9	6		20	20	1/3	2/1	15.5	100	
Trick-ling filter	50	30	20	.25	3	9	6	50	30	20	1/3	2/1	137	0.5	
		30	20	.25	3	9	6		30	20	1/3	2/1	40.5	25	
		30	20	.25	3	9	6		30	20	1/3	2/1	33	50	
		30	20	.25	3	9	6		30	20	1/3	2/1	26.5	100	
Acti-vated sludge	40	30	10	.25	3	9	6	60	50	10	1/3	2/1	134	0.5	
		30	10	.25	3	9	6		50	10	1/3	2/1	40	25	
		30	10	.25	3	9	6		50	10	1/3	2/1	32	50	
		30	10	.25	3	9	6		50	10	1/3	2/1	26	100	

$$C = (C_1)(X_{11} X_{21}/X_{22}) + (X_{12} * X_{31}/X_{32}) + (X_{41} * X_{51}) + (X_{42} * X_{52})$$

TABLE 10

WATER TREATMENT COST TRANSFER CONSTRUCTION MATRIX

LABOR AND MATERIAL FOR SELECTED TREATMENT PROCESSES

TECHNOLOGY LEVEL - II

TREATMENT PROCESSES	LABOR AS PERCENT OF LDC CONSTRUCTION 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}	MATERIAL AS PERCENT OF LDC CONSTRUCTION COST	PERCENT ON-SITE MATERIALS MANUFAC. X_{41}	PERCENT OFF-SITE MATERIALS MANUFAC. X_{42}	COST ON-SITE MATERIALS MANUFAC. LDC/DC X_{51}	COST OFF-SITE MATERIALS MANUFAC. LDC/DC X_{52}	TOTAL CONSTRUCTION COST PER CAPITA DC - US $ C_1	POPULATION SERVERED DC - X 1000 P	TOTAL CONSTRUCTION COST LDC - US $ C
Slow sand filter	50	-		.75		9					1/2		67	0.5	
		-		.75		9					1/2		6	25	
		30	20	1	3	8	6	50	30	20	1/1.5	1.5/1	4	50	
				1		8					1/1.5		2.7	100	
Rapid sand filter	50	30	20	.75	3	9	6	50	30	20	1/2	1.5/1	88	0.5	
				.75		9					1/2		24	25	
				1		8					1/1.5		19.5	50	
				1		8					1/1.5		15.5	100	
Sedimentation filtration	60	35	25	.75	3	9	6	40	20	20	1/2	1.5/1	137	0.5	
				.75		9					1/2		40.5	25	
				1		8					1/1.5		33	50	
				1		8					1/1.5		26.5	100	
Chlorination	25	10	15	.75	3	9	6	75	5	70	1/2	1.5/1	134	0.5	
				.75		9					1/2		40	25	
				1		8					1/1.5		32	50	
				1		8					1/1.5		26	100	

$$C = (C_1)(X_{11} X_{21}/X_{22}) + (X_{12} * X_{31}/X_{32}) + (X_{41} * X_{51}) + (X_{42} * X_{52})$$

TABLE 11

WASTEWATER COST TRANSFER CONSTRUCTION MATRIX

LABOR AND MATERIAL FOR SELECTED TREATMENT PROCESSES

TECHNOLOGY LEVEL - II

TREATMENT PROCESSES	LABOR AS PERCENT OF LDC CONSTRUCTION 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}	MATERIAL AS PERCENT OF LDC CONSTRUCTION COST	PERCENT ON-SITE MATERIALS MANUFAC. X_{41}	PERCENT OFF-SITE MATERIALS MANUFAC. X_{42}	COST ON-SITE MATERIALS MANUFAC. LDC/DC X_{51}	COST OFF-SITE MATERIALS MANUFAC. LDC/DC X_{52}	TOTAL CONSTRUCTION COST PER CAPITA DC - US $ C_1	POPULATION SERVERED DC - X 1000 P	TOTAL CONSTRUCTION COST LDC - US $ C
Lagoon	80	60	20	.75 .75 1 1	3	9 9 8 8	6	20	10	10	1/2 1/2 1/1.5 1/1.5	1.5/1	67 6 4 2.7	0.5 25 50 100	
sedimen-tation Sludge dis	60	35	25	.75 .75 1 1	3	9 9 8 8	6	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	
Trick-ling filter	40	25	15	.75 .75 1 1	3	9 9 8 8	6	60	30	30	1/2 1/2 1/1.5 1/1.5	1.5/1	137 40.5 33 26.5	0.5 25 50 100	
Activat-ed sludge	30	15	15	.75 .75 1 1	3	9 9 8 8	6	70	10	60	1/2 1/2 1/1.5 1/1.5	1.5/1	134 40 32 26	0.5 25 50 100	

$$C = (C_1)\,(X_{11} \times X_{21}/X_{22}) + (X_{12} * X_{31}/X_{32}) + (X_{41} * X_{51}) + (X_{42} * X_{52})$$

TABLE 12

WATER TREATMENT COST TRANSFER CONSTRUCTION MATRIX

LABOR AND MATERIAL FOR SELECTED TREATMENT PROCESSES

TECHNOLOGY LEVEL - III

TREATMENT PROCESSES	LABOR AS PERCENT OF LDC CONSTRUCTION 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}	MATERIAL AS PERCENT OF LDC CONSTRUCTION COST	PERCENT ON-SITE MATERIALS MANUFAC. X_{41}	PERCENT OFF-SITE MATERIALS MANUFAC. X_{42}	COST ON-SITE MATERIALS MANUFAC. LDC/DC X_{51}	COST OFF-SITE MATERIALS MANUFAC. LDC/DC X_{52}	TOTAL CONSTRUCTION COST PER CAPITA DC - US $ C_1	POPULATION SERVERED DC - X 1000 P	TOTAL CONSTRUCTION COST LDC - US $ C
Slow sand filter	60	40	20	1 1 1.5 1.5	3	8 8 7 7	6	40	20	20	1/2 1/1.5 1/1.5 1	1.5/1 1.5/1 1 1	67 6 4 2.7	0.5 25 50 100	
Rapid sand filter	60	20	40	1 1 1.5 1.5	3	8 8 7 7	6	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	
Sedimen-tation Filtration	60	30	30	1 1 1.5 1.5	3	8 8 7 7	6	40	30	10	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	
Chlor-ination	25	5	20	1 1 1.5 1.5	3	8 8 7 7	6	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	

$$C = (C_1)(X_{11} X_{21}/X_{22}) + (X_{12} * X_{31}/X_{32}) + (X_{41} * X_{51}) + (X_{42} * X_{52})$$

TABLE 13

WASTEWATER COST TRANSFER CONSTRUCTION MATRIX

LABOR AND MATERIAL FOR SELECTED TREATMENT PROCESSES

TECHNOLOGY LEVEL - III

TREATMENT PROCESSES	LABOR AS PERCENT OF LDC CONSTRUCTION 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}	MATERIAL AS PERCENT OF LDC CONSTRUCTION COST	PERCENT ON-SITE MATERIALS MANUFAC. X_{41}	PERCENT OFF-SITE MATERIALS MANUFAC. X_{42}	COST ON-SITE MATERIALS MANUFAC. LDC/DC X_{51}	COST OFF-SITE MATERIALS MANUFAC. LDC/DC X_{52}	TOTAL CONSTRUCTION COST PER CAPITA DC - US $ C_1	POPULATION SERVERED DC - X 1000 P	TOTAL CONSTRUCTION COST LDC - US $ C
Lagoon	75	45	30	1 1 1.5 1.5	3	8 8 7 6	6	25	10	15	1/2 1/1.5 1/1.5 1	1.5/1 1.5/1 1 1	67 6 4 2.7	0.5 25 50 100	
Sedimen-tation Sludge dts	60	30	30	1 1 1.5 1.5	3	8 8 7 6	6	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	
Trick-ling filter	40	20	20	1 1 1.5 1.5	3	8 8 7 6	6	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	
Activat-ed sludge	25	5	20	1 1 1.5 1.5	3	8 8 7 6	6	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	

$$C = (C_1)(X_{11} X_{21}/X_{22}) + (X_{12} * X_{31}/X_{32}) + (X_{41} * X_{51}) + (X_{42} * X_{52})$$

APPENDIX III

RESOURCES MODEL

THE RESOURCE MATRIX (THE MODEL)

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 will also be used to guide computation, and this discussion will emphasize the predominantly mathematical methodology of interrelating sets of data to obtain the solution.

Generally, if the problem can be defined in terms of quantifiable variables, including an objective variable, and if these variables can be set in a computational routine or algorithm, an optimum solution may be sought within the confines of the model. What happens when a problem cannot be this highly structured, such as in the case with the one under study? When it does not fit the assumptions required by an algorithm such as linear programming, heuristic programming may be appropriate. Heuristic programming is simply the development of a search pattern which will lead, step by step, toward a feasible solution. The search pattern contains trial and error steps as well as mathematical techniques. The heuristic approach will be used as a solution technique for water and sewage treatment planning in LDC countries.

The procedure takes the form of a network of paths, similar to a maze, that leads from the starting condition (present water or sewage treatment) to two or more final decisions. The choice of the final decision depends on which path is followed. Each path leads to only one decision, although many paths may lead to the same decision. The selection of 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 heuristic program is being 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 will be specified for each junction to determine which route segments are to be selected, and hence, which path will be followed in solving a particular problem. The second form is a computer program to be prepared by transcribing the schematic diagram into a form digestible by the University of Oklahoma IBM 370 computer.

The input information needed to apply the decision rules must be all quantitative or can be assigned a numerical value. The result is a mathematical model. All that is required is an appropriate scaling technique and some dummy variables. This will be described in greater detail in a later section. A heuristic program in mathematical form has the appearance of an analytical model. Inspection will generally not reveal the true nature of the model, although one would suspect that the model is heuristic if it is complex, nonlinear, and especially if it contains many independent variables. A mathematical model can be classified as heuristic if the relationships between the variables are estimated intuitively rather than by mathematical or statistical analysis.

The basic design objective of the heuristic program has been to construct a model that conforms 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, observations of the process in motion, and has traced the procedure from start to finish.

To summarize, the model to be set forth is a heuristic one due to the complexity of the decision making process. At this point the research design calls for a heuristic simulation model to represent the decision making process in the selection of water and sewage treatment processes. The remainder of this section will show the information flow and the detailed description of the model components. The basic structure of the model is shown in Figure 1. Each of the components in the model is discussed in enough detail to show why and how these data are included in the model.

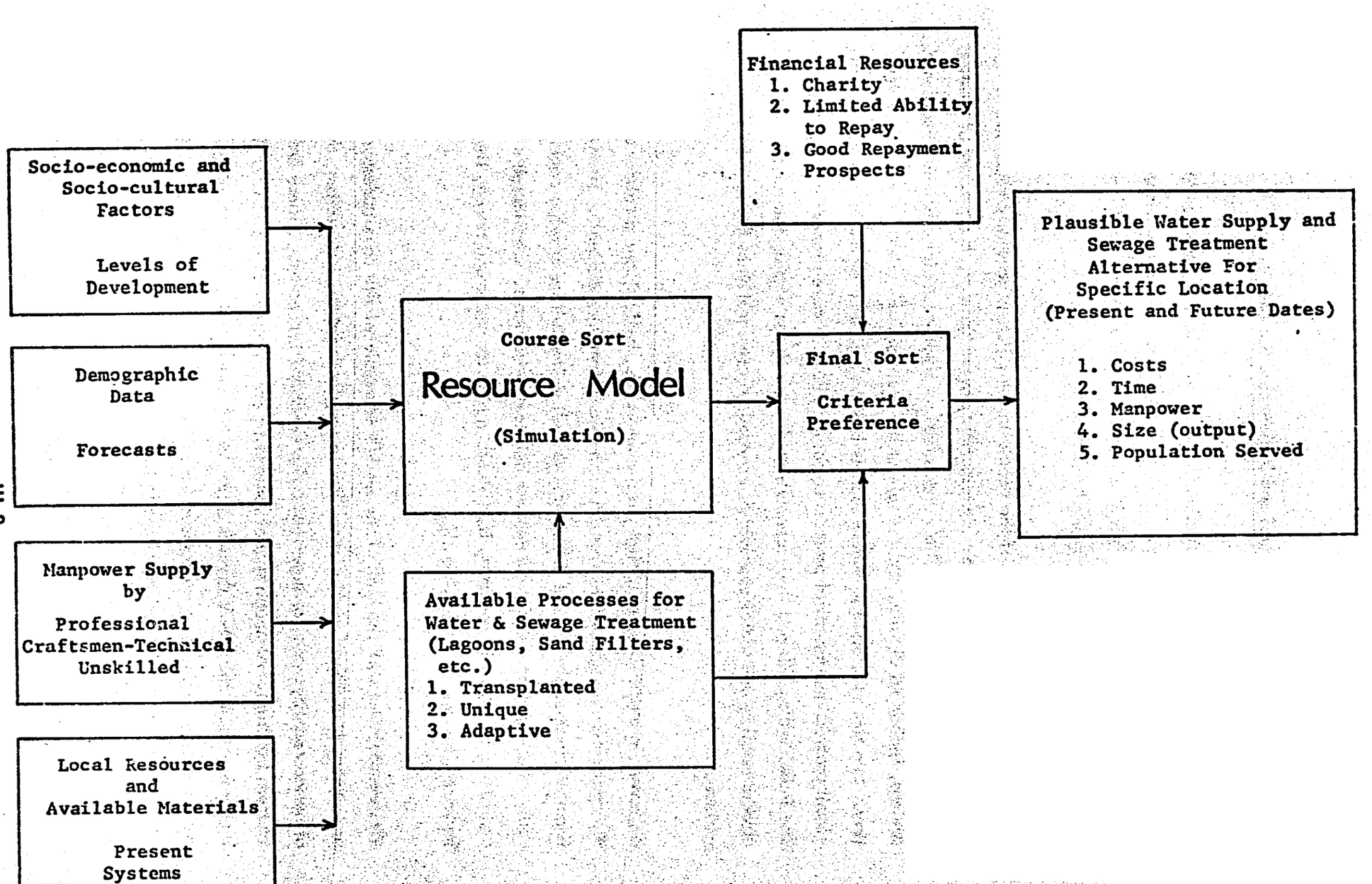


Figure 1 Water and Sewage Treatment Selection Model

Sociocultural and Socio-economic Factors

The importance of noneconomic factors in the planning and implementation of water and sewage treatment processes have long been recognized. Social and cultural considerations supported by institutional rigidities cause people to respond in different ways, often affecting the success of the project negatively.

Improvement of the well-being of the people in the LDC's is generally classified in the development program of an area. Development, as we know it, is a product of Western culture, based upon Western beliefs and values, including special attitudes toward work, savings, individual dignity, and the role of the individual in determining his own destiny. In a free environment, where success is often measured by material wealth, individual progress and industrial progress combine to build a more productive economy. The individual's goals and the economy's goals are, on the whole, the same. Ease of upward mobility and social approval of economic success motivate the individual to achieve.

However, in a non-Western society, different values, beliefs, and attitudes often make the application of a basically Western economic system very difficult. Therefore, it is important to understand these differences as well as the culture of other countries to apply what might be useful from our own development process. Considerable cutting and fitting is generally necessary if, indeed, a plan for water and sewage treatment improvements can be tailored at all.

Western societies with the bulk of the world's economic wealth have undergone and are undergoing a variety of revolutions. Some examples include: materialism, the concept of human equality, and the importance of science and technology. These are a part of Western tradition. Although similar movements are underway in the LDC's, there is a time gap. In all the LDC's there is a lack of adequate institutions to bridge the gap, and in Western countries the acceleration of change is making the gap increasingly wider. The following discussion relates to the importance of the basic social institutions in the LDC's.

The role of the individual in the family affects his contribution to the economy. In the extended family, which consists of many relatives, the individual contributes his earnings to the group and, in turn, is cared for by the group. There is much less emphasis placed upon individual performance, and the individual's rewards are not associated directly with his performance. Individual incentive is dampened; there is little incentive to work harder or to be more productive. The extended family has considerable impact upon labor mobility. The son who is responsible to his father or grandfather will not easily move from rural to urban employment or even to another job. If he does so, he continues to have strong family ties and may abruptly return when instructed to do so

Women in most LDC's have restricted roles; their acceptance in the world of work is negligible. For example, in the Northwest Frontier of West Pakistan, women are essentially restricted to their homes; the purdah custom even prohibits women from showing their faces in public. As a result, very few women are in the work force. Complete emancipation of women, to enable them to compete on equal terms in the world of work, is still not a fact in many developed countries, and some form of discrimination is usually practiced.

Every society has its class structure, even the most economically and industrially advanced which act by the limitation of mobility and relates directly to individual economic productivity. Rigid class consciousness in many traditional societies restricts the mobility of people and limits their potential as productive workers. Societally determined classes of jobs for specific classes of people interject such rigidities that it is useless for many to aspire for better jobs. An example of this is the caste system in India which establishes mobility boundaries for many workers.

Racial discrimination provides another example of societal restrictions which keep individuals from holding jobs in which they can make the greatest contribution to themselves and the economy. Lack of educational and economic opportunities for minority groups in the United States has kept many individuals in below capacity positions. Discrimination has entailed economic costs to the United States, not to mention the social costs or the moral aspects of these restrictions.

Western culture emphasizes the importance of the individual in determining his own destiny. This attitude has, in part, a religious basis. In fact, most individuals have considerable freedom to work, to achieve, and to move from job to job. Where restrictive institutions establish narrow social and economic parameters, the individual is not free to perform at his optimum capacity. If the individual is institutionally "boxed in ", his opportunities and his rewards are less than they might otherwise be. To a degree, such a situation exists in the United States today, and those people affected are said to be victims of the "system." This is not unlike the "system" in LDC's; however, the restrictiveness and the number of people directly affected differ. Many poor people in the United States feel they are poor not because of their own failures, but because their opportunities are limited by the "system." The "system" is the sum total of economic, social, and political institutions that affects people -- essentially the way they live and what they do -- and this leaves much to be desired for the provision in an environment in which the individual could play a more vigorous role in the determination of his own destiny. Incidently, although institutions provide impediments to growth for individuals and economies, they also provide rationales for lack of accomplishments. Fate, the government, and the landlord are often blamed for failures and misfortunes.

As communities become more urbanized, the rigidities of the traditionally oriented rural societies give way to a more flexible way of life. Better communications and far less isolation often foster new social awareness. Family and class become less important; rural customs are questioned and violated. This contact between rural and urban people brings about changes in rural areas. New institutions emerge that are geared to the urbanized and industrialized society. This breakdown in traditional institutions and the establishment of new social and economic rules is called modernization. It brings with it new freedom, and it also means a loss of control and often instability.

Looking at this from a community level, it appears that a good way of considering the sociocultural factors is to determine a community's stage of development. The stage of development is the sum of the sociocultural and socio-economic factors that are such an essential part of any community or group of people. The approach in this research has

set-up four levels of development so that any community can be classified rather easily into one of these levels. The characteristics and details on how each level is determined is described below.

Levels of Development

Level I communities are those whose economic and social progress is dependent upon continued employment of outside high-level manpower in a wide variety of core positions in major public and private institutions. In this stage the indigenous human resources are insufficient to permit these communities to move forward on their own. Almost without exception they require external aid for progress.

Normally, the Level I community is essentially an agricultural society, the majority of the population is rural or nomadic. The bulk of the rural population surrounding the community is engaged in subsistence activities contributing marginally to the market economy. Those engaged in cash crops, such as tea or vegetables, are a small minority. The modern sector of the economy consists of the offices of the central government and with its regional and local branches, a few large plantations trading establishments in the larger villages, and a few industries such as food processing, bottling of beverages, or an occasional textile mill. Where they exist, oil and mining installations and the cities and towns connected with them are only enclaves in a vast traditional society, and they only employ a small fraction of the communities manpower.

In a typical Level I community the "employed labor force," meaning those persons who are in some way connected with the market rather than the subsistence economy, is a very small proportion of the total population. The bulk of the population is engaged in traditional subsistence activities and has very little contact with the modernizing sectors of the community. There is a critical shortage of all categories of high-level manpower: professional and subprofessional, administrative and clerical, teachers, supervisors, and senior craftsmen. In many of these communities the total number of native persons in the population who have a secondary education or equivalent is certainly less than 1 per cent, and in some cases, it may be closer to one-tenth of 1 per cent.

In many Level I communities, the population is no longer stable, but is beginning to increase as progress is made in the control of diseases with the expansion of health services. In some areas, overcrowding on the land, the initial thrust of education into these areas, and the building of roads has encouraged the movement of people to larger towns and cities. Overcrowding and unemployment are becoming noticeable in the larger urban areas.

The education in Level I communities is underdeveloped at every level. It reaches only a small fraction of the population; its quality is low; and it is incapable of meeting even the minimum needs for local high-level manpower. Many of the schools are operated by "voluntary agencies" or missionary organizations and the variations in curricula are wide. In most of these communities, the bulk of the primary school teachers are "unqualified" which generally means that they have had little more than six or seven years of primary schooling themselves. The characteristic pattern of most Level I communities is that many pupils start in the first grade, then drop-out, and then come back again as repeaters and drop-out again. Some schools offer only one or two primary grades. The result is that a great majority of those who attend barely learn to read and write, and most of these lapse again into illiteracy after a few years.

With secondary education, there are usually many more school leavers wanting to enter secondary education than there are available places. Typically the second-level enrollment rate is approximately 4 per cent, but it may be as low as 1 per cent. Of this amount the technical or vocational schools account for a very small portion of enrollment. Like the primary schools, most of the second-level schools are operated by missionary organizations or private groups. Most of these schools charge fees which in terms of average income are high, therefore, secondary education is generally available only to the richer classes and even for them, the opportunities are narrowly limited. Generally, secondary schools are of rather high quality with the curriculum designed to prepare student for higher education.

Higher education (third-level) is available to only a tiny fraction of the population. Most Level I communities send their students abroad or to neighboring communities.

The on-the-job training of high-level manpower is generally not well-developed or properly utilized. Formal in-service training programs are rare. Thus, the sheer experience in working on a particular job with certain superiors and subordinates constitutes training on the job. Promotion and transfer are much more likely to be made on the basis of political considerations and personal connections than on demonstrated competence. In some cases, expatriates are more interested in making themselves indispensable than in training their local counterparts. The private sector often does a better job of in-service development of high-level manpower. The oil and mining companies usually have craft-training centers, formal on-the-job training programs for their own employees.

A final difficulty is the dearth of organized programs in community development, fundamental education, literary improvement, and in many cases agricultural extension services as well. Here the problem is not the inappropriateness of such measures in the less developed communities but rather the inability to get them organized and started.

Because all skills are so critically scarce, the educated local national is in a commanding position upon graduation from a university and can "start at the top" in an administrative position in a larger city rather than a field assignment in some remote rural area. As a result the distribution of high level manpower is far from desirable. It is concentrated in the larger cities, whereas most of the cirtical needs, such as agricultural extension and community development, are in the smaller communities. The occupational composition is generally ill-suited to the communities' needs. For example, engineers are in very short supply, but engineering technicians are even more scarce, and as a result, engineers must perform work beneath their skills simply because of the lack of supporting personnel. Also, there is a preference for administrative jobs over technical jobs because the former are thought to carry more prestige and authority than the latter. And finally, the contact with and lure of the advanced cities and countries, plus the international agencies, causes many of the more ambitious individuals to look outside their local community for even better opportunities.

One last problem deserves mention -- the communities which insist on rapid localization of the government services, a phenomenon called the "leap-frog dilemma;" because of

strong pressure in the political parties, local nationals with very little education and experience may be pushed into senior positions for which they are not well qualified, simply because well-trained people are not available. But they never-the-less acquire tenure in these positions in time, when other local nationals with superior qualifications emerge from schools and universities, they are forced to accept inferior positions. This results in a tragic waste of talent, low morale, and undermining of the efficiency of the employing organization.

LEVEL II COMMUNITIES

Level II communities could also be called "relatively advanced" ones. These partially developed communities for the most part are still dependent upon the more advanced communities or central cities for critically needed scientific and engineering manpower. But they are able to produce the greater part of their own non-technical high-level manpower, such as teachers, managers, and supervisors with some assistance from advanced countries or other areas within the country. They are still unable to develop enough strategic high-level manpower (particularly engineers, scientists, and highly qualified teachers) to progress on the road to industrialization completely under their own power. As in the case of Level I communities, there are wide differences among communities in the Level II category. Those in the lower part of the range still have many of the characteristics of Level I communities and those in the upper part of the range are approaching a state of near self-sufficiency in high-level manpower that is characteristic of the semi-advanced communities in Level III.

The Level II communities are primarily based on agricultural economies. On the average, about 65 percent of the active population are engaged in agriculture related occupations, whereas 83 percent are involved in the Level I communities. In many areas a large portion, approximately half of the population, is engaged in subsistence activities outside the market economy. Most of the agricultural population produces at least some commodities which are sold for cash. In some areas there is a nucleus of modern industry and in some communities the industrial sector is sizable. Some cities have textile factories and light metal manufacturing plants while others have large mining or petroleum companies, most of which are partly owned and operated by foreign concerns. Banking and commercial establishments are much more developed than they are in Level I communities, as are the systems of transportation and communication. Thus, the modern sector of the community is larger and a great deal more complex than that in the Level I community, and government employment no longer dominates the labor market.

In nearly all Level II communities, there is widespread consciousness of the need for rapid economic and social development, yet in most cases there is no clear-cut strategy for

achieving it. But in comparison with Level I communities, there is more widespread participation of the people in the political life of the community and consequently greater pressure for expansion of education and general improvement in the standards of living.

In the area of manpower, a rough profile of the manpower problems in the typical Level II community are:

1. Scientific, professional, and technical personnel of all kinds are in very short supply and the most critical shortages are to be found in the subprofessional categories such as engineering and agricultural technical supervisors, and senior craftsmen. In this level, the community is far from self-sufficient in manpower of this kind, and must continue to import a significant number of persons with critical skills.

2. On the other hand, the Level II communities have little difficulty in filling from local resources its requirements for administrative personnel in the government services, primary school teachers (of low qualification), and most white-collar employees in both public and private establishments. In fact, university graduates with law, humanities, and arts degrees may have difficulty in finding "suitable" employment in the government ministries and often accept menial positions in the white-collar category. They are no longer in the commanding position enjoyed by their counterparts in the Level I communities, while at the same time, they are not so likely to remain unemployed as is so often the case in Level III communities.

3. In contrast with the Level I communities, the pressure for localization of the high-level manpower has abated. Local nationals are in firm control of all government ministries; they own and manage most of the communities' industrial and commercial establishments and they hold fairly high positions, though not necessarily the top ones, in many of the expatriate enterprises. The majority of the second-level school teachers and university professors are local nationals. However, the community is still dependent upon expatriates for technical or senior managerial fields, for which local citizens are not yet qualified for which they have had little incentive to prepare.

4. Many of the new university and secondary school graduates are employed by commercial and industrial establishments rather than the traditional government ministries. However, relatively few of them take teaching positions in secondary education despite the great need in this area.

5. In the larger urban areas, there is mounting unemployment, particularly among primary school graduates who have had just enough education

to make them dissatisfied with traditional rural living and not really enough to make them qualified for medium- and higher-skilled jobs which may be available in commerce, industry, or the government services. In general, there is widespread under-employment and overcrowding in the surrounding rural areas, coupled with backwardness of agricultural methods and feudalistic systems of land tenure.

In short, the profile of the Level II community shows that the partially developed communities are faced both with critical shortages and burdensome surplus of manpower, and it also suggests that the human resource development institutions in these areas are not producing the numbers and kinds of persons which modernizing economies demand.

In the partially developed communities, there are generally many kinds of institutions for on-the-job training of manpower, for eliminating illiteracy among adults and for community development, but in general, they are given much less attention than they deserve and in many cases their potentialities have hardly been discovered, let alone exploited. The large oil, mining, manufacturing, and commercial establishments particularly those which are managed by expatriates do a reasonably good job of training their own craftsmen, technicians, and junior managerial personnel, and it is possible that some of those trained find their way into other activities in the economy. In some cities, the central governments have established public administration training centers, but these reach only a tiny fraction of the government employees.

Some governments' ministries have set up training courses for agricultural assistants, medical assistants, and railway employees. However, in most LDC's the armed forces have rather extensive craft and technical training programs which are effective in developing skilled personnel. In some cases, local industrial employees have started management training programs, occasionally in cooperation with interested educational institutions. Many Level II communities for the most part have not been able to develop comprehensive and intensive programs to increase the capabilities of adult employed manpower.

Probably the greatest need in Level II communities is for massive agricultural extension services and rural community reorganization and demonstration projects so that there can be a transformation of traditional agriculture and rural life. There is a tremendous

need for advisory services to farmers, basic education in community development, and other programs to upgrade the skills and enlist the participation of the rural masses. Despite the fact that techniques of human resource development are known, they cannot be applied effectively until the appropriate organization and institutional structure is built.

LEVEL III COMMUNITIES

In terms of human resource development the average Level III community has traveled about half the distance between the partially developed (Level II) and the advanced communities (Level IV). This secondary school enrollment is more than two times that of Level II; and their third level enrollment ratio is three times higher; its primary enrollment is 50 percent higher. The semi-advanced community (Level III) has available practically all of the high level manpower that it needs except with the possible exception of scientific and technical personnel. Although shortages of scientists and engineers persist, they are not great enough to prevent the community from successfully importing and adapting modern technology without substantial external help. In short, the Level III community is "over the hump" in human resource development. It is on the road to becoming an advanced community and it can travel on that road largely under its own power.

The quantity and quality of high-level manpower in the Level III communities is far below those in the advanced communities. The Level III community is a follower rather than an originator of scientific, engineering, and organizational innovations. Actually a community in this level has a broad base of primary education with generally well-developed secondary schools and maybe an institution of higher education. It has not been able to develop the research manpower and research institutes which are characteristic of advanced communities. At manpower -- building institutions though capable of supplying initial minimum needs are often improperly oriented to meet the challenges posed by rapid modernization. In some cases, too many people are being trained in fields for which the prospective demand does not match the supply.

Industrialization is well advanced in Level III communities. Most of them are no longer predominantly agricultural. Transport, power, and communication are, on the whole, well-developed there are however, bottlenecks in electric production, railroad service, irrigation, etc., partly because of a shortage of the skilled and technical manpower to build and operate them.

Like many of the less developed communities, some of the Level III communities have srupluses of unskilled human resources. There is a relative surplus among certain types of university graduates. Unlike the advanced communities, however, the level of economic development is still not high enough to absorb all these finishing higher education regardless of the field of study. Even among those professionally trained, there are likely to be relative surpluses and shortages. In the absence of alternatives, a relative oversupply of high-level manpower in one community may lead to emigration to other areas where shortages are more pervasive.

Most of the Level III communities have achieved legal universal compulsory primary education for at least six years. There is a continuing problem of primary school dropouts in some Level III communities. In many of the Level III communities, second-level education is still narrowly academic and primarily university-oriented. Only a minority of the eligible age group are exposed to it, and there is often a high dropout rate, as in primary education, there is a shortage of competent teachers at the second level in most of these communities. Limitations on access to higher education and the crowding and consequent poor quality of instruction, have led students in some Level III communities to go to other areas for advanced training. This is certainly less true than students in Level II or Level I communities, but it persists where the system of higher education is not yet adequate to meet the needs of the semi-advanced community.

In some Level III communities attention is being paid to upgrading the qualifications and improving the performance of people already employed in strategic occupations. On the job training has spread more widely among employing institutions in communities of this level. Apprenticeship programs and vocational training are more advanced in Level III communities generally, although there is growing recognition that vocational programs outside the plant may not produce the skills required by expanding enterprises in the absence of close coordination with specific manpower needs of these firms. In some cases, vocational schools have been established in localities remote from enterprises which employ their graduates. This is a wasteful use of human resources.

Generally the salaries paid to high-talent manpower in science, engineering, and manoglical positions in most of the Level III communities are sufficient to attract young people to train for these fields. The prestige of the technically trained man is high, and professional management is more highly regarded as a career than in the lesser developed areas. Government administrative posts also vary high prestige and salaries, but they are no longer the sole high-status occupation; in fact, government salaries may be lower than in other professions requiring equivalent education and skills. Allocation of high-level manpower by other means than the relative salary structure has advanced somewhat in Level III communities. There are public employment services, although these tend to service blue-collar workers rather than professionals. Some attempts have also been made to establish registers of scientific and technical personnel, but generally the employment opportunities for these people are sufficient without the assistance of formal placement procedures.

LEVEL IV COMMUNITIES

The typical community in the fourth level of human resource development is in an advanced industrial economy. It is capable of making major scientific, technological, and organizational discoveries and innovations. This is because it has a relatively large stock of high-level manpower, particularly scientists, engineers, and managerial and administrative personnel. The community has made a heavy commitment to education, especially to higher education, and to human resource development generally. Since rapid changes in technology affect skills and occupations at all levels in the advanced industrial community, education and training tend to be geared to flexibility rather than to specialization.

Measures of educational development show narrow differentials, but they are still substantial. For example, Level IV communities have over 3 times more students enrolled in first-level (primary) education than do Level I communities and about one-fifth more than Level III communities. Even the percentages enrolled in scientific and technical facilities are higher and those enrolled in humanities, fine arts, and law smaller in the advanced communities than in the communities of the lower levels of human resource development. Finally, the advanced communities spend a larger percentage of their income on public education than do Level III communities and percentagewise this is nearly one-third more.

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. For water and sewage treatment projects as defined by the limitations of this research, we are looking at demographic criteria on a local scale or community level. The basic instrument concerned with the details influencing 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.[1]

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 cohorts 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, since 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.

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

In areas where there are few literate people, such as Level I and II communities discussed earlier, the enumerator is often an overworked schoolteacher or local official. The workload and 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:

- Present population by 5 year age groups and sex
- Previous population
- Survival rate
- Birth rate
- Migration
- Labor force by categories:
  - A Professional
  - B Technical-Skilled
  - C Unskilled

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 will be discussed in more detail under the manpower supply input data.

Manpower Supply

Probably the most difficult component of the model is measuring the manpower supply at the micro-planning level (community level). What, then, is the manpower supply of a community, and how can one determine the human resources available? The first step involves becoming familiar with the economy of the community as it is currently and as it is likely to develop in order to identify present and potential areas of manpower stringency. This does not imply a listing of all types of trained people who are in short supply in terms of those required to provide basic services of water and sewage treatment to the population, such as engineers, chemists, physicians, or those needed to speed expansion of the commercial sector, such as qualified managers, accountants, 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--infact, the community is likely to be handicapped in varying degrees along each of these fronts.

Therefore, a manpower study in a 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. It cannot long ignore the relation between this small superstructure and the large base of uneducated population that must sooner or later be caught up.

A common error in both LDC's and developed countries is to focus exclusively on matters of manpower supply and to a failure to give full consideration to manpower utilization. Since underemphasis or neglect of utilization is an error because 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 since 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 towards 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 in the country 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 [illegible] 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, without reliable data about the supply of trained manpower and the flow into and out of the training stream, and without information in depth about the strength of the demand for trained manpower in the various sectors of a society, it is difficult to reach sound judgments about the magnitude and severity of various manpower shortages.

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 of it rather than during the 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.

The distribution of the labor force for each of the levels of community development is shown in the following table:

Table I

DISTRIBUTION OF LABOR FORCE

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

These relationships between the unskilled, semi-skilled, and the professional can more easily be seen in Figure 2.

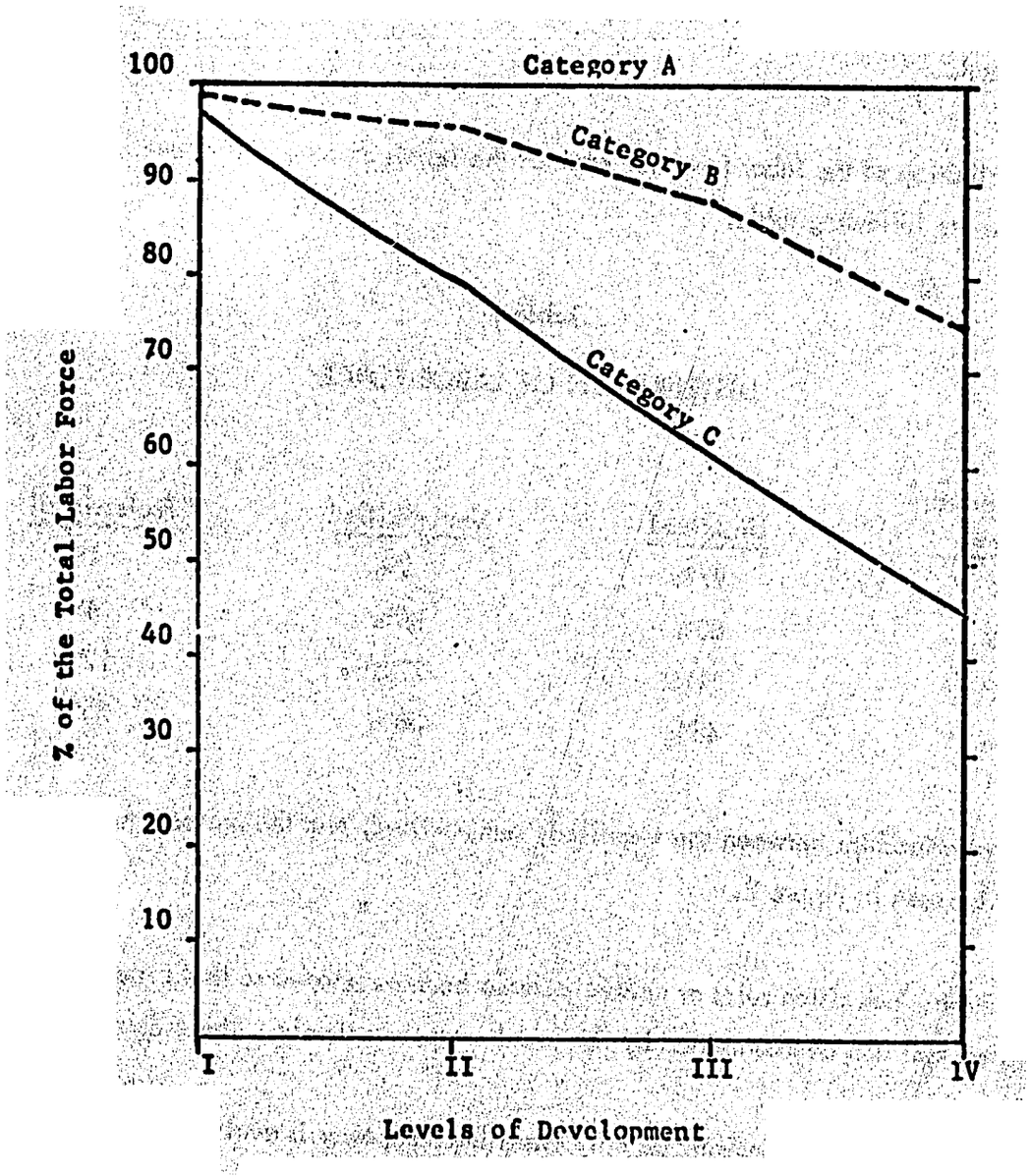
From Figure 2 decision rules or heuristics have been developed so that processes will be selected that can be maintained by the local manpower supply. These heuristics are as follows:

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)

Figure 2

The Percent of Each Category of Workers
For the Various Levels of Community Development



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.

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 purpose of this group of inputs gathers some basic data concerning the physical resources of a community and also determines what processes are currently being utilized to treat water and sewage.

Throughout this paper water and sewage treatment have been mentioned together. 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 supplied to the household and became fashionable with the invention of the water closet.

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 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.

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, will not be considered for sewage treatment. In areas of water shortage, such as arid and semi-arid regions, considerably increased 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 will not be provided with a plausible sewage treatment method for the reasons discussed above. However, the kinds of data requested in the following list are appropriate for requirements of both water and sewage treatment systems:

A. Highest Level of Technology found in the Community
   1. Hand tools
   2. Mechanical tools (i.e. gasoline tractors, electric motors)
   3. Chemical materials (fertilizer, pharmaceutical supplies)
   4. Electronic technology (computers, equipment utilizing transistors)

B. Present Level of Water Technology Development
   1. Central village pump
   2. Piped water supply to houses
   3. Sewage collection system
   4. Sewage treatment

C. Water Source
   1. River or stream
   2. Lake or impoundment
   3. Wells (Is groundwater available?)
   4. Sea or brackish

D. Power Availability
   1. Electricity
   2. Petroleum products
   3. Coal
   4. Other

E. Wastewater Quantity

1. Is a 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 within 10 years.

F. Equipment Available

1. Crawler tractor
2. Back hoe
3. Trencher
4. Crane
5. Pile driver
6. Cement mixer
7. Scraper
8. Welder
9. Hand power tools
10. Trucks
11. Air compressor
12. Meters
13. Lawn mowers
14. Blowers
15. Recording devices
16. Laboratory equipment
17. Portable power plant
18. Motors
19. Pumps

G. Materials Available

1. Plywood
2. Electrical wire
3. Concrete blocks
4. Reinforcing steel

5. Fasteners
6. Blasting
7. Cement
8. Aggregate
9. Structural steel
10. Structural wood
11. Pipe (clay, steel, cement, plastic, copper, etc.)
12. Pipe fittings
13. Paint
14. Valves
15. Tanks
16. Gauges
17. Heat exchangers
18. Silica sand
19. Graded gravel
20. Clean water
21. Gasoline
22. Al_2SO_4
23. $FeCl_2$
24. Activated charcoal
25. Lime
26. Soda ash
27. Chlorine
28. Ozone
29. 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 II 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

TABLE II TREATMENT PROCESSES

ESSENTIAL COMPONENTS FOR CONSTRUCTION AND OPERATION

Basic Water and Wastewater Treatment Processes	Manpower								Materials										Equipment											
	Construction					Operation																								
	Unskilled	Craftsmen	Equipment Operator	Technical	Professional	Unskilled	Skilled	Technical	Professional	Concrete	Structural Steel	Electrical Wire	Reinforcing Steel	Pipe	Paint	Chemicals-Laboratory	Silica Sand	Chlorine	Chemicals-Coagulant	Chemicals-Oxidation	Heavy Construction	Power Tools	Trucks	Welder	Cement Mixer	Pumps	Laboratory Equipment	Recording Devices	Air Diffusers	Meters	Valves	Heat Exchanger
WATER SUPPLY																																
Drilled Well		X	X			X								X							X					X					X	X
Disinfection				X			X	X						X		X		X				X					X				X	
Settling Tank	X	X	X	X		X				X			X								X				X						X	
Slow Sand Filter	X	X	X			X				X			X	X			X				X		X		X						X	
Rapid Sand Filter	X	X	X	X	X		X	X		X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X		X	X	
WASTE WATER																																
Oxidation Pond	X	X	X			X								X							X										X	
Primary Sedimentation	X	X	X	X	X	X	X			X	X		X	X	X						X	X		X	X						X	
Trickling Filter	X	X	X	X	X	X	X	X		X	X		X	X	X	X					X	X	X	X	X	X	X				X	
Activated Sludge		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					X	X		X	X	X	X	X	X	X	X	

that require the technology of a very modern economy. The function of the 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. The treatment 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.

As indicated earlier, the remainder of the chart 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 forthcoming 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. 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 heroic 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 incremental revenues collected by sponsoring organization as an expression of consumer willingness to pay. 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 per capita volume to a larger number of low income families. A high return undoubtedly demonstrates 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. Water is both a producer and a consumer good. As a producer good it is 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 mythical 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 benfits 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 drop 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 project or a beef cattle production project. Generally, water and sewage treatment projects can be 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 is provided for investment.

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 area

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 model a more specific criteria is presented.

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 the determination of the most plausible system to implement. Total cost in all cases consists of the:

Capital cost (construction cost)	maintenance cost for 20 years	=	total cost

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 has been adjusted so that all costs will be on a twenty year basis.

In the LDC's on the national, state, and local level, in nearly all cases, no long-term final commitments can be made for water and sewage treatment projects. General targets are necessary but it is appreciated that flexibility has to be maintained so that changes can be made should overall financial resource priorities change and should experience reveal 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, it 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, migration, 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 in order 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 must be installed. A case in point is the Kyeni water project in Kenya where it is anticipated in the early years of the project only 25 percent of the capacity will be used and that it will be 20 years before full capacity will be utilized.[2] 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 invisioned. For the more typical case, there is inevitably a budget constraint for the project and more people will be served today, for a given sum, if there is no excess capacity in the initial project to allow for growth in demand. This dilemma can be resolved, in principle, by estimating the discounted costs for the two approaches and comparing these with the respective discounted benefits. However, major problems exist with respect to choice discount rate and cost estimation, but 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 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. It has been shown that the amount of water people use is inversely related to the distance people have to walk.[3] White found no such association, though there was a clear difference in volume

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[2] I.D. Carruthers, "Issues in Selection and Design of Rural Water Projects," Discussion Paper No. 88 (University College, Nairobi: Institute for Development Studies, December, 1969), p. 8.

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

used between people who carry water any distance and people who have water in their home.[4] White concludes, "A promoting 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 wide distribution of small amounts of water rather than 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 economics substituting for capital costs by accepting increased maintenance expenditures in principle should prove the best policy because future expenditures 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 bias toward technical rather than economic efficiency is probably not as serious as apparent, but nevertheless, it needs considering.

The Resource Model

The heuristic program which is being developed for selecting water and sewage treatment process consists of two parts: (1) The main program, or the course sort, examines the socio economic -- socio-cultural, demographic, manpower profile, and the local resources. These variables are "matched" against the requirements of the process available to treat water and sewage. (2) 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 are illustrated in Figure 1 which is the flow diagram of the entire program.

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

The upshot of this interplay of variables is shown in Figure 3. The figure gives the water treatment portion of the model. Figure 4 gives the sewage treatment portion of the model. By tracing through the tree diagram one can easily see how the program works. For example, the selection of a water treatment process begins with the calculation of the demographic data for the particular community under consideration. This is shown on the left side of Figure 5. If the water source is from the sea, the model is not applicable since a desaltine package plant will be required to treat 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 laboratory equipment values and metal pipes, silica sand, chemicals, and ground water. This completes the course sort. The final sort evaluates the process selected from the course sort on the basis of maintance costs.

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

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

(Maintenance) $$C_3 = (C_1) \; ((X_{11} \times \frac{X_{21}}{X_{22}}) + (X_{12} \times \frac{X_{31}}{X_{32}}) + (X_{41} \times X_{51}) + (X_{42} \times X_{52}))$$

Consequently the total cost over a twenty year period is:

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

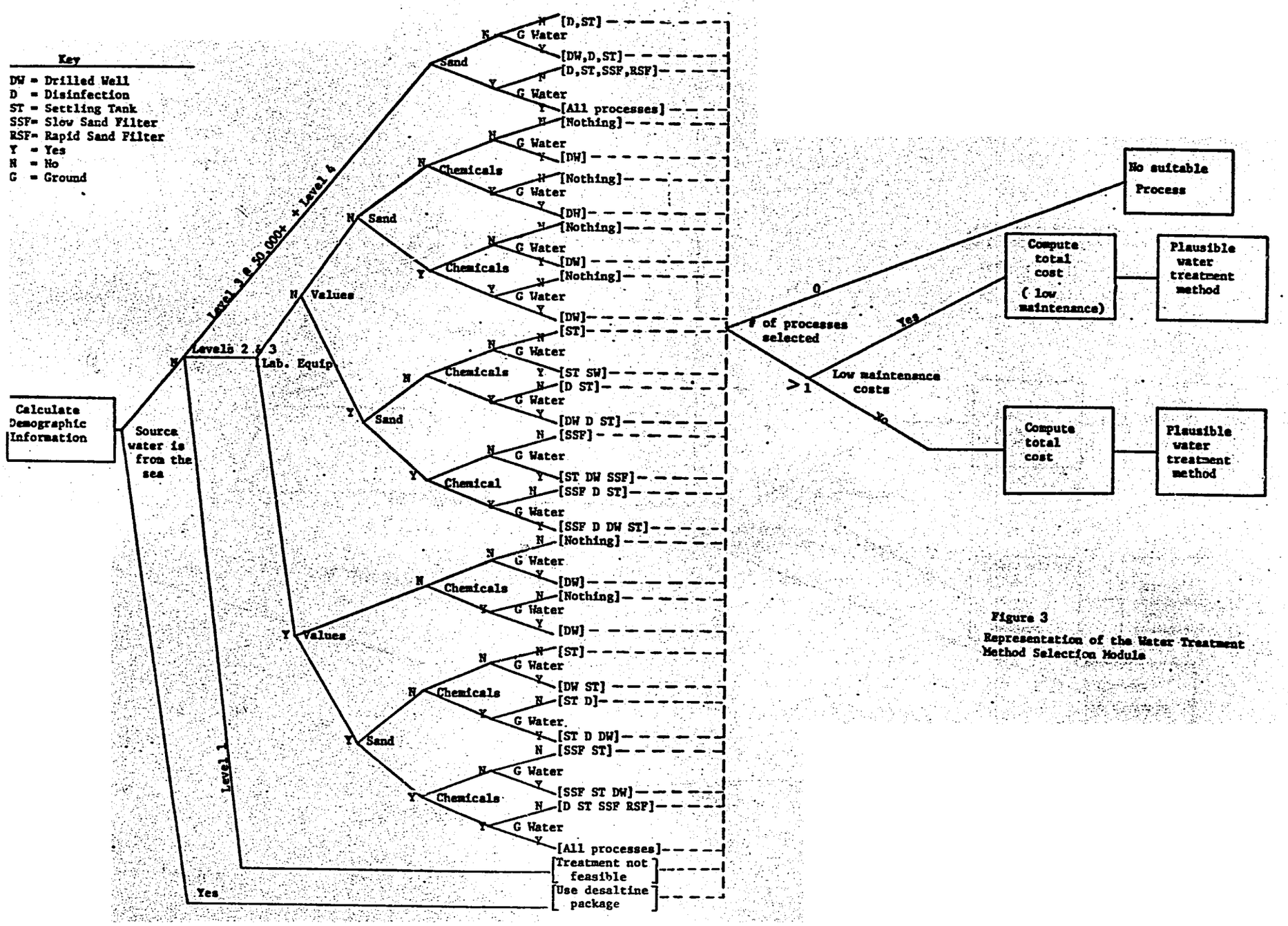


Figure 3
Representation of the Water Treatment Method Selection Module

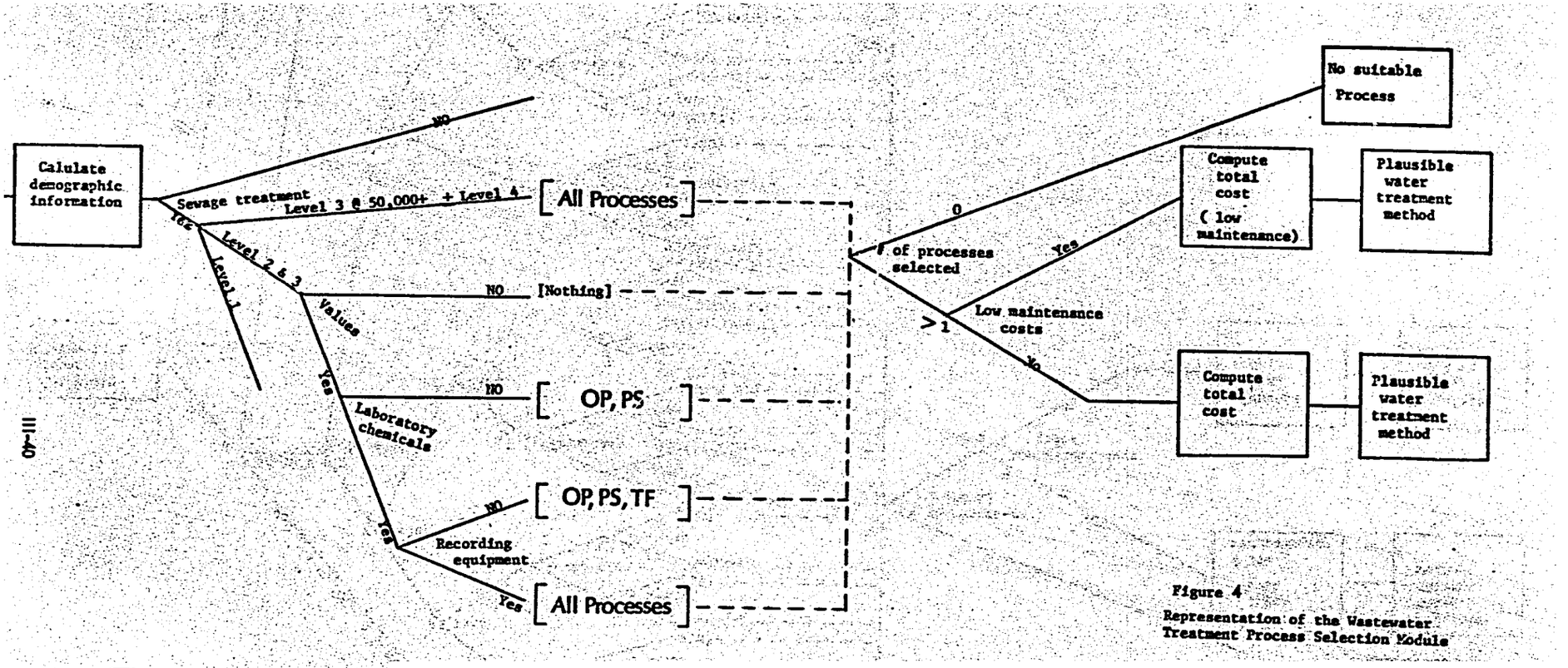


Figure 4

Representation of the Wastewater Treatment Process Selection Module

KEY

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

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

The above variables will vary 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 have been broken down into four population groups:

1. 500 -- 2,499
2. 2,500 -- 14,900
3. 15,000 -- 49,999
4. 50,000 -- 100,000

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

The model will be computerized by transcribing the schematic diagram and cost formulas into a FORTRAN computer language. Figures 3 and 4 represent the water and sewage treatment method selecting process for a community. Few of the decision rules were specified by planners; most were intuitive processes observed by the writer.

The output of both modules provides a seemingly plausible water supply and sewage treatment alternative for a specified community. The details to be 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 has been 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 have been identified for close attention. The proposed heuristic program was discussed next. In this instance, the decision process consists 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.

APPENDIX IV

HISTORIC AND INNOVATIVE TECHNOLOGY OF WATER AND WASTEWATER PROCESSES

HISTORIC AND INNOVATIVE TECHNOLOGY OF WATER AND WASTEWATER PROCESSES

The most challenging task facing Less Developed Countries (LDC) is the adapting of the existing technology to meet the needs of the rural communities. Conditions in LDC's are much different from those of industrial countries. The solution to water and wastewater which are adaptable in Developed Countries may be of little value to the rural communities of LDC's due to climatic conditions, cultural differences, scarcity of technical personnel, and other environmental, socio-economic factors.

Too often LDC Technology transfer is done without the review of the historic technology. The transferred technology is usually too sophisticated, too costly, and does not make use of the country materials and locally available labor (unemployed or underemployed). Sometimes the materials have to be shipped from the cities or overseas to the rural communities, which takes too long. In the project's six months program report (November 1973, page 29) it was shown that most of the failures in water and wastewater treatment plants were due to technical problems or in operational and maintenance and negligence of the operators.

Technology which has been in existence in these countries must not be ignored since it is this type of technology which can be upgraded parellel with new and innovative technology. Some of the historic technology such as the use of bamboo pipe, rice husk, and coconut fibers may answer some of the problems of rural water in LDC's. Evaluation of the historic technology in conjunction with the use of rice husks has been done in Thailand.[1]

The Agency for International Development in co-operation with the University of North Carolina has considered various problems associated with the water supply in Less Developed Countries. The use of local materials, and problems and some of the solutions in LDC were explored.[2]

Coagulation as an aid for water clarification has been practiced from ancient times for household supplies and almost a century for municipal supplies. The ancient Egyptians employed crushed almonds, while Indians used crushed nuts and Chinese alum.[3]

Although a great number of devices for feeding alum are available, they are all expensive and need skilled operators. Since alum is commercially produced in dry and liquid form the amount required for the coagulation must be weighed if in dry or volume taken if in solution. In India for example (Six Month Report, November 1973) operators use alum in great quantities indiscriminately as to actual requirements.

A simple inexpensive feeding device has been successfully operated since 1959 in Santiago, Chile, at the Los Viscachos Water Treatment Plant, a rapid sand filter plant treating up to 6 cubic meters per second (137 millions gallons per day) (2). Locally produced ungrinded alum in cake form has been developed and used at this plant since 1959. It has been found the initial cost is relatively small and little mechanical equipment or maintenance is required.

In Indonesia (2), it was found that the common source of water was shallow wells or surface water collected in earth dams or drawn from streams. Most of the water was subject to bacterial contamination and turbidity was high. It was found a simple purification and disinfection unit could be made of local material for the use in individual houses.

SMALL SCALE PURIFICATION OF TURBID SURFACE WATER
SIMPLER AND LESS EXPENSIVE

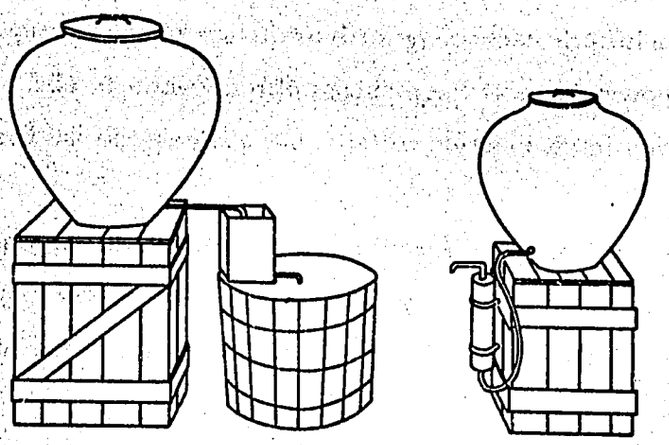


Figure 1a. Household Water Purification Plant.

Figures 1a, 1b, illustrates a simple and less expensive household water purification unit (2). Disinfection sedimentation and filtration could be accomplished by using this type of purification unit in small communities in LDC. The filter can be made of sand of average size about 1/2 mm (2). Activated charcoal, clay, benonite, or charcoal made from coconut shell could be used to aid coagulation. For disinfection chlorine is used.

SMALL SCALE PURIFICATION OF TURBID SURFACE WATER (2)

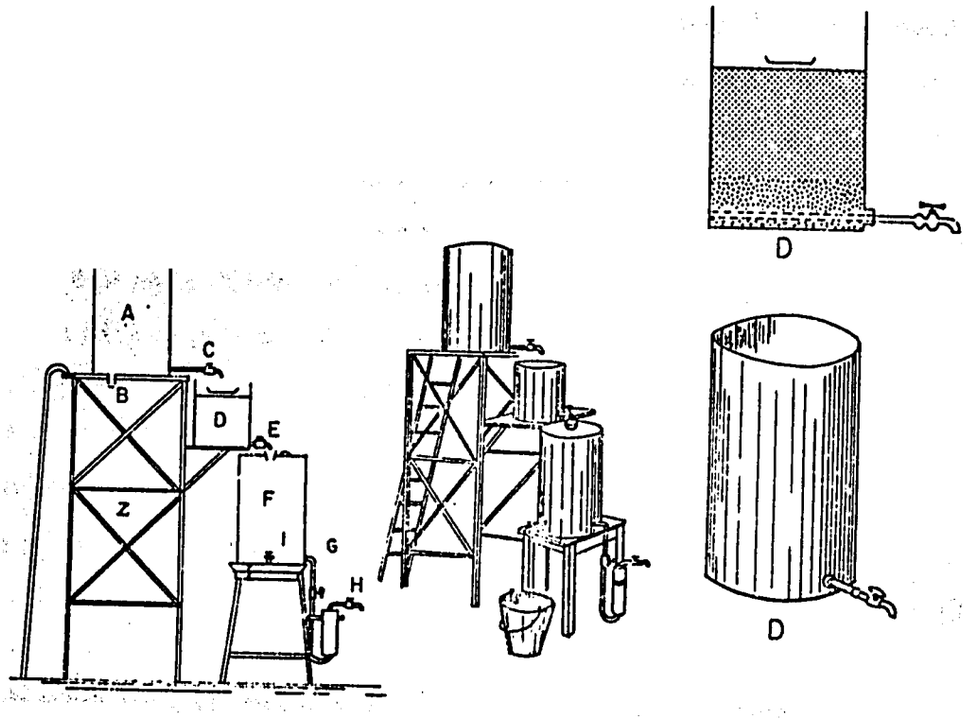


Figure 1b. Household Water Purification Plant.

Broken pieces of alum-cake are placed in a wooden tower or bin. Water then is sprayed from the top of the tower over the alum. The water then passes down over the cakes, alum is dissolved and the alum water solution falls through the base of the boxes and flows to the selected discharge line.

The use of alum-cake feeder solution may be therefore, of significant importance both in capital investment, operation, and maintenance in LDC's. The need for importation

of or investment in complex mechanical equipment is reduced, and operation and maintenance can be met by using local materials and local skills. Because the alum-cake feeder is made of wood the corrision problem is nil. Furthermore, failures due to mechanical or electrical causes is almost impossible. Finally, no expenditures need be made in grinding and screening alum-cake. This low grade unpurified alum can be used without any detrimental effect.

Construction and operation of a small (20 liters) portable chlorinator as shown in Figure 2 has been successfully used in rural water supplies in the Sudan (2). The portable chlorinator consists of invested plastic jerrycans of 20 liters capacity, in the base of which a hole has been cut. A sieve and a loose-fitting, non-airtight cover are removable for filling and access. The float may be made of styrofoam commonly used as packing materials. Glass tees as are used for the liquid intake. In the Sudan, chlorine of lime has been used as a disinfecting agent, and mixed at the rate of 100 grams to 5 liters of water in a bucket and is allowed to stand for some hours before pouring into the chlorinator, taking care that the inactive sediment is thrown away.

Other alum-cake solutions fedder have been used in peru and India (2). Figure 3 shows an upflow alum-cake feeder used in Lima, Peru. The influent water dissolves some of the alum as it passes upward to the overflow level.

As the submerged alum dissolves, it's volume is reduced and dry alum above the overflow level sinks until submerged. In this case the amount of alum submerged remains constant at any constant rate of inflow and the density of the alum solution discharged is also constant.

Allowing for 25 percent chlorine content in the chlorine of lime, a solution of 5,000 ppm chlorine, has been capable of imparting a dose of 1 ppm to 25,000 liters.

The total cost has been about $9 per unit and all materials has been locally obtained except the glass tees.

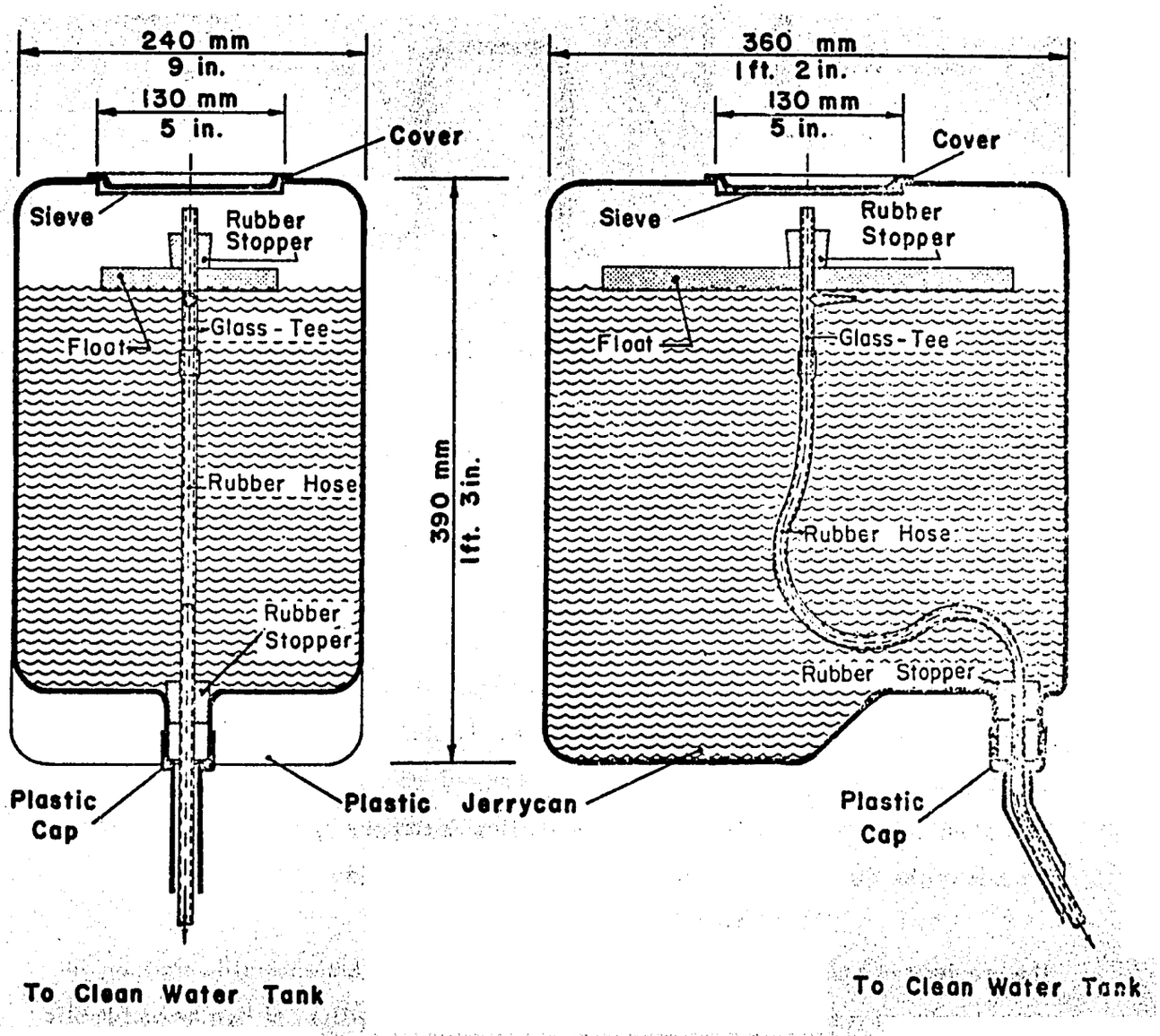


Figure 2. Plastic Jerrycan Chlorinator.

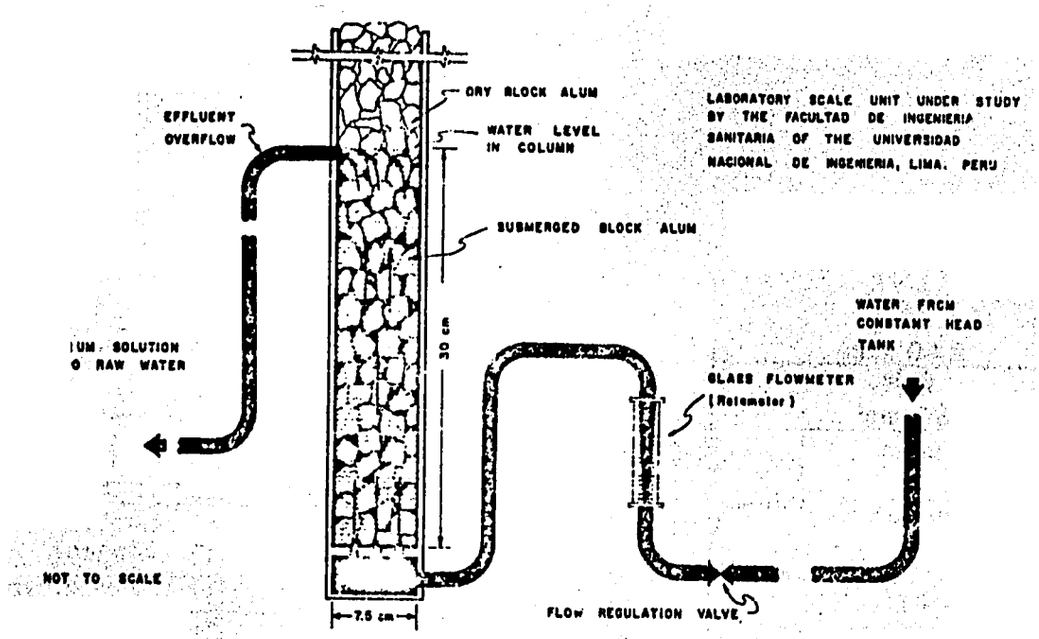


Figure 3. U.N.I. Upflow Alum-cake Feeder.

In Kenya (2) a floating bowl hypochlorite solution feeder was developed to provide low cost chlorination of water supplies. The chlorinator is simple and readily made from local materials and suitable for disinfection of small water supplies. It operates under uniform rate. Figure 4 shows the feeder, which consists of a circular bowl of earthware or plastic with a central hole in the bottom plugged with a tight-fitting rubber stopper. The bowl floats in the hypochlorite solution, desired submergence, stability and trim being achieved by balasting the bowl with pebbles of quartzite. To stop flow from the feeder, the bowl is lifted above the liquid level in the tank and stored (use of a handle) at the top of the tank when the feeder is not in use. When the flow is stopped by closing the outlet at the side of the tank, the bowl will fill and sink to the bottom.

The problems of corrosion and choking of commercially available metallic strainers in water treatment is being studied in India. The AU-India Institute of Hygine and Public Health has initiated research on the use of hand made non-metallic strainers made of coconut shells. The performance of the strainers is still under investigation. The preliminary observation so far indicates that hand made strainers, which can locally be manufactured are cheap and can serve the tubewell as satisfactorily as the factory-manufactured metallic cloth strainers, but their effect on water quality is still under observation

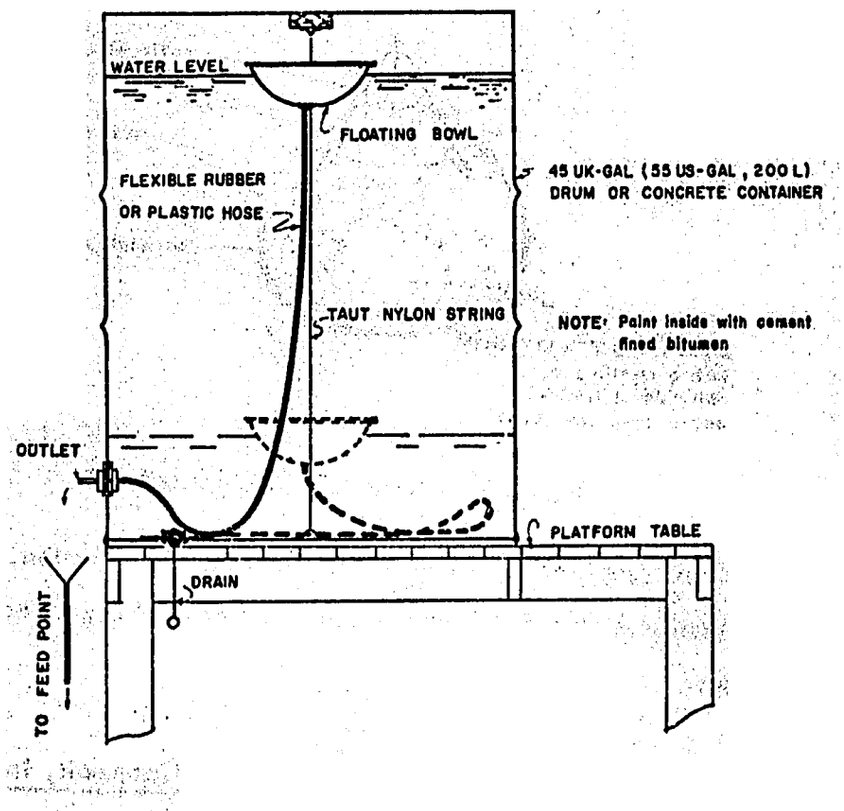


Figure 4. Floating Bowl Solution Feeder.

In Malaysia (4) experimenting of well chlorination with perforated plastic bags containing 91:1 mixture of chlorine of lime and coarse sand which is lowered into the well in a coconut shell is underway. The coconut type chlorinator shown on Figure 5 has been used on 900 liters of water with the withdrawal of ten percent of the content per day; the residual chlorine of 1.0 ppm at the start gradually dropped down to 0.1 ppm in 22 days.

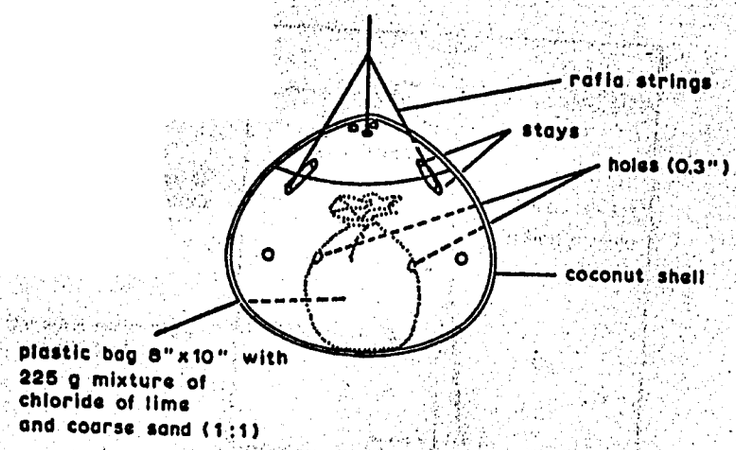


Figure 5. Coconut Type Chlorinator.*

Because practically no supply in rural communities of LDC's are treated, wide use of this inexpensive locally produced chlorinator should be of vital importance in eliminating waterborne diseases.

Bamboo Technology in Water Treatment for Small Community in LDC's

What is needed in LDC's in water treatment is appropriate technology, which uses locally produced materials. Locally produced material means material which can be obtained in the community where the treatment process is located**. What is produced in Nairobi or Bangkok may not be available in a small rural community inland. One reason

*WHO/IRC. For Community Water Supply, Newsletter No. 40, April, 1974.

**A letter from Ministry of Agriculture in Kenya states that it took rural community six months to get repair parts.

may be no access roads to the remote community. On the other hand ordering water treatment chemical, steel pipes, gasoline may take time.

What is needed, therefore, in LDC's is emergency planning for water. In the United States, the American Water Works Association* has published various method of emergency planning of water in time of disaster such as earthquake, civil disorder, hurricane flood, epidemic, industrial discharge, etc.

It is logical to say, LDC's need emergency planning for water treatment. In this case some of the methods used in the United States during emergency could well be applied in rural communities of LDC's.

Most of the failures in water treatment has been observed to occur during operation and maintenance. The construction part is normally simple if technical manpower and means of financing is available.

For a community somewhere in East Africa or South East Asia, the use of bamboo and coconut filters can be the best alternative in water treatment. Bamboo pipes are efficient in transporting water miles away by gravity flow (Figure 6). During an emergency, the bamboo pipes and coconut filter are easily replaced locally. Energy produced by nature such as wind or solar energy can be incooperated with locally produced bamboo and coconut filter or other filters known to the natives to pump water and treat it. Figures 7, 8, show a wind mill and bamboo pipes.

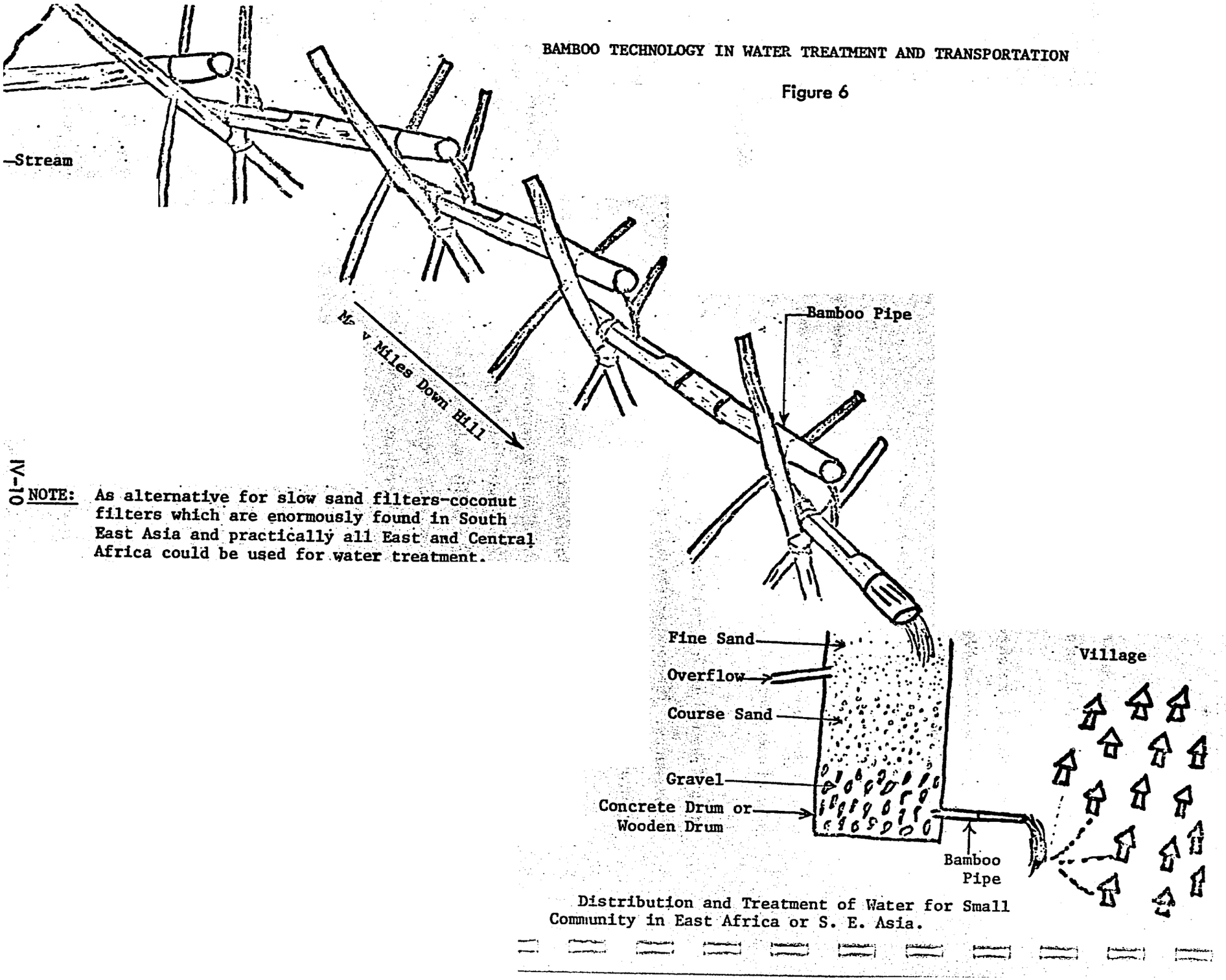
Summary

Both historic and innovative technology research is needed. The unpublished literature in LDC's is needed to correlate the method used by local people before the innovative technology was imported. As such, the project will be reviewing more LDC literature in water and wastewater treatment especially trying to find the unique processes which

*Emergency Planning for water utility Management, AWWA, Manual of Water Supply practices.

BAMBOO TECHNOLOGY IN WATER TREATMENT AND TRANSPORTATION

Figure 6



Distribution and Treatment of Water for Small Community in East Africa or S. E. Asia.

NOTE: As alternative for slow sand filters-coconut filters which are enormously found in South East Asia and practically all East and Central Africa could be used for water treatment.

Figure 7. Windmills, bambo and coconut for water treatment in small rural community of East Africa or South East Asia

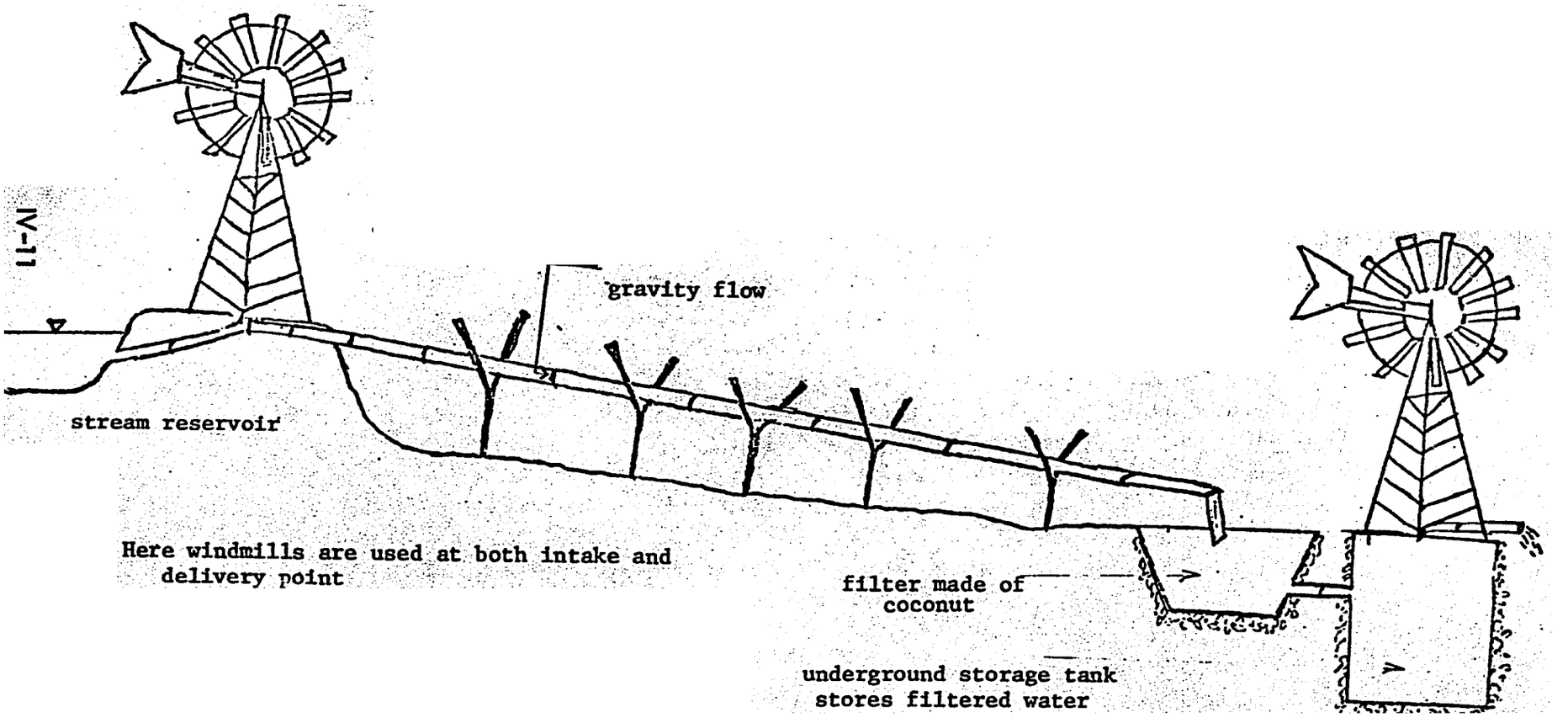
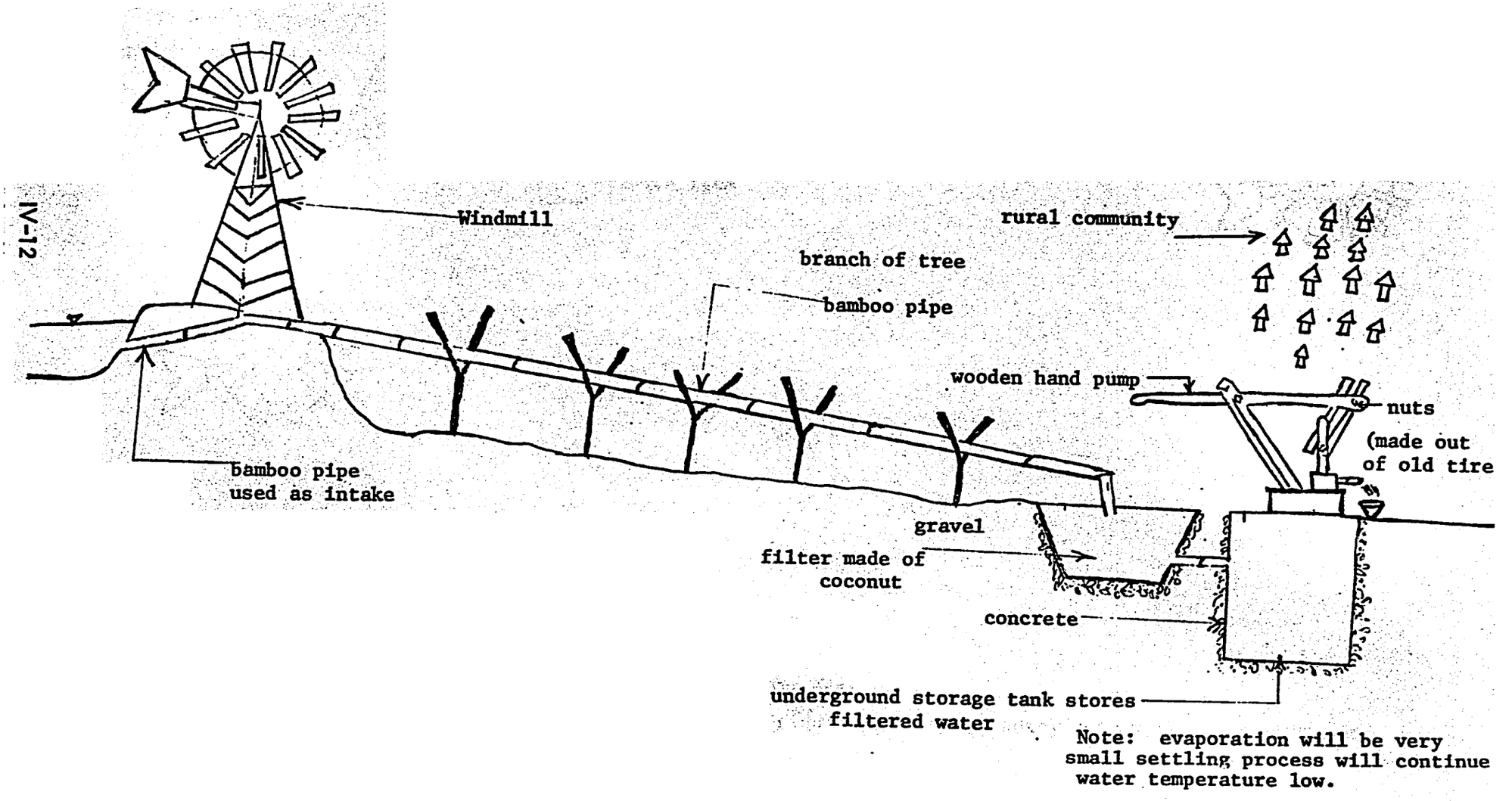


Figure 8. Using Windmill, Bamboo, Wooden hand pump and Coconut Filter for small rural community in LDC.



have not appeared in the published literature. We also plan to develop a matrix for water and wastewater which shows the causes of failures of water and wastewater treatment plants in LDC's. This type of matrix can be useful in updating the existing plants in LDC. Such a matrix will be as shown as on Figure 9.

The other thing which is needed and which we will continue to review is the water demand in each LDC. This allows us to average LDC consumption. Finally a matrix for comparison of water demand in various countries could be as follows (see Figure 10):

Constraints	d1i	For population	P > 100,000
	d2i	For population	P > 50,000
	d3i	For population	P > 10,000
	d4i	For population	P > 10,000

Figure 9. CAUSES OF BREAKDOWN AT THE PAST PROCESS IN LDC MATRIX

Processes	Pumping problems	Lack of raw water	No rain	Distribution	Lack of money	Power failure	Corrosive problems	Operators problems	Lack of chemicals	Etc.	Σ
Chlorination	x								x		K_1
Slow sand filter			x	x							K_2
Pi					x						
Sum	S_1		S_2								

Figure 10. LDC WATER DEMAND MATRIX

LDC	Metro gallon/ capita/ day	City gallon/ capita/ day	Town gallon/ capita/ day	Village gallon/ capita/ day	Summary	Average
Lebanon	d_{11}	d_{21}	d_{31}	d_{41}		
Kenya	d_{12}	d_{22}	d_{32}	d_{42}		
Thailand	d_{13}	d_{23}	d_{33}	d_{43}		
Peru	d_{14}	d_{24}	d_{34}	d_{44}		
Ethiopia	d_{15}	d_{25}	d_{35}	d_{45}		
Ci	d1i	d2i	d3i	d4i		
Average	$d_{11}+d_{12}+\ldots+d1i/i$ $= \sum_{i=i}^{i=1} d1i$	$d_{21}+d_{22}+\ldots+d2i/i$	$d_{31}+d_{31}+\ldots+d3i/i$	$d_{41}+d_{42}+\ldots+d4i/i$		

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APPENDIX V

DATA MANAGEMENT

DATA MANAGEMENT

The project staff has been collecting relevant literature (data & information) concerning the development of water and sewage processes that are compatible with developing countries resources. This effort is a continuing one and has been accomplished for the most part. In addition, work has been done on searching specialized bibliographies and subject categories for all literatures.

Initially, the collected literature is being classified in a manual retrieval system. Presently, work has been done to put together specialized bibliographies and subject categories of various publications. The Subject Category is shown in Table 1. In addition to Subject Category, a bibliography sheet is added to each publication, providing some information as to the nature and contents of the publication. A sample of this bibliography sheet is shown in Figure 1.

The University began by canvassing the worldwide literature on processes and process applications. However, few of the unique applications has been found in this fashion. Therefore, the University and the International Reference Center/The Hague are cooperating to complete the literature survey by looking for locally published or unpublished examples of unique or adaptive processes through a mail survey. The literature search plus the results of this survey will be evaluated by treatment process experts, and a "state of the art" document produced and distributed.

The OU project needs to know the state of the art in Less Developed Nations (LDN's), of water and waste water treatment. The Systems being used have developed largely, but not entirely, from processes used in developed countries. It is necessary to understand high technology, technology transfers, modified or adaptive technology, and finally unique technology. The systems used by developed countries will be found in the literature and this literature search is being conducted by the OU project staff on a continuing basis. The unpublished field report data will be conducted by an OU/IRC instrument using the WHO/PAHO field engineers. These data will then be evaluated, collated and presented as "State of the Art Documents."

TABLE 1

Subject Categories

- 100 Socio-Economic
  - 110 Demographic
  - 120 Economic reports
  - 130 Political criteria
- 200 Technology
  - 210 Water supply
    - 211 Treatment processes
    - 212 Process design criteria
    - 213 Materials for construction
    - 214 Process manpower
    - 215 Process operation and maintenance
    - 216 Quality control
    - 217 Current research and development
  - 220 Waste water
    - 221 Treatment process
    - 222 Process design criteria
    - 223 Materials for construction
    - 224 Process manpower
    - 225 Process operation and maintenance
    - 226 Quality control
    - 227 Current research and development
- 300 Management
  - 310 Planning
  - 320 Programs
  - 330 Environmental
  - 340 Manpower
  - 350 Organization and administration
- 400 Health and Diseases
  - 410 Health protection
  - 420 Health promotion
  - 430 Health planning
- 500 Bibliographies
  - 510 Bibliographies
  - 520 Abstracts
  - 530 Indexes
- 600 Contacts
  - 610 Individuals
  - 620 Organizations

Figure 1

BIBLIOGRAPHY

Subject Category _____

Book ☐ Title: _____

Article ☐ _____

Pamphlet ☐ _____

_____
(Title and Volume # of Periodical if Article)

Author(s) _____
Last Middle First Title (if any)

_____

_____

Publisher: _____
Name Date of Publication

_____
Place of Publication

Specific Citation _____

_____

_____

_____

_____

_____

Comments (Relative Value, Interest, Etc.) _____

_____

_____

_____

_____

_____

Physical Location _____
(where publication can be found)

_____
Initial

The data flow and participating groups are shown in Figure 2.

In order to properly evaluate and categorize the material, it is necessary to develop a logical formatting of information as it is accumulated, where it is stored, manufactured or retrieved by hand or machine.

The formatting, envisioned here, must be manipulated by professionals, clerks, and machines. Basically, the data will relate to water and sewage processes and human and physical resources.

Finally it is necessary to have the formatting inputs responsive to two general groups of data, I data from published, and II data from unpublished (field report) sources.

Table 2 indicates the type of information that will be obtained on the general parameters, Table II outlines the process data being sought and Table III indicates the resource data needed.

Figure 2

THE DATA MANAGEMENT PROCESS

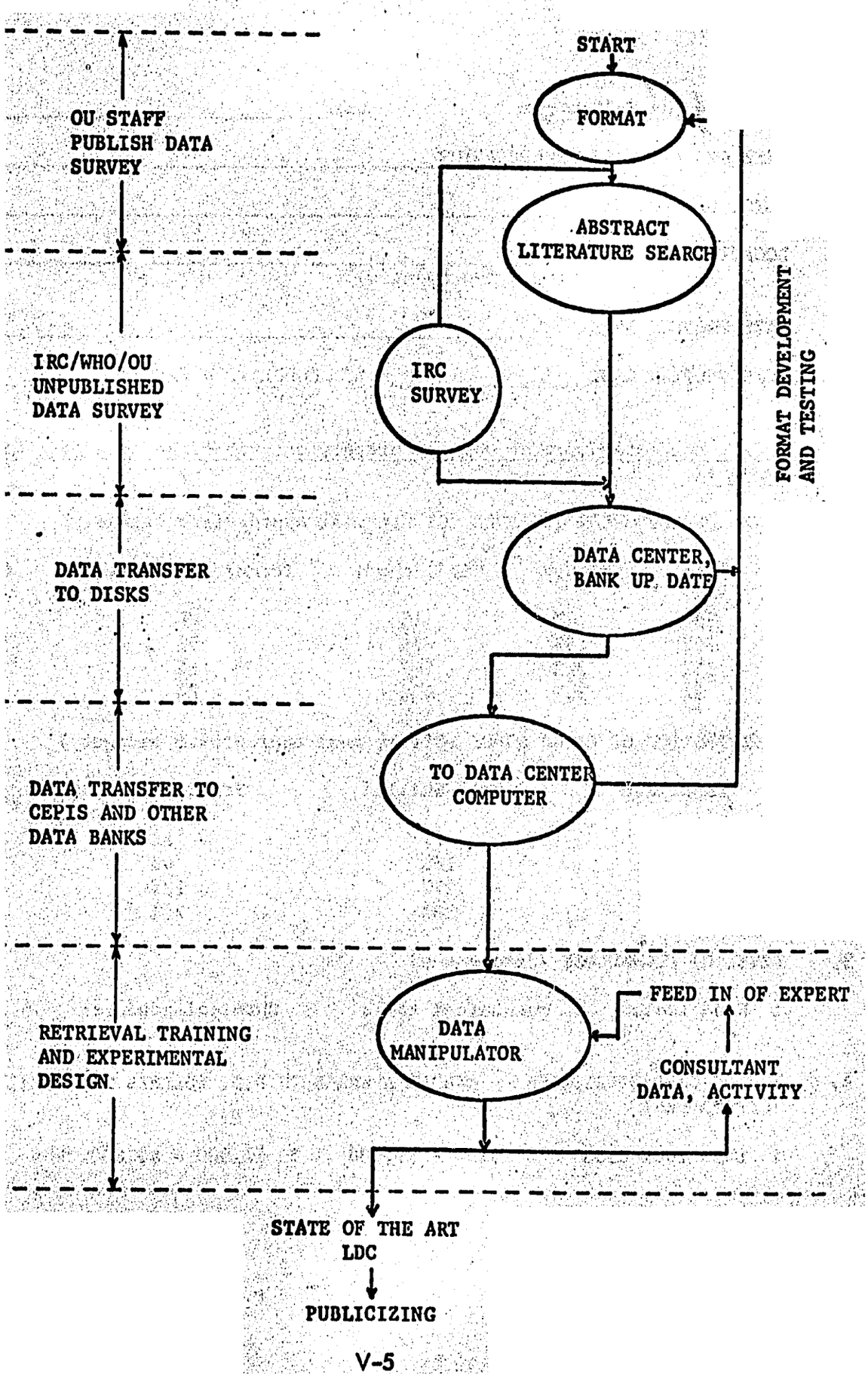


TABLE 2

A. Complete the following: DATE _____

1. NAME AND TITLE OF INVESTIGATOR _____

2. TITLE OF PROJECT _____

3. LOCATION OF PROJECT _____
(city and country)

4. DATE PROJECT DEVELOPED _____

5. CONSTRUCTION COST _____ 6. POPULATION SERVED _____

B. Select the category that most accurately describes the site for this project:

1. LEVEL OF EDUCATION OBTAINED (Circle most appropriate category)

	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%

2. DISTRIBUTION OF LABOR FORCE (Circle most appropriate category)

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

3. LEVEL OF TECHNOLOGY (Circle one)

1 Hand tools 2 Mechanical tools 3 Chemical products 4 Electronic technology

4. INCOME CHARACTERISTICS -- ANNUAL AVERAGE IN U.S. DOLLARS PER FAMILY (Circle one)

1 Less than $100 2 $100 - $1,000 3 $1,000 - $3,000 4 Greater than $3,000

5. LEVEL OF WATER TECHNOLOGY DEVELOPMENT (Circle one)

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

6. FUNDING SOURCE IN-COUNTRY (Circle one)

1 100% 2 75% 3 35% or less 4 0%

7. RESOURCES AVAILABLE IN COUNTRY (Circle one)

1 100% 2 75% 3 Less than 50% 4 0%

C. <u>In the judgment of the investigator, which of the following most appropriately describes this project</u>:

1. TECHNOLOGY ADVANCEMENT (Circle one)

1 Simple transfer of a process that had been successful elsewhere
2 An adaptation of another process but altered to be more suited to local characteristics
3 A unique process developed especially for the characteristics of this site

2. QUALITY OF PROJECT FOR RESEARCH (Circle one)

1 A breakthrough for enhancing the development of this country
2 An important feature for the local people but not significant to overall development of the country
3 Redundant, of little use to the people

TABLE 3

PROCESS DATA

A. Please indicate the appropriate data for this project:

1. IF THE PROJECT CONSISTED OF A WATER SUPPLY TREATMENTS DEVELOPMENT, PLEASE INDICATE BY CIRCLING THE APPROPRIATE DATA:

Source:

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

Treatment:

1 Settling:

a Plain sedimentation
b Coagulation
c Tube or plate
d Upflow
e Coagulation material

(1) Al_2SO_4
(2) $FeCl_3$
(3) Polymer
(4) Other

f Approximate design criteria used

(1) Q/A (Circle one)

(a) Less than 500
(b) 500 - 1000
(c) Greater than 1000

(2) Gradient (G) (Circle one)

(a) 10 - 25
(b) 25 - 50
(c) 50 - 75

(3) Detention time in hours

(a) ½ - 1
(b) 1 - 2
(c) 2 - 4
(d) Greater than 4

(4) Capacity in million gallons per day

(a) Less than 0.5
(b) 0.5 - 5
(c) 5 - 20
(d) Greater than 20

(5) Stirring

(a) Baffle
(b) Puddle
(c) Air

2 Filters:

a Rate of filtration

(1) Slow (2) Rapid

b Filter media

(1) Sand (2) Multi-media (3) Other

c Design capacity in million gallons per acre per day (Q/A)

(1) 1 - 4
(2) 4 - 10
(3) 10 - 100
(4) Greater than 100

d Depth of media

(1) Less than 40 inches
(2) 40 - 50
(3) Greater than 50

e Controls for backwash

(1) Mechanical or hydraulic
(2) Simplified or operator controlled

f Direction of flow through filter

(1) Upward (2) Down flow (3) Both

g Disinfection method

(1) Cl_2 (2) Lime (3) Ultra-violet (4) Ozone
(5) Other

2. IF THE PROJECT CONSISTED OF A WASTE WATER TREATMENT DEVELOPMENT, PLEASE INDICATE THE APPROPRIATE DATA:

1 Type of treatment process (Circle one)

a Oxidation pond
b Primary sedimentation
c Trickling filter
d Sand filter
e Activated sludge
f Aerated lagoon
g Irrigation or land disposal
h Dilution
i Package plant

2 Design capacity (Circle one)

a Less than 1 MGD
b 1 - 5 MGD
c 5 - 10 MGD
d Greater than 10 MGD

3 Type of screens

a Manual
b Mechanical
c For grit removal
d For grease or floating wastes removal

4 Settling rate in clarifier Q/A

a Less than 750 b 750 - 1000 c Greater than 1000

5 Detention time (t)

a Less than 1 hour b 1 - 2 hours c More than 2 hours

6 Secondary treatment design

a Trickling filter loading (lb/acre/day)

(1) 1500 - 7500 (2) 7500 - 10,000 (3) 10,000 - 45,000

b Aeration devices

(1) Compressed air
(2) Brushed
(3) Surface aerator
(4) Paddles
(5) Other

B. <u>Estimate cost breakdown for this project</u>:

1. LABOR

1 Percent of total project cost

a Less than 10%
b 10% - 25%
c 25% - 50%
d 50% - 75%
e 75% - 90%
f Greater than 90%

2 Percent of unskilled labor

a Less than 25%
b 25% - 50%
c 50% - 75%
d Greater than 75%

3 Percent for engineering

a 2% - 4%
b 4% - 6%
c 6% - 10%
d Greater than 10%

4 Approximate hourly wage for unskilled workers

a Less than $.50
b $.50 - $1.00
c $1.00 - $2.00
d Greater than $2.00

5 Approximate hourly wage for skilled labor

a $2.00 - $3.00
b $3.00 - $4.00
c $4.00 - $5.00
d Greater than $5.00

2. MATERIALS

1 Percent of materials found in-country

a 10% - 25%
b 25% - 50%
c 50% - 75%
d 75% - 100%

C. <u>Estimate demographic data</u>:

1. ANNUAL POPULATION GROWTH RATE

1 Less than 1%
2 1 - 3%
3 3% - 5%
4 5% - 10%
5 10% - 20%
6 Greater than 20%

2. POPULATION DENSITY (PERSONS PER SQUARE MILE)

1 Less than 500
2 500 - 1,000
3 1,000 - 1,500
4 1,500 - 2,500
5 Greater than 2,500

3. LIFE EXPECTANCY IN YEARS

1 Less than 40
2 40 - 50
3 50 - 60
4 60+

4. SURVIVAL RATE (INFANT MORTALITY UNDER ONE YEAR OF AGE) PER 1,000 POPULATION

1 Greater than 100
2 50 - 100
3 30 - 50
4 10 - 30
5 Less than 10

5. CALORIES INTAKE PER DAY

1 Less than 1,000
2 1,000 - 1,500
3 1,500 - 2,000
4 Greater than 2,000

TABLE IV

RESOURCE DATA

From the lists of components needed for water and sewage treatment development projects, indicate by group those that generally are available at or near the site. Circle any component in the list that is never available.

1. MANPOWER (Circle if grouping is generally available)

   1 Craftsmen (Circle if never available)

   a Carpenters
   b Masons
   c Welders
   d Pipe fitters
   e Electricians
   f Plumbers
   g Cement finishers
   h Painters

   2 Equipment operators (Circle if never available)

   a Grader
   b Crawler tractor
   c Scraper
   d Crane

   3 Professional and technical (Circle if never available)

   a Design engineer
   b Construction engineer
   c Chemist
   d Biologist
   e Surveyor
   f Estimator
   g Lawyer
   h Accountant

2. EQUIPMENT (Circle if grouping is generally available)

   1 Construction (Circle if never available)

   a Crawler tractor
   b Back hoe
   c Trencher
   d Crane
   e Pile driver
   f Cement mixer
   g Scraper
   h Welder
   i Hand power tools
   j Trucks
   k Air compressor

   2 Operation (Circle if never available)

   a Meters
   b Lawn mowers
   c Blowers
   d Recording devices
   e Laboratory equipment
   f Portable power plant
   g Motors
   h Pumps

3. MATERIALS (Circle if grouping is generally available)

1 Construction (Circle if never available)

a Blasting
b Cement
c Aggregate
d Structural steel
e Structural wood
f Plywood
g Electrical wire
h Concrete blocks
i Reinforcing steel
j Fasteners

2 Process (Circle if never available)

a Pipe (clay, steel, cement, plastic, copper, etc.)
b Pipe fittings
c Paint
d Valves
e Tanks
f Gauges
g Heat exchangers

3 Operation and Maintenance (Circle if never available)

a Silica sand
b Graded gravel
c Clean water
d

4 Chemicals (Circle if never available)

a Al_2SO_4
b $FeCl_2$
c Activated Charcoal
d Lime
e Soda ash
f Chlorine
g Ozone
h Laboratory chemicals

AUTOMATED DATA RETRIEVAL SYSTEM

As part of the problem solution, but not part of the AID project, would be the development of an Automated Data Retrieval System. Through cooperation of the Oklahoma Foundation, an Automated Data Retrieval System has been proposed, to be established at IRC's, countries or PAHO research centers.

Such a system is assembled out of "off the shelf" parts, and is responsive not only to the precise needs of the Aid project, but the continuing environmental needs as well. The system uses a mini computer capable of storage and retrieval as a very flexible mode; as well as providing simulations, it can interface with other systems, and most importantly is available at a very low cost, as compared to larger systems, see Table IV.

Such a system uses $8 discs of 250,000 characters, no special training required and replacable self-diagnostic parts.

The real time data retrieval systems available on the commercial market can be modified to meet essentially any need. The major considerations, other than cost, should be reliability, maintenance and flexibility. The software and hardware design proposed here are a direct result of the experience gained by the Oklahoma Foundation and its Associates from the Ozarks Regional Commission's Resource Management Information System, which is a five state system with over fifty remote terminals. The users of the Ozarks System were inexperienced in retrieval system operations and none were trained in computer operations. Most of the operators were experienced in the fields of urban planning, economic development and industrial development, therefore the system design was such that they could operate the retrieval system in a conversational mode. This experience has resulted in the development of a set of very flexible computer programs that can be operated by non-computer personnel. These programs and the systems experience with the Ozarks project are the basis for this proposed system.

In most systems, the designers are equipment manufacturers and their desire to sell equipment is predominant in the design of the system. Since the Oklahoma Foundation for

TABLE IV

COMPUTER SYSTEM CHARACTERISTICS

ITEM	LARGE COMPUTER	MEDIUM COMPUTER	MINI COMPUTER
Central Computer	$3,000,000	$1,250,000	$100,000
Operating Speed	Excellent	Excellent	Moderate
Storage Capacity	Unlimited	Unlimited	60 million characters
Computation Capacity	Excellent	Very Good	Satisfactory
Core Storage	Excess 100K	32K - 60 bit	32K - 16 bit
Tape Storage	Auto Switching Unlimited	Auto Switching 10 MTU	Auto Switching 4 MTU
Simult. Operations	32	32	5
Cost/Hookup hour	$220	$80	$7.50
Cost/Operating Hr.	$440	$230	$7.50
Cost/Operating Hr. 20% Usage	$2000	$1000	$40
Cost/Maintenance	$40,000	$7,000	$3,000
Maintenance Pers.	Computer Pers.	Computer Pers.	Non-Computer Pers
Operating Pers.	Professional	Professional	Non-professional
Retrieval-Calc. Software	None	None	Complete
Retrieval-Criteria	Extra	Extra	Included
Retrieval,SORT-MERGE	Extra	None	Included
Non-Operating Software	Extra	Extra	Included

Research and Development is a non-profit corporation and is not an equipment manufacturer, our system design is based on maximum utilization of existing technology that produces the best system for the least dollar of capital investment.

One of the major factors to be considered in the initial establishment of the system is the rate at which the clients will use the system. The various remote terminals use rate will vary greatly at the start up of the operation, and expensive high speed equipment for each remote terminal is very uneconomical. However the system proposed enables the system managers to expand the system on a need basis. The cost savings in maintenance costs alone will normally pay for the entire system expansion.

This proposal presents the computer system in several parts; a brief description of the computer hardware components, with specifications given in Appendix D: a description of the operating system in Appendix A: a description of the MERCURY retrieval and analyses programs in Appendix B; a presentation of modular assembly of the computer system, with cost trade offs; and a scope of services with estimated performance schedules.

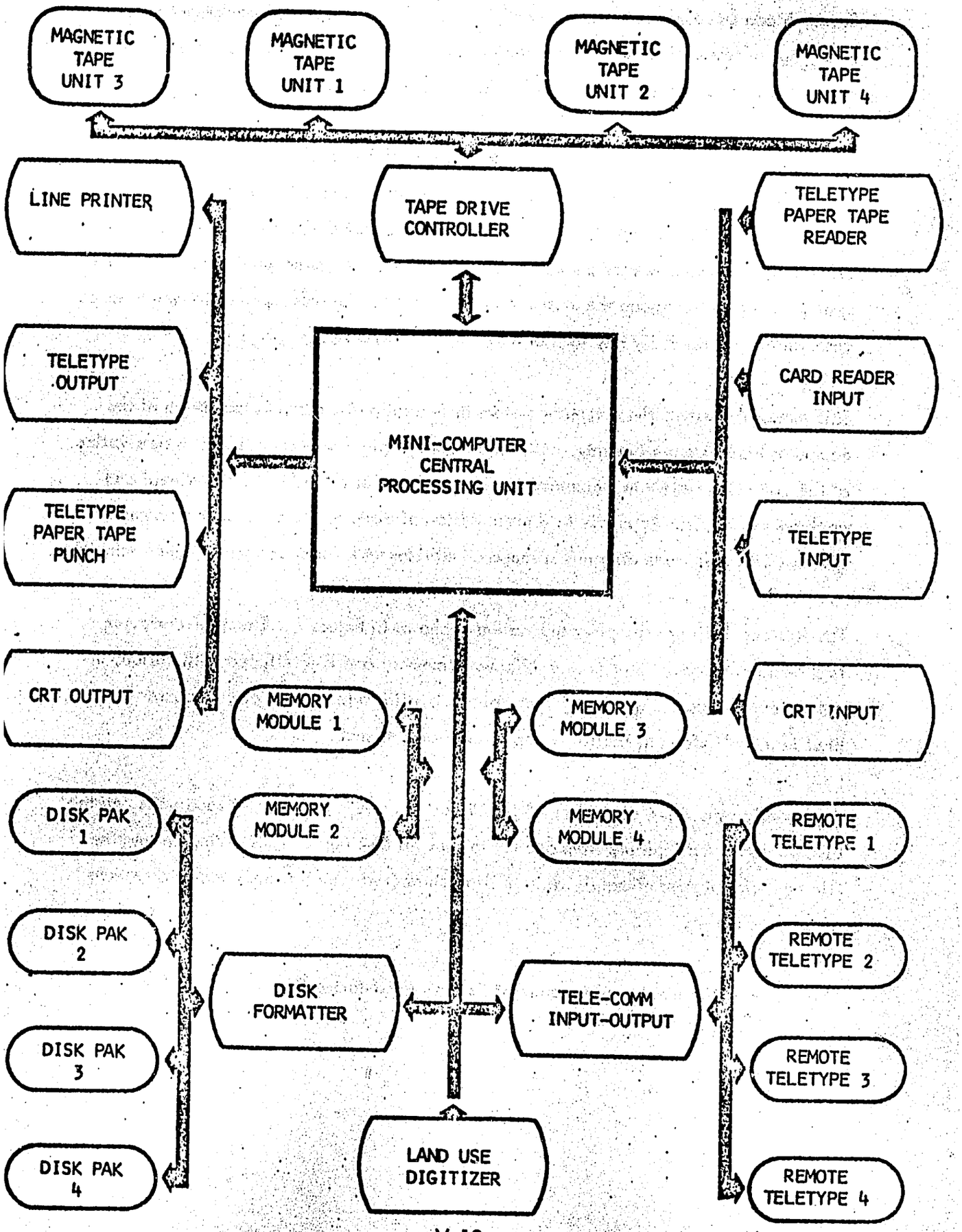
The full capability of the proposed system is shown in Figure 2. The mini-computer, NOVA 1200 or equivalent, has a 3200 word memory and is interfaced with various input-output devices. All of the electronics are solid state printed circuit boards assembled in modular form to facilitate repair and maintenance.

A magnetic tape drive controller will operate from one (1) to four (4) tape units and the disk formatter will operate from one (1) to four (4) disk paks. Thus giving an on-line file capacity of approximately sixty million characters which is equivalent to ten sets of encyclopedias.

The system will accept a wide range of devices for entering files, printing files or for input commands.

FIGURE 2

MINI-COMPUTER SYSTEM



Output Devices

The high speed line printer has an output capacity of 80,000 characters a minute, or assuming an average of eight (8) characters per word, an output of 10,000 words a minute. The nominal operating speed during actual retrievals is approximately 2,000 words per minute.

The output may be recorded on regular paper tape devices associated with the teletype or printed by the teletype on eight of our fourteen inch paper. Normally the teletype is used for entering commands or copying very small files because of its relative slow printing speed, ten (10) characters per second.

The cathode ray tube or "televesion" output devices have great utility in inputting files and particularly in retrieving information where no hardcopy of the output is required. Printing devices are now available which when interfaced with the CRT's eleminate the hardcopy problem and their increased speed, thirty (30) characters per second, make them very competitive.