THE APPLICATION OF ENGINEERING TECHNOLOGY TO DEVELOPING NATIONS

by

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ABSTRACT

In preparing to assist a developing nation, both the foreign student and the foreign bound American student have special educational needs. A format is proposed with which such students can guide their own studies and plan for working in their particular field in another country. Using this scheme, the problem of designing adaptable waste-treatment systems for rural villages in Ecuador, South America is considered and four designs of such systems proposed.

KEY WORDS: appropriate technology, developing nations, waste treatment, oxidation ponds, septic tanks, Imhoff tanks, trickling filters, engineering curriculum.

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INTRODUCTION

Technology can be defined as the "science or study of the practical or industrial arts". In short, it is applied science. Technology has produced as well as solved many problems. Still, by many, technology is looked to as the solution for yet more problems, even those of its own creation. One goal of technology has been strictly economic in nature, the making of money. The concern for economical (i.e., maximized capital gain) has led to most of the problems caused by technology (e.g., pollution of air, water and environment). But there is another goal of technology--the solution of problems relating to people. These "people problems" include health, agricultural, transportional, and educational related needs. It is with respect to this second goal of technology that this study was conducted.

While many problems exist within this country's borders, outside of them are problems at least as grave and of much larger scale. In many countries, the average person lives far below the worst conditions found in America. The motivation behind this study is the feeling that the technology developed in this country, the problems that have been solved and created, can be used as a source of data in the

NOTE: The basic format followed in this paper is that found in many articles which appear in the Civil Engineering magazine of the American Society of Civil Engineers.

aiding of developing countries. This data can be used to solve similar problems while at the same time sidestepping some of the past bad results. Those for whom the humanitarian motive is not sufficient for aiding developing countries should consider the more mundane political and economical dangers of not helping them. In any event, it has been truly stated that "supplying food, housing, health service and education for some six billion people by the year 2,000 is the main engineering challenge for the rest of this century".

The basic philosophy throughout this study has been that of believing rural development to be more desirable than urban development. The unfortunate reality in many developing countries is a lack of rural agricultural solidity. The typical farmer is the small farmer producing only enough food for himself, his family, and a very small amount for market. If he is taken off the farm, or rather drawn off by the hope (seldom realized) of success in the "big city", there is none to farm his land and supply his portion of the market, no matter how small, and none to produce food for himself and his family as he had once done for himself. But all too often, foreign aid does not filter down to the rural areas, and the big cities simply grow bigger and more of a problem. "Rural development will retard massive migration to the cities, forestall unemployment, congestion, urban sprawl, and pollution."

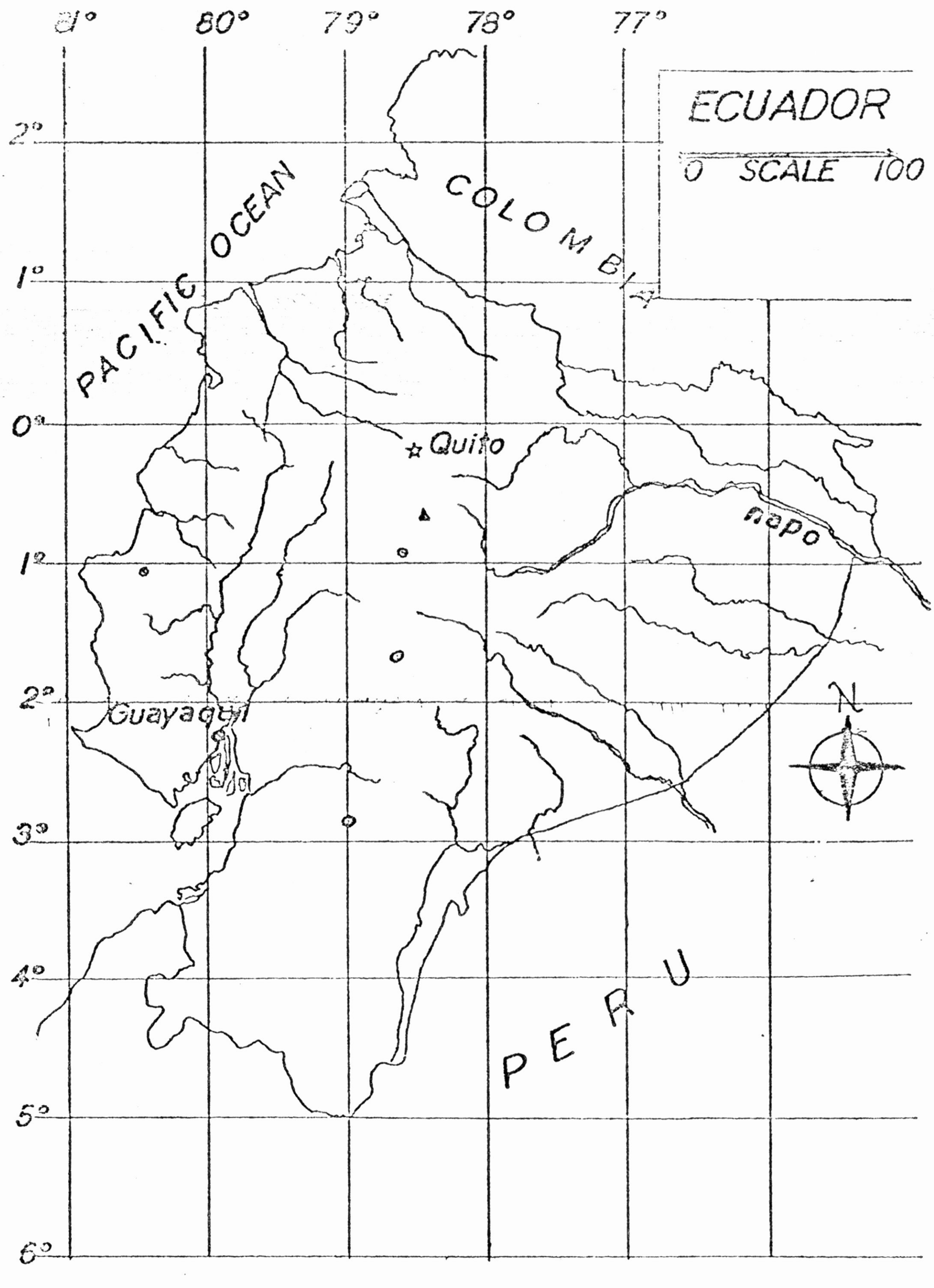
Inorder to achieve a proper perspective for the successful application of engineering technology to developing nations, there must be a change made in the basic approach to engineering education, as it applies to those considering practice in another country. This need is not only felt by those American engineers working in developing countries, but, and perhaps even more so, those foreign students who come to the United States for their education and then return to their country. Generally, the basic curriculum involves theory and practice as they relate to the American economy, technological level, and labor force. In addition, the direct application of American technology, or any advanced technology, to a foreign society would require drastic social changes which, even if possible, would not be practical. It may be that the tendency of the foreign countries to advance their urban areas stems from a failure to differetiate American technology from what has come to be called, appropriate technology. Rhodes scholar and economist E.F. Schumacher has said, "We need methods and equipments which are: cheap enough so that they are accessible to virtually everyone; suitable for small-scale application; and compatible with man's need for creativity." In short, those looking beyond the United States will have to augment, somehow, their educational input.

Keeping these things in mind, the problem looked at in this study falls into two parts. First, to develop a scheme for the supplementing of the typical American engineering curriculum. Secondly, to use such a scheme in the solution of an actual engineering problem existing in a developing nation. The attempt will not be to fabricate a new curriculum but rather to consider those things which may be necessary but which are beyond the scope of the usual engineering curriculum.

THE APPROACH

The country chosen for this study was Ecuador, South America. The main emphasis at the beginning of the project was the gathering and assimilating of data about that country. During this data gathering period an effort was made to identify problem areas related to civil engineering. And while many problem areas were found, it was decided to concentrate on water and sewage treatment problems in the rural villages of the country of Ecuador. As the study progressed, this was later reduced to considering only the sewage treatment problems. Information about Ecuador will be found throughout the report. However, no attempt has been made to make an exhaustive accounting of all of the information available about that country. The interested reader is directed to the references sited at the end of this report.

Additional investigation was being carried out in the area of sewage treatment. The decision was made to attempt the design of an adaptable system which could be modified to meet specific needs rather than to choose a particular site and design specifically for it. Such a system, in addition to being adaptable, must also possess simplicity of construction, operation and maintenance.



81°
80°
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ECUADOR
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6°
PACIFIC OCEAN
COLOMBIA
Quito
napo
Guayaquil
N
PERU

FIG. 1

THE APPROACH

A. Data Gathering

  1. natural and human resources
  2. determine state of the art
  3. investigations
     a. cultural barriers
     b. government planning
     c. economy

B. Design Treatment System

  1. simple, adaptable construction
  2. simple operation and maintenance

C. Education Program

  1. construction
  2. operation

An outline of the original goals and plans of the research for this study.

FIG. 2

THE FINDINGS

During the data gathering process, a logical order began to appear relative to the types or categories of the data. Based on this, a format for investigation was developed to guide in the collection of data. This format is felt to be of use, also, as an outline for the supplementing of a general engineering curriculum (regardless of the particular country or problem under investigation). As it would not be possible to relate all of the data obtained, by way of illustration, the Investigation Format will be presented and explained using sample data.

The Investigation Format presented herein as the fulfillment of the first part of the problem statement is divided into three categories. 1) the obvious areas, 2) the problem area, and 3) additional areas. These will now be briefly explained. The obvious areas are, basically, those of which a national from a given country would already have a general knowledge. Included in this category would be language, customs, natural aspects of the country, economy, and other related areas. The second category, the problem are, is that area which relates to the technical aspects of the given area of technology. The third category, the additional areas, is composed of data sources available, which apply to a broad spectrum of topics. Some of these sources are readily exploitable, while others require development.

FIG. 3

THE INVESTIGATION FORMAT

I OBVIOUS AREAS

II THE PROBLEM AREA

III ADDITIONAL AREAS

FIG. 4

THE OBVIOUS AREAS

A. Language
   1. data gathering
   2. data communication
   3. education

B. Customs
   1. application
   2. implementation

C. Natural
   1. resources
   2. climate
   3. geography
   4. geology

D. Economy

E. Communication with Nationals
   1. state of art
   2. government policy

THE INVESTIGATION FORMAT

I The Obvious Areas

LANGUAGE--this is not a trivial consideration and goes beyond being able to ask the time and how to find the restroom. Those in technical fields in the United States should realize the importance of the communication of data, whether it be to students, associates, or clients. It is none the less important in other countries. Much of the information obtained about the nation of el Ecuador from english sources was old and questionable. Some of the more recent data was gleaned from reading material published in the language of el Ecuador--spanish. The need for educational materials to implement any design, such as maintenance and operations manuals for a waste treatment system, must be met in the language of the country.

CUSTOMS--it was earlier stated that the welfare of people is the worthy object of technology. To produce a technically sound system which the people will not accept is simply to defeat the purpose of that system and technology, in general. Therefore, the understanding of the people, as well as their problems, is essential. Customs may also play an important role in the implementation of a project. In Ecuador, for example, las mingas, a very fervent community cooperative effort toward accomplishing something of benefit to the community, even at personal sacrifice and no wages, is an example of such a positive social trait.[8,10]

NATURAL--all aspects of the country relating to resources, climate, geography and geology are included in this area. For example, mineral resources are abundant in Ecuador though not very exploited, as is the case with the human resources. Oil is now being extracted, but mainly through the efforts of outsiders. The raw materials for portland cement are readily available, and somewhat being developed into a very high quality product. The climate varies with latitude and altitude in the Andes mountains, but in a given locale, the temperature variance is only 10° to 15° Fahrenheit during the year. Much of this is due to the country's equatorial location (el Ecuador means 'the equator') and the stabilizing effects of the Humbolt current. The fishing areas associated with this current are claimed as part of the territory of the republic of Ecuador, and was the cause of a recent seizure made upon an American fishing boat.[20] Geologically, Ecuador is tectonically active, having earthquakes frequently and is covered with active volcanoes. This indicates that some knowledge of aseismic structures must be had by the designer.

ECONOMY--an understanding should be had of the monetary system, which in Ecuador is based upon the Sucre (as of 1973 this was equal to 4.25 American cents)[19]. Also included as part of the economy study should be exports and wage norms and all other related topics. Some of these would require a first hand knowledge to obtain an adequate feel for their importance, but such things should atleast be investigated. To impress a government with ideas requires an understanding of the economic stability and plans of the government.

COMMUNICATION WITH NATIONALS--in order to determine the state of the art for engineering, information relating economic plans, and similar, must be gained from the country under study. This can be done through the use of technical journals, if such are available. In the case of Ecuador, political unrest, including two recent changes in the government, has virtually stopped what technical journals there were as of 1971. Even these are hard to get from prior to 1971; correspondence with nationals has been slow and replies few, with little or no information. From contact with students from Ecuador and, through one of them, with a sanitation engineer in that country, some useful information was gained. For example, only one very small wastetreatment plant exists in the entire country. It is located in a recent housing development in the city of Guayaquil. Also, the main interest of the country at the present time is the development of a nation wide electrical system.[16] The Peace Corps leaflet for the engineering needs in the world supports this..

It should be obvious that any meaningful design must include the data indicated by the above outline. Since the work force in Ecuador is small and not skilled, education must also be considered . Many craftsmen exist, but there is no real labor force to handle heavy equipment and such. Thus, the training and skills of the people on the local village level must be assumed as very limited. While it was originally planned to develope manuals and such relative to the designs proposed in the study (see Fig. 2), it has been deemed as too difficult a task for someone not living in the country and much more familiar with conditions than can be gained from the outside. Nevertheless, some consideration has been made relative to this need for education, as will be pointed out later.

II The Problem Area

FUNDAMENTALS--the importance of understanding fundamental principles is illustrated by an example out of history. Benjamin Franklin's development of the lightning rod made use of the fact that a sharp point at the top allowed the "bleeding off" of a charge, rather than giving a large surface area upon which to hold a charge (such as the spheres which top the Van der Graff generators). Thus, American lightning rods had points. Not to be out done by her rebellious colony, the British also began installing lightning rods on their buildings. However, in order to add 'art' to colony crudness, each British lightning rod was topped with a big ball--voila! --a lightning attractor. While pride and arrogance may still be in men today, the designer must be sure that he retains an integrity in his design which is relevant to the fundamentals of the field in which the design is made. The importance of knowing the fundamentals of the problem area cannot be over emphasized. When studying how to do a certain thing, it is also important to understand why a certain thing is done. The situation may arise, in a developing country, that

FIG. 5

THE PROBLEM AREA

A. Fundamentals

B. Past Applications

C. Present and Future Applications

prevents doing things the way they were learned. If the reason behind a certain procedure is comprehended, then a practical, alternate solution can be obtained.

PAST APPLICATIONS--methods from the past, whether successful or not, can serve as a guide to solving the problems of the present. Perhaps solutions from a non-technical time in American history, can lead to similar applications in developing nations. Large scale waste treatment is fairly new (within the last seventy years) in the United States.[9] And many of the steps along this country's path of development are exemplary of those a developing country can expect to take, also. The possibility also exists of impriving upon the simple techniques of the past based upon the better understanding of the field that exists today. For example, systems which were only moderately effective and placed aside, might be applied efficiently, today.

PRESENT AND FUTURE APPLICATIONS--close examination might reveal that present methods can be readily adapted to a developing country. Another source of possible solutions is present research which is being conducted. Such things as methane gas production and land application of sewage are two examples of such in the waste treatment field.

FIG. 6

THE ADDITIONAL AREAS

A. Satellite Data
    1. ERTS and LANDSAT
    2. Skylab

B. Computer Usage

C. UNESCO

III The Additional Areas

SATELLITE DATA--two basic types of satellite data are available. There is telemetry data from remote sensing type satellites, and actual photographs from the Skylab programs. ERTS and LANDSAT fall into the first group. Though the data from these is not actually photographic, it is available in visual imagery forms (e.g., transperencies and prints). This data can be used to identify many aspects of the site under investigation, by the use of several different scan techniques which are used (e.g., infrared, microwave). Together with the photographic data available, information can be obtained relating to geology, topography, vegetation, and climate (such as rainfall patterns, stream behavior, geologic structures). The limiting factor at the present time is not the amount of data (it is very abundant), but rather the cost. However, while relatively new as a field, the interpretation of satellite data promises to be a very good data source for many fields of study.

COMPUTER USAGE--while not a data source in itself, the computer cannot be overlooked as a tool for technology. The person considering a foreign practice should be aware of the computer as it applies, or can be applied to his field. There may not be anyone else to help that person. (The reader is directed to two timely articles on this subject. "Algorithms", by Donald E. Knuth in Scientific American, April 1977 and "Fast Programming on Small Calulators", by William Wheeler in Civil Engineering, April 1977)

The preceeding scheme is the proposed educational supplementation guide offered for students planning an engineering practice in a foreign country. One very important fact stands out. Those persons planning to assist in developing the technology of another country must realize their responsibility to go beyond their curriculum requirements to prepare for such a work. In many cases, there will be no consultant to call in, no previous solution for the problems that might be faced--and the student must be prepared. In addition, the American student has the oppurtunity to gain some experience in this country prior to going to a foreign country. This is generally not the case with the foreign student who is required to leave the country when completing his education.

THE DESIGN

Following the proposed scheme and keeping in mind the scope of this project, several waste treatment methods were analysed and compared as to their adaptability, simplicity of construction and maintenance and operation, and the possibility of their application to the village level in Ecuador. Four basic methods were chosen. They are, in order of complexity, stabilization ponds, septic tanks, Imhoff tanks, and trickling filters. The first and third represent, more or less, past methods while the septic tank and trickling filters find widespread use today. Some fundamentals should be understood about sewage treatment. These will then be briefly discussed prior to looking closer at the four proposed treament methods mentioned.

Basically, sewage treatment methods take advantage of the biologically degradable nature of domestic sewage (which is not always the case with commercial or industrial wastes that can hinder or stop these biological processes and must be handled differently). In effect, microorganisms ingest the sewage elements, removing these elements from the influent (the incoming "raw" sewage). This biological reduction occurs by one of two processes. If oxygen is present in sufficient quantity, the aerobic organisms, those which require free oxygen for respiration, can "stabilize" the sewage. This type of reduction or stabilization generally is not accompanied with many unpleasant ordors. One of the most efficient treatment methods, the activated sludge process, uses bubbled air to allow aerobic stabilization to proceed at a fast and complete rate. The College Station, Texas treatment plant uses this method. The extreme efficiency of this technique, though requires quite a bit of sophisticated equipment and training to control, which eliminates it from readily adapting it to a developing country.

If, however, oxygen is not present in great quantity, then what is called anaerobic digestion can take place. This is the chemical respiration of food without the use of free oxygen. The production of methane gas and odors are associated with anaerobic digestion. Also, anaerobic organisms are (IN A FEW CASES) harmful to humans if ingested. Another general aspect of anaerobes is that oxygen kills them.

A sewage treatment system, then simply takes the incoming sewage, exposes it to biological reduction, and discharges the "treated sewage". As a rule, sewage systems have some sort of collection system. This ranges from being an elaborate underground pipe network, such as in most American cities, to the "honey wagon" which is driven around to collect household sewage which then is distributed as fertilizer on farm lands (such a system has been used in China for many years). After collection, in systems where there are pumps or other apparatus which which might be damaged, a process of screening out large solids is employed. After this, there is a step to settle out as many suspended solids as possible. This can be done chemically, using a flocculant and settling tanks or settling tanks alone. Following the seperation, the solids, called sludge, are treated by anaerobic digestion, the products of which are methane gas and an inert solid material, which can be dried and used as a soil builder, called digested sludge. The preceeding makes up that portion of sewage treatment refered to as primary treatment.

The liquid portion of the sewage may be further treated (secondary treatment) or simply discharged as the final effluent of the system. There are literally hundreds of different methods and combinations of methods to produce the above desired scheme of wastetreatment. Some can be very complex, such as the College Station system; others can be very simple, such as the stabilization ponds to be discussed later.

One other factor which should be mentioned is the biochemical oxygen demand, BOD. Putting it simply, this is an index of the 'strength' of the sewage. In effect, a measure is made of the amount of oxygen used by microorganisms over a period of time (usually five days) in reducing a sample of sewage. From this, the BOD is computed and is usually expressed in pounds (the usual design value is 0.17 lbs BOD per person per day). The greater the oxygen demand, the stronger the sewage. It should be understood that the design of a system is a function of BOD, method efficiency, and desired BOD of the effluent.

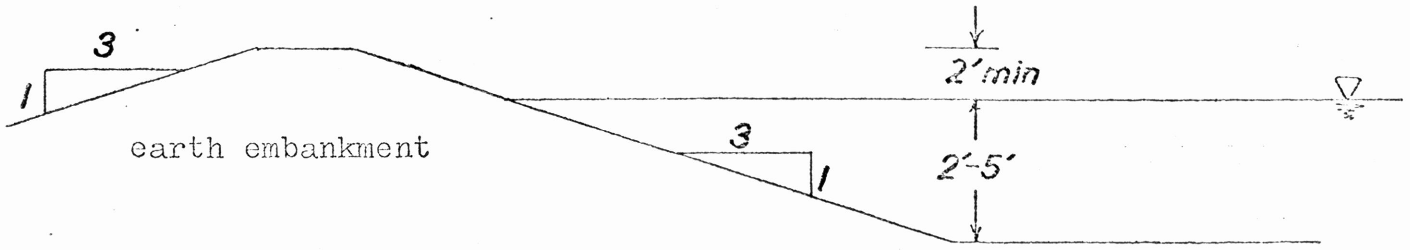
The Stabilization Pond

Also called lagoons and oxidation ponds, the stabilization pond represents the simplest of waste treatment methods. Lagoons are simply man made ponds or lakes into which collected sewage is placed. These lakes provide a location for the biological stabilization of the sewage. The term stabilization should suggest aerobic reduction. In fact, that is the intended process. Ideally, the pond is located where sunlight can cause a large growth of algae (an algal bloom). The algae, through photosynthesis produces oxygen to drive the aerobic stabilization of the sewage.

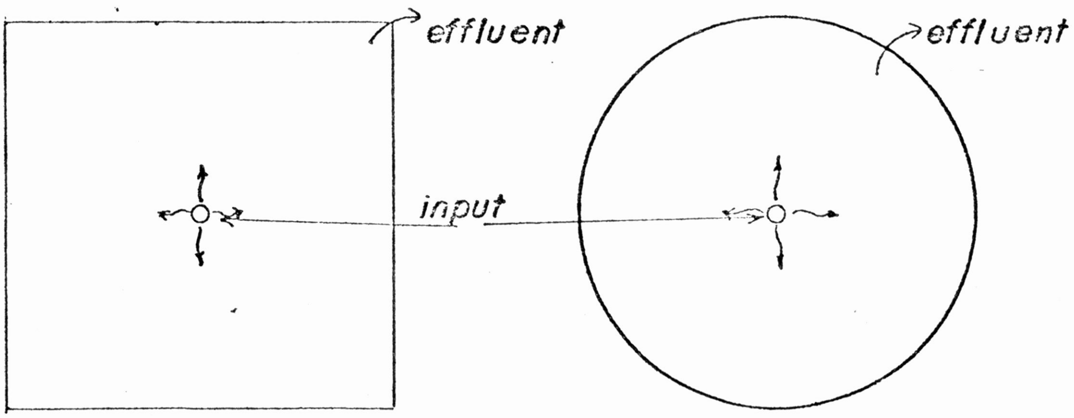
Form the illustration (Fig. 7) it can be seen that there are design limitations on the depth of the liquid in the pond. If it is too shallow, then trees and other undesirable plant growth can develope which might cause leakage or

FIG. 7

LAGOONS



A CROSS SECTIONAL VIEW



CONFIGURATIONS

(A VARIETY OF SHAPES CAN BE USED)

WINTER STORAGE

Winter storage considerations are made so that the total inflow of the winter months can be retained. The winter depth is from the minimum of 2 ft to the maximum of 5 ft (i.e., 3 ft). This is due to the reccommended practice of lowering the lagoon in the fall before the streams shrink. In the spring the lagoon is again lowered when the streams are swollen.

otherwise interfere with the process. If the fluid level is too deep, then the lower portion becomes anaerobic. Because of the nature of the anaerobic organisms, this is to be avoided so as to prevent the discharge of a strongly septic effluent. In permeable soil, the ponds are lined in some way to reduce leakage. The free board of the earth embankment should be sodded to reduce erosion and slidding. In addition to sewage treatment, lagoons have been used to raise food fish such as catfish or carp.

An example design problem is illustrated in Fig. 8. Though the problem has been worked by the algorithm shown, the reader is directed to the appendix where a simple program has been located. This program was written to do the same problem on a Texas Instruments SR-56 programmable calculator. This illustrates the usefulness of computer programs as mentioned earlier, and also shows its adaptability as a teaching device. The designer, however, must use sound reasoning and experience to guide him in the application of the data. If sufficient land is not available, or sunlight is not adequate, then the idea of stabilization ponds should be discarded and another technique sought.

Septic Tanks

One especially adaptable unit, where only one household or a relatively small village is concerned, is the septic tank. In America, septic tanks are primarily used for individual households. They have only occasionally been used

FIG. 8

Example Design of a Lagoon

GIVEN: A village with a population of 100 has a daily per capita BOD and flow of 0.17 lbs and 40 gal., respectively. Using a design loading rate of 25 lbs BOD per acre, determine the surface area needed for a stabilization pond sewage treatment system. If the seepage rate is 10 ins/yr, the evaporation rate 60 ins/yr, and the annual rainfall is 80 inches determine the maximum winter storage time, in days.

SOL'N:

Daily BOD Load = BODpcpd X Population

= 0.17 X 100 = $\underline{\text{17 lbs/day}}$

Total Daily Flow = Flowgpcpd X Population

= 40 X 100 = $\underline{\text{4000 gal/day}}$

Required Surface Area = Daily BOD/Design Load Rate

= 17/25 = $\underline{\underline{\text{0.68 acres}}}$

Available Winter Volume = Acres X Winter Depth X ft/acre

= 0.68 X 3 X 43560

= $\underline{88{,}862.4 \text{ ft}^3}$

Total Water Losses = (losses X acres X ft/acre)/4380

= (10 + 60 - 80)(0.68)(43560)/4380

= $\underline{-67.63 \text{ gal/day}}$ (gain)

Maximum Winter Storage Time = Total Volume/Total Inflow

$= 88{,}864.2/(\frac{4000}{7.48} + 62.63)$

= $\underline{\underline{\text{147.5 days}}}$

as a municipal treatment system, and that without great success. For this reason, design data available is typically for American inputs (the typical design value for flow in America is near 160 gallons per person per day--from the lagoon example, it will be seen that only 40 gpcpd were assumed) and municipal data is scarce and out of date. It is felt, however, that the use of the American household design criteria will not produce unreasonable over design. It is reccomended that where capacity design is based on the number of bedrooms, this be changed to an equivalence of two persons per room as a design assumption and the household size can be used for design (see Table 1). For example, a family of six would require an equivalent amount as a three bedroom house--600 gallons, minimum.[22]

The septic functions in a manner which is different than that of a lagoon. From Figure 9 it can be seen that the raw sewage influent is at "A". The solids are settled out by gravity and the effluent of the tank is discharged at "B". The solids undergo anaerobic digestion. Because of this, the effluent is very septic--thus the name septic tank. Periodically, the solids must be removed when they have accumulated so as to hamper the operation of the tank. This is usually after a number of years, however. The effluent cannot be discharged directly into a stream, as can the lagoon effluent, due to its septic nature. The usual practice is to allow the effluent to discharge into a drainage field, called a soil absorbtion system. This provides a place for the liquids to

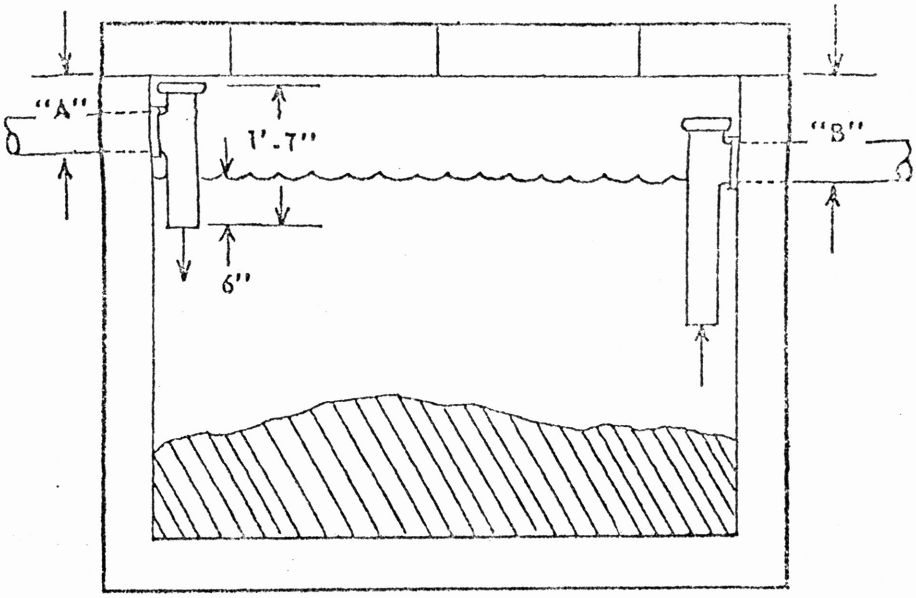


FIG. 9 SINGLE COMPARTMENT SEPTIC TANK

Table 1

Septic Tank Minimum Liquid Capacity

Number of Bedrooms	Septic Tank Capacity (Gallons) A	B
2 or less	500	750
3	600	900
4	800	1,000
For each additional	200	250

A. Without garbage grinder or automatic washer.
B. With garbage grinder and/or automatic washer.

Table 2

Suggested Dimensions For Rectangular Tanks

Tank Capacity (Gallons	Inside Width	Inside Length	Inside Depth	"A" (Refer to Fig. 9)	"B"
500	3' – 0"	6' – 0"	4' – 9"	9"	12"
750	3' – 6"	7' – 6"	4' – 10"	9"	12"
900	3' – 6"	7' – 6"	5' – 7"	9"	12"

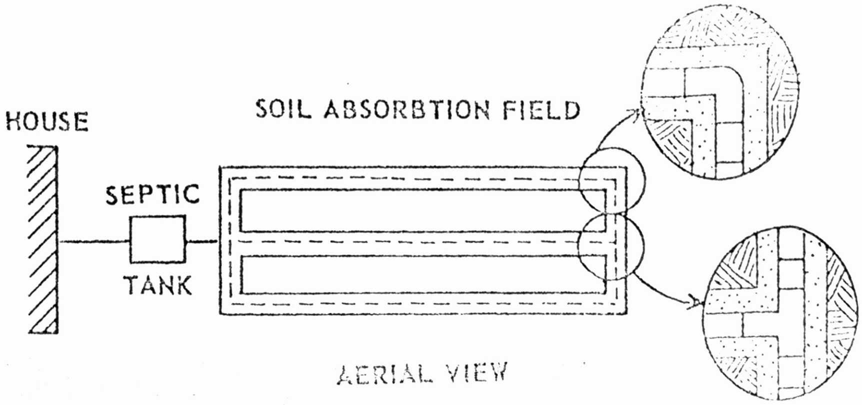


FIG.10 TYPICAL LAY-OUT FOR LEVEL GROUND

Table 3

Minimum Required Trench Per Bedroom

Average Percolation Rate (Minutes Per Inch)	Required Trench Bottom Area (Square Feet)	Total Trench Length (Feet) for Specified Trench Widths			
		18''	24''	30''	36''
1	85	57	43	34	29
3	100	67	50	40	34
4	115	77	58	46	39
5	125	84	63	50	42
10	165	110	83	66	55
15	190	127	95	76	64
30	250	167	125	100	84
45	300	200	150	120	100
60	330	220	165	132	110
Over 60	Unsuitable for soil absorption systems				

Notes: 1. A minimum-sized installation should be designed on the basis of a two bedroom house, i.e. double the minimum area requirement as given in Table IV.

2. Table IV provides for the normal household appliances, including automatic sequence washer, mechanical garbage grinder and dishwasher.

percolate slowly into the ground where there are further reactings which help to reduce any health hazard.(see Fig. 10). There is some discussion about the using of septic tanks in aquifer recharge zones, such as has happened in San Antonio, Texas. Some feel that there is no health hazard involved. Others are not sure. This problem is mentioned only to indicate one of the considerations that the designer must make. Another consideration is soil permeability, which affects the drain field effectiveness(see Table 3). The location of the drain field is also important. Roots from large trees may grow into and damage the field of the septic tank itself. In general, vegetation has a tendency to thrive atop a drain field zone, leading to the possible agricultural criteria for their location under certain above the ground type crops.

It should be apparent that, while not an optimum for municipal needs, a septic tank system could suffice where a small population exits which could not justify the use of a lagoon either because ot the small size or the lack of available land. However, the larger community has limited use for the septic tank. If there is an insufficiency of land, then a lagoon is impractical also. A third alternative is needed. Such an alternative is an improvement on the septic tank--the two story septic tank called the Imhoff tank.

The Imhoff Tank

Essentially, the Imhoff tank (see Fig. 11 for a cross sectional view) is a septic tank which provides for seperation

IMHOFF TANK SPECIFICATIONS

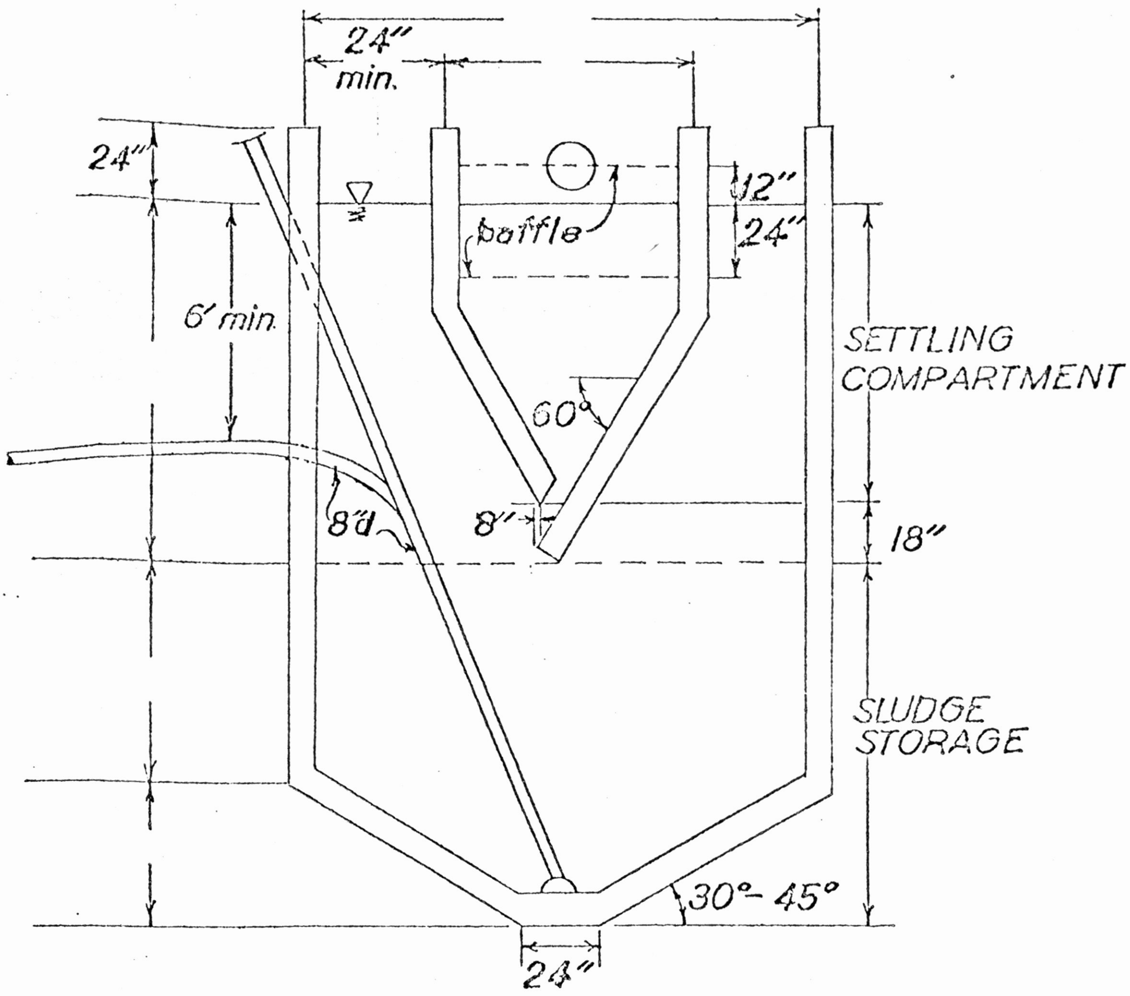


FIG. 11

between the liquid and the anaerobic digestion area. The Imhoff tank is a trough-like structure with upper and lower compartments. The upper compartment is called the settling compartment. The influent enters this compartment, flows the length of the tank and is discharged at the other end. The size of this compartment is base upon the amount of time that is necessary to effect settlement of the solids from the liquid. This time is refered to as retention time and is usually between 1 to 2.5 hours. Too long retention increases the possibility of the effluent becoming septic. Below the settling compartment is the sludge storage compartment. The entrance to the sludge compartment is so constructed as to prevent generated gasses of anaerobic digestion from escaping (and carrying solids) up into the settling compartment. Gas vents are provided along the upper sides of the Imhoff tank. The gas venting area should be atleast 20% of the total sludge surface area and atleast two feet wide, as shown.[2,9] Extraction of the digested sludge is managed by employing the static pressure head of the liquid to 'push' out the sludge when a control valve is opened. This eliminates the need for a pumping setup to remove sludge (digested) and allows, as the preceeding two methods, application where electricity is not available.

The design of an Imhoff Tank is a three step process. The settling compartment volume is determined on the basis of the desired retention time. Next, the sludge compartment volume is calculated based upon the design assumption of the number of cubic feet of storage per capita (ranges form 3 to 12--see Table 4). The third step is that of dimensioning the unit. From Figure 11 it is seen that certain dimensions are fixed. However, length to width ratio (from 5:1 to 1.5:1) are flexible. The object is to obtain a workable design (meeting the specifications) and at the same time requiring a minimum of construction materials.

It is here that the use of the computer is very advantageous. In the example design problem (Fig. 12) for an Imhoff, the steps shown are those taken in using a program written for this project, again using the SR-56 programmable calculator. The first two steps are fairly straight forward. The third step is capable of being repeated to allow for an iterative determination of dimensions based on a trial width. Thus, the designer can quickly try several values and determine the optimal dimensions.

Another feature of the program (see Appendix for complete program and instructions) is that certain design assumptions within the program itself can be varied at the desire of the designer. For example, if the assumed length to width ratio of 3:1 does not yield a practical design, then this ratio can be changed within the program and design steps can continue without the need to reenter data.

The Imhoff Tank is extremely adaptable to population areas of 150 and up. It can also be used in combination with other methods, as can the lagoon, when more efficiency is required. One final method, the trickling filter will now be

TABLE 4 [9]

Sludge Storage Requirements

System	ft^3/capita
Imhoff alone	3 - 4
Imhoff + trickling filter	4 - 5
w/ activated sludge	8 - 12
w/ high rate filter before it	8 - 10
w/ trickling filter before it	6 - 8

NOTE: Add for garbage solids and use larger sludge storage for 5000 population or less.

FIG. 12

Example Design Problem for an Imhoff Tank (computer solution)

GIVEN: Design an Imhoff tank for a village of 150 persons using a design retention time of 2.5 hours and 8 ft^3 per capita sludge storage. The flow is 100 gallons per capita per day (gpcpd) and the day is 16 hours (i.e., the majority of input to the system is during a 16 hour period).

SOL'N: Step 1 Enter Program (see Appendix)

Step 2

Enter Design Data	Display
Design sludge storage(8ft^3)	8 ft^3
Population(150)	1200 ft^3
Daily flow/capita(100 gal)	100 gal
Sewage retention time(2.5 hr)	313 ft^3

Step 3 Trial width for Dimensional determinations

Trial width ft	Sludge comp. Height ft	Settling comp. Height ft	Total Height
7	8.2	6.3	18
7.5	7.1	5.5	16.1
6.5	9.5	7.5	20.5

This yields the following dimensions

Height	Width	Length	
18.0	7.0	21	
16.1	7.5	22.5	←Best of Three Trials
20.5	6.5	19.5	

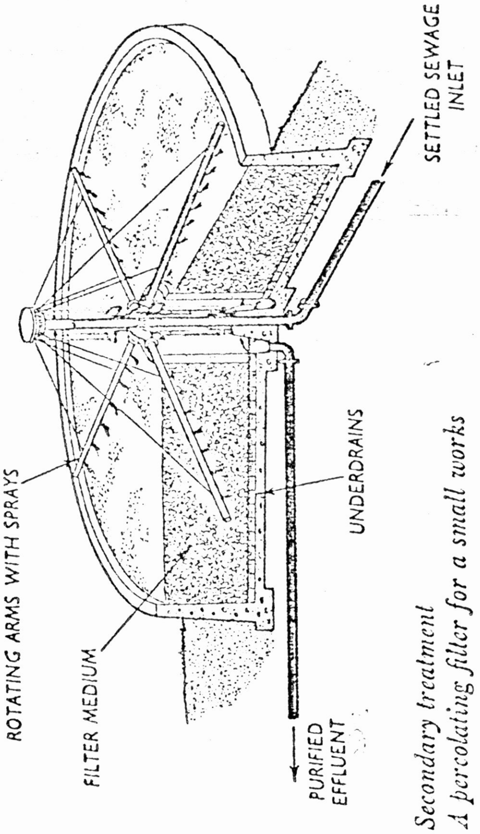
discussed as a means of improving and meeting the problems of larger population centers.

The Trickling Filter

This fourth method of sewage treatment is actually not a method for a typical rural village. However, with the discovery that even large urban centers in Ecuador have no adequate systems of treatment, it was felt that some consideration could be made for this fact. However, no design example will be given, due to the relative complexity of a trickling filter system. Figure 13 shows a standard rate trickling filter. This method is a secondary treatment step for the improvement of the effluent of a larger system. The liquid (seperated from the solids in the primary steps) is fed into the center of the armed mechanism on which are fixed nozzles. The momentum of the fluid flowing out of the nozzles causes rotation of the arms around the filter proper. This allows the even discharge of the liquid onto the filter medium. The filter medium is actually a porous solid upon which aerobic organisms grow. These organisms feed on the liquid as it passes over them, The rotation of the arms allows for air to follow each charge of liquid to keep aerobic stabilization going. The 'filtered' liquid is then discharged from the bottom of the filter structure as shown.

Figure 14 shows the layout of a typical system using a trickling filter (TF). Several things should be noticed. First, in order to prevent clogging the nozzles of the TF,

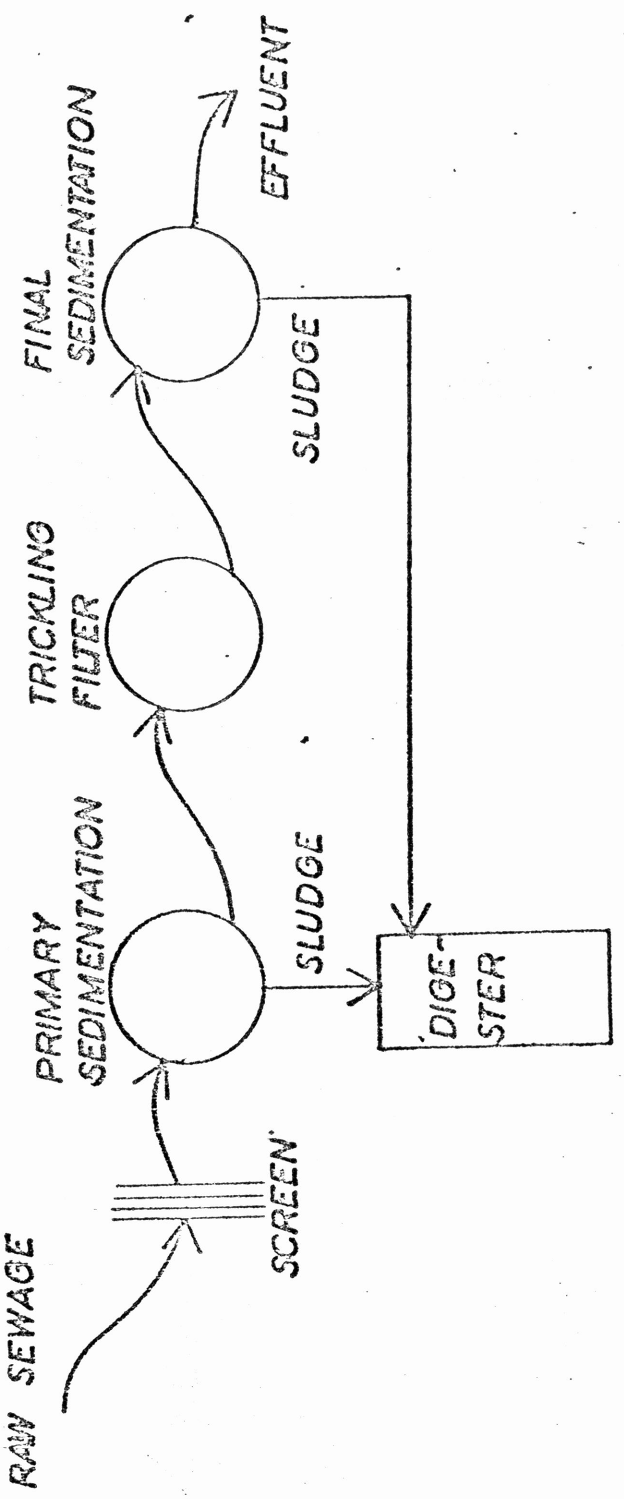
Figure 13



Secondary treatment
A percolating filter for a small works

the solids must be removed by some kind of primary treatment as has been stated. An Imhoff tank could be used, for example. Following the TF is another seperator. This is necessitated by the fact that the organisms on the filter medium are sloughed off into the 'filtered' liquid, and must be settled out before the treated sewage is discharged from the system (though not always necessary). Again, an Imhoff tank can be used. The design of such a treatment system depends upon the efficiency of each step or process, the flow rates, the amount or recirculation, the methods used for seperation (settling), and the over all design efficiency of the system. To develope a single, meaning design format would be beyond the scope of this study. However, the reader should realize that not all problems will have simple solutions, but that such should be applied where practical.

Figure 14



WASTE TREATMENT SCHEME

THE CONCLUSIONS

The central conclusion of this study is that the solution to problems within developing nations can be obtained but that the solutions involving applied technology require the development of talents (skills) and practices which are not always required with American problems and solutions. The student wishing to play a part in aiding developing nations must be willing to assume the burden of extending beyond the mere requirements of an engineering curriculum so as to lay hold of those tools which will be necessary to fulfill that wish. Perhaps certain programs will be established to aid those planning foreign work. In the meantime, other resources must be had.

The Investigation Format employed in this study is submitted as such a resource. While no pretense is made as to the absolute completeness of the format, it is sincerely believed that the conscientious student attempting to use such an outline will find it an adequate guide which can, perhaps, bring other steps of investigation to light. The opportunity to develope such a scheme has been of great benefit to this writer, at least.

The proposed treatment methods are not exhaustive of the possible solutions. They serve simply to illustrate the possible application of technology to a rather fundamental problem in manners not requiring the sophistication and technological levels of the United States. Such methods can be easily adapted to particular locations, easily taught to nationals, and easily implemented and maintained. While it is realized that not every possible question has been answered, the processes leading to the development of these systems as real life applications have been covered so as to present what are felt to be realistic solutions to what are very real problems.

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APPENDIX

LE STABILIZATION POND DESIGN PAGE 1 OF 2

OGRAMMER THIGPENN DATE MAR 77

SR-56 Coding Form

TEXAS INSTRUMENTS
INCORPORATED

OC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS
00	33	STO		25	20	*1/x		50	41	R/S		75	41	R/S	
01	00	0		26	64	X		51	52	(		76	34	RCL	
02	41	R/S		27	34	RCL		52	34	RCL		77	09	9	
03	33	STO		28	04	4		53	07	7		78	54	÷	
04	01	1		29	94	=		54	74	—		79	07	7	
05	41	R/S		30	33	STO		55	34	RCL		80	92	.	
06	33	STO		31	05	5		56	08	8		81	04	4	
07	02	2		32	41	R/S		57	53	)		82	08	8	
08	64	X		33	64	X		58	64	X		83	94	=	
09	34	RCL		34	03	3		59	34	RCL		84	33	STO	
10	00	0		35	64	X		60	05	5		85	09	9	
11	94	=		36	04	4		61	64	X		86	52	(	
12	33	STO		37	03	3		62	04	4		87	32	x≷t	
13	04	4		38	05	5		63	03	3		88	93	+/−	
14	34	RCL		39	06	6		64	05	5		89	84	+	
15	02	2		40	00	0		65	06	6		90	34	RCL	
16	64	X		41	94	=		66	00	0		91	09	9	
17	34	RCL		42	33	STO		67	94	=		92	53	)	
18	01	1		43	06	6		68	54	÷		93	20	*1/x	
19	94	=		44	41	R/S		69	04	4		94	64	X	
20	33	STO		45	33	STO		70	03	3		95	34	RCL	
21	09	9		46	07	7		71	08	8		96	06	6	
22	41	R/S		47	41	R/S		72	00	0		97	94	=	
23	33	STO		48	33	STO		73	94	=		98	41	R/S	
24	03	3		49	08	8		74	32	x≷t		99	42	RST	

REGISTERS	
0	BOD pcd
1	Flow gcd
2	POPULATION
3	DESIGN LOAD RATE
4	DAILY BOD LOAD (lbs)
5	ACRES FOR DESIGN LOAD
6	TOTAL ft³ NEEDED
7	EVAP + (in/yr) SEEPAGE
8	RAINFALL (in/yr.)
9	DAILY INPUT ft³

NOTES

OGRAMMER THIGPENN

PAGE ___ OF ___

DATE MAR 77

SR-56
User Instructions

TEP	PROCEDURE	ENTER	PRESS				DISPLAY
1.	KEY IN PROGRAM & CLEAR						
	REGISTERS		2nd	CMs			0.
2	ENTER DESIGN VALUES						
	BOD (lbs/CAPITA/DAY)	BOD	R/S				BOD
	FLOW (gals/CAPITA/DAY)	FLOW	R/S				FLOW
	POPULATION	POPULATION	R/S				(POPULATION)(FLOW)
*	(*NOTE: IF OTHER THAN DOMESTIC BOD INPUT,						
	SUM THIS VALUE, #s/DAY, WITH DOMESTIC	(ADDITIONAL BOD)	(SUM	4)			(ADD. BOD)
	BOD)						
	DESIGN LOAD RATE (lbs BOD/ACRE)	DESIGN LD. RT.	R/S				REQUIRED ACREAGE
	CALCULATE VOLUME AVAILABLE FOR						
	WINTER STORAGE		R/S				AVAILABLE VOL (ft^3)
	ENTER WATER LOSS/ADDITION DATA						
	SEEPAGE + EVAPORATION (ANNUAL in.)	SEEPAGE + EVAPOR.	R/S				SEEPAGE + EVAP
	RAINFALL (in/YR)	RAINFALL	R/S				RAINFALL
	CALCULATE TOTAL DAILY WATER LOSSES		R/S				0.
*	(*NOTE: IF OTHER THAN DOMESTIC INPUT,						
	SUM THIS VALUE, gals/DAY, WITH DOMESTIC	(ADD. VOLUME)	(SUM	9)			ADD. VOLUME
	VOLUME)						
	(IF THE WATER LOSS VALUE MUST BE						
	KNOWN CHECK THEN RESTORE & REGISTER)		($x \leq t$/	$x \geq t$)			VALUE / 0.
	CALCULATE WASTE WATER INFLUENT (ft^3/DAY)						
	& AVAILABLE WINTER STORAGE (DAYS)		R/S				AVAILABLE WINTER STORAGE
	FOR TOTAL DAILY INFLUENT (ft^3)						
	CHECK REGISTER 9. FOR		RCL	9			DAILY INFLUENT
	ADDITIONAL INFORMATION, SEE						
	REGISTER STORAGE ON REVERSE						

TITLE *IMHOFF DESIGN*
PROGRAMMER *THIGPENN*

PAGE *1* OF *2*
DATE *MAR 77*

SR-56 Coding Form

TEXAS INSTRUMENTS
INCORPORATED

LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS
00	33	STO		25	02	2		50	34	RCL		75	04	4	
01	00	0		26	64	X		51	08	8		76	74	−	
02	41	R/S		27	34	RCL		52	54	÷		77	01	1	} k/4 ⊗
03	33	STO		28	01	1		53	52	(		78	53	)	
04	01	1		29	54	÷		54	03	3	}R ⊗	79	94	=	
05	64	X		30	01	1	THESE CAN BE CHANGED FOR A DIFFERENT FLOW PERIOD(hr)	55	64	X		80	34	STO	
06	34	RCL		31	06	6		56	34	RCL		81	06	6	
07	00	0		32	94	=		57	07	7		82	41	R/S	ENTER NEW K IF ANOTHER PASS IS DESIRED
08	94	=		33	33	STO		58	64	X		83	22	GTO	
09	33	STO		34	08	8		59	52	(		84	03	3	
10	04	4		35	41	R/S		60	34	RCL		85	06	6	
11	41	R/S		36	33	STO		61	07	7		86	34	RCL	86 OPTION
12	33	STO		37	07	7		62	74	−		87	06	6	
13	02	2		38	43	x^2		63	04	4	}k ⊗	88	35	SUM	
14	41	R/S		39	64	X		64	53	)		89	09	9	
15	33	STO		40	03	3	}R ⊗	65	53	)		90	34	RCL	
16	05	5		41	94	=		66	84	+		91	09	9	
17	64	X		42	20	1/x		67	06	6		92	84	+	
18	07	7		43	64	X		68	00	0		93	01	3	
19	92	.		44	34	RCL		69	25	TAN		94	92	.	
20	04	4		45	04	4		70	64	X		95	05	5	
21	08	8		46	94	=		71	52	(		96	~~41~~	~~R/S~~	94 =
22	20	1/x		47	33	STO		72	34	RCL		97	~~22~~	~~GTO~~	41 R/S
23	64	X		48	09	9		73	07	7		98	~~03~~	~~3~~	
24	34	RCL		49	41	R/S		74	54	÷		99	~~06~~	~~6~~	

REGISTERS	
0	DESIGN SLUDGE VOL/PER/CAP. (ft³)
1	POPULATION
2	GALLONS/DAY /CAP.
3	
4	REQ'D SLUDGE VOLUME
5	SEWAGE DETEN TIME (hr.)
6	SETTLING CHACRS. HEIGHT
7	TRIAL WIDTH (ft)
8	REQ'D SET'LN VOLUME (ft³)
9	SLUDGE HEIGHT (TRIAL) ft

NOTES

k = TOTAL DISTANCE ACROSS THE GAS VENTS (FT) (BOTH)

R = LENGTH PER UNIT WIDTH

k & R MAYBE CHANGED WITH VALUES AS INDICATED BY CHANGING THE MARKED (⊗) STEPS

TITLE IMHOFF TANK DESIGN PAGE 2 OF 2

PROGRAMMER THIGPENN DATE MAR 77

SR-56 User Instructions

STEP	PROCEDURE	ENTER	PRESS				DISPLAY
1.	ENTER PROGRAM		2nd	CMs	RST		0.
2.	ENTER DESIGN DATA						
	DESIGN SLUDGE VOL/CAPITA (ft^3)	VALUE	R/S				DESIGN SLUDGE VOL
	POPULATION	POPULATION	R/S				REQ'D SLUDGE STORAGE VOLUME
	DAILY FLOW/CAPITA (gal.)	FLOW	R/S				FLOW
	SEWAGE DETENTION TIME (hrs.)	TIME	R/S				REQ'D SETTLING VOLUME
3.	ENTER TRIAL WIDTH &						
	CALCULATE SLUDGE DEPTH (max.)	TRIAL WIDTH	R/S				SLUDGE DEPTH
	CALCULATE SETTLING DEPTH (fixed)		R/S				SETTLING DEPTH
	FOR TOTAL HEIGHT (FOR TRIAL WIDTH)						
	SUM DISPLAY TO REGISTER 9 & RECALL						
	REGISTER 9. FOR TOTAL STRUCTURE		SUM	9	RCL	9	SLUDGE DEPTH + SETTLING DEPTH
	HEIGHT ADD 1.5 ft FOR NEUTRAL ZONE						
	AND 1.5 TO 2 ft FOR FREEBOARD **						
	(OPTION 86 i.e. GTO 86 R/S)						
*	NOTE: PROGRAM ASSUMES 3:1 RATIO						
	FOR LENGTH TO WIDTH & 18" WIDTH FOR						
	GAS RELEASE. (MAY BE CHANGED, SEE NOTES)						
*	NOTE: PROGRAM ASSUMES 16 hr. TIME						
	FOR TOTAL DAILY FLOW. FOR ANOTHER						
	TIME MODIFY STEPS 30 & 31						
**	FOR SEVERAL TRIALS OF WIDTH (TO MEET						
	DESIGN CRITERIA) RETURN TO PROGRAM						
	STEP 36, ENTER NEW TRIAL WIDTH						
	& REDO STEP 3 (ABOVE)	NEW TRIAL	GTO	36	R/S	R/S	NEW SETTLING DEPTH