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9. ABSTRACT
Past efforts at assisting LDCs to develop low-cost water and sewage treatment methods have not been too successful. The technology transfers have usually been incompatible with in-country resources of manpower and materials. In 1973, A.I.D. sponsored a three-year project at the University of Oklahoma to develop a predictive model for use in selecting water treatment sites and methods compatible with the needs and resources of developing countries. The project produced a predictive model that uses cost and demand analysis. It also produced a data collection system, computer and manual user guides, and an analytic kit that can be used in LDCs. Selected studies were made of the "high make" technologies at several LDC sites in assessments of their economic performance and consumer acceptance. The analytic field kit was also tested for its capacity to monitor water and wastewater treatment processes. The project produced some 32 publications which are being disseminated by A.I.D. and other national and international agencies. However, the analytic tools which were developed have yet to be widely disseminated. A need exists for a prioritizing model to assist in-country programs in establishing orderly construction of facilities. The use of the predictive model is expected to be expanded as information concerning its capacities is disseminated in international conferences.

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Final Report

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

(AID Contract No. AID/CM-ta-C-73-13)

By

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SUMMARY

Low Cost Methods of Treating Water and Sewage in Lesser Developed Countries is essentially one of technology transfer. There is ample evidence that the present transfers have not been successful and that the donor country assistance toward total development has essentially "misfired". The source of the problem is, of course, that the transfers are normally incompatible with in-country resources both manpower and materials. The maximization of in-country resources is of paramount importance and any solution that would lead towards this resolution is important and relevant to assisting in LDC development. The solutions resulting from this research project involve two facets: (1) structural - appropriate process technology development to treat water and sewage in LDC's and (2) nonstructural - methodologies and schemes to assist in the process of selection of in-country compatible methods. If these solutions become widely used, they will extend the usefulness of donor money, and the resolution of water and wastewater problems should lead to increased early self-sufficiency on the part of the receiving countries. This is particularly important to public health and economic development.

The specific products of this research project are: a predictive or selection model supported with cost and demand analysis, computer and manual user guides, and an in-country supportable analytical kit. In addition a data classification and collection system was developed along with in-depth State-of-the-Arts involving historic, unpublished and published sources. Selected studies were made of the "high make"

technologies, at Global sites, of both water and wastewater treatment in terms of not only economic performance but consumer acceptance. The models were tested for consumer acceptance and the field analytical kit was also tested for complete in-country capability to monitor water and wastewater treatment devices.

In summary the project output consists of some 32 publications and research documents as project reports and papers. The project insistence on active participant involvement resulted in the assumption of technical publication and dissemination respectively by several international and national agencies. Questions of consumer acceptance and wide dissemination of the tools developed are yet to be fully resolved and form part of the necessary and recommended follow-on activities.

It is also desirable to extend the forecastive model to include as it does now, not only treatment but the other elements of water supply and distribution, and wastewater collection. There is also a definite need for a prioritizing model to assist in-country programs in establishing orderly facilities construction. It is envisioned that the predictive modeling device and other component parts will be disseminated through Global conferences and through publication distribution and perhaps an on-call service to assist AID supported developing countries or international agencies in its utilization.

ACKNOWLEDGEMENTS

A great number of people here and abroad have been of real assistance. The principal investigator calls particular attention to Dale Swisher, Lee Howard, M.D., Albert Talboys, James Thomson and Victor Wehman of USAID for their sustained confidence and support and to his immediate associates at the University of Oklahoma, Silas Law, Richard Discenza, Michael Muiga, Kay Coffey, Yvonne Stearns and Ralph Martin. In addition, individuals from overseas who made contributions and provided counsel were Hans Van Damme and T.K. Tjiook (IRC), George Ayoub, (AUB), Verne Detrich (WHO), and Odyer Sperandio (CEPIS).

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INTRODUCTION

The genesis of this project was the experience of two senior sanitary engineers who, having worked with USAID in several assignments around the world, recognized not only the tremendous need for water in developing countries but also the abuse, either intentionally or otherwise, of investment by donor countries in the development of water resources. This was an experience that many sanitary engineers have had in common in dealing with Underdeveloped Countries. When this project was formulated three years ago, the more sophisticated definition of the problems was just emerging. Such terms and concepts as technological transfer, appropriate technology, intermediate technology and compatible technology were just developing on a broad, at least, theoretical level, and demanding the attention of a great many people who operate on the leading edge of international problems. As the project developed, so did the emerging concepts of consumer and others' perceptions so essential to the dissemination and utilization of information. As a result of this project and other world activities, development of water resources in underdeveloped countries as a necessary condition for economic and social development has now been widely recognized throughout the developed and developing parts of the world.

The initial project was conceived and developed by AID personnel and the University of Oklahoma (OU) in 1972 and developed into a funded project in March, 1973. Although, the initial objectives were rather limited or more appropriately, needed refinement, they certainly weren't tied into the more sophisticated concepts previously mentioned. Initially, it was felt that there were needed, both structural and nonstructural approaches to the problem. Structured approaches would be to assist developing countries to concentrate on technology that would lead to workable hardware (water and sewage plants). It was felt that a very minimum amount of priming through selected local institutions could perhaps achieve worthwhile results. It was also found that it was necessary to develop a methodology that would select suitable technology to be used in the design of water and wastewater systems. This was the nonstructural approach. As the project developed and more was learned about the various facets of the problem, interest and activities throughout the world grew and is still expanding.

The OU/AID project began at about the same time as the World Health Organization and the International Reference Center in the Netherlands conducted a worldwide conference (known as the Bilthoven Conference) on the subject of low cost ways to treat water and sewage. Out of these sessions, the UN developed an "ad hoc" committee representing several agencies, UNICEF, UNDP, UNEP, IBRD, WHO, IDRC, and OECD which proceeded to study the problem. In the process, this committee spent approximately the same amount of money expended on the OU/AID project, only the money was spent on interviews and field visits to simply identify the problem which in effect was initially identified by the OU/AID project. To attack the problem the "Ad Hoc Committee" suggested a level of funding of ten to twenty times as much as originally funded by AID. In other words, the "Ad Hoc Committee" of the seven international organizations, attempted to develop a program at a two to four million dollar level to cope with this particular problem. At the writing of this final report they have not yet resolved the management aspects of the project nor do they have the funds. The major difference between the OU project and that envisioned by the "Ad Hoc Committee" relates to the area of information dissemination. The authors of the OU/AID reports plan to finish the present studies and let the primary dissemination of the information be carried forward by recognized and active International and National Agencies and perhaps through directed effort as a subsequent activity of AID.

In summary then, this project, with its result and products, was conceived by active field engineers upon recognition of the need for both structural and nonstructural solutions of technological transfer problems involving water for underdeveloped countries.

As stated previously, potable water in requisite amount is necessary to development, both for industry and well-being (health). Donor countries in an effort to provide for this need, have resorted to direct transfers of technology with emphasis on programs to train water and sewage plant operators, the new technology etc. Experience shows that once nationals receive specialized training, it is difficult to keep them in public sector jobs in an underdeveloped country because there usually exists a high demand for trained people in the private sector with concomitant higher salaries. In effect the project evolved from the fact that developing countries too frequently attempt to use a technology incompatible with in-country manpower and/or natural resources. Each failure of a high technology process transfer wastes local resources and so increases real treatment costs. There are many cases of high technology plants built in LDC's that remain inoperable for lack of replacement parts, suitable operating and maintenance manpower, ability to pay, too much dependence on out of country resources, etc. There are also instances of "appropriate" plants built in LDC's but without carefully collected and analyzed engineering performance data. Also there is virtually no total performance data especially those related to socio-economic compatability.*

Such is the problem. Specifically what is required to resolve the problem is a system or scheme that would identify (and/or create an environment for) appropriate technology for water and wastewater treatment in terms of in-country manpower and material. There is also a need for a system to produce usable information on in-country compatible technology and its dissemination. Although there are examples of numerous technology transfers attempted under LDC conditions, there is a real need to know: if they work; how they work.* Nor is there real data on unique solutions utilizing available basic science. The in-country process performance data that is available is incomplete and existing data is not related to socio-economic criteria. What data there is, is seldom synthesized into useful knowledge for transferring from one developing country to another. This definitive need now has been identified with a very high priority by others - the special "Ad Hoc Committee", less developed countries themselves, and financing agencies such as the Asian, InterAmerican, World and African banks.

*A study of successes and failures of transfers reported on page 29. Six Months Progress Report, November 15, 1973.

RESEARCH ACTIVITY

The project activity is shown in Figure 1, Table 1. As has been noted, both structural and nonstructural, contractual and in-house studies were envisioned and achieved. The in-house studies required selection of parameters, processes and process identification, with development of resources, process and cost matrices. For initial starts on these activities and the development of the predictive model see Working Papers 2 and 3, in the First Progress Report (November 15, 1973).

The major divergence from the original plan was in the projected treatment process studies; that is, between those sites originally envisioned in the proposal, and those actually selected. The results of the selection process are shown in Table II and Figures 2,3,4,5,6,7. The problem was to:

1. Determine the 5-6 most appropriate water and sewage treatment processes to be studied, selecting those not being studied by others;

2. Select the most suitable country contractor, with a global design that met our criteria (interest and funding levels).

3. To have all envisioned "high make" processes covered.

Site visits were necessary (Table 1) and a site selection model was developed*.

*(p45, AID Project Working Paper 1, Site Evaluation, Six month progress report, November 15, 1973).

Figure 1

PROJECT ACTIVITY

- **Predictive Scheme** • Model
  → Model Validation — — → Publication by WHO/IRC
  - Data Format
  - Cost and Demand Data → Black Africa In-depth Study — — → Publication by Republic of Kenya
  - Computational Manuals → Conventional → Computerized
- **Field Kit** •→ Validation — — → Follow-on Kit Project — — — →
- **Developing Country Technology**
  - Knowledge
    → State-of-the-Art → Water → Sewage — — → Publication/IRC/NL
    → Innovative Survey — — → Continuing IRC/WHO Activity
    → Historic Survey
    → Individual Catalogue
  - Experimentation
    → Sludge, Sewerless •— → Follow-on Project
    → Sand Filtration •— → IRC Study
    → Sterilization
    → Lagoons
    → Rapid Sand Filters
    → Deck, Tube Settlers
- **Dissemination**
  - Technical Workshop → User Validation and Acceptance — — → Publication, WHO/IRC
  - Papers, Discussions, etc.•— — → Global Publication, Distribution — — → USA, UK, Arabic Cities, Indonesia, Mexico Colombia, Holland
  - Technical Reports

TABLE I

PROJECT BENCH MARKS

DATE	SUBJECT	DOCUMENTATION
SEPTEMBER, 1972	CONCEPT	PROJECT PROPOSAL
DECEMBER, 1972	ADDENDUM TO PROJECT PROPOSAL	
DECEMBER, 1973	CONTRACT INITIATION	CONTRACT
MARCH, 1973	PROJECT BROCHURE	DISSEMINATED WORLDWIDE
APRIL, 1973	BILTHOVEN CONFERENCE	IRC/NL REPORT
JUNE, 1973	DATA FORMAT, SITE EVALUATION, FIELD KIT PROCESS/SYSTEM MATRICES	INTERIM PROGRESS REPORT
AUGUST, 1973	FIELD TRIP - LATIN AMERICA FIELD TRIP NEAR EAST/AFRICA	
SEPTEMBER, 1973	INTERNATIONAL WATER RESOURCES ASSOCIATION	PROJECT PAPER PRESENTED
NOVEMBER, 1973	STUDY COMPONENTS GLOBAL ACTIVITIES LATIN AMERICAN PLAN	SIX MONTH PROGRESS REPORT
APRIL, 1974	CONFERENCE, ENVIRONMENTAL HEALTH ARAB CITIES - BAGHDAD FIELD TRIP FAR EAST	PAPER, LOW COST TECHNOLOGY, ETC.
MAY, 1974	KIT, PROCESS MATRIX, MATHEMATICAL SELECTION MODEL, COST TRANSFER MATRIX, RESOURCE MODEL, DATA MANAGEMENT, HISTORIC AND INNOVATIVE PROCESS	FIRST ANNUAL REPORT
MAY, 1974	AIDIS	PAPER ON COMPATIBLE COUNTRY CAPABILITIES AND TREATMENT SELECTION CONFERENCE, MEXICO CITY
JUNE, 1974	CONFERENCE MONTERREY, MEXICO	PAPER, LOWER COST WATER AND WASTE TREATMENT
JANUARY, 1975	PROJECT PROGRESS	INFORMAL REPORT
APRIL, 1975	USAID PROJECT REVIEW	NORMAN, OKLAHOMA
MAY, 1975	PROJECT PROGRESS	SECOND ANNUAL REPORT
JULY, 1975	DATA REQUIREMENTS	DOCUMENT
SEPTEMBER, 1975	PROJECT PRESENTATION	WASHINGTON, USAID STAFF
OCTOBER, 1975	MODEL AND SUPPLEMENTS KIT MANUAL (SIX LANGUAGES)	DOCUMENT DOCUMENT
NOVEMBER, 1975	GLOBAL CONFERENCE, NL.	IRC PUBLISHED PROCEEDINGS
JANUARY, 1976	DEMAND AND COST STUDY	DOCUMENT
SEPTEMBER, 1976	KIT II MANUAL	THREE LANGUAGES
NOVEMBER, 1976	USAID PROJECT REVIEW	NORMAN, OKLAHOMA
DECEMBER, 1976	FINAL REPORT AND CONTRACT STUDIES ON TREATMENT REPORTS	DOCUMENT PLUS SUBCONTRACT REPORTS

TABLE II

SITE/PROCESS SELECTION

I. LATIN AMERICA

PROPOSED

1. MEXICO (LAND DISPOSAL)
2. COSTA RICA--SAN JOSE (UNIQUE WATER)
3. PANAMA (LAGOON)
4. COLOMBIA--CALI (LAGOON)
5. COLOMBIA--CUCUTA (MULTI-MEDIA
6. ECUADOR--CUENCA (PLATES)
7. BRAZIL--RIO (ELECTROLYTIC)
8. BRAZIL--SAO PAULO (SLOW SAND)
9. ARGENTINA--CORDOBA (DYNAMIC FILTERS)
10. CHILI--SANTIAGO (CONTROLS)
11. URUGUAY--MONTEVIDEO (DOSAGES)
12. BRAZIL--BUENOS AIRES (OXIDATION DITCH)

SUB-CONTRACTED

1. ECUADOR--CUENCA (MULTI-MEDIA)
2. BOLIVIA--COCHABAMBA (DECLINING RATE)
3. BRAZIL--LINHARES (UPFLOW)
4. BRAZIL--PRUDENTOPOLIS (CONTROLS)
5. WEST INDIES--TRINIDAD (SLUDGE)

COLLABORATIVE STUDIES

1. COLOMBIA--BOGATA (KIT, MODEL)
2. BRAZIL--SAN CARLOS (SAND FILTER - IRC)

II. AFRICA/MIDDLE EAST

PROPOSED

1. MOROCCO-RABAT (BLEACH POWDER)
2. CHAD (WATER)
3. NIGERIA (Cl_2)
4. IRAN--TEHRAN (DRY DISPOSAL
5. ISRAEL (FISH POND)
6. KENYA--NAIROBI (LAGOON)
7. ETHIOPIA
8. SOUTH AFRICA

SUB-CONTRACTED

1. TURKEY--ANKARA (AERATED LAGOON)
2. LEBANON--BEIRUT (ESTUARIAL DISCHARGE)
3. KENYA--NAIROBI (DEMAND - COST STUDY)

COLLABORATIVE STUDIES

1. KENYA--NAIROBI (KIT, LAGOON, SAND FILTER - IRC/PC)
2. ALGERIA (MODEL - WHO)
3. TUNISIA (LAGOON - U.C.)
4. GHANA--KUMASI (SAND FILTER - IRC)
5. SUDAN--KHARTOUM (SAND FILTER - IRC)
6. TURKEY--ANKARA (SAND FILTER - IRC)

III. ASIA

Proposed

1. PAKISTAN--KARACHI (LAGOON)
2. INDIA--NAGPUR (VIRUS)
3. VIETNAM--SAIGON (LAGOON, FILTERS)
4. PHILIPPINES--MANILA
5. CHINA--TAIPEI (SAND FILTERS, DECLINING RATE)
6. THAILAND--BANGKOK (LOCAL MATERIAL

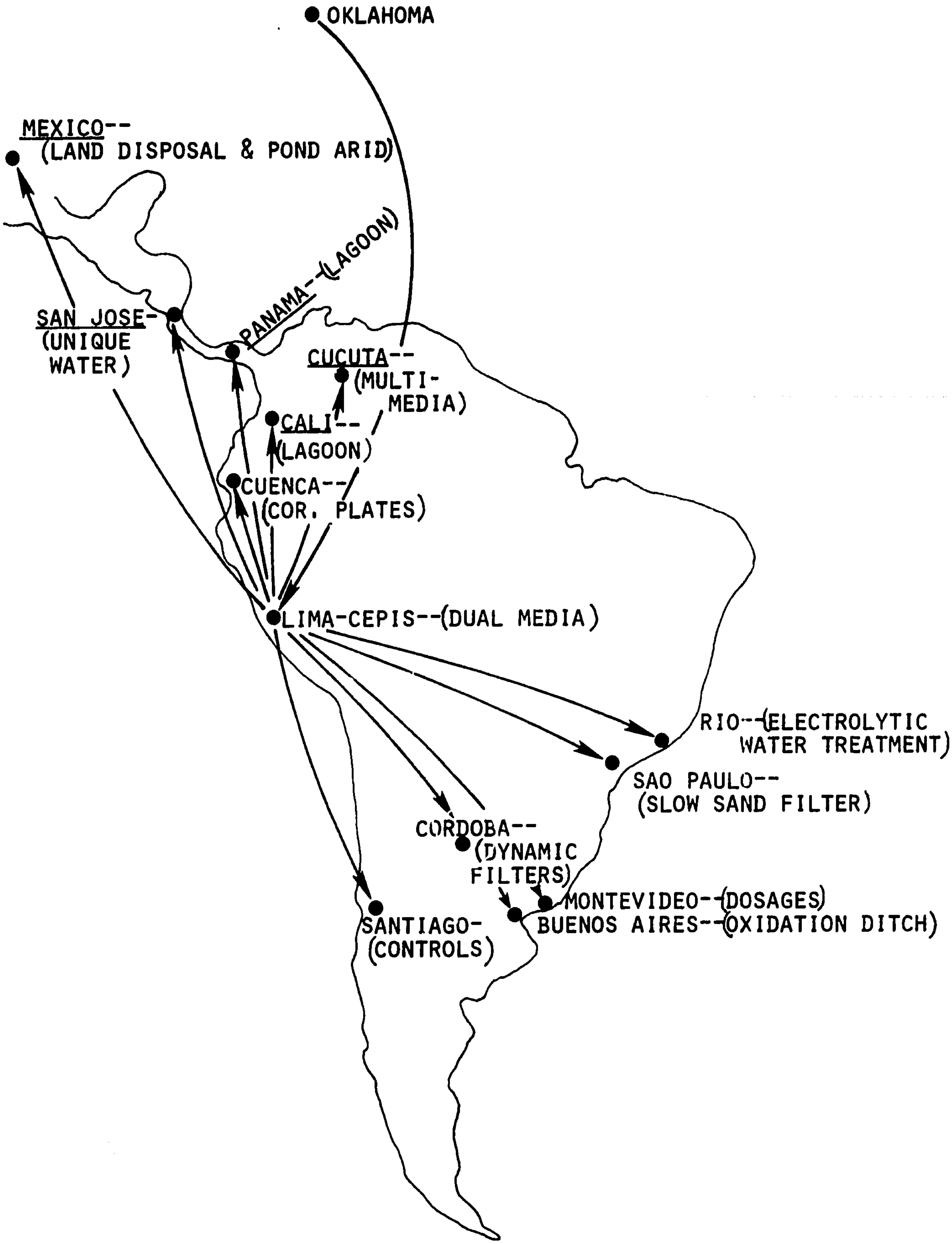
SUB-CONTRACTED

1. THAILAND--BANGKOK (SAND FILTER - IRC)
2. PHILIPPINES--MANILA (ALTERNATIVE TO Cl_2)
3. CHINA--TAIPEI (SLUDGE)

COLLABORATIVE STUDIES

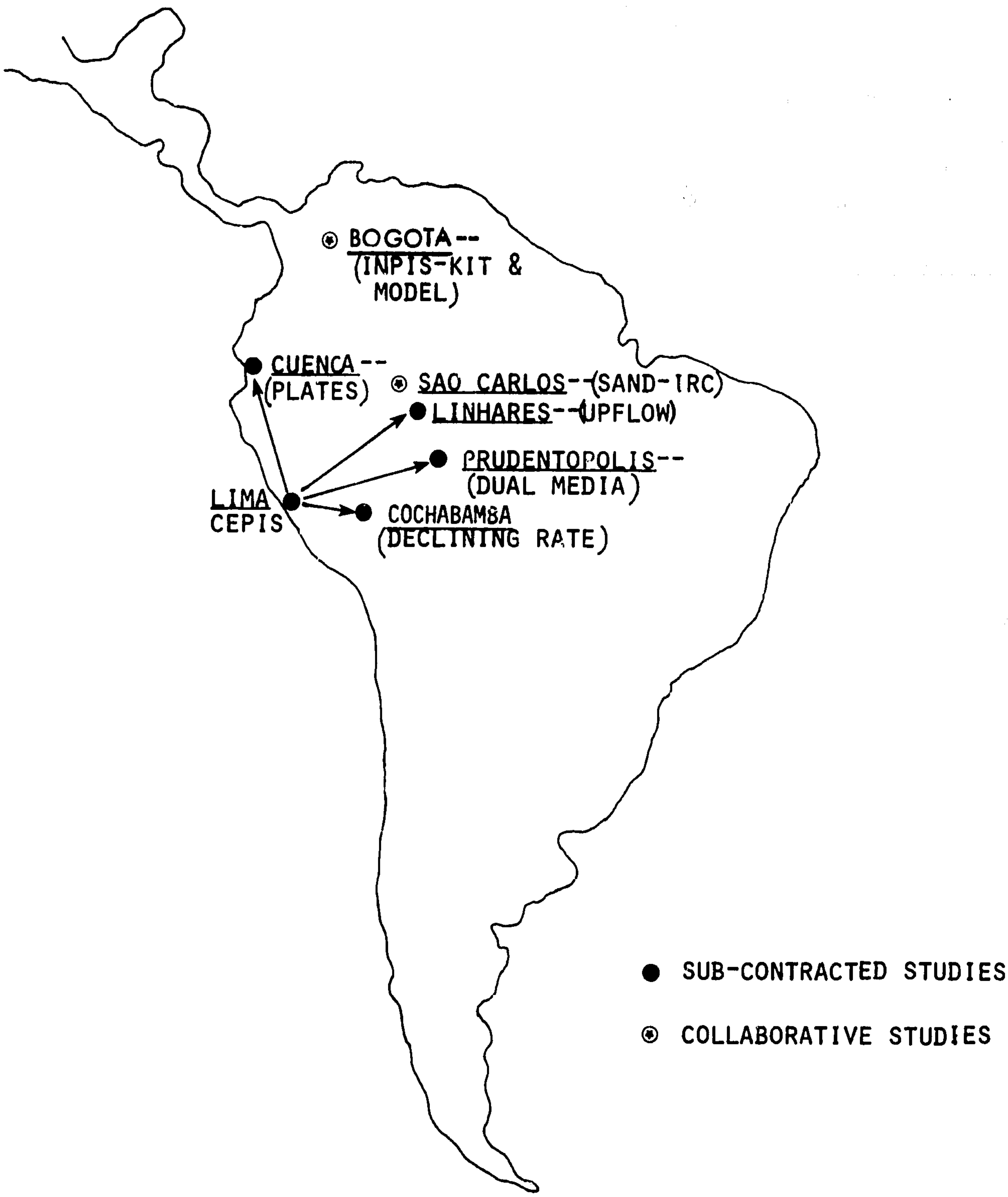
1. PHILIPPINES (MODEL - CDM)
2. THAILAND--BANGKOK (SAND FILTER - IRC/AIT)
3. PAKISTAN--LAHORE (SAND FILTER - IRC)
4. INDIA--NAGPUR (SAND FILTER - IRC)

FIGURE 2



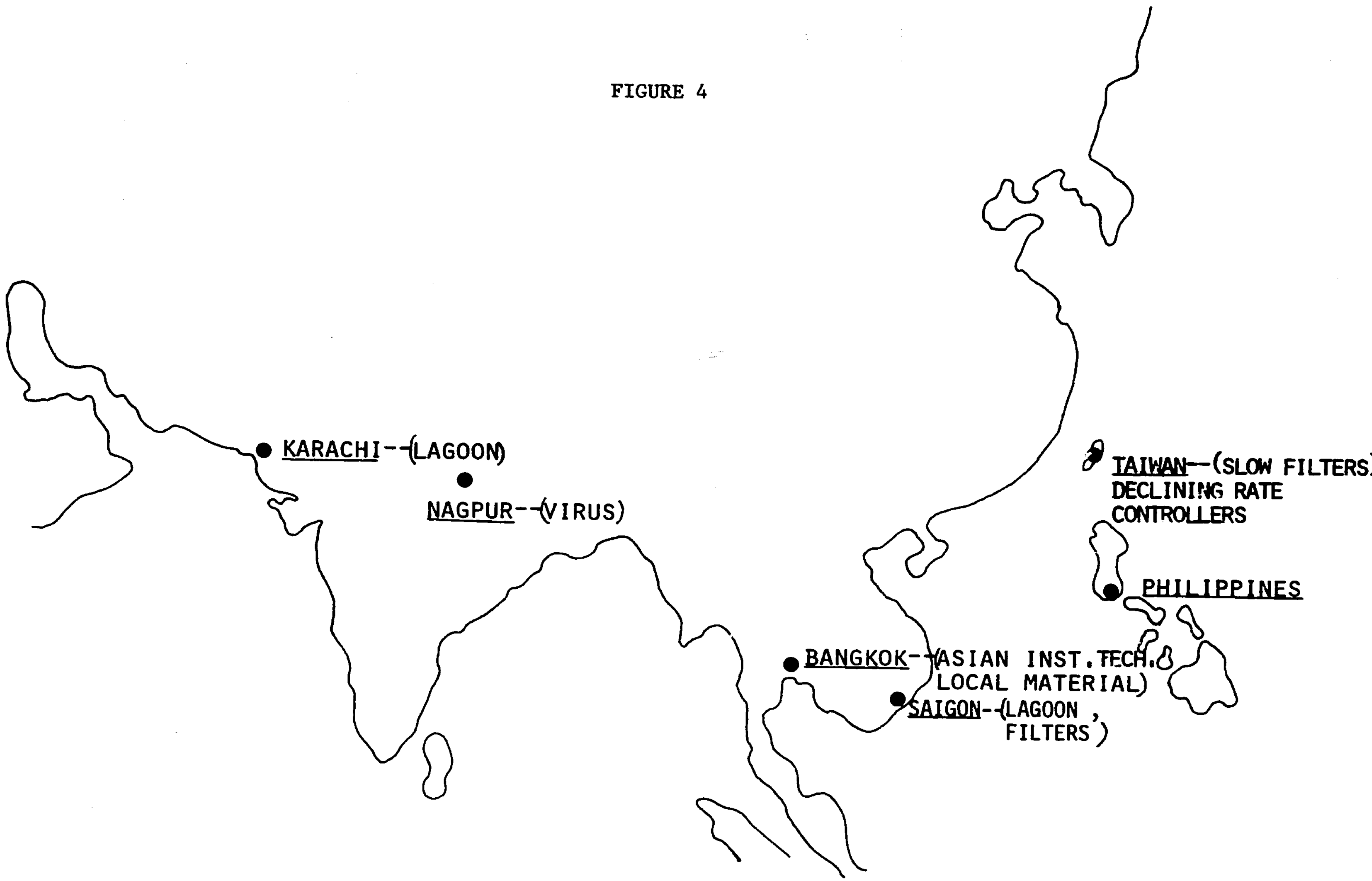
ORIGINALLY PROPOSED STUDY SITES AND PROCESSES IN LATIN AMERICA

FIGURE 3



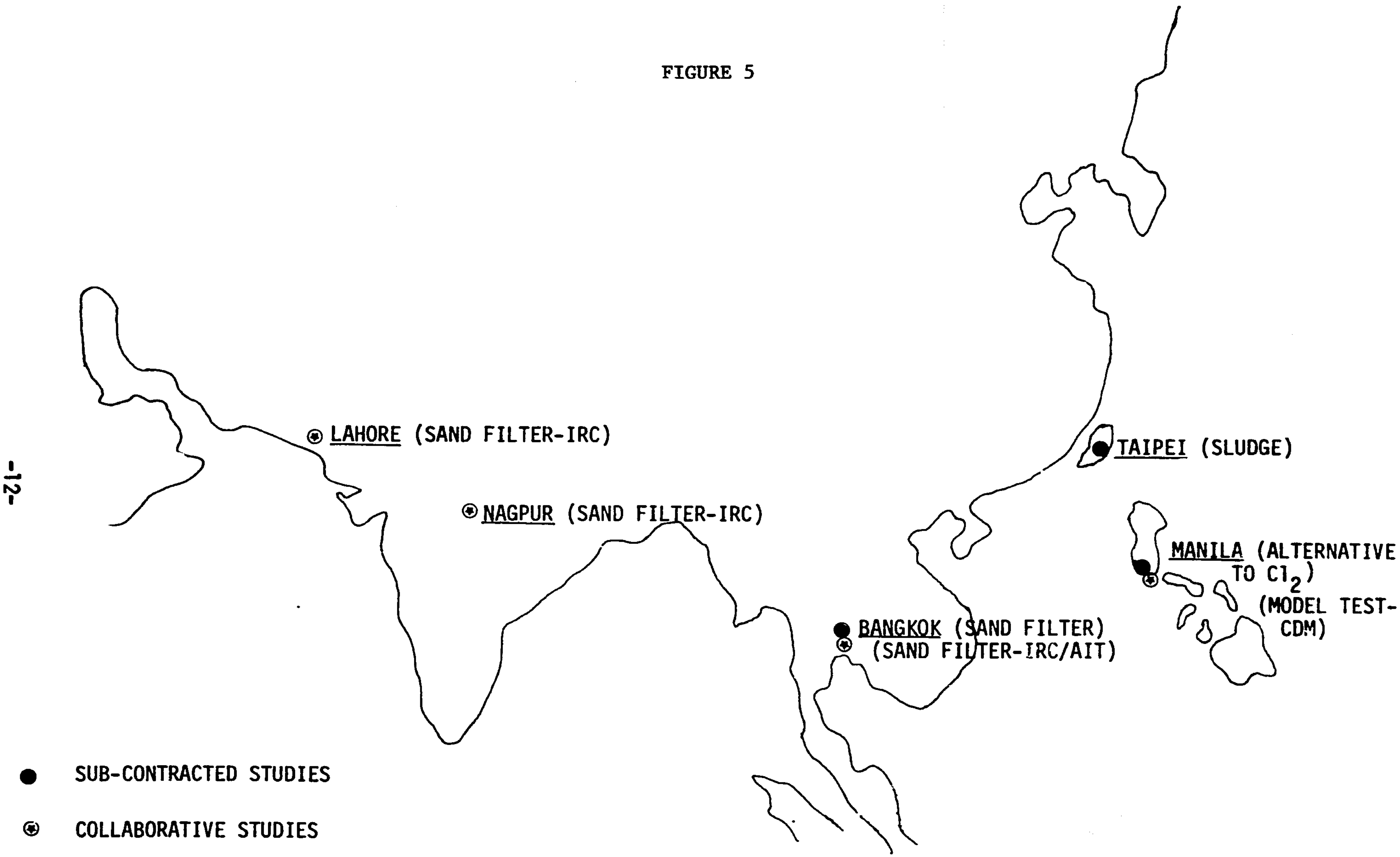
ACTUAL STUDY SITES AND PROCESSES IN LATIN AMERICA

FIGURE 4



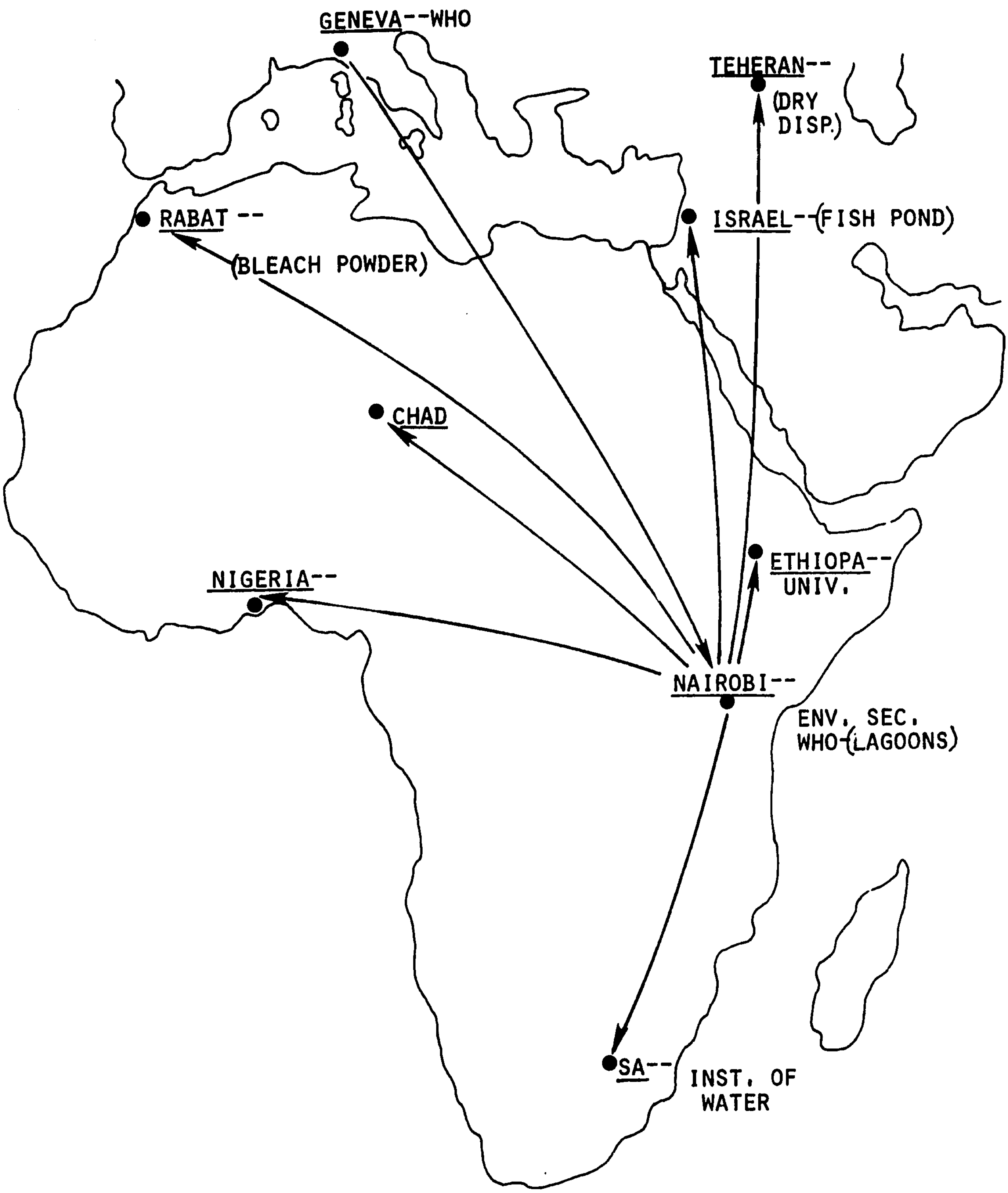
ORIGINALLY PROPOSED STUDY SITES AND PROCESSES IN ASIA

FIGURE 5



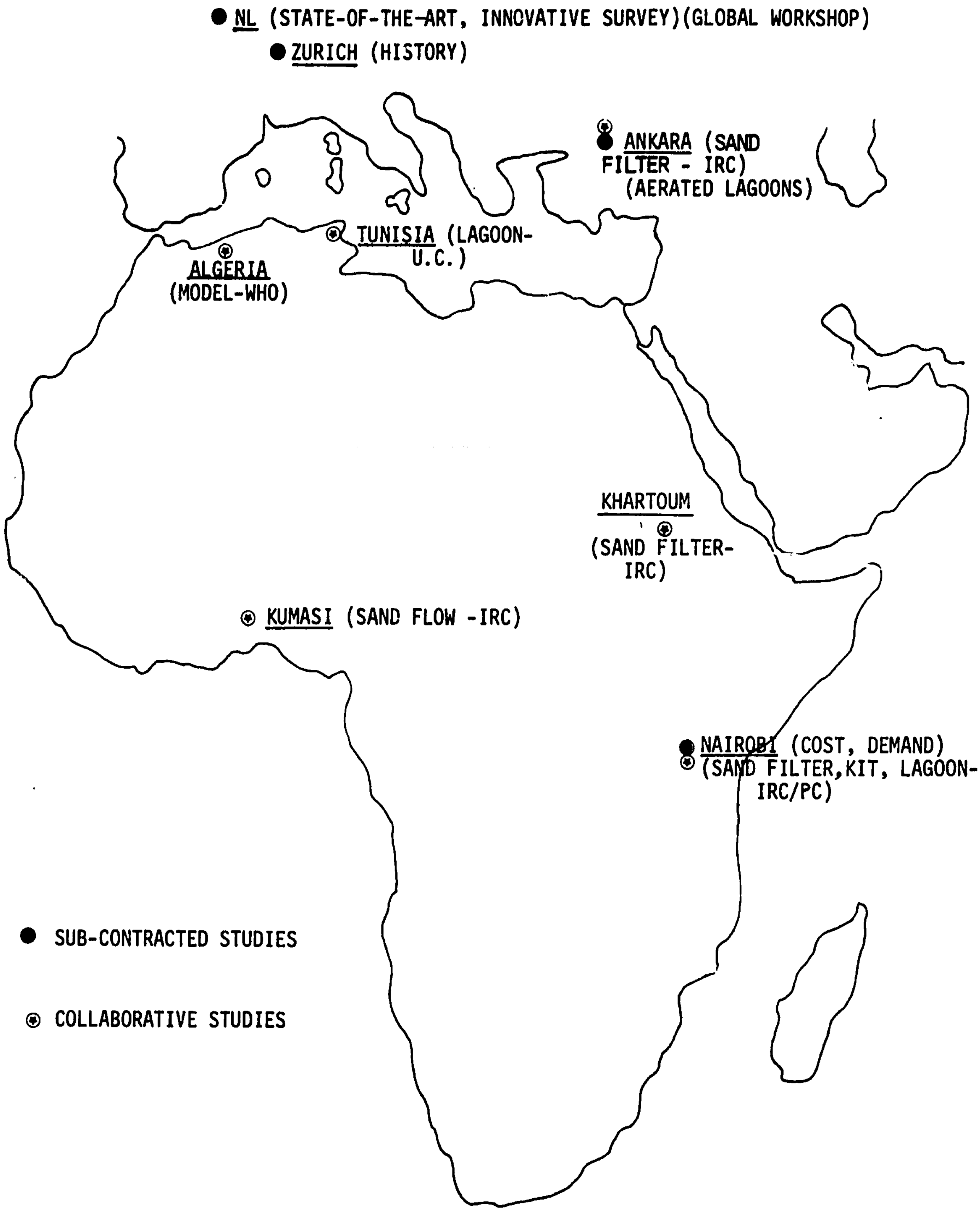
ACTUAL STUDY SITES AND PROCESSES IN ASIA

FIGURE 6



ORIGINALLY PROPOSED STUDY SITES AND PROCESSES
IN AFRICA AND MIDDLE EAST

FIGURE 7



ACTUAL STUDY SITES AND PROCESSES IN AFRICA, MIDDLE EAST AND EUROPE

The OU/AID project in its conception addressed all of these needs as basic activities: (1) those associated with the creation of a global network to study practical transfer of water and sewage treatment technology for in-country performance including costs, reliability, efficiencies, acceptance, maintenance, successful modifications and adaptive techniques; and (2) those associated with a predictive scheme to guide countries in the selection of treatment processes which are low cost and also maximize in-country capability. Toward this goal the following were developed:

1. a technology study network that is truly a global representation with population, lifestyle, and natural resources as determinants and a sincere interest as evidenced by willingness to share cost by participants; a network covering all "high make" processes.

2. a Predictive Model; using available socio-economic data; checking it for availability; user's acceptance; and technical validation.

3. supportive studies attendant to the above, including:

   a. State-of-the-Art (current; historic studies)
   b. field test kits for process control
   c. established data formats
   d. cost and demand studies.

4. validation and dissemination of the results through

   a. a global workshop
   b. publications, technical papers, etc.,
   c. visitation - working with the Ad Hoc Committee, Intermediate and Appropriate Technology Groups, and others.

After initial selection sites were visited (Table II) an analytical model was developed to assist, in an orderly fashion, contractor selection. Developing countries were studied for in-country available data and materials (pharmaceutical chemicals etc.) for the predictive model. Data was formulated and model inputs selected. Several series of each were required until final documentation was initiated. An overview of all these activities is found in Figure 1 and Table III. To be able to coordinate the structural and nonstructural activities, considerable effort was spent in selection, organizing, normalizing, classifying, etc. of data, socio-economic and process, models, costs, demand, etc. Each had to relate to the other and each major activity is covered in detail by its appropriate report all of which are listed in Table IV.

TABLE III

USAID/OU GLOBAL PROGRAM

X - Project Funds

O - Contributions

		LATIN AMERICA						AFRICA			MIDDLE EAST & NORTH AFRICA				FAR EAST								PROJECT STAFF/OTHERS-BC								SUB TOTAL			TOTAL		
		PERU/CEPIS	TRINIDAD UNIV. WEST INDIES	ECUADOR/CEPIS	COLOMBIA/USAID	BOLIVIA/CEPIS	BRAZIL/CEPIS/IRC	GHANA/UNIV. OF GHANA/IRC	KENYA/PEACE CORPS	KENYA/UN. NAIROBI/IRC	ALGERIA/WHO	TUNISIA/OSWALD	TURKEY/METU	LEBANON/AUB	THAILAND/AIT	THAILAND/GOVERNMENT	INDONESIA/BANDUNG	INDONESIA/CDM	INDONESIA/JAKARTA	TAIWAN/IES	PHILIPPINES/CDM	PHILIPPINES/NPPCC	IRC/NETHERLANDS	IRC/SWISS	UNIVERSITY OF LONDON	UNIVERSITY OF DELFT	TEXAS UNIVERSITY	OKLA. UNIVERSITY STAFF	WHO/GENEVA	UNEP/KENYA	O	X	O+X	O	X	O+X
PROCESSES – WATER (5)	Slow Sand Filtration							O		O						X															2	1	3			
	Rapid Sand Filtration (Con.)					X										X																2	2			
	Rapid Sand Filtration (Adv.)			X			XX																									1	1			
	Disinfection (Alt. to Cl_2)																					X										1	1			
	Innovative Filters (Fibers)							O								X															1	1	2	3	8	11
PROCESSES – SEWAGE (6)	Stab. Pond/Fish								X	O							X														1	2	3			
	Extended Aeration Oxid Pond											O	X																		1	1	2			
	Sludge, Night Soil																			X												2	2			
	Sand Filters						O																								1	1	1			
	Dilution/Estuarial																															0	0			
	Innovative Treatment (Severless Toilets)		O																									O			2		2	5	5	10
MODEL/DOCUMENTATION/ WORKSHOP, ETC.	Model User Study	X			O						O							O			O										4	1	5			
	Historial Studies																							X	X	X		X				4	4			
	Demand Studies	X								X																						2	2			
	State of Art																						X		X		X	X	O		1	4	5			
	Innovative - Survey Data - Management																						X/O								1	1	2			
	Technical Workshop																						O							O	2		2			
	Global Conference	O													O															O	3		3			
	Analysis/Kit	X							X								O														1	2	3	12	14	26

TABLE IV

PROJECT DOCUMENTS

*1. Prediction Methodology for Suitable Water and Wastewater Processes (English and Spanish)
English Edition, October 1975.
Spanish Edition, October, 1975.

*2. Supplement I (Model) - Manual Computation Method, October, 1975

*3. Supplement II (Model) - Computer Program, May, 1975

*4. Data Requirement, October, 1975.

*5. A Mathematical Model for Predicting Water Demand, Wastewater Disposal and Cost of Water and Wastewater Treatment Systems in Developing Countries, January, 1976.

*6. Water Test Kit I: User's Manual
English Edition, September, 1975.
Chinese Edition, September, 1975.
Spanish Edition, September, 1975.
French Edition, September, 1975.
Persian Edition, September, 1976.
Arabic Edition, December, 1976.

*7. A Catalog of Water Supply and Waste Disposal Methods for Individual Units, October, 1975.

*8. A Historical Survey of Selected Water and Wastewater Technologies, December, 1976.

*9. Sewage Treatment in Developing Countries, December, 1976.

**10. Report on Global Workshop on Appropriate Water and Wastewater Treatment Technology for Developing Countries, December, 1976.

**11. Contributions to a Mailing Survey on Practical Solutions in Drinking Water Supply and Wastes Disposal for Developing Countries, June, 1976.

**12. Treatment Methods for Water Supplies in Rural Areas of Developing Countries, October, 1975.

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*All under the title of Appropriate Methods of Treating Water and Wastewater in Developing Countries.

**Compiled by IRC/NL.

MANAGEMENT PROBLEMS

Project management problems mostly stemmed from situations beyond the contractor's control; namely, subcontractor delay in finalizing contracts, and keeping deadlines. In addition AID liaison personnel were changed on three occasions thereby causing misunderstandings. These problems required the contractor to spend excessive time on improving communications and preparing repetitive and additional documentation that all together necessitated the request for an extension in time. As an example of some of the contractor problems encountered, it was thought very desirable to develop one project around the concept of aqua-culture or growing vascular plants and fish from sewage. This was to be done at the Bandung Institute of Technology in Indonesia, and following a visit, a contract was proposed and written between this Institution and the University of Oklahoma. In a period of over two years it was impossible to get the contract approved by all involved. So it had to be abandoned. Similar deadlines were slipped in attempting to get the project between CEPIS (PAHO) and the University of Oklahoma approved. This took over a year. The University of Oklahoma was caught in a dilema trying to resolve both CEPIS and USAID contractual arrangements. Another example, was the Turkish contract which involved the supplying of a piece of equipment, namely, an aerator. The aerator finally arrived in Istanbul where it was delayed in customs several months before it could be brought to Ankara.

There were also difficulties arising from the nature of the project and of course, the feelings of the principal investigator. For example, it was the opinion of the principal investigator that each participating group should give something of themselves and should basically operate their sub-contract using students. As such, it meant dealing with universities and initially it was found that some of the most able contractors simply wanted the entire project funding so it was not possible to work with Nagpur or AIT for example because of the funding levels that they've been accustomed to. Other difficulties relate to international agencies; UNEP never came forth with the things that they indicated that they were willing to do. The international organizations in professional activities were found to be almost a "closed shop", and required an inordinate amount of effort to develop the "esprit de corps" necessary for coordination. This came about because the principal investigator was determined not to do things that others were doing nor repeat the work of others but to coordinate relevant work where possible. This was successful but it did take time.

RESULTS

The results were significant. Twenty-three documents have been produced along with six papers. These are listed in Tables IV, V, and VI. In addition two doctoral dissertations and several master theses were accepted by the University of Oklahoma (Table VII). These can be summarized as:

1. A model predicting most compatible treatment processes has been developed and tested, presented to the consumer (LDC's) and accepted for publication and worldwide distribution by IRC/NL.

2. State-of-the-Art documents including, unpublished information, as well as historic and individual technics, has been written and is of interest to wide audiences.

3. An in-country field kit for analysis of treatment process performance has been developed and field tested.

4. LDC Contractor reports on process technology provide much needed in-country performance data of likely prospects.

As gratifying as is physical evidence, or out-puts are, perhaps more importantly will be the human bench marks, the interest of individuals and organizations who became actively involved with the project. As evidence, is the continuing global interest by engineers as well as decision makers in the predictive model and the interest of the IRC to continue the inventory of unpublished research.

TABLE V

TREATMENT PROCESS REPORTS

WATER

Process	Site
1. Slow Sand Filters	Thailand
2. Rapid Sand Conventional Upflow	CEPIS
3. Rapid Sand Advanced Multi-media Valveless Tube Settlers	CEPIS
4. Disinfection - Alternative	
Lime	Philippines
Heat	Philippines
5. Sand/Coconut/Asboestos Fiber Filters	Thailand

SEWAGE

Process	Site
1. Lagoons (Stabilization Pond)	Indonesia**
2. Oxidation Ponds (Extended Aeration)	Turkey
3. Sludge, Night Soil	Taiwan Trinidad***
4. Sand Filter	IRC Study
5. Estuarial Disposal and Chemical	Lebanon*
6. Innovative Treatment (Sewerless Toilets)	University of Oklahoma

*Incomplete due to war

**Incomplete due to breakdown in negotiation

***Withdrawn, due to inability to perform within time frame

TABLE VI

PROJECT PAPERS

1. Reid, G.W., Talboys, Albert, and Swisher, A. Dale, "Lower Cost Methods of Water and Waste Treatment in Less Developed Countries". First World Congress on Water Resources, Chicago, Illinois, September 24-29, 1973.

2. Reid, G.W., "Importance of Low Cost Technologies in Water and Wastewater Treatment in Developing Countries", report for Environmental Health in the Arab Cities, Baghdad, April 6-11, 1974.

3. Reid, G.W., Talboys, Albert, and Swisher, A. Dale, "On Compatible Country Capabilities and Water and Wastewater Treatment Processes Selection", Inter-american Sanitary Engineering Congress, Mexico City, August 4-9, 1974.

4. Reid, G.W. and Swisher, A. Dale, "Low Cost Methods of Treating Water in Developing Countries", (American Water Works Association), the 95th Annual Conference Proceedings published June 8-13, 1975, Minneapolis.

5. Reid, G.W., Law, Silas and Discenza, Richard, "Predictive Methodology as a Tool for Planning Water and Wastewater Processes", presented at the University of Technology, Longborough, England, September, 1976.

6. Reid, G. W., and Swisher, A. Dale, "Low Cost Methods of Treating Water in Developing Countries", report prepared for International Water Resources Association, India, December, 1975.

TABLE VII

STUDENTS WHO WORKED AT ONE TIME OR ANOTHER ON THE PROJECT

Name	Location
James Rasmussen	University of Oklahoma
Kenneth Govaerts*	Peace Corps/Kenya
Junyang Yang*	University of Oklahoma
Richard Discenza*	University of Arizona
Michael Holmes	University of Oklahoma
William Yang*	University of Oklahoma
Michael Muiga*	Federal University of Paraiba Brazil
I. Kay Coffey*	University of Oklahoma
Henry Van*	USN - California
Abraham Fawzy*	Consultant/Egypt
Cuong Q. Tram	University of Oklahoma
Juan Dias	Panama Water System
Gay Adams*	University of Oklahoma
Richard Hall	Peace Corps/Jamaica
Chan Hung Khuong*	University of Oklahoma

*Ph.D. Level

In addition, Kenya and CEPIS have requested permission to publish their findings and follow-on activities have been requested for the field kit, in Mexico, Trinidad, at CEPIS, the Peace Corps, and INPIS in Colombia. A seminar on the predictive model was presented to INPIS engineers as arranged with USAID/Colombia. A forthcoming global conference on Sewerless Toilets (IRC and Mexico) was initiated by the Principal investigator.

So the project has tangible product outputs, but has also produced intangible outputs, basically of interest and involving others. Finally, the methodological approach and data formatting, should be transferable to other researchers and problems for example, other elements of a water system, or prioritizing models, etc. The UN has, as a result, requested studies from the University of Oklahoma on demands and costs and for the coming World Water Conference in South America. The AID/OU study has been incorporated into the United States presentation, at that forthcoming conference.

CONCLUSIONS AND RECOMMENDATIONS

The problem to develop low cost water and wastewater treatment as a precursor to industrial, and other, development in LDC's has certainly not been solved. A predictive technic has been developed, specific in-country technology has been developed, and further development stimulated. But most importantly, a step has been taken in the correct direction. Much more effort needs to be done to get these new tools and concepts accepted and widely used. In the appraisal process to date, three basic questions arise:

1. Given new tools, forecasting, and process designs, will LDC's use them?
2. What about other facets of a water supply system development? What about essentially rural levels?
3. In a country program what site should be supported first?

There are also purely technical questions of accuracy of the forecasts, available data, process definitions, etc. That is, these elements need further verification and refinement through professional use and feedback.

Therefore the model needs to be placed in appropriate hands for use, study and ultimately expansion to the total system of water supply and waste disposal. The problem of consumer acceptance, or LDC's decision makers' perception must be addressed. A global professional input, as feedback from familiarity with the study, must be evaluated and used to upgrade the data and models.

More specifically, the recommended follow-on activities are:*

1. Hold at least three global conference to explain to engineers and other decision makers, the model: its requirements; its limitations; and its capabilities. CEPIS (Lima) AIT (Bangkok) and UNEP (Kenya) are recommended as possible sites with WHO, UNEP, PAHO and IRC as collaborating agencies.

2. An in-depth program of assistance (model utilization) to LDC countries or groups on request. This would be aimed towards the resolution of individual and national water schemes with the inclusion of a prioritizing model for national water and sewage developmental schemes, and maintenance of up-to-date data and upgrading of the modeling capabilities.

3. In-depth study of analytical kits, modifications, upgrading, etc.

4. Applicability of "in-the-home" facilities in LDC's as alternates to elaborate distribution and collection systems. An international conference of sewerless toilets will be held in Mexico sponsored by PAHO/WHO/others.

5. The expansion of the predictive scheme to include, storage, conveyance, distribution and collection.

6. The expansion of the predictive scheme to include, village, or non-nucleated areas, perhaps through development of a cross referenced catalogue.

7. Publication of manuals, and short courses on dissemination of program and findings.

Of these seven items, one, two and five have been proposed to USAID, three and four are already underway. Preliminary studies are ongoing on item two in Indonesia through

*These activities are shown in Figure 1 by dotted lines.

OU/UNICEF. WHO, IRC/NL, and PAHO are particularly concerned and interested in item seven.

A eighth item, one of considerable interest, might be to develop a system, or methodology to locate candidate processes for detailed study in LDC's research centers, centers similar to those supported under this project. Such a program is outlined in Annex F.

The principal investigator and a large number of engineers and scientists from many countries have become involved with this project and its products, and in fact - philosophically committed, over the period of this contract. Also, there is ample evidence of the concern of international agencies and institutions, such as UN, WHO, AIT, AUB, PAHO, UNICEF, UNEP.

It is the authors' considered opinion that this project has produced an effort worthwhile continuing. Because of this "head start", USAID or some representative agency should consider assuming the international leadership role, providing linkages and coordination between vested interests as well. That is to say, currently there is a unique opportunity for the U.S.A. to take a practical leadership role in international health.

ANNEXES

Final Report

LOWER COST METHODS OF WATER AND WASTEWATER TREATMENT IN LESS DEVELOPED COUNTRIES (U.S. AID Contract No. AID/CM-ta-73-13)

The annexes consist of brief decriptions of the following support material:

A. Historic Survey and State-of-the-Art Documents

(Background on processes, including literature search of treatment methods,* mailing survey of treatment methods,* catalogue of devices for individual use, and historic survey of methods.)

B. Prediction Methodology for Suitable Water and Wastewater Processes, and Demand-Cost Model for Water/Wastewater*

(Prediction model for processes with manual computation method supplement and computer program supplement data requirement, and feedback; demand-cost model.)

C. Analytical Kits and User Manuals

D. Global Technology Network Contracts and Studies

(Water and Sewage Sub-Contracted In-Depth Studies Listing, CEPIS,* Turkey, Kenya*, Philippines, Taiwan and Thailand)

E. Global Workshop*

F. Outline of Predictive Model to Locate Candidate Processes for Study

* All individual studies are documented. Individual publication has already been arranged for those with an asterick, with appropriate approval of OU/AID. Other publications have either been previously supplied to USAID or are attached as part of this final report.

ANNEX A

HISTORIC SURVEY AND THE STATE-OF-THE-ART DOCUMENTS*

State-of-the-Art studies were prepared from published material on water and sewage treatment in developing countries. Dr. L. Huisman, Professor of the University of Delft in the Netherlands, prepared the State-of-the-Art paper on water treatment.[1] Dr. Huisman is the author of Slow Sand Filtration, an international text published by the Delft University of Technology, the Netherlands. Dr. Larry Canter of the University of Oklahoma and Dr. J. F. Malina of the University of Texas, prepared the State-of-the-Art paper on sewage treatment.[2] Drs. Canter and Malina have extensive experience in the study of the installation and operation of lagoons in the United States as well as in other countries, particularly in Central and South America. Besides including information on developing countries, these studies solicited material from the United States and Europe.

The studies utilized slightly different formats because of the differences in the subject areas. Dr. Huisman believed it was necessary to relate to some degree to the problems of procurement and distribution of water, which he did. Along with this, because the more conventional methods used in larger urban centers are well known, he attempted to solicit and provide many examples depicting various solutions to problems of procurement and distribution. It was obvious from

*Copies of these documents are attached as part of the Final Report.

the beginning that there are at present two basic methods of choice for use in developing countries in smaller nucleated areas, for water the slow sand filter and for sewage the sewage lagoon. As a result, the papers themselves explain what is going on in developing countries at the present time (although they cover a wide variety of technologies being used) and deal in considerable depth with these two methods. The water treatment report includes references developed by the IRC/ Netherlands independent sand/filtration study.[3]

A third document developed by the IRC in the Netherlands is entitled A Mailing Survey on Practical Solutions in Drinking Water Supply and Wastes Disposal for Developing Countries.[4] This study was conducted by T. K. Tjiook and others to solicit information from the field that did not appear in the published literature.

A fourth sometimes referred to as the "Sears Catalog of Water and Wastewater Devices for Individual Use"[5] attempts to pull together all the various works that have been encountered that are not intended for nucleated communities, that is, those that are intended for single or village installations and most of which are of a rather primitive design. This document was the result of searching the literature, produced by WHO, the Peace Corps, the Intermediate Technology Group, and others. The document was put together by the OU/AID project staff.

Finally, a fifth study, Historic Implication of Developed Countries Water and Wastewater Technology on Developing Countries[6] was completed by Ms. Kay Coffey of the University of Oklahoma. This documents the historic use pattern in developed countries.

References

1. L. Huisman, Treatment Methods for Water Supplies in Rural Areas of Developing Countries, (IRC/NL) October, 1975.

2. L. W. Canter and J. F. Malina, Sewage Treatment in Developing Countries, (OU/AID)September, 1976.

3. Preliminary List of References on Slow Sand Filtration and Related Simple Pre-Treatment Methods: Second Revision, (IRC/NL) November 1976.

4. Contribution to a Mailing Survey on Practical Solutions in Drinking Water Supply and Water Disposal for Developing Countries, (IRC/NL) June 1976.

5. A Catalogue of Water Supply and Waste Disposal Methods for Individual Units, (OU/AID) October 1975.

6. George W. Reid, and Kay Coffey, Historic Implication of Developed Countries' Water and Wastewater Technology for Developing Countries, (OU/AID) December 1976.

ANNEX B

The predictive model for suitable water and wastewater processes in developing countries was provided with material supplementary to its use, namely, the data requirements and a computer program as well as a manual computation method to be used when necessary. A second model was subsequently completed to assist in predicting demand and cost figures for water use and wastewater disposal in developing countries.

This Annex only contains descriptions of:

I. Prediction Model

II. A Mathematical Cost and Demand Model

III. Manual Computation Method

IV. Computer Program for Prediction Model

V. Data Requirement

I. PREDICTION METHODOLOGY FOR SUITABLE WATER AND WASTEWATER PROCESSES: THE MODEL

This project developed a predictive model which can help planners select suitable water and wastewater treatment processes appropriate to the material and manpower resource capabilities of a particular country at a particular time. The detailed description of the model has been reported* and covers the predictive model's format, data requirements, detailed flow, selection of appropriate costs and computerization. It also includes a case study test of the model.

The model has the capability to bring together a number of critical inputs relating to the effective installation and use of various water and wastewater treatment methods, processes, and combination of processes. The output of the model is a list of the plausible alternatives for water and/or wastewater treatment in developing country communities. This output allows planners or project engineers to look at all the plausible processes and their related costs, plus the operation, maintenance, and manpower requirements associated with each of the various processes. This technique can mitigate the problem of overlooking good processes for water and wastewater treatment.

*Reid, George W., and Discenza, Richard, Prediction Methodology for Suitable Water and Wastewater Processes, (English and Spanish) OU/AID, October 1975. To be published by IRC/NL, 1977.

The key elements of this approach are:

1. The systematic evaluation of the importance and interrelationships of all relevant aspects of the problem, such as technical, economic, social, political, and cultural factors.

2. The assessment of alternative courses of action.

3. An analysis of in-country costs as the basis on which policies can be determined and decisions made.

The emphasis is on obtaining a grasp of the total picture so that international health organizations, lending agencies, and regional institutes will have a viable planning tool.

The model has been validated in-house and in the field. The in-house validation included:

1. Comparison of model outputs with data from existing treatment facilities in developing countries.

2. Identification of user application problems, consultants, planners, bankers, etc.

3. Inclusion of new interpretative/adaptive technology and state-of-the-art information to broaden the available treatment processes and levels of applicability.

The field validation work consisted of model runs by users to determine if the appropriate data could be obtained to run the model. The primary objective of this phase of the validation process was to ensure that input data requirements could be met in various developing country situations where substantial national and/or local environmental, economic, and social data are not generally available. In these situations, the test is whether the model outputs still provide the design engineer or planners with useful information on the most acceptable processes.

Although the model is limited from a purely mathematical viewpoint, the output is meaningful in that it allows a rapid examination of the alternatives to planners as well as providing elimination of non-feasible processes on an objective basis. Also, although the model is an important design tool, it does not replace the planner but rather allows him to concentrate his skills and experience on the identified alternatives in the most effective way.

The model has been computerized for a number of reasons. First and probably most imporatnt is that a computerized version relieves the planner from the error-prone task of manually evaluating the alternative processes for the selection of the most appropriate treatment method. Although limited from a mathematical point of view, the number of steps to execute the model, while not complicated, are numerous and time consuming. The computerized version also can be used by the planner to evaluate several communities in one execution of the program. The second reason for computerization is that, in less developed countries, electronic computers are becoming available for use by those involved in planning water and wastewater treatment. The computerized model enables planners to use the latest technology as an aid to decision making and as an operational test for planning. For those planners who do not have access to a computer capable of executing the model, a manual approach was developed. This avoids the problem of sending the data to a central computing center or regional office (if a local computer is not available). In short, the manual approach gives the model applicability even in the remotest of areas.

Finally, computerization provides a basis for a uniform analysis of planning water and wastewater treatment on a regional or national basis. Although the model is limited to evaluating the plausible treatment methods for a single community it contains the type of information needed for a more aggregate approach and can be easily modified to provide cost information on a regional basis.

Another important point is in-country acceptance of appropriate or suitable technology. The information currently available indicates a strong desire on the part of developing countries to be identified with "high technology" (often termed "going first class"). In effect, the developing countries are expressing a desire to have the latest type of water and/or wastewater treatment facilities now being used in developed countries. Such facilities might be feasible in a few of the developing countries' largest cities, but for the most part there simply are not the in-country resources to build, maintain, or man these expensive, highly technical plants. In fact, this project stemmed from the all too frequent waste of developing countries' resources in attempts to build and operate advanced treatment plants, most of which were complete failures. This phenomenon is also prevalent in developed countreis. Even U.S. cities and towns often demand the "best" available technology when an older, proven technology would be more appropriate for their environment and available resources.

The selection model developed by this project helps design engineers and planners mitigate the problems created by this desire for high technology. Through the use of this computerized model, a large amount of data/information can be processed quickly, and the resultant output will display the consequences of all the various actions including all relevant costs. Such a display will, in most cases, enhance the design engineer's professional judgment. Also, in his defense of the selection of a lesser technology, the designer can now say that he has a "high technology device" with the mystique of the computer and the systems approach that evaluates quickly the large number of variables associated with the needs and resources of a specific community and the available alternatives. This evaluation will add the prestige of "science" to professional judgment as well as helping formulate that judgment.

Finally, although the model essentially does the same job done by good designers, it is visible, inclusive, and is of value to either the expert or novice. The model can be run on a computer or operated manually. Both the computer program and manual procedures are provided in technical manuals and are described in the following sections. Table B-1 lists the individuals who have the model publications and who have either reviewed them and/or are applying them.

INDIVIDUALS WHO RECEIVED (REVIEWED) THE PUBLICATION ON PREDICTION METHODOLOGY FOR SUITABLE WATER AND WASTEWATER PROCESSES

	NAME	ORGANIZATION
(1)	Amirtharajah, Dr. A	Chief Engineer Research and Training National Water Supply and Drainage Board Ratmalana Sli Lanka
(2)	Arboleda, J.	Calle 121-A No. 53-98 (Niza) Bogota Colombia
(3)	Arceivala, Prof. S.J	WHO Regional Office for Europe 8, Scherfigsvej Copenhagen DK 2100 Denmark
(4)	De Azevedo Netto, Dr. J. H.	University of Sao Paulo Rua Padre Joao Manual 1039 12411 Sao Paulo Brazil
(5)	Beyer, M. G.	Adviser, Drinking Water Programmes UNICEF P.O. Box 20, GCPO New York, New York 10017
(6)	Bundi, U.	Research Associate IRC for Wastes Disposal Swiss Institute for Water Supply and Water Conservation Duebendorf, CH-8600 Switzerland

B-1
(Continued)

INDIVIDUALS WHO RECEIVED THE PUBLICATION ON PREDICTION METHODOLOGY FOR SUITABLE WATER AND WASTEWATER PROCESSES

	NAME	ORGANIZATION
(7)	Donaldson, D	Department of Engineering and Environmental Sciences Pan American Health Organization 525, 23rd Street, N.W. Washington, D.C.
(8)	Govaerts, Dr. K.	Associate Director United States Peace Corps P. O. Box 30518 Nairobi, Kenya
(9)	Kearney, J.	U.S.Agency for International Development c/o U.S. Embassy Bogota, Colombia
(10)	Korthals Altes, F.W	Senior Technologist Royal Tropical Institute Mauritskade 63 Amsterdam The Netherlands
(11)	Mahmoud, Dr. I.	African Development Bank P.O. Box 1387 Abidjan Ivory Coast
(12)	Malina, Dr. J.F.	University of Texas ECJ 8.6 Austin, Texas 78712 U.S.A.

B-1
(Continued)
INDIVIDUALS WHO RECEIVED THE PUBLICATION ON PREDICTION METHODOLOGY FOR SUITABLE WATER AND WASTEWATER PROCESSES

	NAME	ORGANIZATION
(13)	Miller, Dr. D. G.	Water Research Centre 45, Station Road Henley-on-Thames Oxfordshire RE 9 1BW England
(14)	Murty, Y. S.	Scientist in Charge National Environmental Engineering Research Institute R.R.L. Campus, Hyderabad - 50009 India
(15)	Pescod, Prof. M.B.	Chairman Environmental Engineering Division Asian Institute of Technology P.O. Box 2754 Bangkok, Thailand
(16)	Rahardjo Pringgokusumo	Sanitary Engineer Dipl. S.E. Head of Design Section Department of Public Works and Power 20, Jl. Pattimura Jakarta, Indonesia
(17)	Reyes, Dr. W. L	WHO Regional Office for South East Asia P.O. Box 302 New Delhi India

INDIVIDUALS WHO RECEIVED THE PUBLICATION ON PREDICTION METHODOLOGY FOR SUITABLE WATER AND WASTEWATER PROCESSES

	NAME	ORGANIZATION
(18)	Sieber, D.	Division of Environmental Health Pre-Investment Planning Unit World Health Organization 1211 Geneva 27 Switzerland
(19)	Spangler, Dr. C. D.	International Bank for Reconstruction and Development 10212 Brookmoor Drive Silver Springs, Maryland 20901 U.S.A.
(20)	Yanez, Dr. F.	Centro Panamericano de Ingenieria Sanitaria y Ciencias del Ambiente (CEPIS) P.O. Box 4337 Lima, Peru
(21)	Camp Dresser & McKee International Inc.	A Boston Consulting Engineering Firm One Center Plaza Boston, Mass. 02108

II. A MATHEMATICAL MODEL FOR PREDICTING WATER DEMAND, WASTEWATER DISPOSAL AND COST OF WATER AND WASTEWATER TREATMENT SYSTEMS IN DEVELOPING COUNTRIES*

This study used mathematical modelling techniques to develop predictive cost equations for water supply and waste water disposal models in developing countries utilizing socio-economic, environmental and technological indicators. Predictive cost equations were developed for three regions (Africa, Asia and Latin America) for water demand, waste water amounts, and construction, stabilization lagoon, aerated lagoon, activated sludge and trickling filter processes. The primary objective of this study was to provide engineers, planners and appropriate public officials in developing countries with an innovative technique for more effective development of in-country water resources.

Data analysis indicated that water demand is a function of population, income and a technological indicator (percentage of households connected to water supply) while waste water disposal was found to be a function of water demand, and two technological indicators (percentage of homes connected to public sewerage systems and percentage of household systems). The predictive equations for water treatment costs were found to be a function of a technological indicator (percentage cost of imported water supply materials), population, and the design capacity. The variables which gave the best correlation for wastewater treatment costs were population, design capacity and the percentage of imported wastewater disposal materials.

*Reid, George W., and Muiga, Michael I., A Mathematical Model for Predicting Water Demand, Waste Water Disposal and Cost of Water and Wastewater Treatment Systems in Developing Countries, (OU/AID), January 1976.

III. MANUAL COMPUTATION METHOD SUPPLEMENT TO THE PREDICTION METHODOLOGY FOR SUITABLE WATER AND WASTEWATER PROCESS

The selection of the most appropriate water and wastewater treatment method for developing countries by using the predictive model is not limited to situations where an electronic computer is available. A manual computation method is available in a step by step manner so that a planner can take advantage of the systematic approach developed within the computerized approach. The detailed approach of the model is described in the model publication.* In brief, the twelve step procedure to determine the most plausible treatment method is:

1. Assign weights to the data sheet questions necessary for determining the STL (Socio-technical Level) for the community under consideration. Weighting factors and an example of a complete data sheet are given in the manual.

2. Total the assigned weights for each of the designated individual questions.

3. Compare the above total to a set of given values to determine the socio-technical level of the community.

4. Determine the operation equipment availability.

5. Determine the process materials availability.

6. Determine the operation and maintenance supplies available.

7. Determine the chemical supplies availability.

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* Reid, George W., and Discenza, Richard, Prediction Methodology for Suitable Water and Wastewater Processes: Supplement I, Manual Computation Method, (OU/AID), October 1975.

8. Compare the basic processes and their requirements (in report) against the physical resource groups (these are determined by Steps 4-7).

9. Compare the various combinations of treatment processes (outlined in the report) to the water quality of the community obtained from the community data sheet.

10. Compute the population scale as given in the data sheet according to the following guidelines:

Estimated Population	Population Scale
500 - 2,499	1
2,500 - 14,999	2
15,000 - 49,999	3
50,000 - 100,000	4

11. Determine the total cost of construction and operation over twenty years for the remaining combinations (determined by Step 9) of feasible processes using the appropriate scale (See Step 10) and the appropriate STL Level (see Step 3).

12. Select the lowest total cost process or the lowest maintenance cost combination of processes determined by Step 11.

IV. COMPUTER PROGRAM SUPPLEMENT TO THE PREDICTION METHODOLOGY FOR SUITABLE WATER AND WASTEWATER PROCESS

This supplement includes a computer program for the model to select the most appropriate water and wastewater treatment method for developing countries. The detailed description of the model components is presented in the model publication.*

This supplement consists of five parts:

1. Listing of data to set up a temporary file in scratch tape for the program;
2. Main program listing;
3. Listing of subroutine model;
4. Listing of input data for a sample region;
5. Listing of sample output.

*Reid, George W., and Discenza, Richard, "Prediction Methodology for Suitable Water and Wastewater Processes: Supplement II, Computer Program," (OU/AID), May 1975.

V. DATA REQUIREMENT

As part of this project, data forms* were formulated to collect information on the following:

1. Demographic
2. Socio-Economic Data
3. Process Data
4. Analytical Tests
5. Operational Data
6. Facility Construction Cost Data.

These data are formatted for completeness, easy comparison and easy reduction by a computer. Obviously, some data will not be available, others, particularly those studying processes, will want technological process evaluation data, such as turbidity vs. loading, etc. which is not formatted.

The data requirement forms have been sent out several times for field validation. The format and contents have also been modified many times. However, in order to keep these forms up to date and useful, continuous modifications and improvements are necessary and essential.

*University of Oklahoma, Bureau of Water and Environmental Resources Research, Data Requirement, (OU/AID), October 1975.

ANNEX C

WATER TEST FIELD KITS AND MANUALS

During the period of this project, two water testing field kits, Kit I and Kit II, were developed. The kits were designed to provide quality checks on water and sewage facilities. The seven tests in Kit I and fifteen tests in Kit II were defined as being appropriate to provide an adequate health index of the water. The seven tests in Kit I are pH, Chlorine residual, turbidity, coliform bacteria, relative stability (biochemical oxygen demand), dissolved oxygen and temperature. In addition to the Kit I tests the following tests are included in Kit II: alkalinity, carbon dioxide (and acidity), color, hardness, iron, odor, taste and total dissolved solids.

Objectives of the kits were to be: (1) economical and rugged; (2) responsive to data needs; (3) available for mass distribution; (4) usable with in-country skills; and (5) such that expendables could be replaced in-country.

Commercially available test kits, such as La Motte or Hach, are accurate. However, they require knowledgeable operators, the chemicals and parts need to be ordered from outside the country with total kit costs well over $250. The OU/AID kits consist of materials available locally and components can be made fresh each day before going into the field. Results are adequately accurate and require no special skills or specific knowledge. The cost is under $100 for the entire kit.

The manuals* for kits provide pictures of all operations and equipment needed for each test. Measurements in the manual are given in grams and milliliters. However, all weights are substituted for with measuring spoons provided. Appendices provide alternative methods for performing each test, along with information on references, sterilization and distilling, and conversion tables.

The manuals are also available in Chinese, French, Persian, Spanish and Arabic. These kits have been validated in several developing countries (see Table C-1).

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*Reid, George W., and Yang, Weigun Wl, Water Test Kit I: User's Manual. (English, Chinese, Spanish, French), September 1975; (Persian) September 1976; (Arabic) December 1976.

Reid, George W., and Yang, Weigun W., Water Test Kit II: User's Manual, (English) Steptember 1976; (French, Spanish) December 1976; (Chinese, Persian, Arabic) in translation.

TABLE C-1

USAID/OU WATER TEST FIELD KIT I AND KIT II
VALIDATION STUDY LOCATION

Location	Kit	Institution	Person In Charge	Date Kit Delivered
1. Kenya	I	U.S. Peace Corps % U.S. Embassy Nairobi, Kenya	Dr. Ken Govaerts, Associate Director of Voluntary Technical Assistance to Kenya	July, 1974
2. Taiwan	I	Taiwan Institute of Environmental Sanitation PHA, 161 Ker Yang Street, Nan Kong District, Taipei, Taiwan	Mr. M. C. Lo, Director	Sept., 1975
3. Trinidad	I	The University of West Indies, St. Augustine, Trinidad, West Indies and Water & Sewage Authority, Valsayn, St. Joseph, Trinidad, West Indies	Dr. H. O. Phelps, Professor & Head Department of Civil Engr. Dr. Albert P. Talboys, Project Director, UNDP/PAHO	Oct., 1975
4. Peru	I	CEPIS, Casilla, Postal 4337, Lima, Peru	Dr. Cliff Kirchner	Oct., 1975
5. Mexico	I	University of Mexico, Heriberto Frias 925-6, Mexico 12, D.F.	Dr. Francisco Montejano	Nov., 1975
6. Asia, South America & Africa	I	WHO, Division of Environmental Health Pre-Investment Planning Unit 1211 Geneva 27, Switzerland	Mr. D. Sieber	Nov., 1975
7. Netherland	I	IRC/NL, P. O. Box 140 Leidschendam, the Netherland	Mr. T. K. Tjiook	Dec., 1975
8. Mexico	II	University of Mexico Mexico City, Mexico	Dr. Waldo Bonilla	Oct., 1976
9. Trinidad	II	The University of West Indies, St. Augustine, Trinidad, West Indies	Dr. H. O. Phelps, Professor and Head Department of Civil Engr.	Oct. 1976
10. Peru	II	CEPIS, Casilla, Postal 4337,	Dr. Cliff Kirchner	Oct., 1976

ANNEX D

GLOBAL TECHNOLOGY NETWORK CONTRACTS AND STUDIES

This Annex D describes in-depth studies sub-contracted with CEPIS, Turkey, Kenya, the Philippines, Taiwan, and Thailand. These sub-contracts made a contribution to available information on lower cost or improved methods of water/waste treatment in developing areas or socio-economic conditions of such areas as they relate to water and sewage treatment.

They are:

I. Sub-Contract With CEPIS, Lima, Peru

II. Sub-Contract with the Middle East Technical University Ankara, Turkey

III. Research in Kenya on Socio-Economic Conditions Which Pertain to Cost of Construction and Operation of Water and Sewage Treatment Facilities and Quantity of Water Consumption

IV. A Water Sterilization Study in the Philippines

V. The Study of Microbial Treatment of Nightsoil in Taiwan

VI. A Study of Slow Sand Filters for Water Treatment in Thailand

I. SUB-CONTRACT WITH CEPIS (PAHO)
LIMA, PERU

Background

The arrangement made with CEPIS was the type originally envisioned by the University of Oklahoma (O.U.). In other words use a Regional Center of repute to coordinate several relevant research projects through one communication link. For reasons described in the Final Report CEPIS was the only such sub-contract made.

CEPIS proved to be a worthy choice despite the administrative problems faced. CEPIS, among all the Regional Centers contacted, was the only one that had a countrywide network established and that was conducting or planning to conduct a wide variety of similar (to OU/AID project) projects in dispersed locations. CEPIS was also the only Regional organization willing to conduct the type of research contemplated by OU/AID on a limited budget.

Although a proposal and agreement between CEPIS and O.U. was made in April 1974 an actual contract was not signed by PAHO (CEPIS) until October 24, 1974. Even after signing CEPIS encountered administrative and logistical delays. As a consequence the projects in Cochabamba and Cuenca were delayed excessively. However, CEPIS is an excellent example of a highly trained coordinating Center that is able to deal effectively in a complex system and eventually overcame the difficulties. Under the direction of Eng. Odyer Sperandio (Director of CEPIS) and Eng. José Pérez all four projects were completed as planned in November 1976. The CEPIS FINAL REPORT is attached as part of this report.

<u>The Contracted Project</u>

Since Latin America has more examples of applicable techniques and systems of providing and maintaining low cost water and waste treatment facilities than in any other Third World region, it was logical to look carefully at this experience.

A large number of water treatment plants in Latin American countries are the product of technical know-how and standards adopted by industrialized countries. Often these solutions are incompatible with the resources or the industrial development of the country or region. Technological problems arise which result in the wasting of local resources, the reduction of local economic potential and the disruption of efficient public services. This situation has been brought about by the importation of foreign technology, the technical and commercial promotion of products and solutions from industrialized countries, and the use of a "manual technique" based on pre-established standards in the absence of local basic and applied research.

In an attempt to capitalize on this situation a program was designed around four sites in three countries.

The evaluation of the water treatment plants designed with new technological criteria in the cities of Cochabamba (Bolivia), Linhares, and Prudentopolis (Brazil) and Cuenca (Ecuador) was carried out with the collaboration of the agencies responsible for the operation and maintenance of the local water supply systems: SEMAPA (Servicio de Agua Potable, Alcantarillado y Desagües Pluviales), FSESP (Fundação Serviços de Saûde Publica), SANEPAR (Companhia de Saneamento do Paranâ), and ETAPA (Empresa Pûblica Municipal de Telêfonos, Agua Potable y Alcantarillado).

Preliminary activities involving the acquisition and installation of equipment, preparation, and adaptation of the treatment plants were completed in 1975. In 1976, basic information was gathered to fulfill the data requirements for the system of matrices being developed to help select the appropriate technology for water treatment projects in developing countries as requested by the University of Oklahoma. This includes data regarding demography, technology, socio-economic conditions, process characterization, and operational and construction costs.

The technical evaluation of the plants was done by conducting special tests during the normal plant operations to determine flow characteristics and the response of the reactors to variations of flow. In addition, laboratory tests were conducted to establish theoretical parameters for comparison purposes.

Research Objectives and Activities

The objectives of the coordinated program were:

1. Identification of new water treatment methods
2. Identification of projects in Latin America which use new technological criteria in the design of water treatment plants.
3. Selection of the most outstanding projects in this area and definition of their technical characteristics.
4. Identification of the demographic, socio-economic and technical development characteristics required by the University of Oklahoma to apply the system of matrices developed by the University.

5. The principal objective of the research conducted by CEPIS is the evaluation of the technical, operational and economic efficiency of the selected treatment projects.

The general activities of the program were divided into tasks as follows:

1. Preliminary activities included the signing of contracts, acquisition of laboratory equipment, modification and adaptation of the treatment plants.

2. Gathering of basic demographic, socio-economic and technological development data.

3. Technical research to determine the ideal theoretical conditions by laboratory and/or pilot plant tests, collection of normal operational data in the plant regarding raw, settled and filtered water quality, and the study of the characteristics of the reactors, flow conditions, and response capacity with variations in loadings and water quality.

4. Economic evaluation including general construction, operating and maintenance costs, as well as economic data required to determine the fiscal soundness of the community.

Results

The significant findings were:

1. New technological criteria for water treatment plant design can be used successfully to produce very simple easy-to-operate treatment plants with a high level of technical performance that can be built at a very low cost, usually 30% to 40% that of conventional type solutions.

2. Treatment plants capable of good technical performance can be designed without sophisticated equipment and materials, using solutions compatible with the socio-economic realities and the degree of industrial development in the countries.

3. "Low-cost" technology does not imply the adoption of solutions that mean poorer water quality.

4. The use of new technological criteria implies high loadings, smaller areas of construction, and modification of the basic working criteria of the units, all of which facilitate the construction and operation and bring the cost of water treatment plants down to values between US$ 800 and US$ 1200 per liter/second. This represents a savings of 60 or 70% compared with the cost of conventional treatment plants.

5. The use of simple saturation or suspension feeders in water treatment plants is suitable, because of their low cost and technical efficiency. There are limitations to their use in very small plants serving populations of less than 1000 inhabitants.

6. The use of hydraulic flow rapid mixing units is suitable because of their low cost and high technical efficiency.

7. Mechanical and hydraulic flocculation units are equally effective; their efficiency depends on factors other than the source of power.

8. High velocity gradients are required for rapid mixing and flocculating low turbidity water, while low gradients are needed for turbid waters, when the detention time is kept constant.

9. High-rate sedimentation can be used in water treatment plants with efficiencies greater than 90% at a cost which is 30% lower than with conventional units.

II. SUB-CONTRACT WITH THE MIDDLE EAST TECHNICAL UNIVERSITY ANKARA, TURKEY

The project of "Upgrading an Oxidation Pond to an Aerated Lagoon"* was important for two reasons:

1. The recognized need for a simple and proved sewage treatment process appropriate for use throughout Turkey;

2. Enhancement of U.S. AID/Turkey relationships.

The project almost from the start has been one of frustration in that most efforts to communicate between the Middle East Technical University (METU) and O.U. met with failure. After the Project Director's initial visit to METU in the spring of 1974, the original sub-contract was submitted to METU, November 15, 1974, for its approval. METU did not sign the contract until June 16, 1975.

The proposed research agreed upon with METU was to study the possibility of increasing the capacity of a recently constructed oxidation pond through the use of mechanical aeration. The pond currently serves a population of over 10,000 associated with the newly built METU complex.

In addition to collecting relevant data before and after

*Middle East Technical University of Ankara, Upgrading of an Oxidation Pond to an Aerated Lagoon, Progress Report 1976.

aeration, METU had agreed to prepare an evaluation of the system as it pertains to Turkey with emphasis on the following:

1. Applicability of the methods under Turkish conditions of climate, terrain, etc., giving recommended design criteria under different conditions.

2. Requirements of equipment (such as aerators), materials, instrumentation, etc., and possibilities for local development.

3. Cost of construction and operation of waste-treatment plants under Turkish conditions.

4. Requirement of operational staff and necessary training programs.

5. Requirement of any special staff for design and research work.

6. Relevant socio-economic data/information.

METU personnel had built a fixed aerator prior to signing the contract with O.U. However, the homemade aerator never worked and O.U. agreed to furnish a factory-built, moveable aerator based on METU specification.

After delays by the U.S. manufacturer, the aerator was finally shipped and arrived in Istanbul. Thereafter, communications with METU, even with the assistance of AID personnel, were one-way. There were no responses to O.U. messages that at varying times requested status reports, offered assistance, etc.

Finally, Dr. Michael Muiga, an O.U. project staff member on a personal trip to Africa, was requested by the Project Director, with AID concurrence, to visit METU on his return to the U.S. This proved successful in that we received a status report with the promise of a final report by the summer of 1977.

Current status of the project is as follows:

1. METU claims that the U.S. manufactured aerator cannot be used in as much as the phase and voltage is not compatible with METU's current situation. The manufacturer supplied what METU specified.

2. Operation data/information on the complete plant without aeration, has been obtained.

3. A new locally made aerator has been built and is now installed in the aeration lagoon, and data while using mechanical aeration is being gathered.

4. Over half the sub-contract funds have been encumbered pending receipt of METU's final report.

5. We believe the communication barrier with METU has finally been removed.

III. RESEARCH IN KENYA ON SOCIO-ECONOMIC CONDITIONS WHICH PERTAIN TO COST OF CONSTRUCTION AND OPERATION OF WATER AND SEWAGE TREATMENT FACILITIES AND QUANTITY OF WATER CONSUMPTION

This report* contains an analysis of the socio-economic concitions which pertain to cost of construction and operation of water and sewage treatment facilities and quantity of water consumption in Kenya. The socio-economic conditions which have been analysed must be considered in any situation which requires rational planning for the supply of adequate water and wastewater facilities, their operation, and maintenance, as well as the total cost of construction of such facilities and the total recurrent cost of administration, and operation and maintenance of such facilities for a given population.

The report consists of the following: natural water resources in Kenya; political leadership; the demographic, socio-economic, and socio-cultural factors; analysis of selected water supply sites; nature of water usage and level of water consumption. Report appendices include certain field data from several Kenyan cities arranged according to the following categories:

1. Demographic and technology data
2. Socio-economic data
3. Process data
4. Data identification
5. Operational Data: Water and sewage of cities of Mimbasa, Kisumu, Nyeri
6. Facility Construction Cost data: water and sewage plants of cities of Mimbasa, Kisumu, and Nyeri.
7. Types of Secondary Schools by District

*Muga, Erasto, Socio-Economic Conditions Which Pertain to Cost of Construction and Operation of Water and Sewage Treatment Facilities and Quantity of Water Consumption in Kenya, Final Report October 1976.

IV. A WATER STERILIZATION STUDY IN THE PHILIPPINES

The main objective of this study* was to determine the most effective and economical method to disinfect untreated water in rural areas for safe domestic use. It was envisioned that the method of treatment that would be recommended would be formulated in a form that could be implemented in the rural areas, utilizing materials available in every household, and most important, instructions would be presented in such simple terms that even a layman could carry out and be assured of safe drinking water.

A number of disinfectants previously considered, such as HTH, iodine and potassium permanganate, were originally planned to be used. However, after considering the availability, local costs and application, it was decided to limit the disinfectants to only two: sodium hypochlorite and calcium hypochlorite solutions. These two can be obtained even in rural areas in the Philippines at very minimal cost.

Concerning water supply in the Philippines, available information revealed that there were some 25,500 artesian wells, mostly located in the rural areas, each well supplying about 350 persons. There were also an estimated 1000 big-cased deep wells which served as sources for waterworks systems. Some 7,000 natural springs had been

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*Lasaca, Reynaldo M., A Water Sterilization Study in the Philippines, Final Report April 1976.

developed as water supply sources. More than half of the water sources utilized for domestic use showed the presence of coliform organisms.

Therefore, as secondary objectives of the study, the targets considered for improvement of water supply by disinfection were the rural areas where water problems were most acute, and urban communities where supplementary supplies were provided by deep wells.

The results of this study revealed that the mean concentration of chlorine, added to the water, adequate for effective disinfection, ranged from 1.18 to 1.75 ppm for sodium hypochlorite and 1.28 to 1.82 for calcium hypochlorite. The concentration of chlorine required to purify the samples from the different sources was subsequently analyzed for significant differences. Using the t-tests, the results failed to show any significant differences in chlorine doses, existing either between the different groups of water samples, or between the types of chlorinating agents. Thus both solutions are equally effective.

For effective disinfection of water used in communities, small or large, urban or rural, a method of improving the sanitary quality of water for human consumption can be easily accomplished by the chlorination process. Socium hypochlorite and calcium hypochlorite solutions were found to be excellent as sterilizing agents for drinking water by the procedure used in and recommended by the study.

V. THE STUDY OF MICROBIAL TREATMENT OF NIGHTSOIL IN TAIWAN

The purpose of this study* was to study microbial treatment of nightsoil in Taiwan. There are few sanitary sewerage systems in the cities or towns in Taiwan. Around half of the urban nightsoil is treated by septic tank and then discharged into ditches and rivers. The remaining half is collected by vacuum car. Because of the overload or inadequate design of septic tanks, the effluent from these tanks is the main source of water pollution in the area. To control this situation, the government promulgated standards for septic tanks and the quality of the effluent.

Traditionally, the collected portion of the nightsoil was used as a fertilizer or discharged into fish ponds to grow chlorella as food for fish. Subsequent use of artificial fertilizer and feed diminished this application thereby creating a serious problem in that large amounts of nightsoil had to be disposed of. For this reason the Taiwan Provincial Institute of Environmental Sanitation has run studies on the treatment of nightsoil. First, the government constructed a 30 KL/Day nightsoil treatment plant at Chi-jen, Kachsiung City, a 20 KL/Day at Pingtung, and a 30 KL/Day at Feng-shang. These used anaerobic digestion for nightsoil treatment and an activated sludge method for the supernatant. Although these plants were able to meet

*The Study of Microbial Treatment of Nightsoil, Taiwan Institute of Environmental Sanitation, June 1976.

the design expectations, the remaining bulky sludge created another disposal problem.

To solve the problem, an experiment using the combined microbial method for nightsoil treatment was tried. This study was based on the use of photosynthetic bacteria (PSB) and chlorella to decompose the organic matter in nightsoil and to make it stable. The multiplied PSB and chlorella which contained high amounts of protein could subsequently be collected for animal feed.

Results showed that nightsoil treatment with PSB and chlorella could save more than 20 days on duration time, compared to treatment by anaerobic digestion with the digested supernatant being treated by the activated sludge or trickling filter method, and more than 10 days compared to the aerobic digestion method. Also, this experimental treatment method was able to produce the byproduct-PSB and chlorella as animal feed, very little sludge and few pollution problems. In general it was suitable for domestic use.

To make this treatment method more widely acceptable, it should be easy to operate and economical in the initial maintence and operation costs. Therefore, the depth of PSB and chlorella culture tanks is a keypoint. The problem of how to increase the depth of the tanks to save the land area and still have good PSB and chlorella collection requires further study.

VI. A STUDY OF SLOW SAND FILTERS FOR WATER TREATMENT IN THAILAND

The purpose of this research* was to study problems associated with the design and operation of an already installed slow sand filter in Thailand. Sand filtration remains the main form of water treatment in Thailand. In the rural area, where modern techniques and qualified operators are insufficient, simply constructed and operating systems like the slow sand filter are recommended. The data and information gathered on this project included loading, operational difficulties, operation cost and income, process efficiency and demographic and socio-economic data on the village served.

This study was carried out on only one water treatment plant, the slow sand filtration plant at Kranuan, Thailand. The plant was constructed in 1971 under the responsibility of the Rural Water Supply Division, Department of Health and is located in the north-east part of Thailand about 500 kms. from Bangkok. Construction cost including the treatment system and main distribution pipe was about 1,100,000 baht (1 $ = 20 baht). The government contributed 500,000 baht and the local community contributed 680,000 baht. The plant is designed to serve a population of 9,563 with the capacity of 100 CM/hr.

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*Thailand Ministry of Public Health, Department of Health, Rural Water Supply Division. Study of an Existing Water Treatment Plant of Simple Design and Operating System for Supplying Drinking Water to Rural Communities in the Lower Mekong Basin Countries, Final Report August 1976.

The data and results obtained are not representative of the average value of other slow sand filters in Thailand. Thus, further studies should be performed at slow sand filters which are scattered in parts of the country, so that the data collected would show some characteristics of the total of the filters in Thailand. The information could be averaged and used as a basis of design for new ones. However, the local situation at Kranuan, the population and society, the raw water quality and treatment unit of this plant approximated those of other villages or plants and it was believed that this information could be applied to improve certain design criteria for the Rural Water Supply Division.

The results obtained in the water consumption part were interesting since the design criteria for per capita consumption, daily demand, peak demand, etc., were set up by assumption. Some criteria are very close to the experimental data but some are slightly different.

The filter bed and rate of filtration were checked to be within the range suggested by most water treatment textbooks. Because of a limit in time and budget, some relevant information was not collected, e.g., length of filter run to the time of clogging.

The efficiency of the filter was checked by means of laboratory experiments which compared the quality of raw water and filtered water. The analysis showed that the water quality of the effluent from the filter was within the range of WHO recommended standards for drinking water. If the water was disinfected before distribution, it was considered safe for drinking at the point of delivery.

ANNEX E

GLOBAL WORKSHOP ON APPROPRIATE
WATER AND WASTEWATER TREATMENT
TECHNOLOGY FOR DEVELOPING COUNTRIES

The most important aspect of a technology transfer program such as the Oklahoma/AID project is the actual dissemination and consequent use or nonuse of the project results. With this in mind the O.U. project has made presentations at international meetings and maintained contacts on a global basis. Although the major part of the OU/AID project dissemination effort was to take place after contract termination, we found through our global network of contracts, that there was a definite need to have an international meeting of concerned individuals as quickly as possible.

Because of this need and as a direct result of contact with the WHO International Reference Centre (the Hague) the first of a series of Global Workshops was decided upon and developed. In the spring of 1975 agreement was reached between the University of Oklahoma, AID and the IRC to conduct a technical Global Workshop at the Hague in November 1975.

The primary objective of this workshop was to bring together experienced personnel from developing countries to exchange ideas and approaches to treatment problems, and to evaluate preliminary results of the OU/AID program. The secondary and perhaps the most important objective was to establish a basis of commonality in an effort to further a global acceptance of concepts of adaptive and innovative treatment technology for developing countries.

Because of parallel interests and collaborative efforts with the IRC, Dr. J.M.G. van Damme, Director of the IRC, agreed to hold the workshop at the IRC facilities and to handle all the logistics. This agreement included publishing the workshop proceedings and well as printing and disseminating various documents resulting from the OU/AID project.

The OU/AID project for its part provided the following workshop effort:

1. Participants from the project staff and consultants. Travel expenses were paid for by the project.

2. Background Papers:

   a. Material about the OU/AID project
   b. Draft of the Predictive Model
   c. Draft of the Historic Studies
   d. Draft of the State of the Art on Water and Sewage Treatment in developing countries
   e. Draft of the "Sears Catalogue"
   f. OU/AID Data Requirements
   g. Water Test Kit and Manuals in Five Languages

The workshop was held at IRC Headquarters Voorburg (The Hague) 17-22 November, 1975 with thirty-seven partipants who came from the following fourteen countries

1. Brazil	8. Netherlands
2. Canada	9. Peru
3. England	10. Sri Lanka
4. India	11. Switzerland
5. Indonesia	12. Thailand
6. Ivory Coast	13. Turkey
7. Kenya	14. U.S.A.

The consensus of the meeting was that the workshop was successful and that the primary objectives were met.

The proceedings* included a detailed listing of necessary research as well as identification of courses of action developing countries and developed countries should take to overcome a major barrier to third world development, the barrier being in effect a lack of technology transfer relative to delivery of potable water and the treatment of waste water.

The significant results of the workshop from the view point of the OU/AI project included:

1. What was perhaps the first successful "working" conference on the subject and a prototype for future global conferences.

2. An assimilation of the major needs of developing countries in terms of subject areas and priorities.

3. A better worldwide understanding of what the OU/AID project was all about and opening up of new communication linkages.

4. A frank appraisal of the OU/AID project from the viewpoint of individuals and/or organizations who would be involved in the implementation of the project's products.

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*World Health Organization, International Reference Centre for Community Water Supply, The Hague, "Revised Draft Report on Global Workshop on Appropriate Water and Wastewater Treatment Technology for Developing Countries," Voorburg, The Netherlands, 17-22 November, 1975, December, 1976.

ANNEX F

PREDICTIVE MODEL TO LOCATE CANDIDATE PROCESSES FOR STUDY

This annex outlines a program which might be of considerable interest to develop in the future. This would be a system or methodology to identify candidate processes for detailed study in LDC research centers, centers such as those which were supported under this project. This outline stems from a proposal developed by the staff of the University of Oklahoma Bureau of Water and Environmental Resources Research.

1. Model Objectives

   1.1 Determination of process requirements by regional parameters

   1.2 Analysis of morphological interrelationships among all processes (verified alternatives and speculative alternatives)

   1.3 Process--site study selection

2. Modelling Methodology for Processes (Based on morphological research method)

   2.1 Explicit formulation and definition of problem (refinement of above)

   2.2 Identification and characterization of all parameters that may enter into the solution (see Table F-1).

   2.3 Construction of multidimensional matrix containing all possible process requirements

   2.4 Verified alternative processes put in matrix

   2.5 Conversion of matrix to multi-dimensional space based on assessment of feasibility of technological adaptation and/or evolution (see Figure F-1).

   2.6 Most attractive possibilities identified through calculation of morphological distance (see Figure F-2).

3. <u>Search for site study</u>

3.1 Derived from DC water/waste technology transfer candidates

3.11 New entrants from DC's

3.12 LDC successes

3.13 Obstacles

3.2 Adoptive of DC water/waste transfer candidates

3.21 LDC successes (general)

3.22 From AID global network

3.23 Obstacles

3.3 Innovative candidates

3.31 Basic research (not technology) inventory

3.311 Solids removal, TDS, SS

3.312 Organic removal, BOD

3.313 Disinfection

3.32 Commons of LDC unique successes

4. <u>Array of study projects</u>

4.1 From 3.13, 3.23, and 3.3

4.2 Other (IRC/AD HOC progress), etc.

5. <u>Cost effectiveness ordering of possible projects</u>

5.1 Intern of population, health, etc.

5.2 LDC's

6. <u>Network interest, capability</u>

7. Program development and monitoring

TABLE F-1: POSSIBLE WATER TREATMENT PARAMETERS

--Scale parameters (goals)

1. Populations served

   0-500
   -2,500
   -15,000
   -50,000
   -100,000

2. Treatment levels

   sub-health (pathogens, toxins)
   health (solids, minerals)
   aesthetic (color, taste)

3. Existing status (water source)

   toxic
   ocean
   brackish
   polluted
   dirty
   pure

--Resources parameters (limitations)

1. Capital available for construction and operation

   non-existant--labor tax
   minimal
   adequate but limited
   unlimited

2. Manpower--technology for construction and operation

   unskilled
   small skilled force
   large skilled force
   professionals

3. Materials for construction

   local--mud, bamboo
   concrete
   steel

TABLE F-1 (Continued): POSSIBLE WATER TREATMENT PARAMETERS

4. Materials for operation

   "household" chemicals
   basic chemicals--chlorine and lime
   industrial chemicals
   special chemicals

5. Energy

   natural--sund and wind
   animal
   fossil--coal, oil, gas
   electrical

--Social parameters

1. Social structure

   individual availability
   small group service
   large group service

2. Aesthetic qualities

   pure H_2O
   no chemical taste
   chemical taste required
   taste and/or odor required

3. Other possible considerations

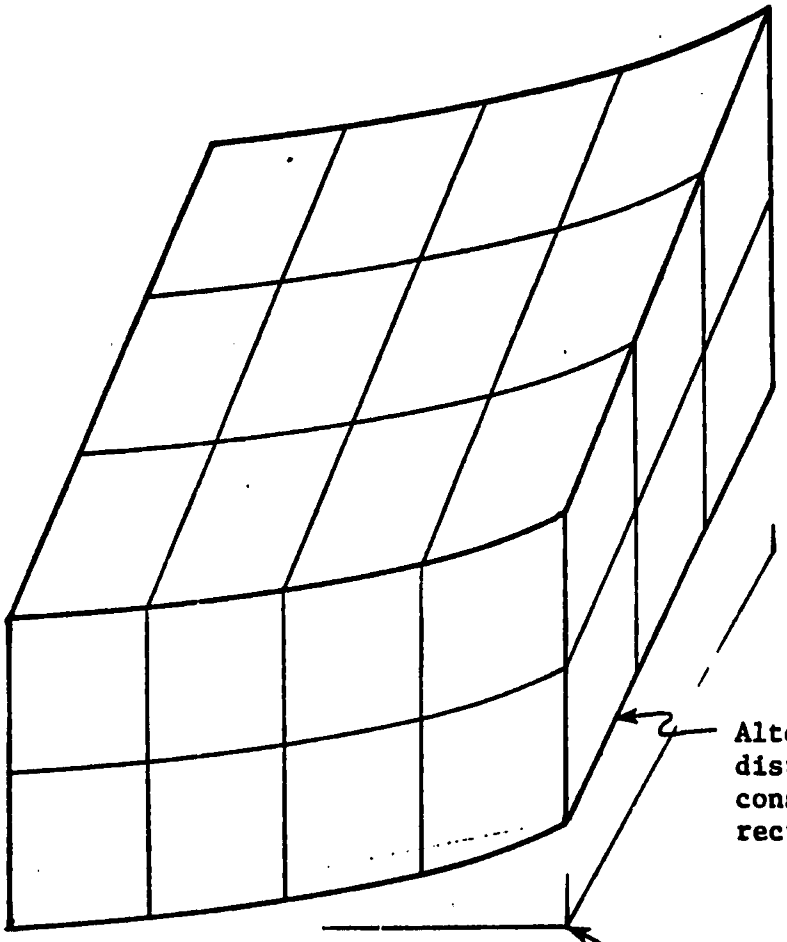

FIGURE F-1: HYPOTHETICAL MORPHOLOGIC SPACE

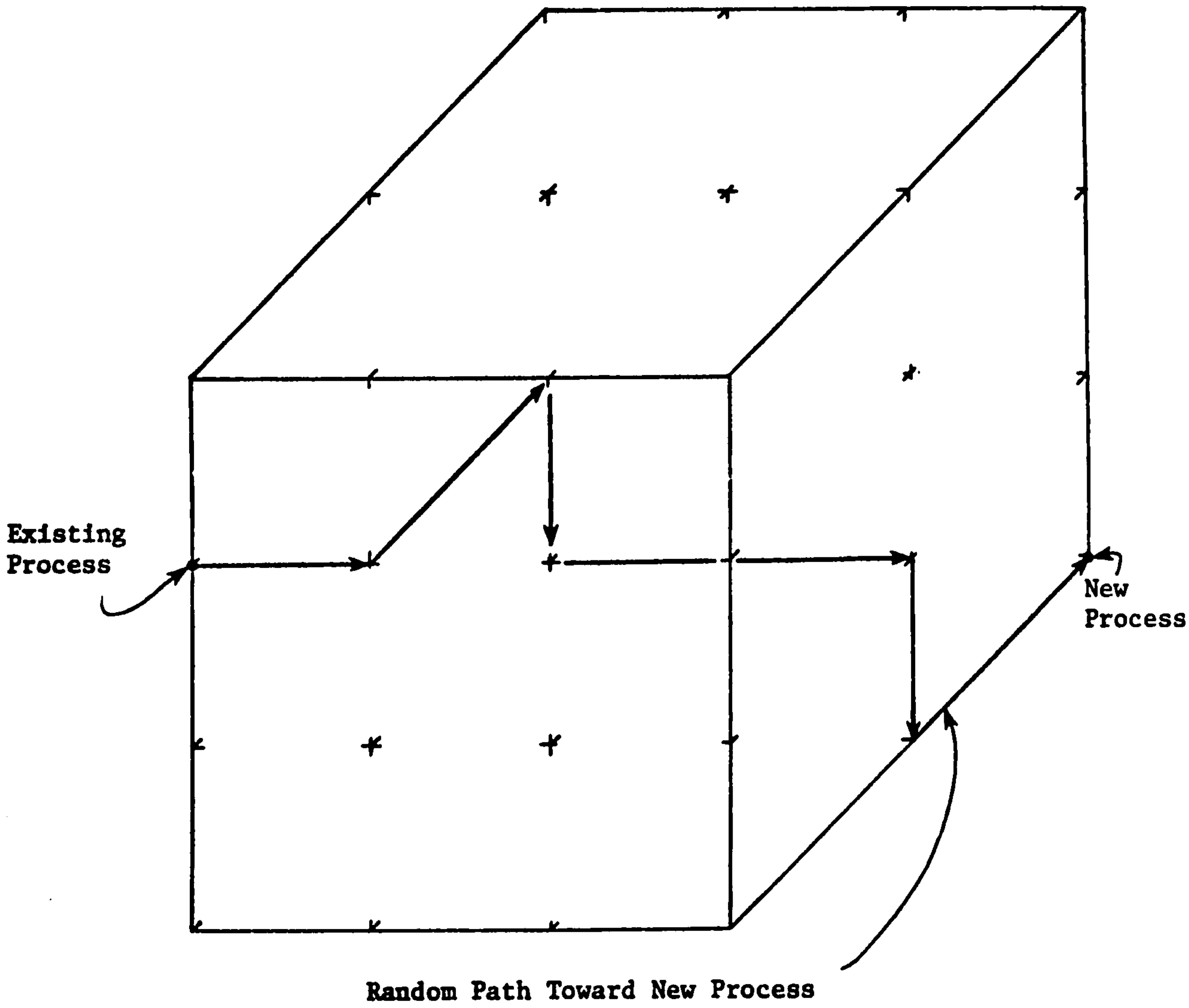

FIGURE F-2: HYPOTHETICAL MORPHOLOGIC DISTANCE