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5th WEDC Conference

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collaboration in water and waste engineering for developing countries

P R O C E E D I N G S

edited by John Pickford & Meryl Murphy

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PAUL KERKHOVEN

cooperation for the water decade

COOPERATION FOR THE INTERNATIONAL DRINKING WATER AND SANITATION DECADE

and

THE CASE OF THE SLOW SAND FILTRATION PROJECT

INTRODUCTION

The progress in the field of community water supply and sanitation in developing countries has been disappointingly slow. The most recent survey of water supply and excreta and waste disposal services carried out by the World Health Organization (WHO) in 1975, found that some 1.230 million or c. 62 per cent of the Third World's population, excluding China, were without a safe water supply and that c. 1.350 million were without adequate sanitation (1).

The need is most urgent in rural areas, where approximately 70 per cent of population live. Of these people only 22 per cent had access to good water in 1975 compared with 78 per cent of the city population, of whom 57 per cent had access through house connections and 21 per cent through public standposts.

For sanitation the figures are 15 per cent for the rural areas (sanitary latrines) and 75 per cent for the cities (25 per cent through house connections to sewerage systems and 50 per cent by household systems). Within the cities the urban poor and squatter communities are much worse off than the other urban dwellers. In fact the need to provide excreta disposal systems in poor urban areas is more urgent than it is in sparsely populated rural areas.

In recent years there has been an increasing call for higher priority to the improvement of this alarming situation. At the United Nations Conference on Human Settlements "Habitat" held in Vancouver in 1976, it was recommended that clean water and adequate sanitation should be provided for all by 1990, if possible (2).

In March 1977, the UN Water Conference held in Mar del Plata, adopted this target and proposed to designate the period 1981 - 1990 the "International Drinking Water Supply and Sanitation Decade". This period then should be used by developing countries to accelerate their programmes, and by international agencies and official development aid agencies (ODA's) to expand and intensify their cooperation (3).

In the meantime, the "Decade" has been endorsed by the UN General Assembly and measures will be taken to interlink the Mar del Plata Action Plan for Community Water Supply and Sanitation with the Third Development Decade of the United Nations.

In conjunction with and partly stemming from this unprecedented appeal to countries, the International Community and donors to give a higher priority to community water supply and sanitation development, there are a number of significant policy changes which will have a direct bearing on the Decade.

A first and major shift in direction which should be mentioned here is the increased commitment to water and sanitation for the poor, at present unserved, groups in developing countries and particularly for the population in the rural and urban fringe areas. This, of course, firstly concerns an increased activity in investment programmes. It also relates, however, to information and technology support, in casu to back-up programmes in the field of information exchange, research and development, training and promotion and demonstration.

The changes referred to, however, are not merely a matter of higher priority for the rural areas. They also particularly concern the new approaches and implementation strategies for rural water supply and sanitation programmes. These are evident for example, in the increased emphasis put on the involvement of communities in basic sanitary programmes and in the importance attached to an improved coordination between the various agencies and disciplines involved in community water supply and sanitation development. They also appear in concepts like Technical Cooperation among Developing Countries (TCDC) and in a stepped-up cooperation between international agencies concerned with the sector. Although these trends relate to various levels and different disciplines, they have one thing in common: an element of increased cooperation. It has therefore been a very opportune and appropriate idea to devote the 5th WEDC Conference to the topic of collaboration in this sector.

This paper presents the Slow Sand Filtration Project as an illustration of elements of cooperation for the Decade, particularly in the field of Information and Technology Support. It should, however, be borne in mind that it is a relatively small Research and Demonstration project and that the overall cooperative action for the Decade is much broader in scope. That the paper discusses these general aspects of cooperation for the Decade at some length, is merely meant to provide a broader basis for discussion during this Conference.

INCREASED COMMITMENT TO RURAL WATER SUPPLY AND SANITATION

The total investment required to reach the target of clean water and adequate sanitation for all by 1990 has been estimated at c. 140.000 million US $. Approximately 66 per cent of this amount will be required for water supplies, the remainder for sanitation. This investment calculation assumes the extension of water supply and sanitation to the entire population of developing countries, with the same levels of service as are currently provided in urban and rural situations respectively. Even so, the target of the Decade implies that the present level of annual investment has to be increased by the following factors: (4)

	Water Supply	Sewage/ Excreta Disposal
Urban	1.2 times	2.1 times
Rural	3.9 times	4.0 times

From these figures it will be clear that it is not only the amount of money that is important, but that it is also a matter of priorities; what is required is a shift in emphasis towards the rural areas.

A major part of the investment will have to come from the developing countries themselves. Hence the success of the Decade activities will turn on the country's initiative and political will to act. A recent background paper on the cooperative action for the Decade (4) says the following about the plan of action at country level: "To most of the developing countries the Decade targets will pose a challenge. The major strategy to meet it will rest on a policy decision to proceed and the creation of an environment that will generate informed and active participation by the community. Of equal importance is coordination at the national and community levels, and the strengthening of overall managerial capacity. Governments will also need to intensify action to improve their absorptive capacity, and to expand their programme capabilities.

In accordance with the Resolutions of the UN Water Conference international agencies are also increasing their commitment to rural water supply and sanitation, both in their programmes and in financial support to projects. A major activity in this context is the Cooperative Action for the Decade in which international agencies concerned with rural water supply and sanitation are collaborating.

Although increased investment is a major prerequisite for reaching the target of the Decade, it is clear from past performance in rural water supply and sanitation projects that money alone will not do the job. The problem of community water supply and sanitation in developing countries is not merely of a technological nature. A much wider set of structural constraints hamper progress. Apart from the lack of internal and external financial resources, the countries themselves listed as their major obstacles the lack of a proper administrative structure, the lack of trained personnel, and the lack of community involvement in planning, implementation and maintenance of systems (5). These are frequently identified as causing the failure of projects.

One of the elements of crucial importance for the Decade is the need for Information and Technology Support regarding the "technology" of management and administration, as well as the technology of physical systems used in water supply and sanitation.

Information and Technology Support programmes may comprise:

- The provision of information and reference services in the field of potable water and sanitation as basic back-up facilities to overcome one of the crucial obstacles in the development of the water supply and sanitation sector: the lack of effective information.

- Research and Development including the identification, adaptation, development and demonstration of suitable technologies and the promotion and application of demonstrated technologies.

- Special studies to evaluate, formulate and promote methods and procedures for the organization, administration, operation, maintenance and financing of water supply and sanitation systems in rural and urban fringe areas, such as studies on: design criteria, levels of service and demand projections, operation and maintenance systems, tariff policies, study of institutional aspects, health education, social and cultural aspects and user acceptance and behaviour, and manpower development methods.

- Training programmes aiming at: promotion of national programmes for training human resources at different levels, and organization of special training courses and other training activities such as workshops and seminars.

At the regional and global level an increased cooperation can help in ensuring a reliable flow of information both published and unpublished by information systems development. It may encourage and provide coordination of such Research and Demonstration projects and special studies on subjects of wide interest and provide liaison with resource institutions in industrialized countries. Regional and global support can also include organizing regional and international meetings and special training courses, supporting national training back-up activities.

INCREASED CALL FOR COOPERATION

As mentioned before there is a call for improved communication and cooperation. This not only relates to the water supply and sanitation sector but in fact reflects the present transition of development, where "cooperation" takes the place of "assistance" and the "do for" approach is shifting towards a "do with" approach. The increased emphasis on cooperation relates to all levels involved from the grassroots level to the United Nations, and to all disciplines concerned. In fact, as much emphasis is put on improved "vertical" lines of cooperation (e.g. between communities and operating agencies, or between member states and the UN system) as on "horizontal" lines of cooperation (such as intersectorial cooperation within countries, Technical Cooperation among Developing Countries or cooperation between various UN agencies).

Without trying to be exhaustive, the following circuits of cooperation that have a direct bearing on the degree of success of the International Drinking Water Supply and Sanitation Decade may be mentioned:

- The UN Cooperative Action for the Decade, in which the United Nations, UNICEF, United Nations Development Programme (UNDP), the International Labour Organization (ILO), the Food and Agricultural Organization (FAO), the World Health Organization (WHO) and the World Bank participate. The Cooperative Action firstly envisages an increased cooperation and coordination among the participating agencies, and secondly an expanded cooperation between these agencies and the member states. The Cooperative Action also tries to improve the cooperation between the agencies and offical development assistance agencies (ODA's).

- Cooperation at National Level. This aims at an increased cooperation between operating agencies and organizations directly concerned with the sector, whether in water supply or sanitation, in urban or in rural areas. It also aims at intersectorial cooperation, in particular between water supply and sanitation agencies and health service agencies, but it can also involve community development agencies and other organizations as appropriate.

- Technical Cooperation among Developing Countries primarily concerns cooperation between governments, whether it be bilateral or multilateral. It can also involve the participation of public organizations, within the framework of the policies laid down by governments, of private organizations and of individuals.

- Community Participation, involving an increased dialogue and cooperation between communities and operating agencies, as well as support to the communities.

THE COOPERATIVE ACTION FOR THE DECADE

As a direct follow-up of the Mar del Plata Action Plan for community water supply and sanitation, which calls for an improved coordination at the country level and regular consultations among governments, international organizations and Non Governmental Organizations (NGO's) concerned, a Cooperative Action Plan has been jointly prepared by UNDP and WHO. The Action Plan first of all aims at improved liaison between organizations within the UN system concerned with community water supply and sanitation development. These organizations have set up a Steering Committee composed of their representatives to initiate the necessary action. At the country level the UNDP Resident Representative is expected to play a central part as focal point for Cooperative Action. He will coordinate the technical and financial cooperation projects of the agencies concerned.

Without any doubt this acceptance of the coordinating role of UNDP at country level by the other agencies can be seen as a major step forward. Together with the Steering Committee it provides a new formula for an improved coordination between the agencies.

The first activity undertaken in the context of the Cooperative Action, was a series of so-called "Rapid Assessment Studies" of the sector in a majority of developing countries. The studies, which were launched jointly by WHO and the World Bank, were meant to help national governments to assess:

- the country's preparedness to accelerate rural water supply and sanitation projects,
- the likely constraints on such an accelerated programme,
- the actions necessary before national plans can be prepared for the 1981 - 1990 Decade,
- the need for external assistance to prepare the national plans.

The rapid assessments clearly showed that in many cases there were serious constraints to community water supply and sanitation development, so that the 1990 target was unlikely to be achieved. In a second phase activities will be generated at the country level in preparation of the National Decade plans, particularly focussing on the provision of support to sector planning.

In close relation with the above activities a few other collaborative projects within the UN system are carried out such as:

- A UNDP - World Bank - project on "Low cost Water and Sanitation Techniques", including the design of demonstration projects which should result in community participation, lower costs, the use of appropriate technology and the creation of employment.

- the UNICEF/WHO Joint Committee Health Policy study on "Rural Water Supply and Sanitation as Components of Primary Health Care", and
- the UNDP/ILO project on "Labour - intensive Public Works".

INCREASED COOPERATION AT COUNTRY LEVEL

In general, a number of agencies and institutes will be actively involved in DWSS development at country level. Some of them deal with implementation programmes, others develop activities in direct or indirect support of the operational work, like information exchange, research and development, education and training. At present, close collaboration between the various operating agencies and the specialised support institutes at national level is very much stressed.

On the operational side this increased cooperation first of all concerns collaboration between the various agencies in charge of the sector within a country, for example, water agencies, public works department, rural water supply and sanitation divisions within the Ministry of Health or (semi-) autonomous water boards or corporations. When various ministries share the responsibility for water, such a coordination, however, often creates serious problems. Moreover, there is sometimes no clear mandate for rural sanitation at all. Therefore, some countries have set up separate administrative systems for rural water supply and sanitation. Even so, cooperation with the Health service agencies is required to integrate water supply, sanitation and health education, since health benefits from basic sanitary services in general will not materialise without improved personal and domestic hygiene practices. Such coordination, moreover, is important when water supply and sanitation are seen as components of primary Health Care. In some Latin American countries, for example in Colombia, the National Institute for Basic Sanitation comprises a special promotion division which takes care of the educational component of rural programmes in communities below 2500 inhabitants.

Since basic sanitary services are increasingly seen as a springboard for further community development a link with Community Development Agencies and possibly other sectorial agencies, for example in the context of Integrated Rural Development projects, is more and more emphasized.

As an element of this intersectorial cooperation between operating agencies, special attention is given in several countries to the development of national collaborative mechanisms for information and technology support. Through these mechanisms a number of institutes will perform support activities of information, research and development, education, training and promotion. This work should be directed as much as possible towards the needs of the operational agencies which are in charge of the planning and implementation of CWSS programmes and projects. Therefore, close collaboration is required between the various operational agencies and the specialised support institutes at national level.

TECHNICAL COOPERATION AMONG DEVELOPING COUNTRIES (TCDC)

The great emphasis placed on the concept of TCDC should be viewed against the background of the transition of world affairs from a situation of dependance of the developing countries to one of interdependance of all nations. The acquisition of technology to accelerate social and economic development is an essential issue in the developing countries programme for a New International Economic Order. This concerns the elimination of constraints which hinder their full access to an effective use of modern technology, and the reduction of their dependance on imported technology. Technology is still mainly transferred by purchase or lease from trans-national corporations. The problems of such a technology transfer are many, including foreign exchange costs, limitations of the use of technology, restriction on exports and excessive reliance on foreign skills.

Against this background, TCDC is a basic tool for national and collective self-reliance of the developing countries. It involves the sharing of technical resources, skills and capacities among developing countries for their mutual development. Hence, it may be used to strengthen existing technological capacities and to improve communication. It can improve the absorptive and adaptive capacity for technology of developing countries and give them a greater degree of participation in international economic activities and cooperation.

Although the main flow of technical cooperation visualised by TCDC would be between two or more developing countries, the support of the UN development system, of industrialized countries and of regional and inter-regional institutions may be necessary. From the report of the United Nations Conference on TCDC, held in Buenos Aires from 30 August to 12 September 1978, (6) we quote : "TCDC is neither an end in itself nor a substitute for technical cooperation with developed countries. Increased technical cooperation of the developed countries is required for the transfer of appropriate technologies and also for the transfer of advanced technologies and other expertise in which they have manifest advantages. Further contributions from the developed countries are required for the enhancement of technological capabilities of developing countries through support to relevant institutions in those countries. TCDC can serve the purpose of increasing the capacity of developing countries to adapt and absorb appropriate inputs from developed countries".

Among the 36 recommendations composing the Plan of Action endorsed by the conference, there are many which have a direct bearing on the International Drinking Water Supply and Sanitation Decade. At national level, <u>inter alia</u> :

<u>The strengthening of national information systems for technical cooperation among developed countries</u>

In order to make the knowledge and experience of one developing country available to other countries, a much easier flow of information is essential, not only on government level, but also among regional bodies and specialist organizations.

The INRES of the UNDP can play an important role here. The information should be transferred through specially designed channels, and pooled, so that all countries are guaranteed easy access to it.

<u>The improvement of existing institutions</u>

A strong institutional organization is indispensable for a successful TCDC. National Institutions should work together on common problems, exchange views and undertake joint development projects.

<u>Promotion of national research and training centres with multinational scope</u>

Research and training facilities should be used to their full capacities. Wherever possible, new centres should be set up. Exchange of students and scientists is strongly recommended.

The formulation, orientation and sharing of policy experience with respect to science and technology

The experience of certain developing countries in the application of science and technology to their respective levels of development can be of great assistance to other countries. Governments should compare notes in order to arrive at the most appropriate policies on science and technology for each country.

The encouragement of technical cooperation among developing countries through professional and technical organizations

The cooperation should also extend to non-government specialist organizations.

Next to a series of recommendations for action at the subregional and regional level, the following recommendations were made, inter alia, for action at the global level :

The exchange of development experience

The UN should assist developing countries with information on the experience gained in other countries, to help them with further programmes.

The fostering of global technical collaboration

Networks of information exchange in various specialist fields are to be set up, so that each developing country can make use of the entire technical literature available on a certain subject.

The improvement of information flows

The activities of INRES and similar organizations should expand and be adjusted so as to ensure the most effective communications with international, national and regional information services and libraries.

Maximization of the use of developing countries' capacities

Developing countries should use their local capabilities and expertise to the fullest extent. If the required expertise should not be available it should preferably be procured from another developing country. Only as a last resort should help be sought in the developed world.

Support by developed countries for technical cooperation among developing countries

Developed countries can assist by voluntary contributions to UN development systems, and to TCDC programmes or national institutions taking part in such programmes. They should give priority to TCDC orientated projects over other ones.

The harmonization of development assistance with technical cooperation among developing countries

Developed countries should exchange their old 'Dutch Uncle' type of aid for a new approach aimed at achieving greater self-reliance of developing countries.

Although these recommendations are of a fairly general nature, very significant changes may be expected in development cooperation once they are implemented. At present, it should be said TCDC is still a philosophy rather than a plan of action and much is unknown about 'how to do it' in practice. This stresses the need for concrete projects developed and implemented on the basis of TCDC, particularly also in the field of community water supply and sanitation.

COMMUNITY PARTICIPATION

The emphasis put on increased cooperation is also extended to the grassroots level, where it manifests itself in the call for community participation. Although this is probably one of the most fashionable terms at present, it cannot be denied that local involvement and dialogue between communities and development agencies are crucial to the eventual success of programmes. As with TCDC, the problem with community participation is that, in spite of the extensive discussions about it at rather "philosophical" level, very little systematic knowledge and experience is available on how to go about it in practice.

Often community participation is simply interpreted as participation in the construction of the supply through contributions in cash, labour, local materials, services and organizational activities. However important this may be, it does not take into account that the programmes should be based on the communities' perceived needs, and that their continued interest and support after the construction must be ensured. Participation of all members or at least all sections of a community in the planning and decision making phase as well as in the phases of operation, maintenance and use of the water supply and sanitation facilities is therefore of even greater importance. This also implies that appropriate local management systems are chosen, allowing the community to develop institutions, and to control the resources, both their own and those planned at their disposal.

The impact of improved environmental sanitation facilities on community health will not be optimal, however, when the adoption and continued functioning of the new technologies are not accompanied by a change in general sanitation practices concerning public, personal and household hygiene. Accompanying sanitary education programmes, in which the villagers are actively participating, will be conditional to success.

Finally, community education and participation will be important when water and sanitation programmes are seen as a catalyst to further village development. Rural water supply and sanitation programmes therefore should not be viewed in isolation, but in their connection with the possibilities and constraints of further village development, including the negative impacts which the water and sanitation programme itself may have on this development.

Community participation does not mean the reduction or withdrawal of higher level support to the communities. On the contrary, it may require that this support is intensified and becomes more complex. In view of the close inter-relation between the technical, organizational, social and cultural component of rural water supply and sanitation projects, this external support necessarily will be of a multi-disciplinary nature. It will involve, next to the technical water supply agencies, health service agencies (including health education), community development agencies and possibly also other sectorial development agencies. A close cooperation between these agencies at all levels and a constant dialogue with the communities is required. It will be clear that from the organizational and institutional point of view such an intersectorial cooperation aiming at community participation in all phases is not easy at all, posing one of the main challenges of the coming Decade.

As has been said, our present "knowledge" of community participation is too academic and not detailed enough to determine its potential feasibility in the planning and implementation of programmes. What is required therefore is a sober assessment of the potential role of community participation under different conditions without ignoring the problems and constraints associated with it. This primarily should be done by action research and pilot projects in developing countries themselves. Support to these activities, however, should be given at international level (7).

THE INTEGRATED RESEARCH AND DEMONSTRATION PROJECT ON SLOW SAND FILTRATION

In order to promote the large scale application of slow sand filtration for community water supply in developing countries, a number of countries have developed an integrated research and demonstration project on slow sand filtration, in close collaboration with the IRC.

The project comprises applied research programmes, demonstration programmes, the exchange of information, and the transfer of knowledge and experience as a preparation of large scale implementation programmes. All these activities are carried out by the developing countries themselves.

The project consists of the following phases:

1. Development of applied research programmes by a core group of project participating institutions on the basis of international collaboration.

2. Development of demonstration programmes by the participating countries on the basis of international collaboration.

3. Provision of information and demonstration activities to other developing countries, by the countries that participated in the preceding phases.

4. Preparation of large scale slow sand filtration implementation programmes by several other developing countries on the basis of the results of the preceding phases.

The applied research programme for phase 1 of the project has been implemented during 1976 and 1977 by Research and Development institutes, in close collaboration with executing agencies in six countries: Ghana, India, Kenya, Sudan, Pakistan and Thailand. Apart from gaining experience with the slow sand filtration process, the specific objective of these programmes was to develop appropriate criteria for the design, construction, operation and maintenance of slow sand filtration schemes under the local conditions of these countries. The results of these research programmes were compiled in country reports.

At present the emphasis of the project is placed on the implementation of the demonstration programmes (second phase), for which Columbia and Jamaica have also joined the core group.

The objective of these programmes is to test and demonstrate alternative implementation strategies in practice, for large scale programmes under different conditions.

The main objective has the following main elements:

1. The development, testing and evaluation of various implementation strategies for slow sand filtration projects at local level, by the implementation of a number of local demonstration projects (two to four per country).

2. The development, testing and evaluation of models for the organizational and institutional infrastructure at national and local level, required for the repetition of these projects within the scope of large scale implementation programmes.

Country	Programme Coordinating Institution
Colombia	Instituto Nacional de Salud
Ghana	Ghana Water and Sewerage Corporation
India	National Environmental Engineering Research Institute
Jamaica	National Water Authority
Kenya	Public Health Department, Ministry of Health
Sudan	Rural Water Corporation
Thailand	Rural Water Supply Division, Ministry of Public Health

Participating countries in the Slow Sand Filtration Project

The Local Demonstration Projects

The local demonstration projects are implemented in selected rural communities ranging from approximately 1.000 - 10.000 inhabitants. Apart from the technical engineering aspects, focusing on the further adaptation of this low cost treatment technology which makes optimal use of local resources, the major components of the projects are:

- the creation of community participation;
- implementation of health education activities;
- special attention for operation and maintenance, including the training and supervision of caretakers and preventive maintenance organization;
- development of local management systems, including a clean division of responsibilities between the agencies and communities;
- detailed monitoring and evaluation.

The follow-up and continued support of the projects, also after the construction phase, is thus sageguarded.

The Organizational Structure at National and Local Level

The planning, implementation and evaluation of the programme are carried out in and by the participating countries themselves. The general responsibility for the programme in each country lies with a Programme Managing Committee in which the various disciplines and agencies involved in the programme are represented. This specifically concerns:

- water supply agencies at national and regional level

- health service agencies at national and regional level (including health education)
- community development agencies at national and regional level
- national research and development institutes in the field of public health and environmental engineering.

The direct responsibility for each of the demonstration projects lies with local coordination committees including representatives of the communities as well as representatives of the executing agencies at local level.

Because of the broad composition of the committees, the various components of the demonstration projects and the organizational requirements can be taken care of in an integrated way.

A major function of the committees is the establishment and/or strengthening of multi-disciplinary collaboration at national and local level, in such a way that liaison is maintained with other sectors like primary health care and integrated rural development. The development of this collaboration and the related organizational institutional infrastructure is a prerequisite for large scale follow-up of the present demonstration programmes.

That is why the country programmes comprise training activities for the stimulation and support of collaboration and coordination between the various executing agencies on the one hand, and between research and development agencies on the other hand.

Aspects relevant to the Decade

Although the demonstration programmes in the participating countries are at present in the implementation phase, it can already be concluded that projects such as the Slow Sand Filtration Project can play a useful, supportive role in the preparation of the coming Decade.

Against the background of the newly emerging policies, the project provides a useful model and test-case for Information and Technology Support Programmes developed and implemented on the basis of the TCDC concept. At the local level the project has created an opportunity to develop, test and evaluate new strategies for the implementation of water supply projects in combination with health education and on the basis of community participation. A rather weak link in the local projects so far has been that sanitation has not always been explicitly included. Some of the participating countries, however, are now planning both excreta and waste disposal systems in conjunction with the new water supplies. In India studies will also be carried out in some of the demonstration villages regarding the use of waste water for fish ponds and agricultural use.

As mentioned before, the broad composition of both the National Programme Managing Committees and the Local Coordination Committees makes an integrated programme planning and implementation possible, while effective links between the agencies and institutes involved at all levels can also be identified and developed. This concerns multisectorial cooperation between the water supply agencies and health service agencies involved in the project, but particularly also the close collaboration between these operating agencies on the one hand and the R & D field on the other. The classical "gap" between research and implementation may be reduced by projects like the slow sand filtration one and the development of a national mechanism for Information and Technology Support be promoted.

A crucial aspect of the project methodology is that the responsibility for programmes lies with the countries and that also the planning and implementation of all research and demonstration activities are carried out in and by the countries themselves. The programmes are not implemented in isolation but they are part and parcel of the national plans for water supply. This is also reflected in the external financial support for the country programmes for the slow sand filtration project, which is no more than 20 to 25 per cent of the overall costs of these programmes. The main function of the IRC is to promote the cooperation and the exchange of information among the participants, as well as between participants and other interested agencies and institutes. In this respect the project has a clear demonstration function. The Programme Managing Committees have already proved to be very useful in focal points for such international cooperation. Given the set-up and methodology, the progress of the slow sand filtration programmes primarily depends on the country action. Apart from financial support mentioned above, support is only given in the field of international coordination and information exchange. This concerns for example the organization of international meetings or bilateral working visits of participants. It also concerns the dissemination of relevant information and the preparation of general project documents and their publication if required.

As a result the progress of the country programmes is different in different countries. This may sometimes hamper an optimal internal collaboration, since TCDC as a process of interaction in fact first presupposes action at the national level. Secondly it requires that this action is at least partly similar and so much in line that a meaningful information exchange and cooperation can be developed.

However, the case of the Slow Sand Filtration Project shows that TCDC is not a simple matter. The development of cooperation both at the international and the national level is a process that takes time and effort, rather than a once-and-for-all recipe.

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discussion

CHAIRMAN: Mr B M U BENNELL, BSc, FICE
Principal Engineering Adviser
Ministry of Overseas Development

Professor L L JONES (Acting Head of the Department of Civil Engineering) welcomed participants to the 5th WEDC Conference and hoped it would be as successful as past Conferences.

2. The CHAIRMAN introduced the first speaker of the first session of the Conference who was Mr Hans van Damme, Manager of the WHO International Reference Centre in the Hague; Mr van Damme would present the paper written by Mr Paul Kerkhoven, as the author was in the Sudan.

3. Mr Hans van DAMME Applying the law of "time schedules" on water supply and sanitation projects: 90% of the work (installation) takes 90% of the time and 10% of the work (maintenance) takes up the other 90% of the time!

4. Mr van DAMME said his main topic was the collaboration needed to reach the goals of the International Drinking Water Decade. The objective was rather difficult and many people had discussed the possibility or impossibility of achieving this objective. As with many things, there would be an equilibrium in this water supply and sanitation decade between the possibilities and wishes. Mr van DAMME went on to say how that reminded him of a story about a missionary in Papua New Guinea, who had set up a very nice plantation there but was getting very worried as he was going to leave to return to his home. He worried about what would happen to his plantation and so he called the people together and told them what to do and when to do it. Then an old Papuan stood up and said, "Yes Padre, but if we worked as hard as you did we would get tired". He sat down and someone else stood up and said, "Yes, and on top of that, Padre, if Papuan people get tired they can get sick". He also sat down and a third man stood up and said, "Yes Padre, and if Papuan people get sick, they can die even with a big plantation". So the moral of that story is that indeed, it is good to spend a lot of effort but there will be an equilibrium and it is not possible to do more than the thing which can be done and we can learn a lot from that.

5. He would talk about four things:-

(a) the situation as it was;

(b) what could be done to implement the recommendations of the Water Conference and what was the best approach if these recommendations were followed;

(c) the need for international collaboration;

(d) the case of IRC's slow sand filtration programme.

6. There were 1 300 million people without water and sanitation. It was said in 1970, it was repeated in 1975, and it would be repeated in 1980, so when would it stop? No-one knew but we did not seem to make much progress. An Indian doctor once told Mr van DAMME that one in four beds in Indian hospitals were occupied by sick people who had drunk polluted water. From the Primary Health Care Conference, two other statistics given were 25 000 deaths per day globally by diarrhoeal diseases and 80% of the

diseases were caused by bad quality water. What were the recommendations made by the Water Conference? Countries would have to set targets and standards, and would have to ensure coordination with other sectors: they would have to adopt policies so that integrated approaches could be taken and people mobilised; they would have to prepare long-term plans; they would have to take care of programmes for health education and they would have to establish training programmes etc. Of course, the Water Conference could not go as far as saying how this all would have to be done! The International Community would have to provide technical assistance and financial assistance.

7. At the Water Conference it was said that research should be promoted. Research was needed in demonstration projects, using low-cost water processes and equipment with an emphasis on the use of local skills and local materials likely to be available in rural communities. Public health education should be promoted as this would have to go with water and sanitation. The exchange of information should be strengthened by expert meetings, clearing house functions and training. Financial contributions should be increased, and there should be cooperation. There should be cooperation in manpower surveys, establishment of manpower programmes, research and promotion of participation of the local people. The things said at the Water Conference were perhaps not really new, but indeed very true.

8. There were, Mr van DAMME continued, a number of contradictions which would have to find their equilibrium somewhere.

(a) How to decide on the short term or long term. In Calcutta where poor people lying about the street without water made one want to help by installing some means of water supply immediately. Again, if one walked through the Sahel and saw people dying through lack of water and the crops and cattle dying, this too made one want to help right away. But there was a need to look at the long term. As the Malaysian proverb says, "If a man is hungry, don't give him a fish, give him a net or he will be hungry again tomorrow".

(b) Construction vis-a-vis the fundamental development, such as availability of manpower, organisation, research institutions etc. It was necessary to have legislation to protect the people and their rights. Perhaps it was better to have a hand pump factory than use imported hand pumps. This led to a new password: "ITS" (Information and Technology Support). There was more information about this in the paper.

(c) The integrated vis-a-vis the sectorial approach. During the last 25 - 30 years there had been a sectorial approach to water supply. Now there should be more of an integrated development, especially in the rural areas. A cooperative programme between NEERI in Nagpur, India and the IRC was an example of integration of water and sanitation. Mr van DAMME promoted slow sand filtration and the Director wondered if it would be a good idea to integrate this with sanitation work. So it was agreed that a slow sand filter would not be put up before all people had their latrines, which they had to build themselves. If all families in the community had latrines, they would then get their slow sand filter subsidised by an outside agency. This worked well. The village leader was involved, a piece of land for the slow sand filter was promised and within a few months the latrines were built and now the sand filter was being built. That perhaps was a low level of integration and some might wonder if the system was good and honest, but it worked. There was of course more to integration if one looked at rural areas - not only water supply and sanitation, but also irrigation and housing. If a man were given a house, a piece of land and a water supply, then he would be happy. If he had a water supply and no house then he would not be happy. Also roads were important, electricity for the pumps and schools which perhaps should come first. Integration was not easy.

(d) The involvement of the community vis-a-vis involvement of the Government. In India there were thousands of villages and of course it would be impossible to train people in such a way that all the water supplies and sanitation works would be maintained by the end of this decade - it was an impossible task as this would need hundreds of thousands of people. So we had to draw on the expertise and goodwill of the people in the communities themselves. He recalled a cooperative in Peru for providing water supply for a village. People could buy themselves in for a small sum and then choose whether they wanted a house connection or use a central standpost. From the money which came in, a caretaker was hired on a continuous basis, and the work was extended. This worked well in one village, but in the next it did not and then again in the next it did and so it went on. Investigations were made and it was found that the people in the villages where it did work were enthusiastic and were involved. There was a Board which one way or another motivated people to really care about the water supply and the extension. The people in the villages had to want the water. If a person did not want water, he would not pay for it. So many times it has happened that the water was supplied by the Government and the people had not really wanted it.

(e) Trial and error vis-a-vis evaluated approaches. How hand pumps were being tested and people published their efforts and wanted to demonstrate things. There had been a lot of trial and error in the past and this contradiction had to be changed.

(f) International cooperation vis-a-vis the isolated approaches by different countries. There was another password "TCDC" described in the paper. TCDC means self reliance for developing countries to solve their own problems collectively in cooperation. It implies strengthening their capacity to analyse the main issues of development in order to formulate their strategies and conduct both international and economic relations with a view to the establishment of a new international economic order. Another thing is to increase the communication so that there is a better awareness among people who are involved. By TCDC it was hoped that the capacity for absorption would increase.

9. Mr van DAMME discussed what the project on slow sand filtration had to do with this. In developing countries slow sand filtration is the most complete single treatment process. Provided there is a water source of a reasonable quality it would produce a bacteriologically safe effluent while various chemical and physical parameters were also improved. It was an appropriate method. Slow sand filtration was in line with a number of criteria, as it was a small scale, low cost, labour intensive, simple in design, construction and operation, maintenance and management. Local resources could be used and it was possible to have the participation of the local people. Finally, it was cheaper than other methods of treatment such as rapid sand filtration.

10. Mr van DAMME said the IRC project on slow sand filtration consisted of three stages. The first was to find out what elements were weak and strong. A number of countries working with the IRC decided which item of research each country would do, cooperating with each other and spending their resources in a very useful and economic way. New design criteria had been put together. Based on project reports, the second phase was now underway. It was a demonstration phase where a number of filters would be built in India, Ghana, Thailand, Columbia and Jamaica. In this demonstration part, Mr van DAMME said there would be the creation of community participation and aspects of health education centred around slow sand filtration. Caretakers were being trained so that when a slow sand filter was finished, there would be someone who could take care of it and ensure smooth running with the backing of the government. There was a considerable exchange of experiences amongst the parties and there was emphasis on non-technical subjects such as training and education.

11. This project was a TCDC subject because it led to self-reliance, the community was involved and as it was a simple system, people were able to run it themselves. There was an awareness in the communities, who were told about the project and were shown pictures. Mr van DAMME had given six equilibriums. The emphasis so far had been very much on the short-term and on construction, on the sectorial approach and on the government responsibility, on trial and error and on isolated approaches. In the future emphasis should be on the long-term, fundamental and integrated development, community responsibility and evaluated approaches. There was need for increased international cooperation.

12. Mr van DAMME ended with a quotation

from the field of computers. IBM said that, "Hardware rots, software remains".

13. The CHAIRMAN thanked Mr van DAMME for an illuminating introduction to Mr Kerkhoven's paper. As an engineer, he felt rather worried about the International Drinking Water and Sanitation Decade and thought the engineer was going to be very much "in the hot seat". Engineers were being held responsible for things which were not their fault. In particular, they were blamed when the pumps broke down. Administrators forget that engineers were provided with no money to buy spares and inadequate staff for operation. The engineer would be blamed when a reservoir silts up but it would be forgotten that the environmentalist and agriculturalist who permitted overgrazing of the catchment. So it was worth examining all the problems surrounding the relatively simple technology associated with drinking water supply and make sure that the chances of failure were minimised.

14. It was also unfortunate that, try as they may, it was impossible to evaluate the correlation between water supply and improvement in health. It made it very difficult in some cases to justify the considerable expenditure which was needed to improve a modest water supply in rural communities. It had been said that there was no direct improvement in health when the water supply was improved because it was not an engineering matter but a social and environmental problem. This in turn led to the question of educating the local people in becoming more health conscious.

15. Mr S D PRADHAN thanked Mr van DAMME for a most interesting paper. He said there were 35 000 villages (1971 census) in Maharashtra State alone and a considerable amount of money was required for maintenance.

16. Mr John PICKFORD asked whether the World Bank provided money for maintenance and operation. Mr Jozsef BUKY said the simple answer to the question was generally no. The World Bank did not have enough money and to finance recurring costs would add fantastic demands to the Bank's resources. Money for the poorer countries could only come from the soft options, which did not come from the Bank's normal sources raised on the international financial markets but from contributions made by the member countries in what was essentially a grant form. Every year the Bank tried to get a higher contribution from member countries. The Bank had a basic philosophy that services provided in water supply and sanitation should be paid for. The whole service should never be entirely free. The recipients should pay for it to the extent of their ability to pay. A target (which was seldom achieved) was that operation and maintenance costs, and possibly depreciation, should be covered by the beneficiaries. There should be a cost recovery at all times because if the services are given free there is wastage, lack of appreciation and, above all, the system could not be replicated. Water supply was not the only section where this problem comes up. For new schools money was needed to hire teachers; for roads money was needed for maintenance. General taxation provided this money. Water supply did lend itself more readily to cost recovery. In the villages it was more difficult but there was not much cost involved in keeping a hand pump working. The Bank does include some funds for a short period to provide spare parts for equipment in their projects, but to give money on a continuous basis to maintain services was out of the reach of the Bank. So without some form of cost recovery to maintain the service, it was just a waste of time putting in the initial finance.

17. Mr J F JACKSON said that Howard Humphreys, when estimating the cost of the project, built in the cost of the spare parts for the whole economic life of the plant, (20 years or so). Spares were part of the project cost considered in the feasibility study, which also discussed the ability of people to pay.

18. The CHAIRMAN asked Mr JACKSON how he ensured that the money was available to pay mechanics and operators. Mr JACKSON replied that the cost of labour was built into the estimated costs.

19. Mr John PICKFORD asked whether such a project estimation could be made for rural water supplies, for example in India. Had estimates of total cost been worked out to see whether the people could carry that cost. Mr PRADHAN said that in India the capital cost was borne to a great extent by the State. The maintenance cost depended on the kind of services provided. Piped water supply with house connection cost about Rs 1500 per person per annum (£14/p.a.) In the case of standpipes it would be £6/p.a. and for a fairly small village it would be £2/p.a. In parts of India there was resistance to the installation of hand pumps. People

did not find them convenient and were going for power pumps.

20. Mr M Z KARIM spoke about the maintenance programme in Bangladesh. Bangladesh had about 450 000 hand-pump tube-wells serving 85 million people. 60% of the people had this water supply within a reasonable distance at a rate of 300 people per well. Although the government was responsible for maintenance, during a recent study by UNICEF, it was found that 40% of the hand-pump tube-wells were being maintained by the people themselves. So they started experimenting in certain areas where the entire responsibility was given to the beneficiaries, the cost of which was £1.50 - £2.00/p.a.

21. Mr van DAMME asked about the 40% of the hand pumps being maintained by the people themselves. By how far did they pay for their water and if they do that, how was it organised? Mr KARIM said that the tube wells in Bangladesh were located in front of the Caretaker's house. Usually the farmers paid for the maintenance costs of the tube wells. In some areas they had tried to set up Unions responsible for maintenance of public pumps. The Chairman of the Union was elected by the people. Whenever something went wrong the caretaker bought spares from the Union's official store and the beneficiaries paid on the basis of their ability to pay. The installation was subsidised. In the past the installation cost was paid by the Government but since 1976 the beneficiaries pay half the installation cost, which was about £15 - £20 for a tube well.

22. Mr KARIM asked whether there was a restriction on operation and maintenance because of cost. Mr C K SIKRI said that during the emergency drought of 1969, only construction of hand pumps was undertaken and maintenance was neglected.

23. Mr Ken ELLIS asked for more information about Stage 1 of the slow sand filter project. What weaknesses and strengths of slow sand filters had come out of this international investigation. Mr ELLIS was particularly interested in the possibility of the early blocking of slow sand filters with excessive algae and with the possibility of the schmutzdecke rising in large sections during hot weather. Mr van DAMME did not have all the details of the project. In some cases a slow sand filter could be used on its own, but in other cases sedimentation was needed prior to the slow sand filtration. Full reports were available from IRC.

24. Mr S CHAUDRHY said the World Bank gave a loan to Lahore Water Authority for rural water supply. Many communities refused to accept a water supply because the World Bank placed restrictions which would increase the cost of water supply.

25. Mr Jozsef BUKY said that in all cases where the World Bank proposed to lend money they examined the financial viability of the project. Their primary purpose in lending was not just to buy a pump or build a water supply or a pipeline. The underlying purpose was that they help to create an entity which would be capable of replicating these exercises and maintaining the operations, so institutional improvement is a very important consideration. In a major municipality or district where a whole cross section of people from the poorest to the richest received water, tariffs must be set to achieve adequate cost recovery. The ultimate target was that people should pay for the marginal cost of water. The analysis should include all the long term operating expenditure. This might be unaffordable to a large section of the population and the next exercise was to set up a tariff structure to cross subsidize from the high consumer to the low consumer, so the people in the lower income categories could pay to the extent of their ability. Mr BUKY said the World Bank considered that something like 5% of the annual income could be paid for water supply. In rural areas the government could pay for puplic standpipes as a subsidy, but the principle of paying for water should be maintained wherever it was at all possible. In the Philippines some communities refused to have a water supply system in the form originally devised. Nobody was prepared to accept the debt service. They had cut the project in half and said that in a few years they would think again. They were told that they were doing a foolish thing and that they would have to pay much more for the scheme that way than if they had gone for the optimum solution at first. When water was provided in a town or city, the people who can afford to pay should not be subsidized. If tariffs were uniform, the people with multiple taps who watered their gardens would pay the same rate as the poor man with a single tap who only used five, six or seven gallons a day. The Bank was trying to devise structures so that the lowest income group paid an absolute minimum

which might be well below the marginal cost of the water, but was subsidized from the higher income consumers.

26. Mr PRADHAN suggested that while it is difficult to provide capital cost for construction of water supply schemes, it is more difficult for the villagers or poor local bodies to bear the maintenance cost. Many local bodies refused to go in for water supply facilities for want of adequate finance. Such towns and villages caused heavy pollution of water courses which gave rise to epidemics of water borne diseases. The Government had then to spend substantial sums in controlling these epidemics. It is therefore desirable to look at water supply and sanitation problems more as preventive measures on the public health side and, therefore, advocate the use of such schemes even though these may not be economically viable in the beginning.

27. Mr BUKY agreed that the minimum requirement for human consumption and basic hygiene should be provided for all and this was the fundamental basic policy of the Bank's water supply programme. If funds were not generated it would not be possible to expand the service. So 40% of the population consume 60% of the water and these are the people who pay for it. Recently he looked at some projects in the Punjab where the financial commitment was to be built up gradually. In the first couple of years the tariff should cover operation, maintenance and depreciation. Two years later they would contribute something like 20% of the capital repayment. In another two years this would rise to 40% and so on. These are relatively high figures for a relatively advanced system. Another simpler system starts at rock bottom, paying only for the basic cost of operation and maintenance.

28. Mr W A GILLINGHAM said he was interested in the collaboration that should exist. Ministries did not seem to cooperate one with another as well as international groups. His firm was involved in a group of boarding schools in Tunisia which were to be provided with water supply and a sewage treatment plant. They were built in areas where there were rural communities who had no water supply and no sanitation except the bush, and tried to encourage the Department of Education on the one hand and the local people on the other to cooperate. The education authority had the ability to maintain the unit but were not allowed to integrate the outside people with the school or to give the services to the local authority and let them take over. There needs to be a great deal more effort in national cooperation so that we do not have this sort of compartmentization - education, social, housing and so on. There should be an integrated community.

29. Mr van DAMME said that the role of the United National Development Programme resident representative would be outstanding in future. That would limit the development of the sectorial approach because the UNDP rep would look at development as a whole. In the Water Decade he would be a focal point together with a national committee in each country in order to make sure that the coordination from the outside world and in the country itself was safeguarded. Hopefully, membership of the national committees would include people from the health and public works ministries and also people from education and community development ministries so that aspect of education training and development as a whole would be integrated with the rural water supply and sanitation sector.

30. Mr GILLINGHAM said they had the situation where a sophisticated and educated student or young person coming to the school knowing all about water supply and how to use the closet went home to a place that had no facility whatsoever - and that seemed to be ridiculous.

31. Mr R MUNGRA said poor countries sacrificed some of their budget to buy arms. He suggested that countries of the world should spend less on arms and devote more of their resources towards community water supplies and sanitation. The CHAIRMAN said he had a point but how would he suggest that the world communities should try and redress the balance. Surely the United Nations through their efforts to promote the water supply and sanitation were doing something to draw attention to the problem.

Mr MUNGRA replied that progress could be increased if more funds were put at the disposal of the people who were in charge of the type of work the World Bank was involved in.

32. The CHAIRMAN said speaking from the experience of the Ministry of Overseas Development it is not lack of finance that was the constraint, but lack of .

projects. There is always money for good projects. Mr MUNGRA said he came from a country where they have several projects but needed funds. The CHAIRMAN believed that the problem in Mauritius was lack of absorbtive capacity. They did not have enough engineers in the water development department for the design and supervision of new works.

33. Mr van DAMME said this matter was discussed at length at the Water Conference and the issue of arms was raised. Where there was not enough absorbtive capacity, the priority was to train people and this had been said for 25 years and still there were not enough people trained. It should become a political issue and then the governments would want to spend their internal money and therefore the external money on water supply. Mr van DAMME was not sure that it would change very much if we spend less on arms; water supply would not necessarily get a higher priority.

34. Mr Len HUTTON said that in Botswana he took a United Nations Resident Representative to check an air pollution problem in a copper nickle smelter. Whilst they were walking around the smelter they were hit by a cloud of 3% sulphur dioxide at about 200°. They were on the point of being unconscious when they were rescued from this situation and the UN Res Rep agreed that they had a problem and their funding improved no end. Mr HUTTON suggested that often experts did not actually see the people who need water. In the planning situation it was not 100 litres a day which would make the difference, but the first ten litres, as the sociological conditions would then improve and people would begin to see that water was the key to healthy living.

35. The CHAIRMAN said it was not the question of providing the first ten litres, but of providing the first ten litres of uncontaminated water. There must be some water supply there or the village or house would not exist, and it was trying to convince people that it was worth paying for purified water that was the difficulty. Mr HUTTON said there was, to a certain extent, a built-in resistance to disease. He agreed that we should provide good quality water, but thought we had to be careful about the standards. The WHO standards were recommendations to aim for. He thought that we should try to look for bacteria-free water rather than worry too much about the quality in the other respects.

36. Mr van DAMME said that on the one hand there was the WHO standard and on the other hand 80% of the world population were suffering from disease because of drinking bad water. The World Health Organisation was developing new ways, but also emphasised the need to be practical in applying standards. People became to realise worldwide that it was better to have a little bit better water than almost ideal water for a few.

37. Mr M SANE suggested that this situation with regard to rural areas would not change in any of the developing countries until the drift from the country to urban communities was stopped by the redevelopment of the rural areas, so that people would become more interested in staying where they were and looking after their own environment. As was expressed at Buenos Aires, the drift from the country to urban areas, particularly in the developing countries, was such that by the year 2000 the infrastructure required to serve the urban areas would need to be expanded something like threefold. It is not surprising, therefore, that countries with limited resources give priority to the urban areas at the expense of the rural communities. Surely the development of rural communities to be self-sufficient in terms of work and housing would be preferable to saying, "Here's ten litres of pure water". Let us give them a reason for staying in their rural environment and developing their own communities, and thereby not only improve their own situation, but also relieve the pressures on the cities.

38. Mr PRADHAN asked whether Mr van Damme thought there was a fair chance of providing clean water and adequate sanitation for all by 1990. Mr van DAMME said it was not going to be easy and in many cases it was not going to be possible. First of all this slogan, "All people - water and sanitation by 1990" was a goal and goals, by definition, were not reached, but strived for. If we worked very hard and got in 1981-90 real interest in water supply and sanitation and reach only 50% of the target and the other 50% by the year 2000, we should be pretty happy. The World Bank and other agencies were collectively working on preparation for the Decade and there had been assessments in 100 countries. The first step was to see what the problem was. Identification

missions were going to many countries and then projects would be developed with the governments. By 1981 it was expected that in many countries at least there would have been an assessment of the situation and plans ready to start with the work.

39. The CHAIRMAN drew the discussion to a close saying that this debate could go on for a very long time but the programme was such that this was not possible. He thanked Mr van DAMME for presenting the paper for his colleague and for the replies he had given to all the questions.

SERGIO R MENDONCA

waste stabilization ponds in Paraiba state, Brazil

INTRODUCTION

Brazil, because of its rapidly increasing population and industrial expansion, is one of the leaders among the developing countries. On the other hand, for its territorial extent, climate, diversity, regional resources and customs, it is a country where the problems reach great proportions.

The Brazilian provision of water supply and sewerage facilities situation by the end of 1960, was not favourable. Data from the Brazilian Institute of Geography and Statistics (IBGE) and the National Housing Bank (BNH) showed a challenging situation (Table 1). This condition should be moved at a reasonable time reaching rates of population served by basic sanitation facilities comparable to those of developed countries.

THE NATIONAL SANITATION PLAN (PLANASA)

In 1971, the Federal Government of Brazil initiated the National Sanitation Plan (PLANASA). This programme was designed to supply treated water to 80% and conventional sewerage facilities to at least 50% of the urban population by 1980. The PLANASA scheme provides finance for specific public health engineering works in accordance with national and regional programmes prepared by the state basic sanitation companies.

An important part of the duty of each state company is to study the water resources of its state and to ensure that all towns within the state should be equally served even though this might mean that the larger towns subsidised the smaller ones.

The money required to implement PLANASA is derived from two sources: loans from the National Housing Bank (BNH) and an investment by the state of 5% of its local taxation revenue (Water and Sewage Fund - FAEs). Normally, 50% of any capital investment would come from BNH and 50% from

FAEs. However, in those states unable to provide their half share, BNH is able to provide additional loans or the Federal Government may make a direct grant.

In order for each Water and Sewage State Company to be able to repay its loan to BNH and to maintain the liquidity of its FAE, it has to make as economic a charge as possible for the services it supplies within the ability of its public to pay. These charges are related to the official minimum salary payable to all workers, as follows:-

- water: 5% of minimum salary;
- sewage: 80 - 100% of water charges.

The basic water charge is for a hygienic minimum of 10 - 20 m^3 per dwelling per month with quantities above this amount charged for at the appropriate rate to the consumption.

TABLE 1

PROVISION OF WATER SUPPLY AND SEWERAGE FACILITIES IN URBAN AREAS IN PARAÍBA-BRAZIL (DATA FROM CAGEPA)

ITEM	PERCENTAGE OF URBAN POPULATION SERVED BY BASIC SANITATION FACILITIES			
WATER SUPPLY	1966 (state data)	1971 (state data)	1977 (state data)	1980 (estimate)
Piped supply to dwelling	47	61	72	88
Well or spring	29	25	19	9
Other	24	14	9	3
SEWERAGE				
Piped network	25	25	41	52
Septic tank	23	29	32	48
Ditch or similar	32	33	18	0
No provision	20	13	9	0
Total population of Paraíba x 10^6	1.6	1.9	2.4	2.7
Urban population x 10^6	0.8	1.0	1.3	1.7
% TOTAL	50	53	57	63

PARAÍBA - BASIC DATA

Paraíba State which covers an area of 56 372 km^2, is one of the most densely populated states in the Northeast, with some 2.5 million inhabitants spread over several physically and economically distinct regions.

The most important economic activity of the region is farming and cattle raising. The state of Paraiba is Brazil's second largest producer of sisal and the second largest grower of cotton in the Northeast. Additionally, Paraíba is the largest producer of pineapple in Brazil and produces sugar cane, tobacco, corn and rice. Its cattle raising activity is well developed due to cultivation of palm fodder.

The major concentration of industrial enterprises is in Campina Grande. Joao Pessoa, the capital, with cement factories, and Rio Tinto, with processing of farm produce plants and textile mills, are also important industrial centres. Sisal, cotton, pineapples and hides are among the principal exportable products.

In Paraiba there are 171 municipalities. Water supply works started five years before PLANASA, and in 1972 the construction of new sewerage facilities was initiated.

Table 1 shows the basic sanitation data in Paraiba State from 1966 to 1977 and the forecast for 1980. Comparing it with Table 2 (basic sanitation in Brazil) we see that this State has achieved higher levels in water supply and sewerage facilities. Its goals for 1980 are even more ambitious.

TABLE 2

PROVISION OF WATER SUPPLY AND SEWERAGE FACILITIES IN URBAN AREAS IN BRAZIL

ITEM	PERCENTAGE OF URBAN POPULATION SERVED BY BASIC SANITATION FACILITIES		
WATER SUPPLY	1960 (census data)	1970 (census data)	1980 (estimate)
Piped supply to dwelling	42	55	80
Well or spring	29	24	20
Other	29	21	0
SEWERAGE			
Piped network	28	30	50
Septic Tank	21	15	50
Ditch or similar	30	41	0
No provision	21	14	0
Total Brazilian Population x 10^6	70	93	120
Urban Population x 10^6	32	53	80
% TOTAL	46	57	67

TABLE 3

TYPES OF PONDS CONSTRUCTED IN PARAIBA-BRAZIL (DATA FROM CAGEPA)

CITY	Type of Treatment	Area (ha)	Cost ₢ 1000	Date
JOAO PESSOA	Primary Sedimentation Tank	-	-	1976
CAMPINA GRANDE	Aerated Lagoon	2 x 1.95	2 090	Aug/75-Oct/76
SAPE	Facultative Pond	2.6	1 250	Aug/75-Feb/76
PATOS	Aerated Lagoon	2 x 1.5	435	May-Sept/74
SOUZA	Facultative Pond	5,4	736	Apr-Aug/76
CAJAZEIRAS	Facultative Pond	5.4	1 022	May-Sep/76
SANTA RITA	Anaerobic + Facultative	-	482	1978
BAYEUX	Discharges directly in Joao Pessoa Treat	-	-	1977
ITAPORANGA	Facultative Pond	-	353	1974
ALAGOA GRANDE	Facultative Pond	-	780	1977

All the sewage treatment works in Paraiba are for domestic sewage, although water quality standards are being established there for both coastal areas and inland rivers. The major states in Brazil have already established their own standards.

It is very difficult to compare regions in Brazil because of its enormous area. The Northeast of Brazil is a tropical region and its climate is ideal for the use of sewage treatment works such as waste stabilization ponds, aerated lagoons and oxidation ditches. Due to the high ambient temperatures it is possible to minimize both costs and maintenance requirements.

In Brazil there is more than sufficient land available. Therefore, waste stabilization ponds should always be the first method adopted for sewage treatment in hot climates. The principal reasons are: a) low cost; b) extreme simplicity of operation and maintenance; c) superior removal of faecal bacteria and d) protein production in the form of algae, fish, ducks and crops.

Aerated lagoons and oxidation ditches are usually reserved for use in large cities whereas ponds are suitable for all community sizes, from rural and urban towns to the largest of cities.

WATER POLLUTION CONTROL SITUATION AND GOALS

Originally there were only two sewage treatment works in Paraiba. Both Joao Pessoa, the Capital, and Campina Grande, the second most important city in this state had only primary treatment for their sewage works.

The primary treatment for Joao Pessoa, consists only in a primary sedimentation tank divided in two equal parts for domestic sewage decantation. This tank was built near the Sanhaua river and its operation is due to the flux and reflux of the tide. While one is empty the other is full of sewage. The retention time is about six hours. The new design provided two more tanks. The forecast population is up to 1990. Due to the tank shape, it will be possible in the future to increase the efficiency of each tank, at least twice, without modifying its civil construction. It will be supplied by mechanical aeration through the installation of horizontal cage rotors placed across each tank (channel). They will be adapted to oxidation ditches.

The former sewage treatment for Campina Grande was a primary treatment which consisted of screening, grit-chamber, primary sedimentation tank and digestor. It was adapted to be used for research as an experimental station under the supervision of the University of Paraiba. Nowadays, sewage is taken from the new interceptor and metered into the following reactors:-

- 4 independent facultative stabilization ponds;
- 5 ponds connected in series (one anaerobic, two facultative and three maturation ponds);
- 2 anaerobic ponds, each discharging into a facultative pond, with facility for recirculating the facultative pond effluent;
- 1 high rate pond.

These facilities have been in operation since February 1977 and are intended to be expanded to cover aerated lagoons, oxidation ditches, upflow filters (for septic tank effluent), bio-filtration and activated sludge including the ANOX process for nutrient removal.

A new laboratory block has been constructed where sophisticated waste water analysis equipment such as an atomic absorption spectrophotometer, a complete gas chromatograph and a visible and UV light spectrophotometer were installed. Watson-Marlow variable speed peristatic pumps are used to meter the influent into each pond.

The new sewage treatment plant designed for Campina Grande was a system of aerated lagoons, with two cells. In each cell there are 12 aerators. At the present time all of them are out of work and the two cells are working as facultative pond because of the weakness of the sewage.

In order to create adequate conditions for research in the state, many different kinds of ponds were designed. In Brazil there is an acute shortage of local design parameters for certain treatment processes, e.g. waste stabilization ponds. The types of treatment used in the eight biggest cities in Paraiba are listed in Table 3. Types of pond in use are:

- facultative ponds
- aerated lagoons
- 1 anaerobic + 1 facultative + 1 maturation pond.

DISCUSSION

Table 1 shows a tendency of a continuous increase in the urban population in Brazil. In 1978 it comprises over 60% of the total population, and the forecast for 1980 is about 67%. Therefore, at the starting of the national programmes held and sponsored by the National Housing Bank (BNH), all their targets and goals were directed to urban populations.

Last year the first programme for small and rural communities was initiated. By 1980, 80% of the urban and rural population will be supplied with treated water and 50% of them will be served by sewerage facilities.

CONCLUSION

The incidence of water-borne diseases such as typhoid fever, dysentry and other internal disturbances caused by pathogenic micro-organisms, has suddenly dropped after the implement of PLANASA.

Life-expectancy is gradually increasing, ranging from 52 years in the poor regions to 68 years in the more prosperous ones.

Within a few years Brazil is expected to reach a good level of basic sanitation all over its territory.

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discussion

CHAIRMAN: Mr B M U BENNELL

Mr SERGIO MENDONCA said that Brazil was a very big country with a population of about 150 million inhabitants and an area of about 8 500 000 square kms. The goal for 1980 was to provide water supply for 80% of the urban population and 50% sanitation. In 1940 the urban population of Brazil was about 40% and by 1980 it would be almost 70% of the total. So their main goals were to provide water supply and sanitation for the urban population first.

2. His small state Paraiba State was in the north west of Brazil. Paraiba had a tropical semi-arid climate. It is very dry and very poor, the poorest region in Brazil. In the last ten years many things have been done in sanitation in Brazil. In 1971 the Federal Government of Brazil initiated the National Sanitation Plan, PLANASA, which included water supply and sanitation. This programme was designed to supply water for 80% of population, but now they had more ambitious goals. They intend to provide piped water for 88% and sanitation for all of the urban population. In 1970 74% of the probable population to be supplied with water by 1980 was already connected. For sanitation at that same date the systems already constructed or under construction represented 54% of the probable population to be served by 1980. Paraiba State was more ambitious than Brazil as a whole, even though it was a very poor state. Future expenditure on water supply would be about 1 billion dollars for the next two years and about 700 million dollars for sanitation.

3. In the rural areas a programme was initiated in 1978 because their main purpose was to supply water for the urban population first. About 28 million dollars had been allocated for capital expenditure.

4. The ponds listed in Table 3 had been constructed in the State. All kinds of stabilization ponds were built because they could do some research later on. Mr MENDONCA showed photographs of some of the ponds. Two were of the ponds at Souza and Cajazeiras. Although they had the same area the prices were different, because the Cajazeiras pond was constructed on rocks. It had a strange shape to avoid the rocks, as it was impossible to give it the normal rectangular shape.

5. All the treatment plants were designed five years ago and when they began to construct the ponds, they had many problems because the population growth rate was 3% per year. Some areas were expected to have a lot of people but there were a lot of people there. So they have had to adapt for the new situation. When they had finished construction of the ponds, they noticed that all of them were oversized because all the mechanical parts were imported. All the stabilization ponds were constructed for twenty years, but Mr MENDONCA thought they would last for at least 40 years. This was good because they would not invest any more for the second stage; they could not afford any more.

6. Mr R WILSON asked whether providing urban water supply before rural created more problems by attracting people from the rural areas into the urban areas. Mr MENDONCA agreed but it was a problem for the government. In a very big country the population should be spread

around the country. In Brazil small cities were bing developed.

7. Mr S CHAUDHRY asked what problems and difficulties had arisen during the operation of the oxidation ponds? Mr MENDONCA said the main problem in the construction of the oxidation ponds was the alienation of the land. Although there was plenty of land available the owners knew that the government was in a hurry to construct those ponds, so they would not agree on a price. Because it could create political problems, the government had to pay more for the land than the normal price. Mr MENDONCA could not comment about the operation because the ponds had only just been completed.

8. In reply to questions from Mr PRADHAN, Mr MENDONCA said the state goal was to provide sewers for at least 50% of the urban population by 1980, they started with cities having at least 20 000 inhabitants. All the water and sewerage companies in Brazil were state companies. Although there were few industries in his State, there was considerable pollution because of the sugar cane. This was grown on small farms but all of them together constituted a high pollution load. Water was required for irrigation, and all demands for water were considered at the same time as a whole.

9. In reply to a question from Mr J C YADAV Mr MENDONCA said the treatment he had described was for domestic sewage and the BOD concentration was taken as 300 mg/l or about 54 grams per person per day. Industries had to treat their wastewater separately and were obliged to have their own treatment plants. Another problem was that in Brazil the rivers had low flow and sometimes were completely dry, especially in summer.

10. There were no criteria for selection of the type of pond other than that every type of system should be constructed so they could be used for research in the near future. All were oversize and, for example, one aerated lagoon system for the bigger city had two cells, with twelve aerators in each cell. It was designed to use at least half of the aerators, but they had found that they did not need to use any because the sewage was so weak that they are not necessary. They were working as facultative ponds instead of aerated lagoons.

11. Mr P P C M LAURIJSSENS asked if effluent was used for any agricultural purpose and whether fish were stocked in the maturation ponds. Mr MENDONCA replied that they recharge the effluents to the rivers and they do not use it for anything else.

12. Mr Daza SIERRA said that in Colombia, adequate education of the people was needed to encourage motivation towards sanitation programmes. Could Mr MENDONCA tell of Brazilian experience in this field? Mr MENDONCA said it was very important to educate the people because without it they would not make use of the system. For example in one of the cities, two treatment plants were planned and they were told by the local people that one was not necessary because the sewage could be discharged directly into the river. Many people living near the river did not want to pay for the sewerage. In one of the cities the people criticised the government for buying vitrified clay pipes instead of black plastic pipes for the sewerage. The President asked Mr MENDONCA to go there and explain that the vitrified clay pipe was better than the plastic pipe. He had explained that vitrified clay pipes had been in use since the Romans and were still being used today and in Rio de Janeiro there was trouble with plastic pipes which had been attacked by protozoa.

13. Mr GILLINGHAM was puzzled because PLANASA had gone into a built-in project for experiment across the State. He thought there was enough experience about what type of sewage treatment plant to choose out of the many. He could understand them building pilot plants but to actually build a full-scale model on an experimental basis seemed very puzzling. Mr MENDONCA said that at the University there was plenty of research and there were pilot plants. But they were in a hurry and he now doubted whether it was a good thing as a lot of money had been wasted.

14. Dr B M El HASSAN asked if there were any insects and flies in the lagoons. Mr MENDONCA said they were just starting to operate and he had not heard anything about the flies yet, but there were big problems with mosquitoes.

15. Mr M Z KARIM asked what was the experience in motivating the people of the urban slums to have this water supply and sewage. Mr MENDONCA said that in the big cities there was no problem for motivating the people, because everyone was anxious to have connections. Although

some people were illiterate they were proud to have a connection, and thought it was raising the level of their lives.

16. Mr F S KUMWENDA said the programme only dealt with domestic sewage. What was the government trying to do for the industrialist? Mr MENDONCA said that in his State there was little need to treat industrial wastewater. In the south of Brazil, which was the most developed part, most of the industries had their own treatment plants and the effluent standard was very rigid.

17. Mr A JOSEPH quoted from the paper ... "Therefore waste stabilization ponds should always be the first method adopted for sewage treatment in hot climates". What evidence was there for this statement? Mr MENDONCA said the stabilization ponds were very simple and in aerated lagoons the aerators were simple to use. He in turn quoted from the Conference paper by the WEDC Group......"stabilization ponds must remain the obvious first choice for wastewater treatment"..... Sometimes a sophisticated treatment plant has no skilled operator so the efficiency becomes lower than for example primary sedimentation alone. There were plenty of papers about the cost of stabilization ponds for example in India.

18. Mr Jozsef BUKY said that one of Mr Mendonca's conclusions was that the incidence of water-borne diseases dropped suddenly after the implementation of PLANASA in 1971. Were there any figures to support this? Mr MENDONCA said that there were no reliable figures but they were sure that the incidence of water-borne disease had decreased. He added that it was easy to construct everything if you have money but the problem was not to construct, but to maintain. The only way to do that is to have adequate water rates and in Brazil the change for the minimum quantity of water was 5% of the minimum salary, and for sewerage it was between 80-100% of the water charge. The basic water supply for hygiene was between 10-20 cu.metres per person per month.

19. Mr Ken ELLIS said it was well recognised that one of the dangers of stabilization ponds was the possible development of mosquitoes in the water. Did the design of the maturation ponds take into account the control of weeds? In the paper there was mention of fish for the production of protein. Fish were also used in many parts of the world for controlling the growth of weeds. Were there plans to use fish for this purpose and if so what specific varieties of fish would be used in maturation ponds? One final question was whether a minimum distance between the nearest habitation and the stabilization pond had been set.

20. Mr MENDONCA said that for protection against the mosquitoes and flies the banks of the oxidation pond were protected with asphalt covers to prevent the growth of plants. He thought the government had plans for using fish and the designers were worried about the smell they could produce and the problems they could create if they were not located adequately.

21. Mr M SANE asked what volume per person per day was provided in the water supply scheme. What percentage of this was allowed for losses in the water distribution system? Secondly, in designing stabilization ponds, did they use published criteria or did they develop their own criteria and if so, did their design vary very much from the published criteria for stabilization ponds?

22. Mr MENDONCA said that in their water supply design they allowed for losses between the source and the treatment plant of about 20%, and between the reservoir and the water supply about 50% In his State the design figure for the bigger cities was 200 litres per person per day. The oxidation ponds were designed five years ago when they had not started their research. They were trying to finish within two years and would prepare their own criteria which would be published.

23. In reply to a question from Mr CHAUDHRY, Mr MENDONCA said that all the water they provided was treated. For the small towns they only use groundwater supply if possible, so save money on chemicals. For the bigger cities they have to construct sophisticated treatment plants where they spend more on chemicals. They use standards similar to the AWWA and World Health Organization standards.

24. The CHAIRMAN was sure everyone would wish him to thank Mr MENDONCA for the capable way he had answered the questions we had fired at him and for his brilliant command of the English language.

R R BANNERMAN

regional water supply in Ghana

The planning and execution of a regional water supply project for northern Ghana

INTRODUCTION

As part of Ghana's Upper Region Water Supply Project which commenced in November 1973, a regional rural water supplies development programme was implemented. The Project was jointly financed by the Government of Canada through a loan administered by the Canadian International Development Agency (CIDA) and funds provided by the Government of Ghana. The loan was to be used by Ghana for the purchase of services, materials and equipment not available in Ghana that was required to carry out the Project. Additional financial contribution was made by Canada, under her Commonwealth Africa Assistance Programme, to cover engineering, advisory and other services, and equipment and material requirements for the expansion of the Project.

The participants are the Ghana Water and Sewerage Corporation (GWSC) which is the executing agency for the Government of Ghana and the Canadian International Development Agency (CIDA) which contracted the services of a Canadian engineering consulting firm to act as project managers and advisers in the implementation of the project. The cost of services of the Consultant was borne by the Government of Canada through a technical assistance grant.

The objectives of the Project are to:

- construct hand pump wells in the rural areas.
- construct wells for mechanization in specific intermediate size towns.
- rehabilitate some 250 existing wells, in 130 rural communities.
- establish well maintenance facilities and procedures in five district centres and a base centre at Bolgatanga.
- provide training for GWSC staff in all aspects of ground water development and equipment maintenance.

The project area encompasses 11 000 square miles which includes the entire Upper Region of Ghana (figure 1). The physical characteristics of the region are typical of that portion of the pre-Cambrian shield of West Africa lying between the Sahel sub-region to the north and the rain forest to the south. The tropical climate and contrasting long dry and short rainy seasons combined with the geological environment have resulted in a modest groundwater resource.

Figure 1

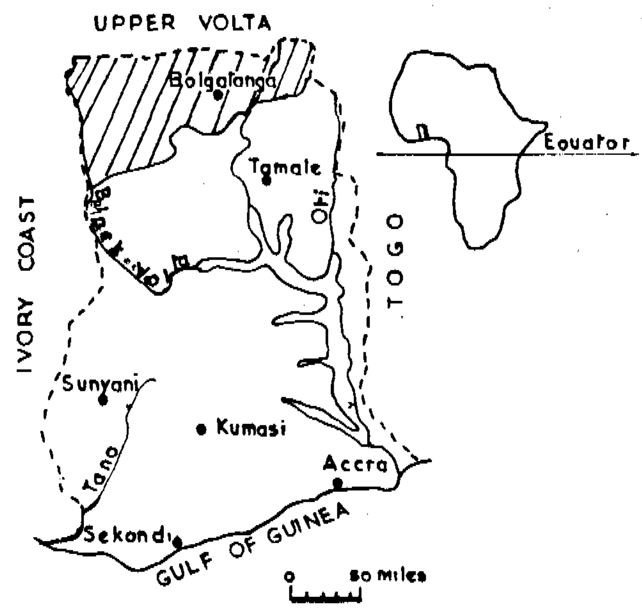


FIG. 1 LOCATION MAP OF GHANA

— PROJECT AREA

It was established that the water supply needs of the rural population of the Upper Region could be satisfied by the installation of 2300 new hand pump wells. Rural population in some 33 communities were scheduled to be satisfied by construction of wells suitable for mechanisation wherever sufficient groundwater supplies were identified.

The first phase of the programme was completed in February 1977 by which time 1430 hand pump wells had been installed in over 800 villages throughout the Upper Region. Sixty wells suitable for mechanisation were constructed in six intermediate size towns. In addition some 250 existing wells fitted with hand pumps which were not functional were rehabilitated.

A well maintenance programme was conceived and implemented to assist the long-established GWSC Regional Maintenance Organisation expand its capability to provide long term repair and service for the new water supplies provided by the Project.

District Maintenance Workshops and facilities were established. Ghanaian staff were trained in the repair and maintenance of hand pumps, mechanised water supply systems and other equipment provided on the Project.

The second phase of the Project which is a continuation of the programme commenced in February 1977 and is scheduled for completion at the end of 1979. An additional thousand wells are being installed. Expansion and improvement of routine water supply maintenance to accommodate the additional wells are being carried out.

Comprehensive training has been provided in all aspects of groundwater supply planning, exploration and development, including hydrogeological investigations, well drilling, pump testing, well maintenance and equipment repair and maintenance. Technical and managerial skills of GWSC personnel have been upgraded, so that they have the expertise necessary to utilize the equipment provided by the Project on a continuing basis to develop the much needed groundwater supplies throughout Ghana.

PROJECT MANAGEMENT AND CONSULTANCY SERVICES

The services of a Consultant were provided to the Project under Canadian technical assistance grant. Five Canadian engineering consulting firms, who had been pre-qualified by CIDA, and approved by GWSC, were invited to Ghana, to familiarise themselves with local conditions prior to submission of proposals. Selection of the consultant was made by CIDA and an agreement was signed between CIDA and the consultant which spelt out the consultant's responsibilities and relationship to GWSC.

The Consultant provided technical, advisory and training services to the GWSC to assist them in meeting the overall objectives of the Project. They provided key personnel - comprising a Project Director based in Canada and on-site project manager, drilling superintendent, drillers, hydrogeologists, mechanical superintendent and well maintenance superintendent - who worked with a Ghanaian counterpart manager and other staff appointed by GWSC. The curriculum vitae of all the Consultant's personnel was submitted to GWSC and CIDA for approval to ensure that only personnel with expertise were engaged. Schedules of the various activities including the frequency of joint evaluation of progress were also submitted.

The Consultant was responsible for all aspects of the Project in the first phase, with the Ghanaian staff assuming increasing responsibility. However, as scheduled the Ghanaians who had been trained in the first phase staffed all line management positions for the second phase and took full responsibility for the technical and managerial aspects of the Project with limited Consultant participation.

A joint plan of operation was prepared by the Consultant in conjunction with GWSC which outlined the ways and means to be used to carry out the various elements of the Project.

The Consultant was also appointed as purchasing agent on behalf of GWSC for the procurement and expediting of imported materials and equipment required by the Project and associated Water Supply Maintenance Programme. Purchasing procedures were set up by CIDA and GWSC.

Other responsibilities of the Consultant were to conduct technical studies such as design of well pads and aspects of well and aquifer contamination and to prepare reports on project evaluation through monthly, quarterly and annual reviews of Project activities.

PLANNING CONSIDERATIONS

Population distribution

The total population of the Upper Region is approximately 862 000 and over 90% of this is described as rural, that is living in communities with population less than 5000. The density of the population varies considerably across the Region. The east side is heavily populated; the middle portion lightly populated and the west side moderately. The majority of this rural population is located on individual family-compound farms and in small communities with populations of a few hundred to about 15000.

Rural water supply policy

The distribution of the population is such that pipe-borne water supply facilities are not appropriate to serve the majority of them. It is the rural water supply planning policy, that such scattered rural populations be best served with wells equipped with hand pumps, where each hand pump is to serve a population of 300 to 350 people.

For communities having population of 1500 or more it is the policy to provide pipe-borne water systems. In order to take advantage of the drilling activities in the Region, 60 wells suitable for mechanisation would be constructed in 33 communities. Mechanisation of these wells is, however, excluded from the present Project. Each of the wells would be fitted with a hand pump in the interim. The total population to benefit from this added programme is approximately 64 000.

Before the start of the Project only 30 000 of the rural population were served with pipe-borne supplies; another 60 000 living in 130 small communities had access to adequate supply of potable water for drinking, personal hygiene and other domestic purposes through 250 wells equipped by hand pumps. The rest of the population totalling 772 000 were dependent upon dug-wells, dugouts, small dams, ponds, rivers and other unreliable sources. Based on one well for each 300 people the foregoing population would require a total of 2573 installations. Since the availability of groundwater was not certain in all areas of the Upper Region, provision was made for only 2300 hand pump installations.

Allocation of wells

Consultation was held among various organisations - Project Management, Consultant and the Department of Health, Regional Administration, to establish criteria and guide-lines for the equitable distribution of the wells. The Departments of Rural Development and Social Welfare, the Ghana Highway Authority and the Regional Planning Committee were consulted on accessible roads and routes to the numerous sites during the various seasons.

A strategy for the construction of the wells proposed by the Consultant was reviewed in terms of local (intra-regional) politics. It was decided that the most rational allocation of wells across the region was to base it on population distribution.

The Region was divided into 13 Districts and the rural population in each district was determined. Table 1 shows the relationship between population and wells allocated to each district. A system of priorities showing areas of priority considering water borne diseases, drought and other needs was prepared.

TABLE 1 - UPPER REGION WATER SUPPLY PROJECT SUMMARY OF HAND PUMP WELLS

MAINTENANCE DISTRICT	AREA	RURAL POPULATION (1970 Census)		NO OF WELLS				TOTAL WELLS BY 1980
		Total	Percent of Region	Pre-Project	Phase 1	Phase 2	Total	Percent of Region
BAWKU	Bawku	53 000	7	7	135	45	187	7½
	Garu	61 700	8	11	216	1	228	9½
	Pusiga	38 600	5	6	116	0	122	5
	Zebilla	44 700	6	10	90	65	165	6½
	Northern Region Phase 1	-	-	-	4	-	4	-
	District Totals	198 000	26	34	561	111	706	28½
BOLGATANGA	Bolgatanga	153 000	20	29	282	173	484	19
	Chiana-Paga	50 900	7	28	83	35	146	5½
	Navrongo	38 600	5	9	56	31	96	4
	Sandema	50 100	6	15	61	92	168	6½
	District Totals	293 100	38	81	482	331	894	35
TUMU	Tumu Total	38 000	5	21	64	56	141	5½
LAWRA	Lawra-Jirapa	68 000	9	26	80	89	195	7½
	Nandom-Lambussie	41 800	5	12	62	79	153	6
	District Total	109 800	14	38	142	168	348	13½
WA	Nadawli-Funsi	63 900	8	12	68	115	195	7½
	Wa	68 700	9	14	91	155	260	10
	District Total	132 600	17	26	159	270	455	17½
	REGION TOTALS	772 000	100	200	1408	936	2544	100%

Topographic maps of 1:30 000 were available for the entire Region. There was also complete coverage with aerial photographs at the same scale. Geological maps at a scale of 1:125 000 were available for the portion of the Region east of Tumu; but for the west side, the geological maps were at a scale of 1:1 000 000. These maps were found invaluable in the location of the communities, the determination of access and the siting of the wells.

A well numbering system was designed and used to identify well drilled by the Project. Pre-project wells were incorporated into the new system.

Lists of all communities that were to benefit from the programme were prepared and approved by the Regional Administration. Their locations were plotted on district maps, which were in turn discussed with the various District Councils for final approval.

The allocation of the proposed wells to a community was based on the following considerations:-

(a) The total number of wells to be drilled or rehabilitated is 2575 (about one for every 300 people in rural areas).

(b) Rural population not served by pipe-borne water should be provided with a hand-pump well within a half mile walking distance.

(c) Each hand-pump well should serve a maximum of 500 people and a minimum of 150 people.

The population figures for the 1970 census were used. For centres not shown on the census lists, population was estimated by referring to number and location of compounds shown on air photos.

Actual field location of proposed wells, of course, varied from siting shown on the planning maps due to:-

(a) Availability of groundwater.

(b) Access problems for rigs.

(c) Field assessment showed different distribution of population.

WELL CONSTRUCTION PROGRAMME

Staffing and organisation

The well construction programme encompassed drilling rig and service rig operations, plus workshop, hydrogeological, electrical and transport services. An organisation of the operational responsibilities was set up for each category. Some equipment and manpower were on site in March 1974; however, the full complement of equipment was assembled in January 1975 and the well construction activity was underway by March 1975.

Briefly the well-drilling equipment consisted of three drilling units each composed of a drilling rig, a water truck, and a truck-mounted air compressor. Support equipment included two service rigs, a mobile drilling camp, camp generator set a prefabricated base workshop, workshop tooling, radio communication equipment, (a fleet of pick-up trucks, a dump truck, fuel truck, transport trucks).

Initially, the drilling operation was under the Consultant's management and supervision with six Consultant's drillers operating the drill and service rigs in the field and Ghanaian crews assisted. However, as time went on GWSC staff acquired progressively higher levels of technical and managerials skills and assumed more responsibility.

By the beginning of the second phase, a full complement of over 190 trained and experienced GWSC staff of various categories were available to carry out the operations. The number of Consultant staff was thus reduced to four with only two of these directly involved in the field drilling operation, the rest providing support services as advisers.

Schedule of operations and well production rates

It was scheduled that the construction of the 2300 wells should be carried out in two phases with installation of 1200 wells in the first phase.

The phasing had a considerable merit, in providing an initial few wells in each community with the intention of returning as part of the second stage operation, to install the remaining wells. The advantages of this were that by the end of the first phase, about one-half of the population spread across the region would have access to some of the well supplies rather than leaving one-half of the region untouched and that areas which would otherwise have had to wait up to five years for the installation of their wells, were partially served by end of the second year.

It was also possible to establish maximum efficiencies and rates of production in the first phase, so that in organising the second stage considerable advantage was taken of the experience gained. Actually the second phase operation proved to be more efficient, because of a better understanding of the hydrogeological conditions.

Taking into account the time which was lost throughout the early stages of the rainy season, the actual shut-down for the peak rains in August-September, the poor production rates during the heat of the day for the two driest months March-April plus normal breakdowns and annual maintenance, about 280 working days were realised each year.

The first 12 months of the programme was allowed core drilling equipment selection, tendering, delivery, transport and initial mobilization, break-in period and training. The number of wells completed by the end of the first, second, third, fourth years of drilling were 508, 1208, 1650, 2006 respectively. (Figure 2 shows the monthly well construction totals). Figure 3 shows the locations of all wells drilled in the Regions.

The actual drilling programme would be completed within 54 months.

Field Operations

The main base of the drilling operation was at Bolgatanga, the Project Headquarters where permanent staff accommodation was provided. Field drilling operations moved across the Region on a planned sequence working from a mobile camp set at 9 locations. All drillers, drill crews and other supporting staff were housed at the camp in mobile trailers. Depending upon the access roads and topographic conditions, the drilling operation worked within 20-30 radius of the work camp (Figure 4).

Areas of easy access for work were reserved for the beginning and end of the rainy seasons (June through September). This allowed for field operations in all months except August and September which were used for annual leave and equipment overhaul.

GHANA UPPER REGION WATER SUPPLY PROJECT HAND PUMP WELLS & MECHANIZED WELLS

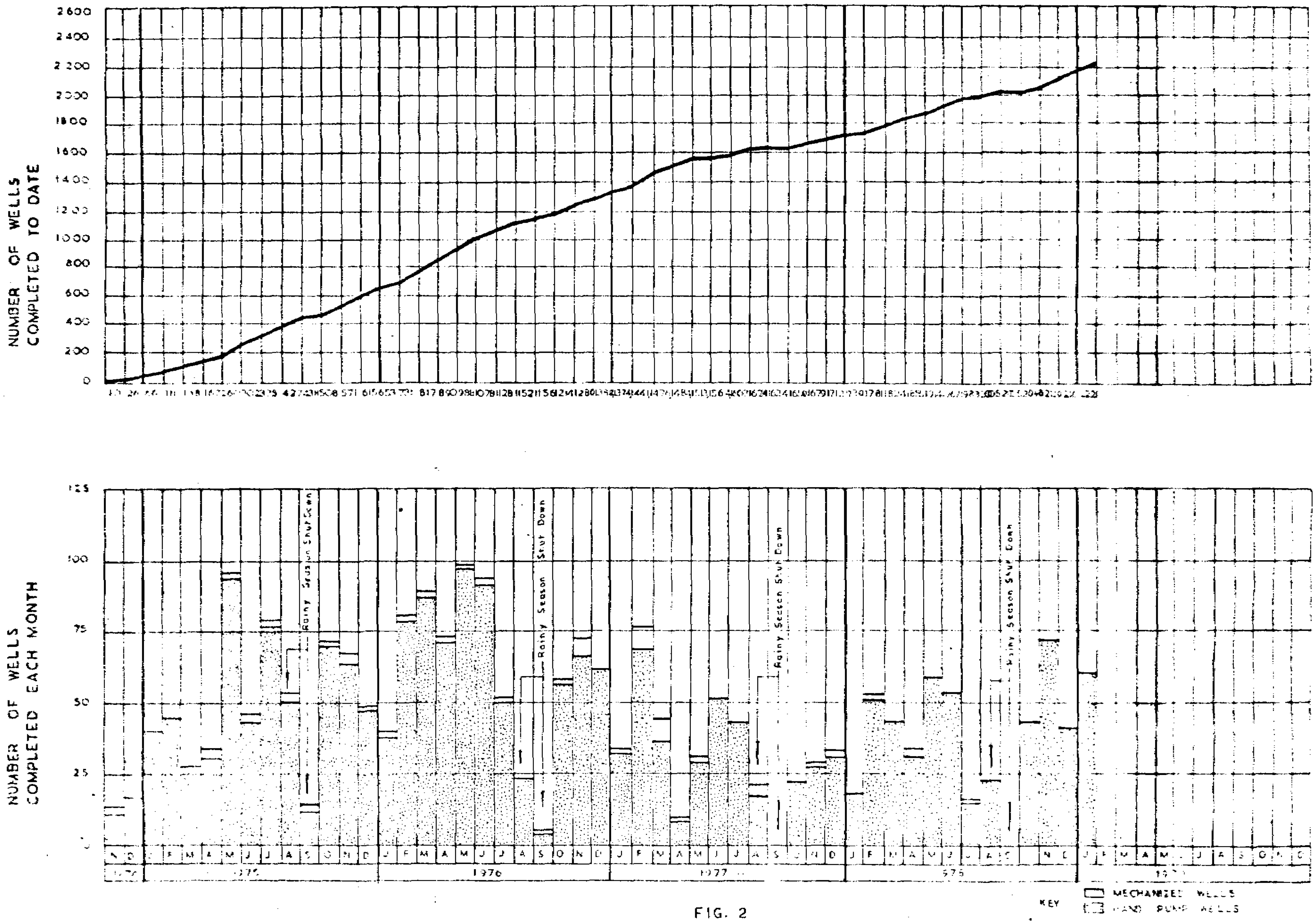


FIG. 2

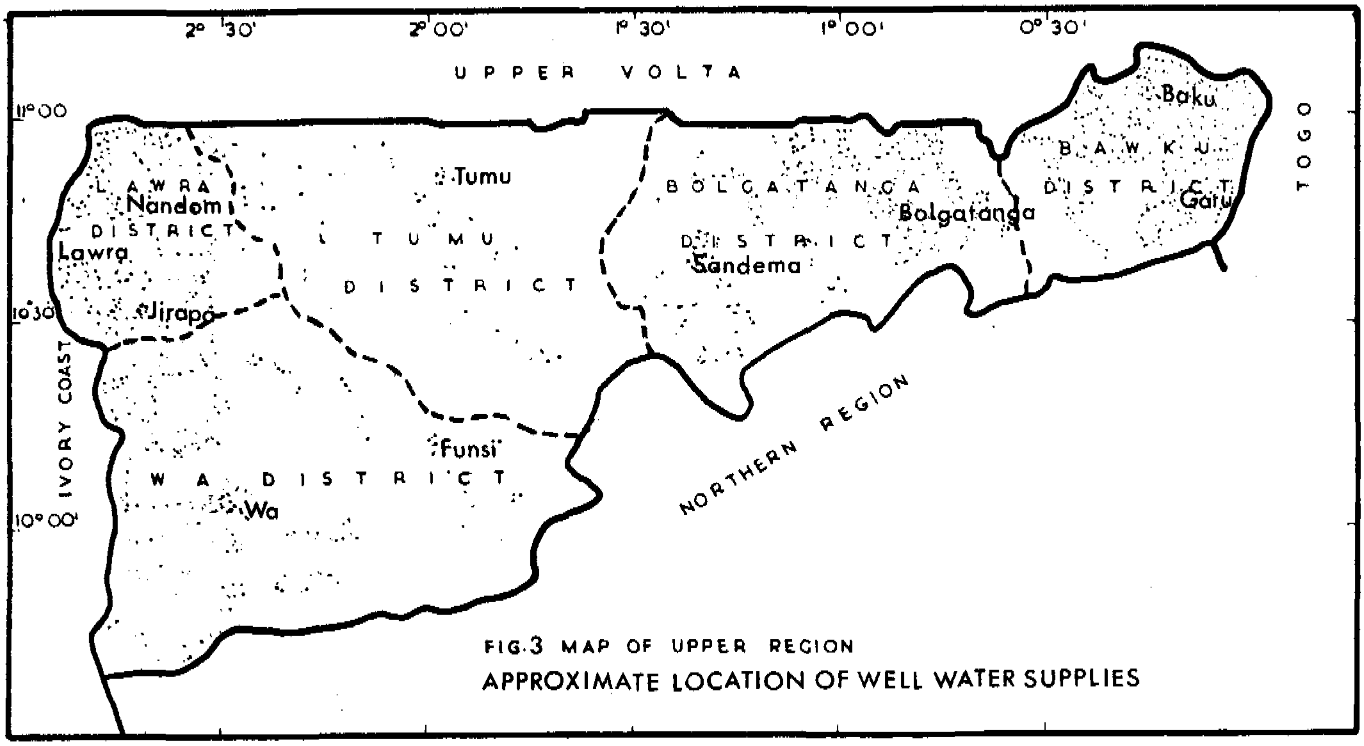


FIG. 3 MAP OF UPPER REGION

APPROXIMATE LOCATION OF WELL WATER SUPPLIES

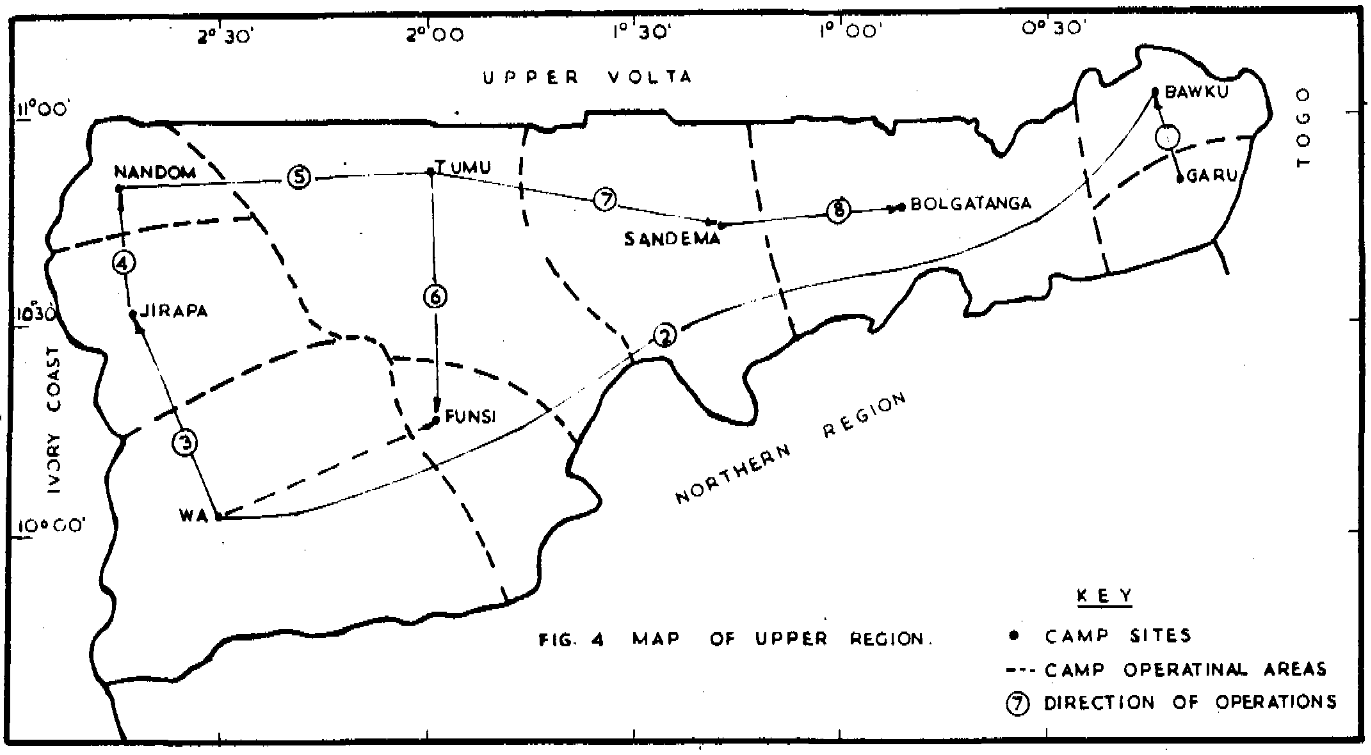


FIG. 4 MAP OF UPPER REGION.

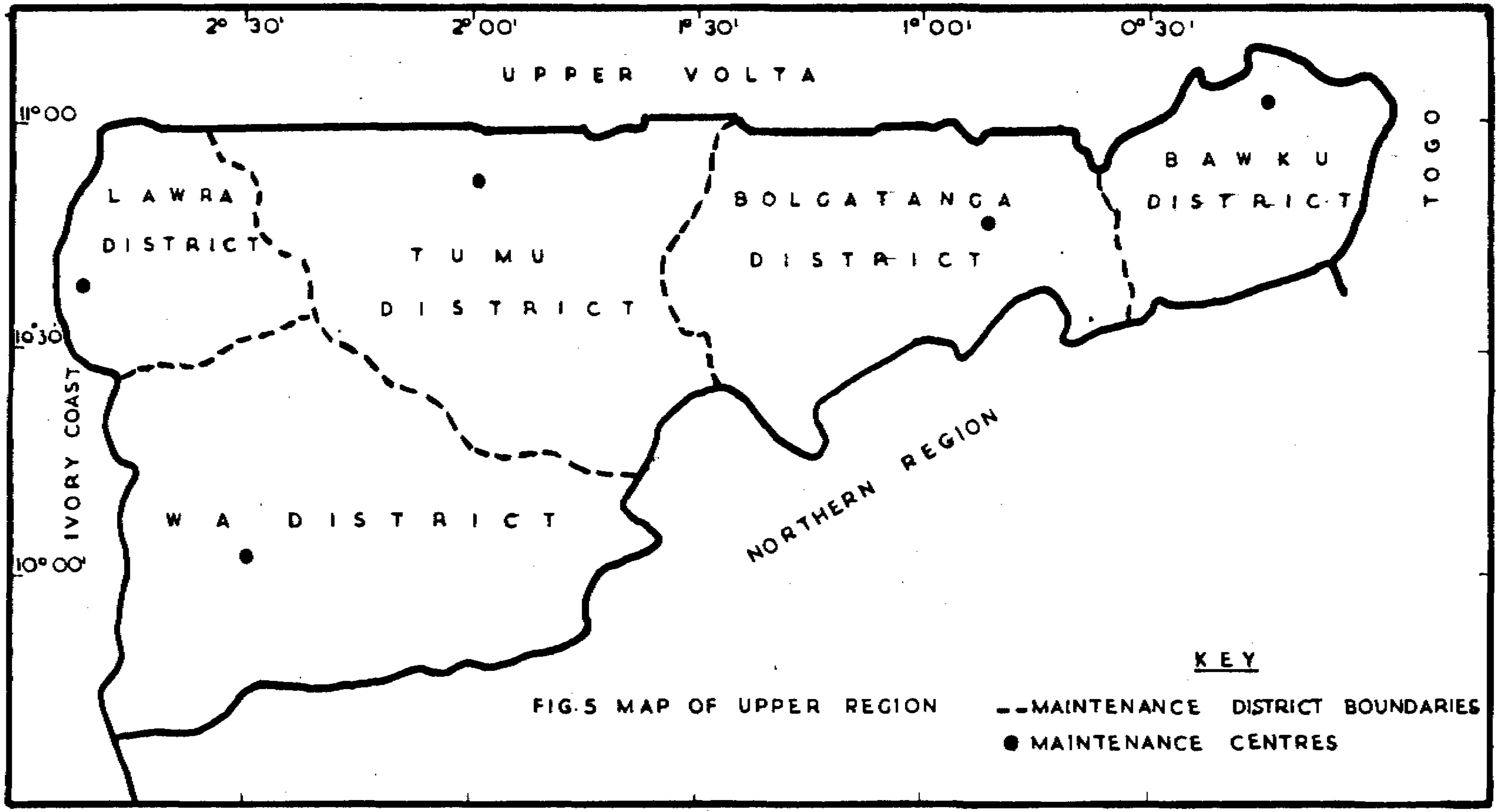


FIG. 5 MAP OF UPPER REGION

Site selection crews from the Hydrogeological Section worked in advance of the drilling operation identifying potential well locations for the hand pump wells. The main well production unit, consisting of three rotary drilling rigs and two service rigs supported by cementing and well-pad construction crews were run on standard contracting principles. To ensure full utilization of equipment each crew worked 21 days in the field and 7 days off. This allowed each crew sufficient time to return to base for rest. The operation was carried out 7 days a week, working 10-12 hours every day. The drill rigs concentrated on drilling holes and the service rigs fulfilled all the subsequent tasks, thereby efficiently accelerating production.

Preventive maintenance and minor repairs were carrid out at the drilling sites or at the camp, but major repairs were carried out at the main workshop at Bolgatanga.

Exploration and development techniques

Efficient methods were adopted for the selection of well sites and the construction of the well. The selection of equipment and techniques was based on mobility, flexibility, speed and ease of operation. The use of a simple, quick earth resistivity survey technique for well site selection combined with air-rotary drilling equipment for well construction resulted in a high rate of well completion.

Site selection

The selection of a well site in a particular village began in the office with an examination of the aerial photographs to determine the distribution of family compounds. A tentative selection of the site was made based on locating the well to best serve a group of compounds - normally this meant locating the well so that the distance to the farthest compound was about one-half mile. Then the site selection crew visited the chief of the village to determine the local preference for the well siting. A compromise as to the general location of the well site was reached with the chief. The site selection crew would then examine the preferred site location. Avoiding any outcroppings of rock, a series of earth resistivity readings were taken to identify points near the preferred site location with the best possibility for completing a well successfully. Normally a prime site and one or two alternate sites were chosen in this manner.

Two basic tools were used in the site selection process; aerial photographs and the earth resistivity instrument. Aerial photographs were used primarily to determine population distribution, establish access routes and determine field location. Relatively good success was achieved in using the resistivity technique to locate most of the well sites in decomposed rock at a reasonably low cost. However, in areas where difficulty was encountered in locating suitable well sites deep bedrock fracture systems were identified on the aerial photographs. This technique however required considerable experimentation.

Although the earth resistivity technique was used to identify sites with reasonable confidence, this did not guarantee that a successful well could always be completed. This was particularly so in schist rocks where the determining factor was often the presence of shattered quartz veins whose presence could not be determined by this method. The resistivity survey nevertheless proved a valuable tool in guiding the well drilling operation and reducing the number of dry holes.

Drilling Operations

The air-rotary and mud-rotary drilling techniques were used to complete wells on the Project. The air-rotary technique was used wherever possible primarily because it made the identification of water bearing zones much easier. However, caving conditions, particularly in schist terrain, sometimes forced the use of the mud-rotary technique.

Three rotary drilling machines were used for the construction, one Gardner Denver 15W rotary table drive and two TH60 Cyclone top drive machines. For pilot holes 4-7/8 inch insert bits were used while for hand pump well completion 6-1/4 inch rock bits were used. Down the hole hammers were used for drilling in the hard rock.

At the outset of the programme, electric logs (resistivity and self potential) were taken in many testholes in order to assess the technique as means of identifying water bearing zones. Although in some cases the E-log provided useful information, normally the E-log was not helpful in selecting water bearing zones. In any case this was not critical since air drilling was the normal method and therefore, identification of water bearing zones was quite easy.

Well Completion

All wells drilled were completed with PVC casing manufactured in Ghana. For hand pump wells PVC casing with an internal diameter of 100 mm was used while for mechanized wells casing with internal diameters of 150 mm and 200 mm were used. A section of slotted casing was placed opposite the water bearing zone. The slotting of the pipe was done by machine at the Project base workshop. Slot sizes ranging from 0.028 inches to 0.060 inches were used.

The slotted casing produced on the Project was found to be quite adequate for the hand pump wells and resulted in a very economical installation as compared to using wire round screen. The use of slotted PVC casing for completion of mechanized wells also proved satisfactory. Step drawdown tests on the mechanized wells indicated no serious loss of efficiency in spite of the open area being less than that for wire wound screens.

A gravel pack stabilizer was placed in the annular space between the screen and the water bearing zone. During the first phase, this stabilizer material was obtained from Tema, the main Port for Ghana, where there was a beach sand quarry operation. Some alluvial sands in the Upper Region were found to be satisfactory for stabilizer material and were used to supplement the supplies obtained from Tema.

Each well was completed with a cement pad, and the upper ten feet of the annular space around the well casing was filled with cement as an integral part of the pad. The cement pad extended one foot above normal ground level. Then the pad was backfilled with coarse aggregate thus providing good drainage away from the well head. Wherever possible the local villagers were relied upon to place the back-filling material.

On completion each well was pump tested. For hand pump wells, one-hour pump tests using the rig pump were conducted, while for mechanised wells pump tests lasted 24 hours using submersible pumps. To eliminate the possibility of contaminating the groundwater during the drilling operation, it was standard practice to chlorinate the drilling water. On completion of the pump test, each well was disinfected with a concentrated chlorine solution. Also when the hand pump was installed in the well all parts were washed with a concentrated chlorine solution. Similarly, whenever the pump was removed from the well for repair or inspection, it was washed with chlorine solution before re-installation. As a further precaution against contamination each well would be chlorinated at least once a year as part of the well maintenance programme.

For the intermediate size towns, extensive test drilling and pumping of test wells was undertaken, to determine groundwater availability and subsequently establish well fields in the most suitable locations.

Selection and installation of hand pumps

It was recognised at the outset that a durable hand pump would be required to meet the conditions in the Upper Region, where the hand pumps will serve as a community pump. The selection of the hand pump was therefore done with the greatest caution and in stages.

Prior to the Project, Ghana has had some experience with two types of hand pumps, about 300 of which had been in use in the Upper Region for some time. Both types of pumps did not give satisfactory performance due to constant failures, so it was decided that a different make of pump should be considered for the Project needs.

Search for hand pumps

The experiences of some international organisations on hand pumps were solicited and extensive literature review was made. Contacts were made with known hand pump manufacturers. Two types of pumps were identified as possibly meeting the requirements of the Upper Region and these were evaluated over a six-month period through field and shop tests. As there was still some uncertainty about the long term performance of both types of pumps, one type which at that time was much preferred was selected and an order was placed for only 500 units.

Sometime after the installation of these pumps, a number of deficiencies and failures were identified. Through the Well Maintenance Programme which was already in place, extensive modifications were made, some of which involved the manufacturer and the problems were alleviated to a large degree. Various design changes intended to overcome the deficiencies were incorporated into the order of the next lot of pumps.

Field testing of pumps

In spite of the respectable service performance which was achieved there was the need for a higher order of durability in future pumps. Efforts were continued to identify a hand pump suited to use as a community pump in the rural conditions of the Upper Region. It became clear that the only means of selecting a type of pump, was through a field test evaluation programme of hand pumps available on the world market. Fifty hand pumps from 15 different manufacturers from 10 different countries were subjected to test under normal use conditions in the Upper Region. The hand pump evaluation programme was run for two years. Recommendation was made for the selection of two types of pumps to be installed in the Upper Region using the following criteria: (i) Test performance of pump (ii) long-term cost of pump (iii) suitability of pump to eventually being partially maintained at the village level as a means of minimising the long-term maintenance cost.

Hand pump installation

The hand pumps were installed by separate crews using service rigs. The hand pump base plates were set in concrete as part of the drilling operation thus facilitating the installation of the pumps later.

ESTABLISHMENT OF WELL MAINTENANCE PROGRAMME

With the large number of well water supplies being installed in the Upper Region, it was evident from the outset that a comprehensive well maintenance programme should be established.

The objective was to assist the existing GWSC Regional Maintenance Organisation expand its capability to provide long-term repair and service for the new water supplies provided by the Project. The support provided was in the form of plant, equipment and technical assistance.

The programme was implemented by establishing five maintenance districts at Wa, Bawku, Tumu, Lawra and Bolgatanga. In each district, a system of motorcycle inspectors, service trucks crews and workshops was provided.

The GWSC Regional Manager is responsible for the programme and provides general direction. The Regional Engineer assisted by maintenance engineer and field supervisors are responsible for its continuous function. A total of 250 GWSC workshop and field staff with a core of trained and experienced technicians and supervisors were assigned to maintenance. Two Consultant advisers also participated in the programme.

Field operation

Each of the district organisations operate independently under the general direction of the Regional Office represented by the Maintenance Engineer and Field Supervisor. The District Officer is responsible for the repair, servicing and maintenance of wells in his district. Records are compiled to monitor the performance of each hand pump and each mechanised pump. These records are based on field reports completed by the motorcycle inspectors at the time of each inspection, and by the service truck crews at the time any repair or maintenance work is performed on a pump.

Due to the poor access to the pumps occasioned by the limited road network, and due to the ever-increasing cost of fuel, it was decided to utilize lightweight trail motorcycles for routine inspections of the hand pumps. The inspection is along designated routes, providing a site visit every two to three months on the average.

Eight motorcycle inspectors based at the five district centres carry out oiling of the pumps, provide preventive maintenance as well as make minor repairs and report pump failures. Through the inspector's site visit a rapport is established with the villagers, educating them on pump usage, water conservation and well-head sanitation. Approximately 80% of the total hand pumps in the Region are inspected each month.

Eight specially equipped service vehicles also based in the districts carry out major repairs on the hand pumps which cannot be completed by the inspector. These units do not make routine inspections, but respond only to reports from the inspectors or the villagers of hand pump failures. The service vehicle crews undertake also maintenance and repair of mechanised well pumps and periodic chlorination of the wells and pumps.

Normally a reported breakdown of hand pumps is scheduled into the work programme of the service vehicles. A response time of pump repair is at least 3-4 days after a failure is reported.

The workshop services include repair of the maintenance vehicles and motorcycles; repair of pumps and storage and control of supplies tools and equipment.

Radio communication has been established between the districts to facilitate the regional maintenance functions.

The objective of the Well Maintenance Programme is to maintain a performance level of 95% of the hand pumps in operation at any point in time. However, since July 1976, a continuous serviceability of 90% of the hand pumps has been maintained and this is considered an acceptable pump performance. With the staff and equipment now in place and through a continuous training in technical skills and communication with the villagers, it is expected that a higher level of service will be maintained in the long term.

CONCLUSION

By the end of the Project, the main objective of providing safe water for domestic purposes to the majority of the rural population of the Upper Region should be met. The maintenance programme which has been set up will aim at ultimately involving the villagers in the servicing and repair of the hand pumps, and in maintaining sanitary conditions at the well sites. These will be done through an educational campaign.

A number of Ghanaians have acquired expertise, that it is hoped, they will be able to carry out a similar operation in other parts of the country on their own.

The Collaboration which was achieved between Project Management and equipment and other material suppliers on one hand and with various government and international organisations on the other, during the Project has provided an intercourse between the various bodies and has proved invaluable in fostering better relations between Ghana and Canada.

discussion

CHAIRMAN: Mr B M U BENNELL

The CHAIRMAN introduced Mr W S Moffat who would present Mr R R Bannerman's paper as unfortunately at the last moment it was found that the author could not attend the Conference.

2. Mr W S MOFFAT said that he had never met Mr Bannerman, but by a strange coincidence he worked in the same part of Ghana doing the same type of work more than twenty years ago.

3. The project was a joint enterprise by CIDA (the Canadian International Development Agency) and the Government of Ghana. It was carried out in a semi-arid area in the north of Ghana. The population distribution is very variable, with greater concentrations in the east and west; the central area being thinly populated. The geology is granitic gneiss, which means that the chances of having large supplies of water are not great. The water comes from fissures and weathered zones. The climate consists of a long dry season with a wet season which is short and sharp.

4. The purpose of the Project was to construct new wells for rural areas and some intermediate size towns, to re-habilitate existing wells, to establish maintenance facilities and to train Ghanaian staff. Mr MOFFAT thought that some of the wells which were being re-habilitated were those he had dug in the late 1950's. Although the Project was confined to the north-west of Ghana, it was hoped to extend it to other parts of the country later.

5. The Project was carried out in two parts. In the first phase Canadian consultants provided key-men, each of whom had a Ghanaian counterpart. This was successfully completed in 1977. For the second phase Ghanaians were in full control. Mr MOFFAT suggested that the phasing was particularly interesting in that the first phase included half the wells throughout the region. In this way every part of the region would have some work done quickly.

6. Mr MOFFAT showed slides taken when he worked in the area being supplied with water. One showed a rotary hand pump of the type which was installed to replace reciprocating lever pumps which were often broken by exuberant use by the young people of the villages.

7. A major problem in the Project was how to allocate the bore holes. It was decided to provide 2500 hand pumps which would give one well for every 300 people. Wells were normally sited so that people did not have to walk more than half a mile. The sites were provisionally located by using aerial photographs. The exact location was found by walking round the area, discussion with the chiefs and using earth resistivity methods.

8. Air-rotary techniques were used for drilling and the rate of drilling was quite slow. PVC casing manufactured in Ghana was used. The gravel pack was at first brought all the way from Tema in the south-east of Ghana although local sources were exploited later.

9. Mr MOFFAT thought that the employment of motorcycle-mounted inspectors for maintenance was very sound. There are many footpaths in the region for which motor bikes are ideally suited.

10. Mr G S CANSDALE said that the area around Bawku was one of the most densely populated districts of Africa, with 450 people to the square mile. The trees shown in one of Mr Moffat's slides were all fruit-bearing. The method of agriculture carried out in the Region includes the burning of all vegetation. Erosion is a serious problem and it is increasing.

11. Mr CANSDALE could not understand why it was necessary to bring gravel from Tema as there were deposits of suitable granite-derived material available locally. He asked for further information about the depth of the boreholes, the overall cost (excluding expatriate staff) and the expected life of the water sources. (This was later provided by Mr BANNERMAN - see paragraph 22 below).

12. Mr MOFFAT said that the water is relatively recent recharge. In his experience the depth of boreholes varied between eighty and a hundred feet and hand pumps operating at this depth have produced yields of 700 - 900 gallons per hour. The depth of the aquifer was variable. He had selected well sites according to what was most socially convenient for the users. This had been done "by eye" after finding out the needs of the people. Of the 85 wells he had dug only one failed, and this was because the drill hit hard rock before reaching the required depth. With sites selected by geophysical methods he had obtained a yield of 1800 gallons per hour.

13. Mr S D PRADHAN asked a number of questions (see paragraphs 23 and 24 below). One of these referred to the duration of pump tests. Mr MOFFAT said that although Mr Bannerman employed a one-hour test for hand pumps, he (MR MOFFAT) recommended a 48-hour test.

14. Mr M H CHAUDRHY asked how wells were rehabilitated. The CHAIRMAN said that it was unlikely that wells would need re-habilitating. (See also paragraph 25).

15. Mr D G DUROSARO asked why hand pumps were used in the Project. Mr MOFFAT said that in his time it was decided that a large number of small convenient supplies were thought to be better than a smaller number of large inconvenient supplies. Obviously there was the same thinking when planning the Project. Mr CANSDALE added that for mechanical pumps the supply of fuel always presented problems, and this was particularly true now. However, he pointed out that in some parts of the Region water was only to be found in the sandstone at depths too great for hand pumping. Mr MOFFAT agreed that in the sandstone areas the success of boreholes was much less. At one place he had drilled to a depth of 2000 feet and still found no water! Mr CANSDALE said that in the sandstone area the population is very scattered, and some people have to go as far as five miles to obtain their water. Mr Jozsef BUKY said that in these areas contractors on the Project had a great deal of difficulty, but the deepest boreholes were 200 feet deep.

16. Mr M Z KARIM asked what community participation there was for the Project. Mr MOFFAT said that the people built and maintained feeder roads in his time. There were very few main roads built by the government, but the villagers maintained an excellent system of minor roads. The people were also very good at watching their pumps to ensure there was no wanton damage.

17. Mr D V ALLEN asked what casings and screens Mr Moffat had used. Mr MOFFAT had not used a screen or gravel pack, but the top forty feet had casing concreted in. The pipe was left proud of a concrete apron which was always provided. This led to further questions about water quality from Mr PRADHAN and Mr ALLEN. Mr MOFFAT said the water was not brackish and the bacteriological quality was good - provided the pump was properly installed. There was no problem with matter in solution or fluorides, nor from pollution by excreta as the population was scattered over a large area. He had no idea of the pH, but the water was not aggressive. Mr ALLEN said that in parts of Nigeria the pH was 5.2.

18. Mr R TRIETSCH asked for details of maintenance difficulties. (See paragraph 24 below). Mr BUKY said that the Ghanaians seem to cope very well with maintenance, although there are problems because spare parts are not available in Ghana.

19. Mr K B NYASULU had encountered considerable problems with discolouration of water in Malawi. Although water was clear when pumping started, it became brown after some time. He wondered whether similar discolouration was noticed in Ghana. Mr MOFFAT had not had any problems of this kind. Mr ALLEN said that in Nigeria he had come across borehole supplies with an iron content of

1-2 mg/l, and this was often discoloured. He had used upward flow filters filled with limestone chippings to treat the water. The filters were back-washed every two or three months.

20. Mr KARIM noticed that the time to repair wells was three to four days. What percentage of wells were out of use at any one time? (See paragraph 23 below).

21. The CHAIRMAN said that Mr Bannerman would be able to enlarge on some of the answers given by Mr Moffat. With regard to the failure of pumps the U.K. Ministry of Overseas Development was supporting a very extensive pump testing programme, the results of which would be discussed at a Conference to be held at Harpenden Rise.

Mr BANNERMAN visited the Editor on 1 May 1979 and gave the following information.

22. In reply to Mr CANSDALE (paragraph 11) Mr BANNERMAN said that the water table was generally about thirty feet below ground level. Boreholes were mostly 100 - 120 feet deep. The average cost of a borehole for hand pumping was ₵ 3500. The Project has a planned life of fifty years.

23. In reply to Mr PRADHAN (paragraph 13), Mr TRIETSCH (paragraph 18) and Mr KARIM (paragraph 20), there were less than 10% of wells out of use at any one time. It had been hoped to achieve 95% utilization, but Mr BANNERMAN thought that 90% was satisfactory in the conditions of northern Ghana.

24. So far, with new boreholes and new equipment, maintenance was at a minimum. The maintenance programme was based on district workshops, motor-cycle inspection and village caretakers. The caretakers were unpaid volunteers, and were able to carry out minor repairs to their own pumps. The annual allocation for maintenance was 25% of the capital cost. Troubles with maintenance had been largely due to break-down of vehicles. Petrol engines had been used at first, but vehicles with diesel engines were now being used and it was hoped that the down-time would be reduced. There was a constant shortage of fuel and tyres. With regard to the maintenance of the wells, it had been found that the life of leather cups in the pumps was much less than the estimated five years.

25. Rehabilitation of wells (paragraph 14) usually consisted of replacing the casing and providing a new gravel pack.

26. The yield of wells with hand-pumps was only required at a rate of three gallons per minute. For mechanised pumps there was three-day pumping test followed by a three-day recovery test.

27. Mr BANNERMAN said that associated with the Project there was a "water utilisation programme", in which the effect of improved water supplies were to be studied, and a "well contamination programme" to find the effect of fertilizer, cattle and latrines. In general contamination arose from pollution close to the wells, as aquifers were not polluted. To reduce pollution at well-heads the bases of the pumps had been raised above the aprons. There was also to be pilot study on primary health care in the Project area.

28. In the Project planning no provision had been made for watering of animals. There should have been!

J F JACKSON

sewerage, sewage treatment and refuse disposal for the city of sana'a

1. INTRODUCTION

The Yemen Arab Republic lays at the South West corner of the Arabian Peninsula, and comprises two well defined areas, namely the highlands in land, and the coastal strip along the Red Sea.

Sana'a, the capital city of the Yemen Arab Republic, is the administrative, political and judicial centre of the country. It is situated centrally on a mountain plain at an altitude of some 2 250 metres, with mountains on three sides rising well above this level.

The Old City, which lies to the East of the modern city centre, is most ancient and contains many buildings of historic and architectural importance, in particular the Great Mosque which is said to be one of the most ancient mosques in the Islamic World. The Old City is characterised by narrow streets, mostly unpaved, running between tall buildings, enclosed gardens and the local market places.

The city has expanded greatly over recent years and is still growing rapidly. It is predicted that due to the natural increase of population, and immigration from the rural areas, the annual rate of increase in the population will probably exceed 5% until the end of the century.

The rapid rate of expansion, which in the three years prior to 1976 incurred the building of nearly 3 000 dwellings, has overstretched existing sanitary facilities of the City and precipitated the need for modern sewerage and refuse collection services.

The paper now being presented is concerned with the study, and the development of the designs for Sewage Treatment and Refuse Disposal.

1.1 Consultants Terms of Reference

The appointment of Howard Humphreys & Sons, as Consultants to the National Water and Sewerage Authority for the Sana'a Sewerage Project, was made in

May 1976 following selection from proposals submitted in competition with other Consulting Engineers.

Funding for the study and design stage of the project was provided partly from a credit from the International Development Association.

The duties of the Consultant under the Terms of Reference of the Consultancy Agreement may be summarised:

Sewerage Project

The preparation of a Project Report incorporating the following main features:

(i) A review of the Sana'a Water Supply and Sewerage Master Plan which was drawn up by the Italian company Italconsult under the sponsorship of the World Health Organisation.

(ii) Projected water demands and determination of the expected per capita sewage flows, peak flows and pollution loads.

(iii) Definition of drainage areas, location of area pumping stations and the sewage treatment works.

(iv) Selection of sewage treatment method and disposal of the final effluent and sludge.

(v) Preparation of outline designs, and cost estimates.

(vi) Investigation of local storm water flooding, and proposals for remedial action.

(vii) Investigation of intermediate arrangements for the improvement of sanitary facilities in the areas of Sana'a not served by the initial stage of the sewerage project.

The preparation of detail designs and contract documents in accordance with the scope of works agreed by the Authority from the recommendations made in the Project Report.

Refuse Disposal Project

The preparation of a Project Report on the present and future requirements for refuse collection and disposal for the City of Sana'a, incorporating the following main items.

(i) Investigation of existing methods of collection and disposal.

(ii) Study of the quantity and composition of the refuse currently generated, and prediction of future quantity and composition.

(iii) Outline design and specifications with cost estimates of alternative methods of collection and disposal suitable for various stages of development of the City.

(iv) Recommendations for the implementation of an effective refuse collection and disposal system.

Howard Humphreys and Sons were not involved with the economic viability aspects of the project, as this work together with institutional and tariff studies, had already been carried out by other Consultants.

1.2 Organisation of the Project

Though Howard Humphreys and Sons had carried out many similar assignments in the Middle East, and elsewhere in the developing world, the Sana'a Sewerage Project with the Refuse Project were the first projects to be entrusted to the company in the Yemen Arab Republic. In accordance with the company's policy of maximum involvement and liaison with the client during the report and outline design stage of the project, a local establishment was set up in Sana'a to provide domestic and office accommodation for up to eight persons, and three vehicles were purchased to cover transportation requirements.

The study team resident in Sana'a for the six months duration of the study, consisted of the Deputy Project Manager of Principal Engineer status, with a Senior Engineer and two Assistant Project Engineers, all members of the Consultant's permanent staff. Three Yemeni Engineers on secondment from the staff of the National Water and Sewerage Authority completed the resident study team, which was backed-up by visits from the Consultant's Head Office of the Project Manager, and staff with specialist inputs.

The establishment set up in Sana'a by the Consultant for the purpose of the study has been retained to the present day to provide continuity of presence in liaising with the client, and to service other projects which have emerged subsequent to the appointment for the sewerage and refuse projects.

2. THE SEWAGE TREATMENT PROJECT

2.1 Existing Water Supply

The traditional source of water for the people of Sana'a is from hand dug wells situated locally within the curtilage of properties, and all inside the City limits. The wells are usually about 1.0 metre in diameter, masonry lined in the upper part and sometimes 40 metres or more in depth.

In more recent times, from about 1965 onwards, some wells were constructed using cable tool rigs to serve localised communities, and these go down to a depth of 150 metres.

The supply from the deep wells is distributed either by a limited pipework system, or by tankers.

Analysis of samples taken from various parts of the City indicated a high level of pollution, and there was also a serious problem of over abstraction due to increased domestic and irrigation demands which has caused a significant decline in the level of the water table. The average domestic consumption in 1976 was estimated at approximately 22 litres per head per day.

The inauguration of the first stage of the Sana'a Water Supply Project in October 1978 has done a great deal to improve the supply, particularly in the priority area of the Old City, but a large proportion of the population will remain dependant on local sources of supply for some time to come.

2.2 Existing Waste Disposal Facilities

At the present time, the City of Sana'a has no municipal or public sewerage system in the generally accepted meaning of the term. Within the confines of the Old City, where in the past water consumption per head of population has been relatively low, the multi-storey buildings which mostly prevail are served by rudimentary toilets consisting of a hole in the floor through which faecal matter is discharged, dropping through a shaft into a chamber within the confines of the building at street level. The contents of the chamber are removed periodically and transported to public bath houses where they are used as fuel for heating water. Alternatively the contents are used as fertilizer. Urine, and other liquid wastes, are separated from faecal matter and channelled to the outside walls of the building, where they are then discharged to the street.

In other areas of the City, particularly the modern properties served by tankers or local piped water supply, cesspits and septic tanks are in general use.

2.3 Health Conditions

In the absence of statistical documentation the only evaluation available is of a qualitative kind without numerical reference. Quoting from a report by Dr Lantini, who was a member of the Italian Medical Mission to Sana'a, the most commonly occurring diseases in Sana'a are:-

"1) Parasitic, including amoebic dysentery, ascariasis etc.

2) Dysentery, In all its forms and in all seasons is extremely frequent, and the consumption of antibiotics to combat it is enormous.

3) Viral Hepatitus. Seems most frequently to attack the expatriate community. Milder forms, which affect the local population, probably not brought to the attention of a doctor.

4) Trachoma. 60 - 70% of the school population in Sana'a suffer from this disease."

The report concluded that the high incidence of disease was attributable to the insanitary conditions prevailing.

2.4 Design Data

General

The purpose of the Project Report was to review and update the Master Plan and Preliminary Engineering Feasibility Studies for the Sewerage of Sana'a, under the sponsorship of the World Health Organisation, and to provide recommendations to form the basis of the final design.

Under the Consultancy Agreement, the area covered by the Project Report was contained within the boundary designated in the Master Plan as the city limits in the year 1985.

The implementation of the project was identified in two stages, according to priority of sanitary improvement and funding available. Stage 1 covers the older parts of the City, and the central area, where the density of population is highest and where sanitary conditions are generally least satisfactory. Stage 2 covers the balance of the area to the 1985 city limits, and generally represents an area of lower population density and more satisfactory sanitary arrangements.

The demarcation of the city limits in 1985, and the boundaries of Stages 1 and 2, are shown on Drawing No. 1.

Population

The task of predicting population growth in developing countries can be a notoriously difficult task.

In the case of the Sana'a Sewerage Project, population projections were made based upon data available from the first official census, made in January 1975, and the demographic studies carried out by Italconsult in the same year. Certain adjustments were made by Howard Humphreys and Sons because we found that certain areas formerly designated as green areas were being developed as residential areas. Our task was made easier by the fact that within the project area, most of the land was developed and hence the trends in land usage were quite clearly defined.

Project population estimates may be summarized:-

Stage 1 Construction Area population in 1985	108 217
Stage 2 Construction Area population in 1985	83 680
TOTAL	191 897

Sewage Flows

From the preliminary investigations carried out by Italconsult in 1972, it was estimated that the average water supply consumption for domestic purposes was 22.3 litres per capita per day. In formulating our designs, we have predicted that with the inauguration of the first stage of the Water Supply Project the per capita consumption would increase to 50 litres per day, and then continue to increase progressively to 200 litres per day until the year 2000.

Our estimated sewage flow per capita daily has been taken as 80% of the water consumption. These per capita projections are shown in Figure No. 1.

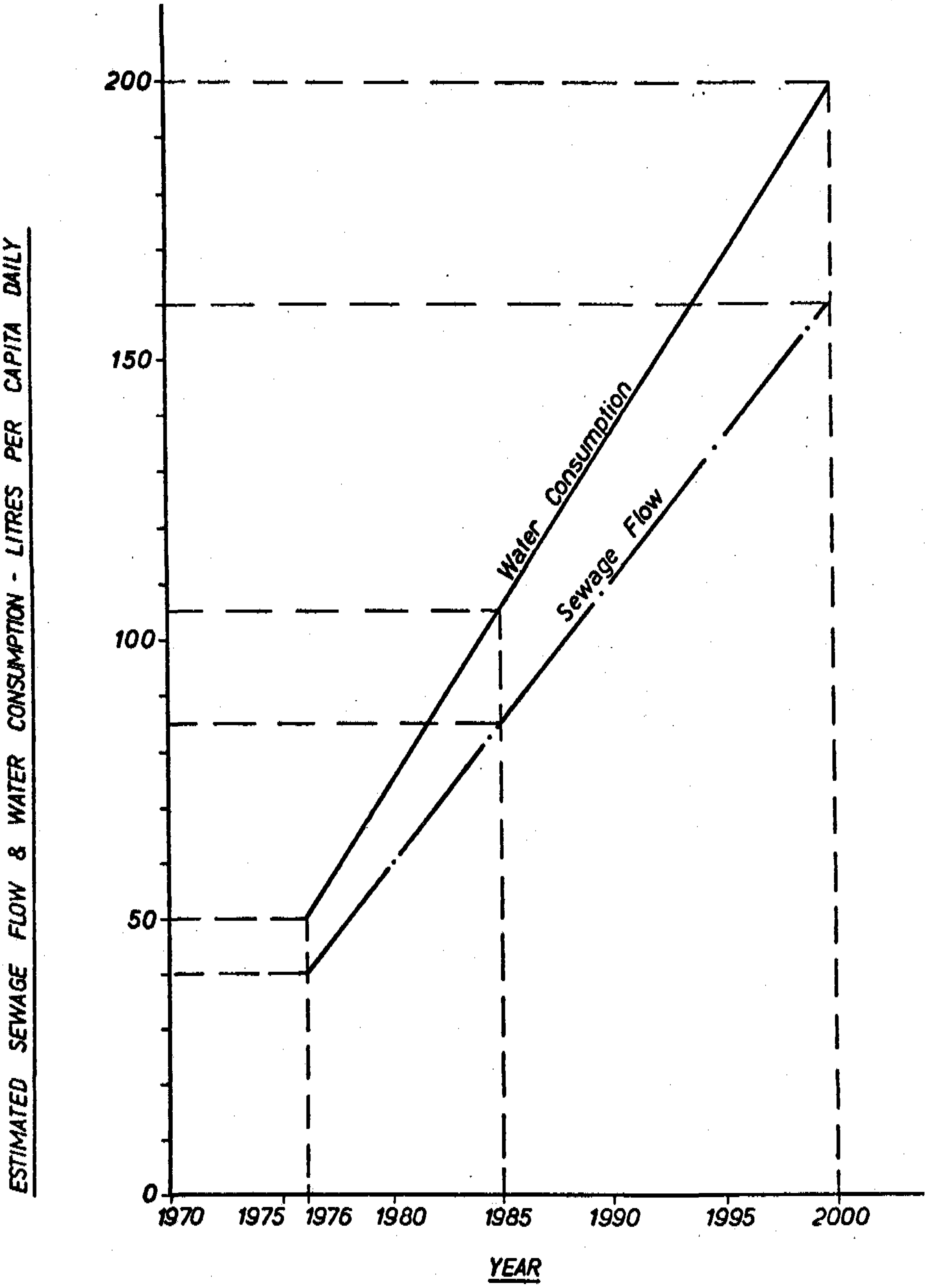
The daily sewage flows are expected to be 85 litres per person by 1985, and are deemed to include for commercial, institutional and industrial flows.

With the exception of the discharge from a textile factory, dealt with as a separate entity since it has its own water supply, the industrial flows are minor.

The design flows at the sewage treatment works may be shown as follows:-

Expected Dry Weather Flow in 1985

	Domestic, Commercial, Institutional, & Industrial Flows m^3/day	Discharge from Textile Factory m^3/day	Total Dry Weather Flow in 1985 m^3/day
Stage 1	9 198	1 860	11 058
Stage 2	16 310	1 860	18 170



PROJECTED PER CAPITA WATER CONSUMPTION & SEWAGE FLOW

FIGURE 1

Sewage Strengths

In the absence of a sewerage system in Sana'a, or indeed elsewhere in the Yemen Arab Republic, it was not possible to use the analysis of existing flows as a basis for estimating active design loads, and this work has been done by using data available from comparable projects elsewhere in the developing countries.

The figures adopted for the two basic parameters of Biochemical Oxygen Demand, and Suspended Solids were:-

Biochemical Oxygen Demand	54 gm/person/day
Suspended Solids	60 gm/person/day

With population equivalent allownaces for industrial, commercial and institutional contribution, the biological load used in the design of the treatment works are tabulated as follows:-

Estimated BOD Load

Stage 1

Industry etc.	1985 Population Served	1985 Equivalent Population	1985 BOD Load at 85 grm per head per day (KG)
	108 217		5 843
Textile Factory		8 600	464
Tanneries		300	16
Miscellaneous		750	41
Total Stage 1 BOD			6 364

Stage 2

	83 680		4 519
Slaughterhouse		9 000	486
Industrial Estate		1 200	65
Total Stage 2 BOD			5 070
Total 1985 BOD Load			11 434

2.5 Effluent Quality and Disposal

General

The method of final disposal of the treated effluent was considered to be an integral part of the Sewerage Project. In a region such as North Yemen, effluent was regarded as a resource which could be used to improve the environment and to benefit the community.

Effluent Re-Use and Disposal Methods

A number of disposal methods were considered:-

i) Disposal to the Wadi.

ii) Recharge of underground aquifer.

iii) Industrial use.

iv) Potable water

v) Irrigation

i) Disposal to the Wadi

Disposal to the Wadi was regarded as a method which achieved little benefit from the valuable water resource. It was recognised as being available in the immediate term, and as a means of disposing of the effluent in emergency circumstances.

ii) Recharge of Underground Aquifer

Recharging of the aquifer either by surface ponding or by deep well injection was not considered desirable or necessary at the present time because the underground resources, remote from Sana'a which are now being developed, appear to be sufficient to ensure supplies for the immediate and medium term requirements.

iii) Industrial use

Sana'a is not an industrial centre and due to its remoteness from the coast, it was considered unlikely of ever becoming a major manufacturing city.

The most important existing factory, the textile factory, has its own water supply and was not interested in utilizing treated effluent.

iv) Potable Water

Our report gave consideration to the possibilities of reclaiming potable water from sewage effluent and concluded that due to the high cost and level of technology involved, the process could not be justified at this time or in the foreseeable future.

v) Irrigation

The method of disposal considered most suited to local requirements was the re-use for irrigation of certain crops of areas of forestry.

It was proposed that treatment works effluent would be passed initially to an area on the site of the treatment works reserved for future extensions. The area would be planted with trees and grass requiring little maintenance, and securely fenced off to ensure that no unofficial and uncontrolled use is made of the area or of the effluent. Treated effluent not required for irrigation would be disposed of into the nearby Wadi.

The development of the irrigation potential is subject to further study as the works are completed.

Effluent Quality

The quality of effluent recommended in conjunction with disposal on to an area planted with trees and grass was 75 mg/l BOD and 75 mg/l SS.

2.6 Sewage Treatment Methods

General

In the selection of the sewage treatment process for Sana'a, consideration was given to the following factors.

a) The climatic conditions.

b) The volume of waste water to be treated.

c) The degree of operational and maintenance skills required.

d) The availability, cost and location of land.

e) The availability and nature of operatives.

f) The relative off-shore and on-shore costs.

g) The effluent disposal method.

From an assessment of the local conditions we concluded that three methods warranted detailed investigation:

i) Stabilisation ponds

ii) Biological filtration

iii) Oxidation ditches

In the absence of any definite data on the strength of sewage to be treated the various treatment methods were designed using conservative parameters to ensure that the effluent quality would comply with the disposal requirements.

The elements in common to the three treatment processes considered were:

Peak flow to treatment	3 x Dry Weather Flow
Effluent standard	75mg/l BOD 75mg/l SS
Inlet Works	
Emergency Stormwater Overflow	3 x DWF
Coarse Screens (Before Screw Pumps)	Bar Spacing 75mm
Mechanically raked fine screens and disintegrator (After Pumps)	Bar Spacing 15mm
Constant Velocity grit channels	Velocity 0.3m/sec.
Standing wave flumes for flow measurement	
Dual Screw Pumps	

Waste Stabilisation Ponds

Waste stabilisation ponds were selected as a possible method of treatment because they are relatively simple and very effective particularly in climatic regions similar to Sana'a which has a high incidence of sunshine. Though the land available for the treatment works was not expensive, most of it was already owned by the Government of the Yemen Arab Republic, our preliminary calcuations showed that the area required for treatment could be reduced by about 20% if mechanical aerators were introduced into the first stage of treatment. Another reason for the introduction of mechanical aeration was to obviate the potential problem from smell nuisance.

By comparison of the other treatment processes, the advantages of waste stabilisation ponds were seen to be:

a) Relatively low power consumption by the aerators.

b) No complex machinery.

c) Desludging required only at 5 to 10 year intervals, and the sludge fully stabilised.

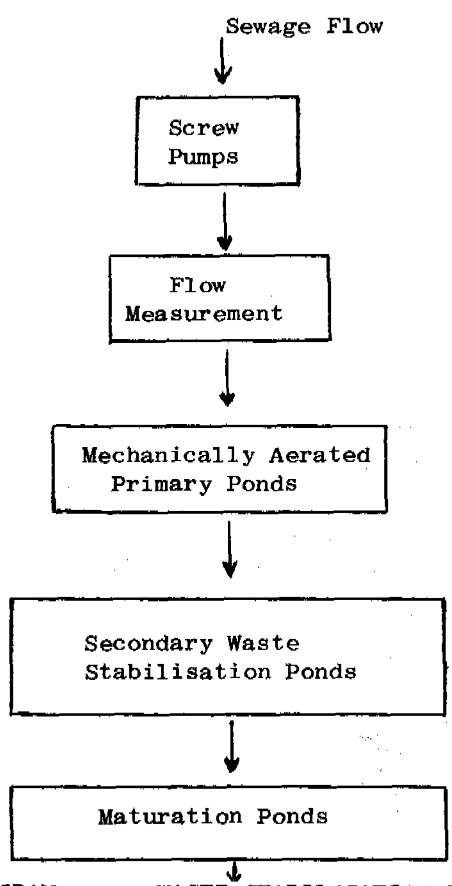
d) The maturation ponds would ensure a high bacterial die-off and would be available for fish culture at a later date.

e) The ability to absorb shock loadings.

f) The favourable ratio of on-shore to off-shore construction costs.

The flow diagram for the waste stabilisation pond method considered is shown in Figure No. 2, and the parameters for the designs, which followed the Thirumurthi method, are reproduced below:-

FIGURE 3



FLOW DIAGRAM - WASTE STABILISATION PONDS

Local Controlling Termperature	11°C
Dispersion Factors	
a) Mechanical aeration	2.5
b) Facultative Stage	1.0
Pond Depths	
a) Mechanical aeration stage	3.5m
b) Facultative stage	1.75m
c) Maturation stage	1.0m
BOD Reduction	
a) Mechanical aeration stage	60%
b) Facultative stage	75%
BOD entering maturation pond	60 mg/l
Maturation pond detention period	9 days

The general arrangement of the waste stabilisation ponds is shown on Drawing No.3.

Biological Filtration

The biological filtration process was considered because it is a well proven sewage treatment method which has been used successfully in many parts of the world.

The merits of the process were seen to be:-

a) Reliable and well proven form of treatment.

b) Relatively simple to operate, and with low maintenance requirement.

c) Low running costs.

d) The ability to absorb shock loadings.

The disadvantages of the process were seen as:-

a) High hydraulic head loss.

b) Potential fly and odour nuisance.

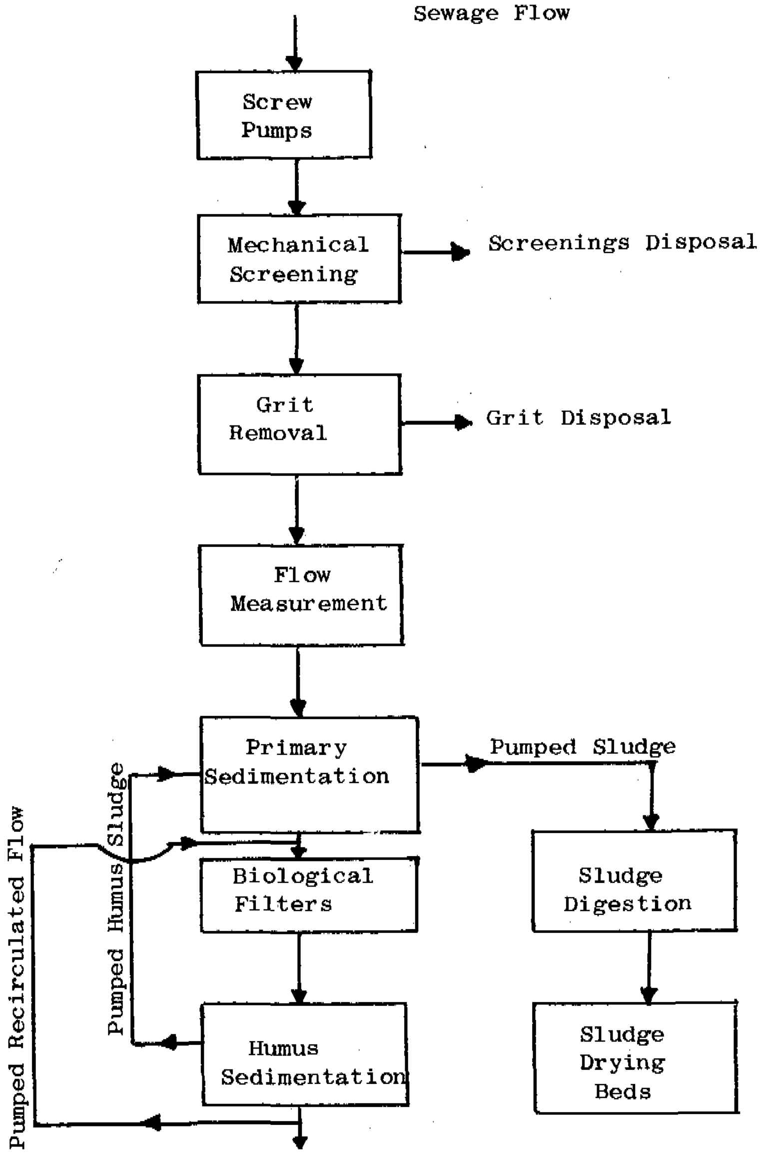
c) Relatively high construction costs with an undesirable element of off-shore cost incurred by the associated machinery.

The essential stages of the biological treatment process are shown diagrammatically in Figure No. 3, and the parameters adopted for the designs are shown below:

Primary Sedimentation Tanks

Radial flow type, 10° floor slope	
Max. Surface Loading at peak flow	= $33m^3/m^2/d$
Retention Period at dry weather flow	= 6h
Minimum Weir Overflow Rate	= $100m^3/m/d$
Maximum Weir Overflow Rate	= $250m^3/m/d$
Estimated BOD removal	= 35%
Estimated SS removal	= 60%

FIGURE 4



FLOW DIAGRAM - BIOLOGICAL FILTRATION & RECIRCULATION

<u>Biological Filters</u> (rectangular) with recirculation of humus tank effluent

Single filtration, settled sewage	=	o.2 kg BOD/m^3/d
Average depth of media	=	2.00m
Estimated reduction in BOD	=	90%
Rate of Recirculation	=	1 - 2 times d.w.f

<u>Humus Tanks</u>

Radial flow type, 15° floor slope

Max. Surface Loading at peak flow	=	60 m^3/m^2/d
Retention Time at dry weather flow	=	6h
Minimum Weir Overflow Rate	=	100 m^3/m/d
Maximum Weir Overflow Rate	=	250 m^3/m/d

<u>Sludge Drying Beds</u>

Undigested sludge	=	8 persons/m^2

The general arrangement of the biological filtration plant is shown on Drawing No. 4.

Oxidation Ditch

The oxidation ditch was considered as a possible method of treatment because:

a) The machinery is not complex, and the operation and maintenance of the works would be within the scope of the skills available.

b) The relatively small sludge produced is stabilised and would require no further treatment except air drying.

c) The process has the ability to absorb shock loadings.

d) The land requirement is minimal.

e) Construction costs are low.

The stages in the oxidation ditch process indicated diagrammatically in Figure No. 4, and the parameters adopted in the designs are shown below:-

Oxidation Ditch

Capacity	=	210mg BOD/l of ditch
Oxygen Supplied/BOD removed ratio	=	2 to 1

Final Settlement Tanks

Radial Flow type 15^{o} floor slope

Max. Surface Loading at peak flow	=	22 $m^3/m^2/d$
Minimum Retention Period at dry weather flow	=	4.5h
Minimum Weir Overflow Rate	=	100$m^3/m/d$
Maximum Weir Overflow Rate	=	250$m^3/m/d$

Return Sludge Pumps

Capacity equal to the dry weather flow

Sludge Drying Beds

Undigested sludge	=	10 persons/m^2

The general arrangement of the oxidation ditch plant is shown on Drawing No. 5.

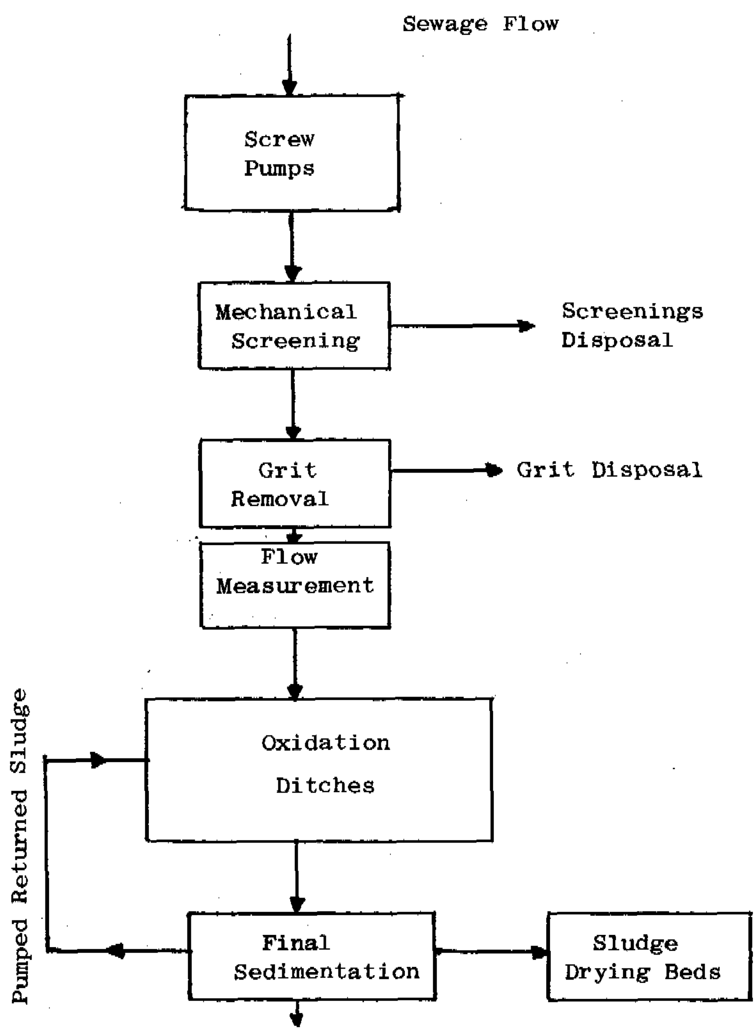
2.7 Cost Estimates for Sewage Treatment Works

General

The cost estimates were prepared using data obtained from Contractors working locally, from the Ministry of Public Works, and from the National Water and Sewerage Authority. The estimates for machinery were prepared from manufacturers' budget quotations.

The estimates are given in the local currency, Yemen Rials, which are converted to sterling at the rate of YR 8.5 = £(sterling) 1.0.

Capital costs for the three methods of treatment considered, together with running costs are given in the accompanying tables.



FLOW DIAGRAM - OXIDATION DITCHES

FIGURE 5

Capital Costs: Waste Stabilisation Ponds

Item	Unit	Rate (Y.R.)	STAGE 1 Quantity	STAGE 1 Cost (Y.R.)	STAGE 2 Quantity	STAGE 2 Cost (Y.R.)
Civil Costs						
Bulk excavation	m^3	20	210,000	4,200,000	147,000	2,940,000
Bulk fill in embankments	m^3	10	240,000	2,400,000	168,000	1,680,000
Pumping station and inlet works		lump sum		300,000		300,000
Administration building and watchman's house		lump sum		360,000		
Connections of ponds and site pipelines	m	785	6,000	4,710,000	3,800	2,983,000
Valves and penstocks		lump sum		450,000		250,000
Garage and workshop		lump sum		480,000		
Waterline protection to ponds (Rip-rap)	m^2	50	36,000	1,800,000	25,200	1,260,000
Fencing		lump sum		100,000		50,000
Land acquisition	ha	22,750	40	910,000		
Civil construction Costs				15,710,000		9,463,000
Electrical and Mechanical Plant Costs						
Sewage pumps		lump sum		280,000		280,000
Bar screen		lump sum		100,000		100,000
Flumes and flow recording		lump sum		80,000		80,000
Surface aerator		lump sum		1,600,000		1,080,000
Generator and transformers		lump sum		560,000		
Cabling and distribution board		lump sum		500,000		350,000
External electric supply		lump sum		70,000		
Laboratory equipment		lump sum		200,000		
Recirculation effluent pumps		lump sum		80,000		
Spares		lump sum		200,000		100,000
Electrical and Mechanical Plant Costs				3,670,000		1,990,000
Total Cost				19,380,000		11,453,000

Capital Costs: Biological Filters

Item	Unit	Rate (Y.R.)	STAGE 1 Quantity	STAGE 1 Cost (Y.R.)	STAGE 2 Quantity	STAGE 2 Cost (Y.R.)
Civil Costs						
Bulk excavation	m^3	30	31,400	942,000	23,500	705,000
Reinforced concrete	m^3	1,350	10,720	14,472,000	8,030	10,840,500
Pumping station and inlet works		lump sum		400,000		
Administration building and watchman's house		lump sum		360,000		
Site pipelines		lump sum		4,000,000		1,770,000
Valves and penstocks		lump sum		450,000		200,000
Garage and workshops		lump sum		480,000		
Site roads	m^2	220	13,100	2,882,000		
Sludge storage compound		lump sum		360,000		
Filter media	m^3	110	13,300	1,463,000	10,000	1,100,000
Fencing		lump sum		100,000		
Land acquisition	ha	22,750	25	568,750		
Civil construction Costs				26,477,750		14,615,500
Electrical and Mechanical Plant Costs						
Sewage pumps		lump sum		280,000		160,000
Bar screen		lump sum		100,000		80,000
Flumes and flow recording		lump sum		80,000		80,000
Settling tanks (primary)		lump sum		320,000		240,000
Filter beds		lump sum		2,400,000		2,400,000
Humus tanks		lump sum		256,000		192,000
Generator and transformers		lump sum		640,000		
Cabling and distribution board		lump sum		500,000		240,000
External electric supply		lump sum		70,000		
Laboratory equipment		lump sum		200,000		
Recirculation effluent pumps		lump sum		200,000		
Spares		lump		500,000		300,000
Electrical and Mechanical Plant Costs				5,546,000		3,692,000
Total Cost				32,023,750		18,307,500

Capital Costs: Oxidation Ditches

Item	Unit	Rate (Y.R.)	STAGE 1 Quantity	STAGE 1 Cost (Y.R.)	STAGE 2 Quantity	STAGE 2 Cost (Y.R.)
Civil Costs						
Bulk excavation	m^3	30	36,000	1,080,000	27,000	810,000
Reinforced concrete in:– ditches, settling tanks and drying beds	m^3	1,350	4,630	6,250,500	3,470	4,684,500
Lining of ditches	m^2	70	11,500	805,000	8,500	595,000
Pumping station and inlet works		lump sum		300,000		
Administration building and watchman's house		lump sum		360,000		
Site pipelines		lump sum		2,000,000		1,000,000
Valves and penstocks		lump sum		450,000		150,000
Garage and workshops		lump sum		480,000		
Site roads	m^2	220	11,700	2,574,000		
Sludge storage compound		lump sum		360,000		
Fencing		lump sum		100,000		
Land acquisition	ha	22,750	20	455,000		
Civil construction Costs				15,214,500		7,239,500
Electrical and Mechanical Plant Costs						
Sewage pumps		lump sum		280,000		96,000
Bar screen		lump sum		100,000		80,000
Flumes and flow recording		lump sum		80,000		80,000
Rotors and weirs		lump sum		1,440,000		1,080,000
Final settling tanks		lump sum		560,000		406,000
Generator and transformers		lump sum		480,000		
Cabling and distribution board		lump sum		400,000		150,000
External electric supply		lump sum		70,000		
Laboratory equipment		lump sum		200,000		
Recirculation sludge pumps		lump sum		80,000		40,000
Spares		lump		350,000		200,000
Electrical and Mechanical Plant Costs				4,040,000		2,132,000
Total Cost				19,254,500		9,371,500

Estimated Power Consumption and Costs

Biological Filtration Plant	Power Consumption (kWh/day) Stage 1	Stage 2
Inlet works: Screw pumps	272	444
Bar screen	8	16
Grit remover	–	80
Primary Tank sludge scrapers	80	140
Filter bed machinery	960	1,680
Humus tank sludge scrapers	96	168
Recirculation pumps	444	444
Sludge pumps	12	18
Washout pumps	8	12
Total	1,880	3,002
Power consumption cost per day at 0.6 Y.R./kWh	1,128 Y.R.	1,801 Y.R.
Oxidation Ditches		
Inlet works: Screw pumps	92	149
Aeration rotors	3,360	5,880
Final tank sludge scrapers	192	336
Recirculation sludge pumps	130	212
Total	3,774	6,577
Power consumption cost per day at 0.6 Y.R./kWh	2,264 Y.R.	3,946 Y.R.
Waste Stabilization Ponds		
Inlet works: Screw pumps	182	296
Pond aerators	3,226	5,376
Recirculation effluent pumps	256	256
Total	3,664	5,928
Power consumption cost per day at 0.6 Y.R./kWh	2,198 Y.R.	3,557 Y.R.

Summary of Estimated Capital Costs for Sewage Treatment Works

Biological Filter Plant	Cost – Yemeni Rials Stage 1	Stage 2
Civil	26,477,750	14,615,500
Electrical and Mechanical	5,546,000	3,692,000
Total	32,023,750	18,307,500
Oxidation Ditches		
Civil	15,214,500	7,239,500
Electrical and Mechanical	4,040,000	2,132,000
Total	19,254,500	9,371,500
Waste Stabilization Ponds		
Civil	15,710,000	9,463,000
Electrical and Mechanical	3,670,000	1,990,000
Total	19,380,000	11,453,000

Summary of Estimated Annual Operating Costs for Sewage Treatment Works

Biological Filtration Plant	Cost – Yemeni Rials Stage 1	Stage 2
Staff	228,000	250,000
Electrical Power	411,720	657,365
Consumables	60,000	80,000
Total	700,520	987,365
Oxidation Ditches		
Staff	211,600	230,000
Electrical Power	826,360	1,440,290
Consumables	40,000	50,000
Total	1,077,960	1,720,290
Waste Stabilization Ponds		
Staff	197,200	210,000
Electrical Power	802,270	1,298,305
Consumables	30,000	40,000
Total	1,029,470	1,548,305

2.8 Recommended Treatment Process

Following the comparison of construction, operational and maintenance costs for the three methods of treatment considered, it was concluded that the waste stabilisation process was the most suitable method of treatment under the prevailing circumstances at Sana'a.

Referring to the outline design of works shown in Drawing No. 3 the design features of the works are now described further.

Sewage flow reaches the works through a single 1,400mm diameter sewer. At the inlet works, the sewage is raised through a height of 5 metres by two screw pumps, working on duty and standby basis, to allow gravity flow through the treatment process. The flow is measured using critical velocity flumes. Coarse screening is provided before the pumps, and this is followed by mechanically raked fine screens. Screenings will be disposed of by burial or by incineration.

The layout of the primary and secondary facultative ponds, and the maturation ponds together with the associated pipework, has been arranged in two parallel streams to give flexibility in operation, and individual ponds can be by-passed as required for maintenance purposes.

The primary facultative ponds have been designed with mechanical aeration to assist with the transfer of oxygen into the sewage. It is not intended that complete mixing of the pond contents will take place, and the ponds will therefore remain facultative. The use of aerators in the primary ponds reduces the area that would otherwise be required, by about 60%

The aeration plant will take the form of vertical spindle floating aerators either secured to the banks of the ponds by cables, or fixed to towers standing on the bed of the pond. The depth of the primary ponds is 3.5 metres.

A pond depth of 1.75 metres has been adopted for the secondary ponds with a length to breadth ratio of 1 : 1. The length to breadth ratio is subject to modification at the final design stage when more detailed ground level information will be available. The pond depth of 1.75 metres was adopted to ensure adequate sludge storage, to balance temperature variations, and to inhibit weed growth on the bottom of the ponds.

The maturation ponds, with a depth of 1.0 metres, have been provided to ensure a high bacterial die-away, and to produce further reductions in BOD.

The ponds will be constructed by using excavated material to raise the surrounding embankments which will be lined with rip-rap to give protection from wave action, and to discourage the growth of vegatation which could provide a breeding ground for mosquitoes. The site conditions are such that it will be necessary to seal the bottom of the ponds to make them watertight.

A pumping installation has been provided adjacent to the maturation ponds to enable treated effluent to be recirculated to the head of the works to give dilution, and to maintain the water levels, particularly during commissioning and the flow build-up stage. The pumping station also serves to dispose of treated effluent to the irrigation area. Final effluent from the pumping station is used for general washing down purposes, with a high pressure facility to break up floating mats of algae should they occur.

The following tables give the predicted BOD reductions between the various stages in the treatment process, together with pond data.

B.O.D. Reduction by Pond Stages

B.O.D. reduction	1985	
	Stage 1	Stage 2
Total flow (D.W.F.) m^3/day	6364	11434
Total B.O.D. load kg/day	11058	18170
B.O.D. load on Works mg/l	575	629
B.O.D. reduction in primary ponds (mechanically aerated)	60%	60%
Effluent B.O.D. from primary ponds mg/l	230	252
B.O.D. reduction in secondary ponds	75%	75%
Effluent B.O.D. from secondary ponds mg/l	58	63
B.O.D. reduction in maturation ponds	65%	65%
Final effluent B.O.D. mg/l	20	22

Pond Data	1985	
	Stage 1	Stage 2
Primary Ponds (mechanically aerated)		
Depth m	3.5	3.5
Surface area ha	4.0	6.5
Detention days	10.0	10.0
B.O.D. reduction	60%	60%
Number of aerators	24	48
Power required kW	130	235
Secondary Ponds		
Depth m	1.75	1.75
Surface area ha	10.0	17.0
Detention days	15.0	16.0
B.O.D. reduction	75%	75%
Maturation Ponds		
Depth m	1.0	1.0
Surface area ha	10.0	17.0
Detention days	9	9
B.O.D. reduction	65%	65%
Total pond surface area ha	24	40.5

2.9 Sewerage System

General

The area around Sana'a forms one of the many plains that exist at altitudes in the mountains. The Sana'a plain is generally flat and oriented in a north-south direction. Ground slopes are very gradual and, in the area around Sana'a, the slopes fall towards the Wadi Saila which forms the natural water course for surface water run-off from the area.

The Old City of Sana'a was built on the east bank of the Wadi, on the lower slopes of the Jebel Nuqum. The development and expansion of the City in recent times has resulted in the city expanding westwards so that the City now straddles the Wadi.

The plain of Sana'a has a downward slope towards the North, and with the availability of land in this direction, it followed that the sewage treatment works would be located to the North of the City. It is a feature of the sewerage system that, with the exception of the screw pumps at the inlet works, all the flows are by gravity.

Drawing No. 1 shows the location of the treatment works site, and the routes of the trunk sewers and interceptor.

Design of Sewers

The design of the sewerage system was carried out according to the following parameters:

i) To allow for illicit rain water connections, and to accommodate variations in the population density above those predicted, we recommended that sewers up to and including 500 mm diameter should be designed on a peak flow factor of 6, and sewers in excess of 500 mm diameter should be designed with a peak factor of 3.

ii) To minimise the possibility of blockages, and to facilitate maintenance, it was recommended that the minimum diameter of sewer should be 200 mm.

iii) The sewers were designed on the Colebrook-White formula, with the roughness factor (K) taken as 0.6mm.

iv) A velocity of 1.0 m/sec. at peak flow was adopted as the minimum desirable.

Sewer Construction

The strength requirements of the sewers were designed generally in accordance with the recommendations of National Building Studies, Special Report No. 37.

The strength of the pipes was selected such that the sewers would be constructed on granular bedding, with concrete bedding in more extreme loading conditions. A high proportion of the smaller diameter sewers will be laid within the confines of the narrow streets in the Old City where it will be necessary to use concrete in backfill to the trenches of the sewers to safeguard the foundations of the existing buildings.

Pipe Materials

With the exception of a factory in Taiz manufacutring unplasticised poly vinyl chloride pipes up to 250mm diameter there is no pipe manufacturing industry in the Yemen Arab Republic. To obviate shipping delays at the Red Sea port of Hodeida, and to take advantage of the credit available, it was decided that the basic construction materials, including the pipes, would be procured under a separate supply contract to be implemented in advance of letting the main construction contracts.

The pipes to be supplied under the supply contract, which do not include materials for the house connections, range in size from 200mm to 1400mm in diameter. The pipe materials specified are unplasticised polyvinyl chloride, asbestos cement with sulphate resisting cement, vitrified clay and glass fibre reinforced plastic.

The award of the materials supply contract will be made on the basis of delivery times and the cost of the materials delivered to the stockyards of the National Water and Sewerage Authority in Sana'a.

Cost Estimates for the Sewerage System

The summary of estimated capital costs for the sewerage system is given as follows:-

	Cost in Yemen Rials	
	Stage 1	Stage 2
Sewer Network	68 501 000	77 614 200
Interceptor	17 670 000	2 460 000
Local Flood Relief	320 000	-
Public Conveniences	1 258 300	-
	87 749 300	80 074 200

Yemen Rials are converted to sterling at the rate of YR 8.5 = £(Sterling) 1.0

3. THE REFUSE DISPOSAL PROJECT

3.1 Introduction

As part of the main project study for the sewerage and sewage treatment for Sana'a, a study was also carried out to determine the immediate and future needs for Refuse Collection and Disposal.

This chapter, describing the background conditions to the refuse project and the recommendations formulated for dealing with the problem, is submitted as a supplement to the Sewerage and Sewage Treatment paper.

3.2 Background

The city of Sana'a is some three thousand years old and the old city walls and streets are still intact today. The Old City is situated to the east of the new modern city centre and consists of narrow streets and alleys, all highly congested with pedestrian and vehicular traffic, and bordered by the traditional Yemeni houses of five or six storeys, many with shops on the ground floors. A similar area, Gaal Ulufi, lies to the west of the town centre and consists of similar streets and houses.

The modern expansion of the city of Sana'a with typically Middle Eastern villa development and wide streets, has expanded the total area of the city many times, but the existence of the two distinct styles of building creates a total contrast, and presents also special problems for any refuse collection service in terms of vehicle selection to cater for the narrow congested streets of the Old City and Gaal Ulufi and to provide effective collection in the modern sprawling suburban areas.

The Project Report for the Sana'a Refuse Scheme was submitted in the Autumn of 1976. Whilst the recommendations were approved, implementation had to await the allocation of funds. However, in January 1978 further instructions were given to the consultants, and work commenced on the design of the various buildings, service facilities and tip facilities, and on the preparation of contract documents and specifications for the equipment. Delivery of equipment commenced in January 1979 and is expected to be completed in Summer 1979.

3.3 Existing Conditions

A rudimentary system exists in Sana'a whereby refuse is picked up periodically from collection points within the City, and then transported to the outskirts and deposited on to open ground.

Being undermanned, and with insufficient equipment, the system is totally inadequate, and the inhabitants of Sana'a have resorted to dumping their refuse in the streets, or on to vacant building plots. Sometimes the refuse is dumped into disused well shafts.

As the refuse collection service cannot keep up with this indiscriminate dumping, there is a backlog of refuse waiting to be cleared away.

The dumping grounds outside the City are not controlled in any way, and efforts to bury the wastes are ineffective. The tips frequently catch fire and are allowed to burn in an effort to reduce the fly nuisance, and scavenging by vermin.

3.4 Proposed Collection and Disposal Service

Concepts

It was considered that the most important immediate need was to provide effective facilities for legitimate disposal of refuse which was collected. Having established an effective means of disposal, efforts could be made to improve the efficiency of the collection service, to extend the service to provide collection to the rapidly expanding suburban development, and to provide facilities suitable for a collection service to serve the Old City areas.

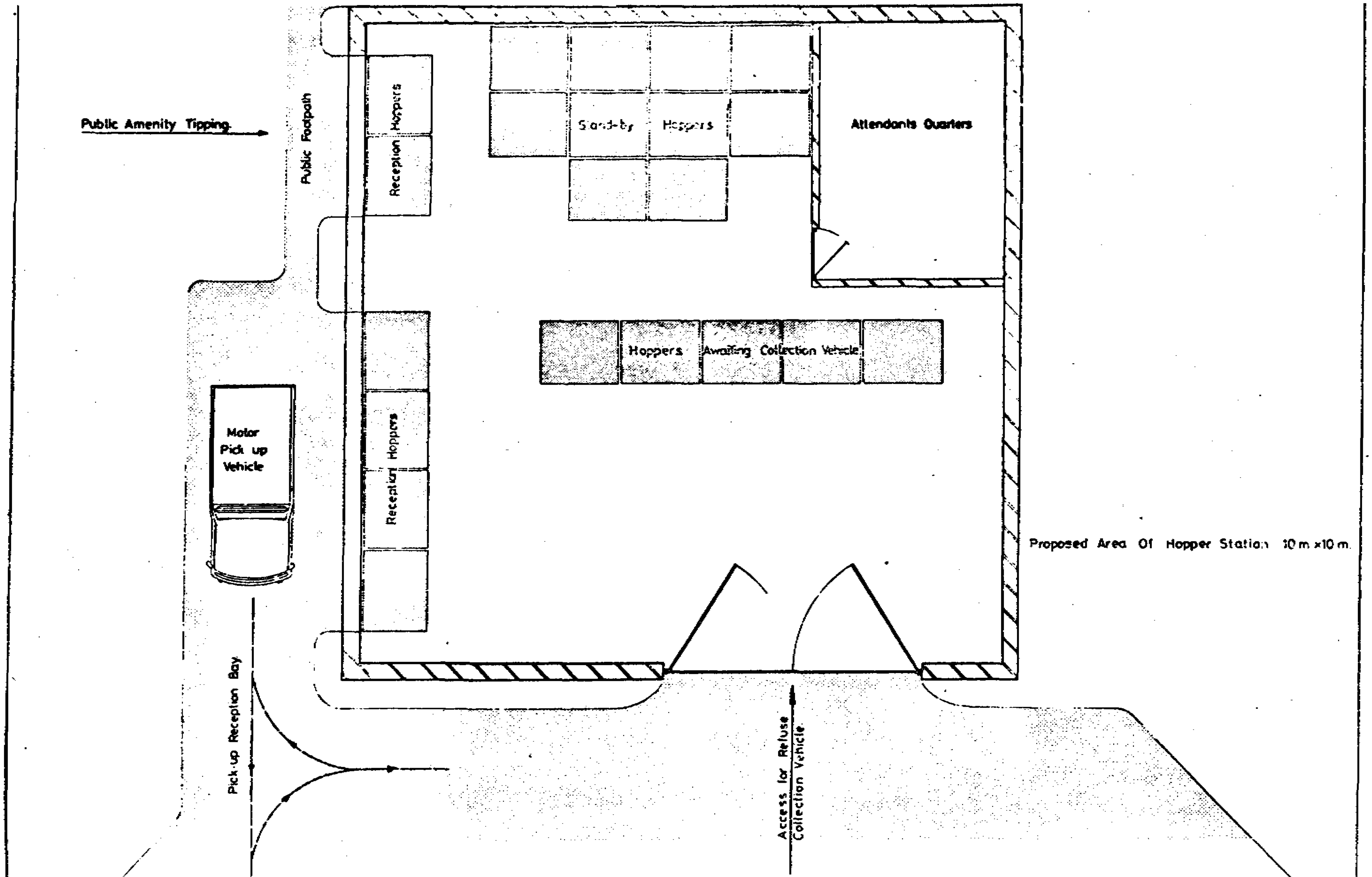
If a system could be implemented that would have real visible results in improvement of street cleanliness, removal of unsightly insanitary dumps within a short period, then public support for the project in the long term would be forthcoming.

Any system had to be simple to operate and relatively easy to administer. It was desirable to have a service which was labour intensive, but low in capital cost.

Collection Service

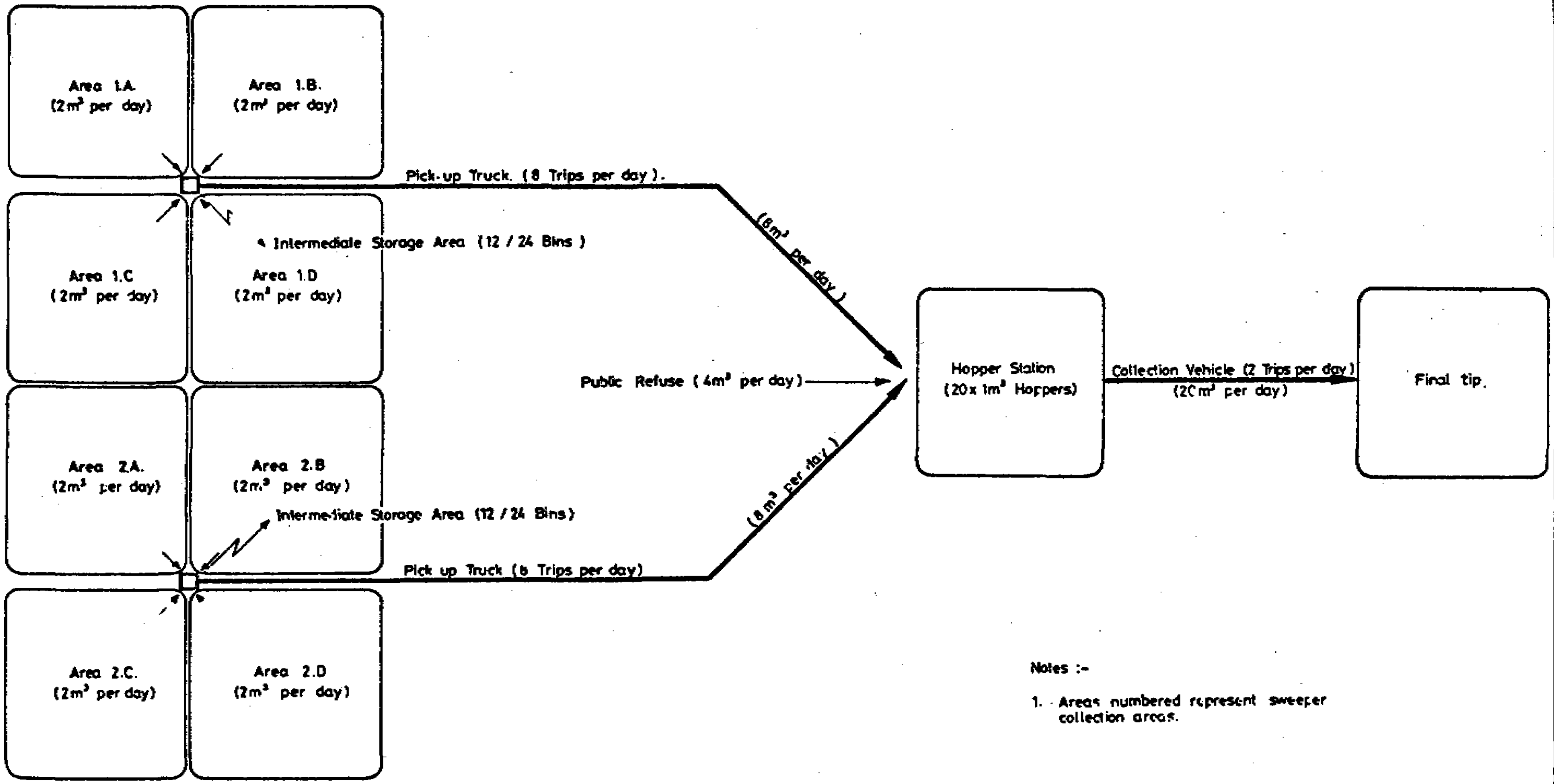
It was apparent that it would not be possible to service the entire city area with one style of domestic refuse collection. The difference in development density and street widths and access were too great to be suitable for service by one type of vehicle.

It was proposed that the Old City and Gaal Ulufi with their acute problems of vehicular access, should be served by a system employing a large number of manual collectors and little mechanisation. Street collectors equipped with hand orderlies carrying two eighty litre bins would carry out house to house collection. When the orderly bins were filled, the collector would leave them at determined collection points and replace them with empties and resume his collection. Small pick-up trucks, which were the largest vehicles which could be effectively



Refuse Collection Service - Old City and Ga-al Ulufi.

Fig No. 5 Hopper Station Layout



Notes :-

1. Areas numbered represent sweeper collection areas.

Refuse Collection Service - Old City and Ga-al Ulufi.

Fig. No. 6 Operation Chart.

employed in these areas, would be used to transport the full bins to hopper stations situated on the periphery of the high density development areas. The hopper stations would also serve as civic amenity sites for local disposal. Refuse would be collected from the hopper station by standard compression fitted collection vehicles, and the refuse transported directly to the tip site.

The arrangement for the collection of refuse in the Old City and Gaal Ulufi areas is shown diagrammatically in Figure 5. Figure 6 shows the layout of a typical hopper station.

The more modern areas of the City, including the modern city centre and suburban areas, would be served by compression fitted collection vehicles. Refuse collection containers of one or two cubic metre capacity would be positioned at intervals along all streets, generally to provide a container within a maximum of one hundred metres and normally less than fifty metres of every home. It had been considered that house to house collection from villa style residences was impractical because of the time required, and also because of the problems of gaining access to private houses in Moslem communities. The collection vehicles were all to be fitted with container lifts to facilitate emptying of these streetside containers which were fitted with hinged lids to prevent refuse scatter or animal refuse nuisance.

Other collections from institutions, hospitals and trade premises were to be handled either by containers similar to those for the kerbside system or using bulk, eight cubic metre, containers serviced by a container transported vehicle.

The collection service for the high density areas will serve 104 hectares of the Old City and 16 hectares in Gaal Ulufi. The two areas will be serviced by a total of five hopper stations. The areas have been divided into forty-eight collection districts of approximately 130 households each, served by one collector carrying out a daily household collection. Ten small pick-up trucks will be continuously employed in transporting refuse to the hopper stations from the collecting areas. In addition one hundred street sweepers will assist in maintaining street cleanliness. Two fifteen cubic metre compression fitted collection vehicles will be employed fulltime on transporting refuse from the five hopper stations to the disposal site.

Other parts of the city have been divided into eleven collection districts for which a twice weekly collection will be serviced by a total of fifteen collection vehicles, eleven $15m^3$ and four $10m^3$ capacity, including standby vehicles. Each vehicle will make two trips to the disposal site per day. The smaller districts serviced by $10m^3$ vehicles will contain approximately 1 870 households, while the larger districts serviced by $15m^3$ vehicles will contain approximately 2 800 households. The population served, and the total daily production of refuse, is shown in Tables 1 and 2.

Refuse Disposal

Sanitary landfill was the proposed method of disposal and various tip sites were investigated. Geological investigations in conjunction with the water resources studies were carried out.

Land ownership is highly complex in the Yemen and eventually, after long protracted negotiations, a suitable site was acquired which was just on the economic limit of distance from the city for transportation of refuse in collection vehicles.

The tip site was situated to the North West of the City on a slope adjacent to a main highway.

Site works which were necessary included the provision of a surface water cut-off ditch to divert run-off from the surrounding hillsides.

A system of sanitary landfilling was devised and special provisions were made for the disposal of large items such as scrap vehicles and other scrap by burial.

It was further proposed that the existing unsightly open dumps should be cleared and reinstated, the refuse being transported to the new disposal site.

Street Cleaning

A very important ancillary to the refuse collection and disposal was the provision of an effective system of street cleaning and sweeping to cater for the dust and general litter which is dropped in the streets.

As few streets in Sana'a are yet fully metalled and kerbed, mechanised road sweeping would be premature. Over the next few years, with the installation of sewers and water service pipes in the majority of streets, such methods which are high in initial capital cost, would be ineffective in producing the desired results.

Manual sweeping using sweepers equipped with hand orderlies and eighty litre bins similar to the collectors in the Old City were proposed. An initial intensive cleaning of an area, prior to implementation of the collection and sweeping service, would assist in gaining public support, and the sweepers would then maintain the clean state of the roads and alleys. In support, mechanised cleaning would be provided for the kerbside refuse containers. A container cleansing vehicle would service all the kerbside contained locations, washing the surroundings and the outside of the container. At necessary intervals, the containers would be removed to the central depot for steam cleaning, lubrication and maintenance checks.

Table 1

Total Population of the City of Sana'a

Year	Population
1976	141 873
1980	176 404
1985	225 971
1990	283 258
2000	424 651

Total Projected Refuse Production - City of Sana'a

Year	Total Daily Production m^3
1976	288
1980	451
1985	756
1990	1 321

Organisation and Maintenance

As part of the consultants' continued work on the project, organisational reports and recommendations have been prepared, including a staff structure, job descriptions, wage levels and levels of responsibility. Maintenance schedules for all vehicles and equipment, including steam cleaning, lubrication and safety checks for all vehicles and equipment, have been worked out. An equipment replacement programme was devised to enable the client to plan the Solid Waste Management Department's future budget.

A central service depot is to be constructed to provide all the necessary maintenance and service facilities for the Solid Waste Management Department. The depot will contain administration offices, a vehicle workshop with ancillary workrooms and stores, vehicle washing and steam cleaning facilities, fuelling provisions and vehicle parking areas. In addition, stores and reporting facilities for all manual labourers and sweepers have been included.

Operation of the Service

The consultants work includes the provision of an Advisor to assist with the initial running of the service, including training of operators and development of new procedures to implement the overall plan for the Department. Recruitment of top personnel is a difficult problem in the Yemen, where all people with technical or managerial abilities are in great demand in all the expanding Government services.

It is proposed that the collection service be implemented in stages; one collection district at a time, with service in other districts being initiated only when adequate trained personnel and supervision is available. Such a start will also give time for adjustment, as necessary, to cope with problems such as significant local increase in refuse or difficulties with collection rounds due to traffic congestion, which is an increasing problem in Sana'a.

It is anticipated that the initial phase of the project will be accomplished within the six months and that, by Autumn 1979, a comprehensive and efficient refuse collection and disposal service will be operating in Sana'a.

3.5 Cost Estimates

The project is being implemented under two main contracts.

Contract R1 covers the Supply of Vehicles and Equipment, and Contract R2 covers the Civil Engineering Works which includes for the construction of the Hopper Stations, the Central Depot and the Tip Site Works.

The estimated capital costs for the project, expressed in Yemen Rials, are given as follows:-

	Yemen Rials
Contract R1	12 300 000
Contract R2	9 000 000
	21 500 000

The conversion rate for Yemen Rials to Pounds Sterling is YR. 8.5 = £(Sterling) 1.00.

discussion

CHAIRMAN: Mr B M U BENNELL

1. Mr John F JACKSON introduced his paper by describing the political and economic situation in the Yemen Arab Republic. The country lay between Saudi Arabia in the north and South Yemen, and acted as a buffer between the ideologies of the West and communism. It seemed to have found the answer to living with both systems and benefited in terms of aid from its political and geographical position. Funding for its development programme came from the World Bank, Saudi Arabia, Kuwait, West Germany and the Netherlands. One of the latest arab countries to emerge, it was the most rapidly developing country in the world. It was a relatively small country, but had a large population, estimated to be about 7½ million. Sana'a had a long history and Mr JACKSON had found it to be a fascinating place.

2. The paper described the study and development of designs for sewerage, sewage treatment and refuse disposal which had been carried out by Howard Humphreys and Sons in the previous twelve months and which had now been completed. The Terms of Reference had been summarised in the paper. HHS were now engaged in the detailed design and the preparation of contract documents and equipment contractors were about to be appointed.

3. Mr JACKSON showed slides illustrating the country and the city of Sana'a. The insanitary conditions and especially the accumulation of refuse were pointed out.

4. The shaft latrine, as shown in figure 7, was widely used. Excreta was stored below the shaft and all liquid, including urine, was discharged to the street. Provided the pit was properly sealed, the system seemed to work well. In Sana'a as a whole there were a variety of sanitary arrangements from no sanitation at all to a fairly modern water-carried system. Modern houses, such as those occupied by expatriates, used septic tanks.

5. Mr Ken ELLIS thanked Mr Jackson for a very informative paper. The loading of the proposed facultative ponds had been given as 350 kg/ha d; what was to be the loading on the primary aerated lagoons? Mr ELLIS wondered why the primary lagoons were to be mechanically aerated as this only gave a 20% saving in land. Mr ELLIS suggested that it would have been better to provide covered anaerobic tanks for the first stage and keep to facultative lagoons. He doubted the value of recirculating effluent, which would add to the cost and to the equipment requiring maintenance.

6. Mr ELLIS asked whether consideration had been given to the transmission of parasites in sludge when designing the mesophyllic digestors for the biological filtration alternative.

7. Mr JACKSON said mechanical aeration had been included because the ponds were quite expensive. It was not just a question of the area required, although land was quite expensive. The ponds would be lined with rip-rap to prevent erosion and weed growth and the bottom would be sealed to prevent pollution of groundwater. Anaerobic ponds had been considered for first-stage treatment. However, Sana'a was at a high elevation and the temperature was quite low at times. Unless anaerobic ponds were

covered (which would increase their cost considerably) there would always be an odour problem. The site selected for the works was four miles from the centre of Sana'a away from the prevailing wind, but there was a village down-wind of the site, and the development of the city was such that residential areas were likely to extend around and beyond the treatment works.

8. Mr JACKSON said that his firm had possibly been cautious in their choice of treatment. Effluent was to be disposed on-site, thus reducing the risk of nuisance from smell. An interesting conclusion of the study was the small difference in total cost between the alternative methods. This was of course partly due to the lining and sealing of the ponds.

9. Mr M T UDEDI asked why screw pumps had been proposed. These were difficult to repair even in the U.K. Mr JACKSON said that the whole sewerage system was to be gravitational, but this would result in quite deep sewers at the works. Some form of pumping would be necessary and it was considered that screw pumps were most reliable.

10. Mr K B NYASULU asked how the excreta which accumulated at the bottom of the shafts in the traditional latrines was removed and used. Mr JACKSON said that the outside wall was broken down and the excreta were raked out. This was done at about five year intervals, so most of the excreta had become stabilized and innocuous. The material was mixed with straw and clay to make dung cakes which were used for heating. Any surplus was used as a fertilizer. It had a certain amount of mineral value.

11. Mr NYASULU asked whether it was proposed that this method should continue. Mr JACKSON replied that this type of latrine would be abandoned. It had been used for hundreds of years. The tall building construction was typical of the whole of the Yemen, and shaft latrines were common in all the towns and villages.

12. Mr NYASULU asked why the sewerage and sewage treatment proposals were in two stages. Would it not be cheaper to carry out the whole scheme at one time? Mr JACKSON said that the whole project had been designed as a whole. However, as the work was not to be completed until 1985 and as there were financial and physical constraints on the rate of development it had been decided to carry out the work in two stages. The most important improvements were to be included in the first stage, and construction would be started within a few months.

13. Mr P P C M LAURIJSSENS noted that the design was based on a daily BOD of 54 grammes per person, which was the same as used in Europe. He wondered whether the different habits and diet in the Yemen would produce a different BOD. Was there any other experience of similar conditions? Mr JACKSON suggested that 60 g/pd was standard. His firm had experience in similar countries and particularly in Libya, where the sewage was comparatively weak, and 54 g/pd seemed reasonable. In Sana'a the standard of living was already high as Yemen was one of the rich developing countries. The standard of living and diet were closer to European levels than to those of the poor developing countries. In reply to a further question from Mr LAURIJSSENS, Mr JACKSON said that water was at present largely obtained from wells. By 1985 it was expected that the standard of living and provision of water would be such that a sewage flow equivalent to 85 l/pd was likely.

14. Mr D V ALLEN asked where there was much nuisance from the 'long-drop' shaft latrine, apart from the pollution of wells. Would it lend itself to appropriate technology in rural areas? Mr JACKSON said it was an appropriate method which was quite sanitary provided the access hole at the bottom was properly sealed. Most buildings were constructed in the same sort of way. However, Mr JACKSON had found that many shaft latrines in the Old City were very insanitary because the holes at the bottom of the chamber were not sealed and the contents flowed into the streets. Also waste water was discharged directly into the street and as there was also indiscriminate dumping of refuse, the streets were hazardous and insanitary. The general state of health was not good. Although people seemed to develop a natural immunity to many diseases, the infant mortality rate was high and life-expectancy was low compared with the western world. People suffer from illnesses which are not diagnosed, but much of the illness was thought to be fly-borne.

15. Mr R TRIETSCH asked for more information about the costs of the project.

From the figures given in the paper there seemed little advantage in any one alternative over the others. Mr JACKSON said that the selection of the method of sewage treatment was not entirely based on total cost. Important points were the relationship between on-shore and off-shore costs and the number of staff required. The costs were to be recovered by a combined water and sewerage rate, which at present was 2 Yemeni Rials per cubic metre for water supplied plus YR 1.5/m^3 for sewerage (based on the water consumption). To give some idea of wages, Mr JACKSON said that his housekeeper was paid YR 1500 per month.

16. Dr B M El HASSAN asked on what basis do consultants decide on the rates of flow and growth of the cities when designing for developing countries? He mentioned the Khartoum South sewage works which had been designed by Mr Jackson's firm. The flow to this works now greatly exceeded that for which it was designed. Mr JACKSON had recently visited the Khartoum works. These had been commissioned in 1959 and he was told that the finish of the work was better than that on the Khartoum Hilton. The works, which consisted of biological filters, seemed to be functioning well in spite of overloading. Spare parts were obviously a difficulty: Howard Humphreys had included generous provision of spare parts in the original contract, but these had been used up long ago. Only one sedimentation tank was in use with its arms hanging off. But the works were still operating and could be refurbished.

17. Mr John PICKFORD said that Khartoum provided an interesting comparison between biological filters and waste stabilization ponds. The South Works using filters were still functioning after twenty years, but the condition of the North works with waste stabilization ponds was appalling. Dr HASSAN pointed out that the North Works had been designed for combined domestic and industrial flow, but only industrial flow was received.

18. Mr ELLIS commented further on two points he had already made. With cold digestion there was a real danger of pathogens passing through the treatment process. Sludge should therefore be stored for six months or a year before being spread on agricultural land. As for percolating filters, the drawback was the danger of gross fly nuisance to people living down-wind of the plant.

19. Mr R DIGGINS was interested in the choice of pipe materials and asked what criteria were used in their selection. Mr JACKSON said that although the temperature in Sana'a was high during the day, it became quite cool at night. He considered that clay pipes were best for small sizes, from the point of view of durability. All materials were considered: asbestos cement would be satisfactory because of the night-time drop of temperature; uPVC pipes were manufactured locally so the local manufacturer was allowed to quote; GRP was also considered. The decision was largely based on cost. Asbestos cement pipes manufactured with sulphate-resisting cement, and with bitumen lining and flexible joints, were selected for smaller diameters. For 1200 mm and 1400 mm diameter pipes GRP was to be used because transport costs were less as the sections could be nestled.

20. Mr DIGGINS said that there were one or two instances in the U.K. of AC pipes collapsing after ten to fifteen years. Mr JACKSON said his firm had used AC pipes extensively in Libya but there had not been any failures. Failure was most likely with consistently high temperatures.

21. Mr J D ARROWSMITH wondered whether the local population wanted to adopt the water-carried system and whether they could afford it. Mr JACKSON replied that for all Arab countries water-carried sewerage was the first choice. The Yemen could afford it, and it was only political considerations which determined the rate at which it would be installed. Mr ARROWSMITH suggested that the 'long-drop' latrine were a viable alternative to other types of composting latrines which were advocated by the World Bank partly because they provided for the conservation of valuable material.

22. Mr G S CANSDALE noted that the daily quantity of refuse was expected to be 1300 cubic metres by 1990. This would require a tremendous amount of space for controlled tipping. Had Mr Jackson considered incineration? Mr JACKSON replied that his programme for refuse only covered the next ten years.

23. Mr Jozsef BUKY said that in planning the Project the consultants had taken into consideration operating costs, capital costs, on-shore and off-shore

costs and so on. A design period up to 1985 seemed very short for the first stage. Mr JACKSON said that although the Yemen was to all intents and purposes an oil-rich state, the funding for the project was from the World Bank and therefore the programme had to be geared to availability of capital. He emphasized that design work for Stage 2 was already in hand. Mr BUKY confirmed Mr Jackson's remarks about the demand for sewerage. The Yemenis insisted on house connections for water supply and full sewerage.

24. Mr R MUNGRA was concerned about the contaminated wells, and asked if there was other pollution. Mr JACKSON said that groundwater was abstracted for the city's piped supply at some distance from Sana'a. All groundwater under the city was polluted.

25. The CHAIRMAN thanked Mr Jackson for his interesting and informative paper.

J G EVANS

drainage problems of a south pacific island

GENERAL

1. The kingdom

1.1 In Tonga natural resources,[1] as raw materials, are few but the Kingdom has much fertile agricultural land. Exports include copra and bananas and the principal trading partners are Australia, New Zealand, Britain and Japan - not always in that order.

1.2 Communications are good and there are regular air services to/from New Zealand, Fiji, the Samoas and elsewhere, with internal air/sea schedules connecting the outer islands with the capital, largely, by way of the international airport at Fua'amotu on Tongatapu, the main island, and the three wharves at the capital.

1.3 The ruling monarch and Head of State is H.M. King Taufa'ahau Tupou IV who ascended the throne in 1965, and who rules through the single-chamber Legislative Assembly consisting of the 7 Cabinet Ministers, 7 representatives of the 33 hereditary Nobles and 7 members elected by the Commoners. The Head of Government is H.R.H. Prince Tu'ipelehake, Prime Minister.

2. The town

2.1 Nuku'alofa lies on the north coast of Tongatapu Island, at 175^{o} 12'W, 21^{o} 08'S. In 1978 the population of the town was estimated to be 22 000.

2.2 During/following rainy periods parts of the town are flooded and it is common for the accumulated water to remain on the surface for days/weeks. Flooding should, however, not be confused with exposures of natural groundwater which are evident in parts of the town throughout the year, although most are reported to have eventually dried out during the drought of 1977.

[1] Unsuccessful attempts have been made to locate oil under Tongatapu. It is said that offshore drilling may be more fruitful.

2.3 Existing surface water drainage provides for Talamahu Market, Government Offices on Vuna Avenue and certain lengths of Taufa'ahau Street and Salote Avenue. The two lines serving this area discharge to the ocean.

2.4 There is no formal sewerage network and properties rely on individual wastewater disposal facilities (septic tanks or latrine pits). During rainy periods it is fairly common for septic tank effluent to be spread by the surface runoff, thus creating a health hazard in certain areas. Increased development and a rising population contribute to the dangers.

2.5 Rainfall averages 68 in (1727mm) per annum. Most of this falls in the summer period (the wet season) in January, February, and March. There are on average 167 wet days per year. The maximum daily precipitation recorded is 11 in (280mm) (in January 1952). There are no records of rainfall intensity.

2.6 The town consists of a number of drainage areas, each with its own characteristics.

2.7 Topographically, the surface slopes generally from Vuna Avenue, on the ocean front, southwards towards the lagoon. There is also a fall from west to east over much of the town area, to a trough of low ground from Vuna Avenue through Ngele'ia to the lagoon. There are other, isolated, low areas.

3. Public Health

3.1 In terms of water-borne or water-related diseases, filariasis is endemic as is typhoid but the latter is under control, largely due to an immunisation programme.

3.2 A filariasis control centre exists and dispenses tablets, free of charge, to residents and long-term visitors.

3.3 Only one species of mosquito, Culex quinquefaciatus Say,[1] is present. This species has been shown to be a vector of sub-periodic W. bancrofti[2] in Fiji.

3.4 The Kingdom appears legally well-equipped to deal with contagious and infectious diseases. Legislation provides for penalties for failure to report, and/or submit to, prescribed treatment.

3.5 The very common practice of pig breeding often results in the escape of these animals from their quarters; loose pigs/piglets are frequently encountered, even in the town centre. They constitute a traffic hazard and a health risk, and should be effectively confined.

3.6 There must be a significant risk that pigs act as vehicles for the transmission of certain micro-organisms. Little imagination is needed to picture cases where wandering pigs root about in areas frequented by children. The animals may thus become contaminated by excreta containing active pathogens which are then transferred to crops, cooking utensils, etc. when the pigs move elsewhere, or transferred to a host when the animal is handled. (The infections which pigs could transmit include typhoid, salmonellosis, cholera, and conditions associated with Escherichia coli).

3.7 Excreta is the first step in the transmission route of many diseases and any interruption to the route is a useful contribution in the fight to protect health.

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[1] also known as C. pipiens fatigans and C.p.quinquefaciatus. The preferred name is C. fatigans (S J Miles, Systematic Entomology, 1, 263-270, 1976).

[2] Wuchereria bancrofti.

4. Land tenure

4.1 Land tenure has a traditional importance in Tonga where all land is the property of the Crown.

4.2 On reaching the age of 16, each male Tongan subject is entitled to apply to the Minister of Lands for a grant of land not exceeding 8¼ acres (3.33 ha)[1] "as a tax allotment and where any such grant is less than 8¼ acres the Minister may from time to time as land becomes available and as he deems expedient make further grants to such holder until the area .... has a total area of 8¼ acres. He shall also be entitled to receive .... an area not exceeding 1 rood 24 perches[2] in a town as a town allotment".

4.3 The local name for the allocated land is "'api", the "'api kolo" being the town plot and "'api tukuhau" the tax allotment or cultivation area, in the bush.

4.4 This method of land tenure - thought to be unique throughout the world - ignores income and social status of the occupier. It is fairly common to find a well-appointed house, with electricity/bath/septic tank, alongside a very much more modest home having no power connexion, no bath, an outdoor cooking area, and a pit latrine.

4.5 The disparity may also have other physical manifestations. In low-lying areas prosperous householders often use soil/coral fill to raise their land/homes above flood level. The less well-off cannot afford fill and consequently, during wet periods, their sites accumulate not only the direct rainwater but also runoff from their more elevated neighbours.

5. Population

5.1 Population of the town is increasing as indicated by the following table. The 1978 population is estimated by the Government Statistician to be 22 000.

Town Area	1966	1976	% Change
Kolofo'ou	8 685	9 088	+ 4.6
Ma'ufanga	2 420	3 650	+ 50.8
Kolomotu'a	4 440	5 618	+ 26.5
Haveluloto	1 334	2 245	+ 68.3
	16 879	20 601	+ 22

5.2 Much of the population increase is said to be brought about by immigrants from other islands in the Kingdom. The attractions of Nuku'alofa include good schools and it is customary for many Tongans to leave the outer islands[3] and move to the capital for the better education of their family. They stay with relatives/friends perhaps, or erect simple homes in the 'api kolo of others; some occupy 'apis left vacant[4].

[1] sufficient to grow a substantial stand'd of coconut/banana/taro/yam and other produce, and to rear a good number of pigs/goats/fowl, etc.

[2] 1 rood 24 perches = 0.4 acre = 0.16 ha.

[3] the Kingdom consists of some 150 islands (although not all are inhabited.

[4] possibly vacated by Tongans working/living in New Zealand/Australia/elsewhere.

5.3 From all the foregoing it can be seen that land acquisition is of much importance. An occupant can subsist from his own crops/livestock whereas a re-located person has to rely on friends/relatives for support. Fortunately, Tongans are by nature comradely people and are traditionally hospitable. They also have strong family and extended family relationships with defined duties/obligations between members.

6. Schools/Colleges

6.1 In Nuku'alofa there are 27 schools/colleges with a total of 10 687 pupils/students.

6.2 The various premises are scattered throughout the town and no good opportunity exists for any scheme of joint sewerage. Accordingly, there is no proposal to modify the drainage facilities which presently consist of septic tanks.

6.3 Effluent from the tanks percolates into the ground and is lost by absorption/evaporation. By and large the method functions well.

6.4 One might easily recommend regular emptying[1] of school tanks, in the interests of efficient working. On the other hand they cope remarkably well when ignored. No important changes are proposed but there is need for greater efforts at improved cleanliness/housekeeping/ maintenance in some cases (defective flushing cisterns seemed a fairly common fault).

7. Hotels

7.1 The Tonga Visitors Bureau list details of the 6 hotels in the town. They vary in capability from the 76-room International Dateline Hotel to the Beach House, which can take 8 guests. Total available accommodation is for about 214 persons.

8. Hospital - Vaiola

8.1 The hospital was opened in June 1971. There are 200 beds and a recently completed psychiatric ward, not yet in use.

8.2 All foul/kitchen/laundry wastes discharge by gravity to an existing treatment plant inside the hospital grounds.

8.3 The plant is said to have been originally designed to treat 12 000 gallons per day (55 000 L/d). In 1972, from 3rd January to 30th June, the Tonga Water Board recorded a consumption of 25 600 gallons per day, (117 300 l/d) average.

8.4 In July 1978 the measured amount supplied was said by the Water Board to be 1.48 mgd (6.6 mld) or about 47 740 gal/pd (218 800 l/pd) average.

8.5 The existing plant is overloaded. The compressor equipment is in operation 24 hours, in efforts to achieve some form of treatment, and it is a credit to the standard of maintenance and to the reliability of equipment that the plant copes as well as it does.

8.6 It would be easy to recommend a package treatment plant, employing one of the many oxidation methods available. This would require skilled maintenance and expenditure on electricity; there would also have to be regular sludge removal.

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1 This is an expression of convenience. Septic tanks should not be emptied - around 20% of the contents should remain to ensure continuation of the anaerobic action.

8.7 A plant of this type would not be satisfactory on the existing site which is relatively difficult of access. There would also be problems with maintaining the present facilities while the new units were being built.

8.8 Because of the disadvantages outlined above, it is held that any form of package plant would be inappropriate and hence this method of treatment is not recommended.

9. Miscellaneous

9.1 Tonga lies in an active seismic belt and minor earth tremors are common.

9.2 The last noteworthy earthquake was in June 1977 when the epicentre was some 138 miles (218 km) south-south-west of Tongatapu; magnitude was 7.2 Richter. The New Zealand Department of Scientific and Industrial Research has predicted[1] that disturbances of at least this magnitude may be expected on average every 13 years.

9.3 The Water Board records show that the average consumption of potable water is 13 million gallons (60 Ml) per month, say 433 300 gallons per day (1.98 Ml/d). Of this, 43 000 gallons (197 000 l) are said to be used at the Dateline Hotel and 50 000 (229 000 l) is assumed to be the daily demand at Vaiola Hospital.

9.4 Thus, 340 300 gallons (1.56 Ml) seems to be the demand, for a population of 22 000, producing a present average consumption of 15.5 gallons (71 l) per person per day. This is the demand from the mains supply; as stored rainwater[2] is also used the per capita total consumption per day must currently be somewhat in excess of 15.5 gallons (71 l).

PROJECT POLICY

1. It would be tempting to prepare sophisticated drainage proposals, with a number of stormwater pumping stations discharging into the ocean. Such a scheme may well emerge in due course but it would rely on imported plant/equipment, skilled maintenance, adequate finance and other requirements - all of which may well be readily available in other countries - but the capital/recurrent costs would be unlikely to be attractive in Tonga. Thus nothing would be achieved.

2. The need in Nuku'alofa now is for engineering work which is comparatively inexpensive and which can be cheaply maintained. This is the ruling principle underlying the contents of this Paper.

RELATIVE LEVELS

1. In terms of drainage, ground surface elevations represent an essential item of data. Insufficient levelling detail was locally available and the first priority was seen to be the setting up of reliable datum points throughout the town, for reference later.

2. The British Admiralty soundings datum for Nuku'alofa is "9.8 ft (2.99m) below B.M. cut on W face of pedestal of Prince Wellington's monument[3]" inside the grounds of the Royal Palace.

3. This datum was used for all the levelling in the town. The effects of any earthquake, since that bench mark was established, have been ignored.

1 "The Tonga Chronicle", 3rd March 1978.

2 rainwater storage is a common feature in many islands - in the Caribbean, the Pacific and elsewhere.

3 from Admiralty chart 1385, (B.M. = Bench Mark)

4. A simple tide gauge was set up and observations were made during the high spring tide cycle of 23rd June 1978.

5. Measurements were also logged at the lagoon on the same day - see accompanying curves, figure 1.

6. The results show an ocean tidal range of +4.85 ft (1.48m) relative to Soundings Datum (rSD) to -0.8 ft (-0.24m) rSD while the lagoon amplitude was from +3.25 ft rSD (0.99m) to about +2.4 ft (0.73m) rSD. Mean levels were: ocean +2 ft (0.61m) and lagoon +2.8 ft (0.85m). The lagoon peaked 3 hours (theoretically, this is probably 3hrs 6mins) after the ocean.

7. There was 1.4 in (35.6mm) of rain on the 23rd June, which must have influenced the height of the lagoon peak. Accordingly, a further set of spring tide observations was recorded on the 24th July, following a dry day. The lagoon on that day peaked to +3.05 ft (0.93m) rSD or 0.2 ft (0.06m) below the level on the rain day. This result tends to support the view that surface/rainwater has a noticeable dwell period in the lagoon.

8. The lagoon outlet was visited and found to be relatively narrow and shallow[1]. Thus there can be but little opportunity for the lagoon to rapidly discharge into the ocean the precipitation falling on it, and draining into it from the catchment area. Heavy rainfall can therefore raise lagoon high water level above the observed height.

9. Whereas the observed maximum in the lagoon was +3.25 ft (0.99m) rSD, indications on adjacent walls suggest that a fairly common maximum is nearer +3.5 ft (1.07m) and it is this value which has, generally, been used for the outlet level of drainage pipes into Fanga 'Uta Lagoon.

10. At times of very heavy rain the lagoon is thought capable of rising to approximately +4 ft (1.22m). This should be regarded as unusual and is held to be within the limits of the locally acceptable flooding risk.

11. Although the lagoon mean level is higher than that of the ocean, most of the gravity surface water system must be designed to discharge into the lagoon. This is because the ocean high water peaks to a higher level than the lagoon.

12. The use of pipes to the ocean/foreshore and having flap valves was considered but abandoned as representing too high a flooding risk. Failure of such valves at a time of highest astronomical tide and a sustained on-shore wind would cause widespread flooding by seawater.

13. On the other hand, uncontrolled outlets to the lagoon, at invert levels of +3.5 ft (1.07m) rSD or higher, are thought to represent an acceptable level of risk.

SURFACE WATER DRAINAGE

1. There are no natural watercourses in Nuku'alofa and no network of surface water drains. During heavy rain the water gravitates to low points, a number of which remain inundated for days/weeks.

2. In due course these accumulations percolate/evaporate exposing, in some low areas, the natural groundwater which may form a permanent feature (except during drought, as in 1977, when even the groundwater evaporated to below surface level).

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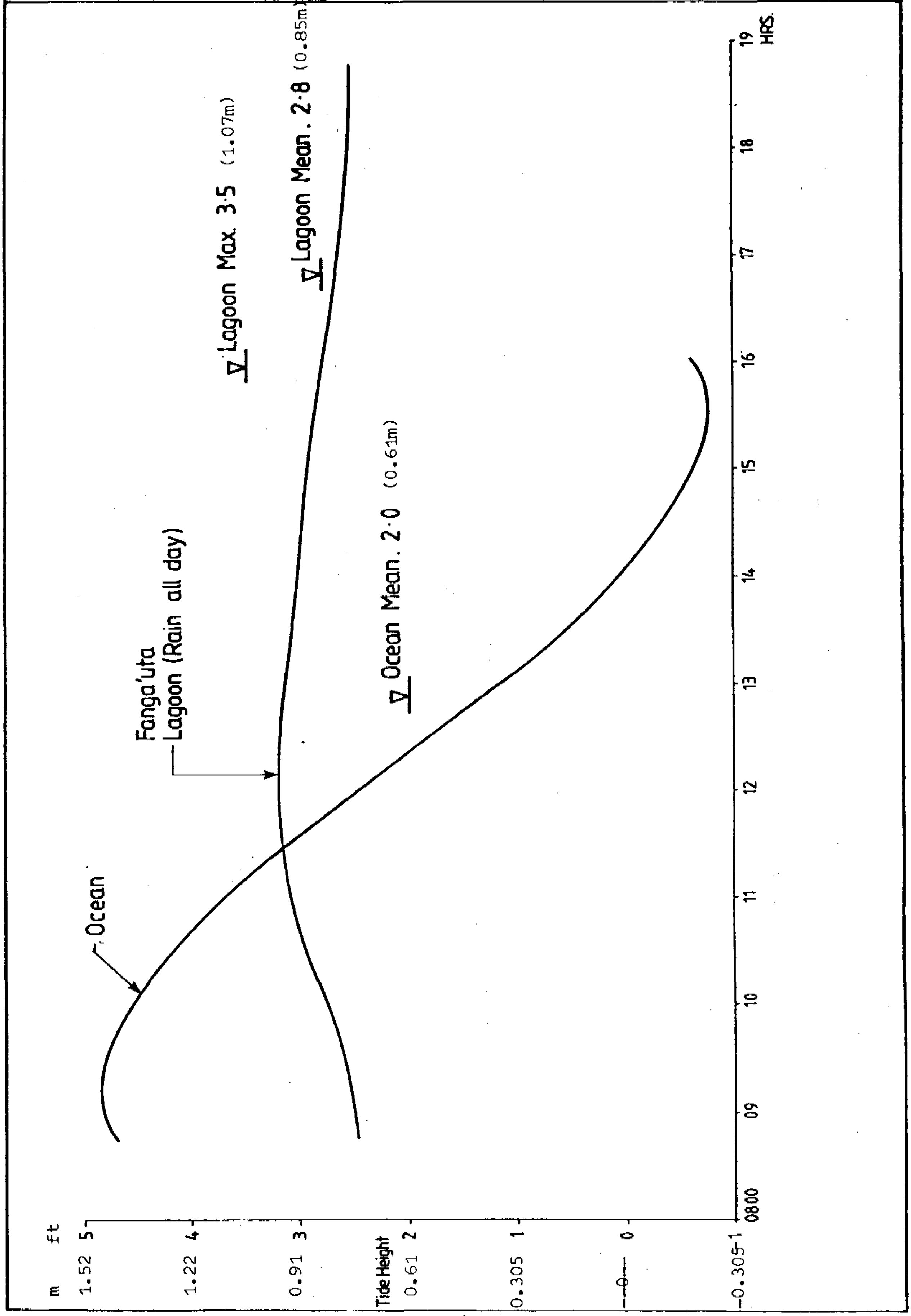
1 the visit coincided with high water in the Ocean.

Tide Height vs Time. Fig. 1



3. The rise of the lagoon to about 3.5 ft (1.07m) rSD regulates groundwater level in these low areas. The underlying/surrounding coral is pervious but not sufficiently open-textured to permit the groundwater to at once follow the lagoon tidal fluctuation. Accordingly, groundwater is exposed where surface levels are around 3.5 ft (1.07m) or below.

4. This level must be maintained and any attempts to depress it must, for the present, be strictly prohibited.

5. In this context one should not lightly consider any proposals to reclaim land from the lagoon which involve lowering the groundwater level, without adequate investigations/review by an experienced hydrogeologist.

6. Interference with the groundwater would result in the depression of the water table level throughout the catchment area, including points appreciable distances from the seat of abstraction. It is doubtful if the drop in water level could be followed sufficiently rapidly by the roots of plants/trees, many of which might be put at risk.

7. Furthermore, knowing that the ocean peaks to +4.85 ft (1.48m) it is possible for any interference with groundwater to cause saline intrusion, another danger to vegetation. What effects there might be on the island's underground water resources are unknown.

8. For these reasons there must be no interference whatever with the level of natural groundwater. In those areas where it is almost permanently exposed the means of its "removal" is to fill, and to drain off any rainwater which seeks to rise above the critical level of 3.5 ft (1.07m) rSD.

9. Under normal conditions, the engineering design of storm drains requires pipes of adequate diameters to accept the flow. Thus a gravity-only drainage system usually commences at its apex with comparatively small pipes while at the point of discharge the conduits are at their largest in that system.

10. In much of Nuku'alofa such customary practice would not be possible. The ground in some areas has very little fall and, over large pipes, there would be insufficient or no cover to allow discharge at the recommended minimum level of 3.5 ft (1.07m) rSD. To cross roads, pipes larger than about 9 in (225mm) diameter would need local humps in the carriageway - an unacceptable solution from traffic and drainage viewpoints.

11. To meet the special needs, it would be necessary to use a number of comparatively small pipes laid side-by-side. Also, because of the poor available cover such pipes should have thick walls, in efforts to avoid the concrete surround normally provided for physical protection. The pipeline should have no formal joints so that water may enter freely - another reason why standard concrete surrounds cannot be used.

12. (Thick-wall concrete pipes, imported, would be prohibitively expensive. The MoW[1] now make concrete pipes for their own use, but the existing production facilities/output would be inadequate for the amount of pipework necessitated by the proposals herein - whichever method of drainage is selected).

13. Where pipes would be in road verges there is of course a risk of fracture/displacement; vehicles are frequently driven and parked on verges. Such risk will be accepted. In any event, thick-wall pipes would be better able to accept loads than conventional pipes.

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[1] MoW = Ministry of Works

14. Another limiting factor is the roadside space available for pipes/pipelaying. If side-by-side "small" pipes were used then there is a physical limit to the number which could be accommodated in the road margins, and hence a limit on the rate of removal of runoff. (This last remark ignores existing services such as water lines, overhead cable supports and underground telephone cables - two other constraints on land availability).

15. On most roads gulleys would presently be totally useless. There are, generally, no kerbs/channels to confine rainwater and the carriageway is often above the ground alongside, onto which it sheds its runoff flow.

16. Coral fill above and around the pipeline would delay the time of entry of flow into the pipe, especially if its upper levels were obstructed by soil/vegetation. The immediate dissipation of flooding would therefore be unlikely, with an all-pipe system of drainage.

17. Furthermore, because of the poor gradients large diameter pipes would be necessary to ensure no-flood conditions. But, as explained, large pipes could not be used.

18. In some respects this could, curiously, be fortuitous. A highly effective gravity drainage network could be designed to prevent all flooding - at least within a stated statistical return frequency. At the same time it would introduce, very rapidly, a considerable volume of fresh water into the lagoon. This would be in addition to the rainwater directly entering the lagoon, the level of which would thus rise by reason of the two forms of inflow.

19. As argued elsewhere, under present conditions lagoon level can rise to around 4 ft (1.22m) rSD during heavy rain. The rapid addition of rainwater from a catchment area of some 700 acres (285 ha)[1] would certainly raise the level higher, having regard to the two somewhat confined channels connecting the lagoon to the ocean.

20. To assist in the overall drainage difficulty the proposals allow for the subdivision of the large urban catchment into constituent areas, requiring smaller pipes (or channels, as appropriate) and giving a greater number and spread of outlets into the lagoon.

21. Subdivision is by drains alongside the north-south aligned roads. These drains alone will give useful relief in as much as they will remove the pools commonly seen besides many roads after rain.

22. This interception of runoff will reduce the opportunities which now exist for septic tank effluent to be spread by surface runoff. Accordingly, the needs of public health will be met by the installation of storm drainage.

23. In certain critical areas surface levels are around 3.5 ft (1.07m) rSD, or groundwater level. If it is accepted that there must be no lowering of this water, then the only way for its "removal" is to fill; a common enough step already in many an 'api kolo[2] in Nuku'alofa.

24. Only the minimum depth of fill should be used, the governing criterion being that depth necessary to (just) accommodate 6 in (150mm) thick-wall concrete pipes. In practice, this means fill to a level of 4.2 ft (1.28m) rSD.

25. The ultimate in floodwater removal would require watertight[3]

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[1] estimated from the 1:25000 series of maps of Tongatapu.

[2] 'api kolo = town dwelling plot.

[3] to secure watertightness and protection against earth movements "plastic" pipes would be useful but in large diameters they would be very costly, in Tonga.

pipes under carriageways, laid to adequate gradients and discharging to suitable pumps.

26. An alternative to the piped drainage referred to in the foregoing sections is a method employing channels as the main conduits for floodwater removal (to the lagoon).

27. The alternative is more effective in that it would remove flooding more rapidly (but with greater risk to lagoon life). It is also, generally, less expensive in capital cost and maintenance will be cheaper. Thus the alternatives become self-selective insofar as channels are seen to be more attractive. However, in some cases drainage will require channels and pipes.

28. In terms of effects on lagoon life, channel drainage will have the greater impact. Accordingly, an ecological study[1] should include a careful review of the final proposals.

29. One very useful feature of channel drainage would be the opportunity to provide a kerb, for any adjoining road, merely by extending the sidewall of the channel above carriageway level. Simple openings in this extension would admit run-off from the highway and there would also be useful mechanical support for the highway material/traffic.

30. For satisfactory detailed designs further site study will be essential. Nonetheless, the present alternatives are thought to be a good guide to the requirements.

FANGA 'UTA LAGOON

1. As argued elsewhere most of the surface water discharges will enter the lagoon. This is unfortunate. The shallow depth - adults often ford the lagoon on foot to reach Kanatea Island - coupled with its poor circulation provide little dispersal of any pollutants. In this context readers should note that, to certain forms of lagoon life, even fresh rainwater is a pollutant.

2. It might be thought that the shallow depth and large surface area would encourage useful photosynthesis and good oxygen transfer. However, it is likely that the turbidity of the water militates against the former and temperature effects influence the latter.

3. A report[2] published in January 1978 suggests that the lagoon ".... is and will continue to be a significant environmental management problem ...." and continues " .... it will be necessary to be extremely careful with further development around it if the situation is not to deteriorate further".

4. The report includes the results of bacteriological tests of the ocean water and of the lagoon. It is significant that the highest levels of coliform bacteria appear in the lagoon.

5. Much of the pollution must originate from properties on the lagoon shore, a number of which have no septic tank - the occupants freely discharge crude sewage directly into the water.

6. Because of the low-lying level of the lagoon shore - in its natural state this land was mangrove swamp - water is encountered above, at, or at best only a few inches below, the surface (depending on the lagoon level). Accordingly, even if septic tanks were in use

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[1] an ecologist has now been appointed.

[2] Environmental and Ecological Report on Tonga Part 1 - Tongatapu, Dr A L Dahl, South Pacific Commission.

the effluent therefrom would have little or no dry soil into which to percolate.

7. One remedy involves the eventual removal of buildings in the vicinity of the lagoon, particularly in the area from and including Haveluloto to near Ngele'ia Avenue, a length of some 1.2 miles (1.93 km).

8. Land vacated should be restored to its original condition as a mangrove strip. Mangroves are the natural habitat of various life-forms and tend to act as protection during hurricanes. (This latter aspect was discussed with a consultant on Natural Disasters who fully upheld the principle). The law also recognizes the situation - Sec. 7 of The Birds and Fish Preservation (Amemdment) Act, 1974, makes it an offence to "cut, damage, remove or destroy any mangrove".

9. The above remarks represent one solution. Another might involve the construction of a wall edging the lagoon and the use of coral fill to raise the ground to a suitable level.

10. Sufficient detailed study was made of the lagoon margins to show that the situation requires much further review, and a clear evaluation of alternative courses of action.

11. It is recommended that a careful investigation be carried out by an ecologist (recently appointed).

12. Meanwhile, it would be prudent to prohibit all further development along the lagoon shore, in the length described and in a strip of at least 50 ft (15.2m) from lagoon high water mark.

13. The possibility will always exist that waste sump oil, for example, might enter the drainage system and thus reach the lagoon. Only public awareness can frustrate such an event, although in a dry period the dangers will be much reduced.

14. Furthermore, at times of rain there will be suspended matter in the discharge, from the coral roads, and some of this will also enter the lagoon. The low velocities in the system should restrict its distribution to the vicinity of the various outfalls. In addition, catchpits will be included to intercept some suspended particles.

15. In efforts to reduce the impact of any pollutants, surface water pipes could be bifurcated at the lagoon and extended along its bed. They will also be perforated along their length, to present a number of outlets, to benefit as much as possible from the dilution factor and to lessen any shocks to lagoon life. (Such practice should be considered for existing discharges to the lagoon).

16. These remarks relate to the piped system of drainage. The preferred alternative of pipes/channels will have appreciably more impact on lagoon life because the rate of removal of floodwater will be greater and there will be little opportunity to separate suspended matter from the run-off.

17. As with a piped system, the channel drainage scheme will include the attendant risk of admitting pollution into the lagoon from leakages of septic tank effluent, oil spillages, leaching of domestic wastes, etc. At storm times such pollution will be diluted and the dangers will be thus reduced. If pollution enters the channels in dry periods it can at least, with a measure of routine inspection, be detected and its source traced.

18. Accumulations of rubbish in the channels will tend to hold back water, giving opportunities for insect breeding. In storm periods any small accumulations of rubbish will be swept into the lagoon. Both these dangers may be largely prevented by routine maintenance.

19. On balance, it is considered that occasional entry into the lagoon of diluted pollutional loads can be better handled by the natural agencies than the steady and concentrated pollution - in wet and dry seasons - from the present development along the lagoon bank. No doubt the ecological study will throw further light on this aspect of the situation.

WASTEWATER

1. Sewerage

1.1 In Tonga as a whole there are no planning laws and development is permitted/tolerated without control. In Nuku'alofa, plans/drawings of new buildings are submitted to the Ministry of Health where they are examined/approved. The developer is required to indicate the location of the septic tank and he is handed a detail of the tank which is thought to be appropriate to the accommodation.

1.2 (Standard tank designs embrace 1 - 50 persons served and the range includes 10 tank sizes varying linearly from 325 to 2 400 gallons capacity - 1 500 to 12 000 litres).

1.3 In the absence of formal building/development planning it would be some years premature to propose a conventional sewerage network for the town. Nonetheless, it would be wrong to dismiss the subject. There is little doubt that Nuku'alofa will emerge as a planned and structured community and it is thought right to consider formal sewerage facilities for the central, commercial, area of the town. This includes a modern bank, post office, government buildings, shops, offices, market, cinemas and other publicly-used premises. These buildings should not be permanently committed to the use of septic tanks but should be adequately drained by a piped system.

1.4 The argument for this suggestion rests mainly on the changing pattern of tourist/visitor traffic. Formerly, outsiders could arrive only by sea and the duration of the journey - having regard to the relative isolation of Tonga - would generally overlap the incubation period of most diseases. Thus, infected persons would in most cases be identified, probably, even before arrival (except disease "carriers").

1.5 An attempt is being made to encourage the tourist industry, with noticeable success, and hence efforts to improve health conditions and/or to safeguard health should also be encouraged.

ARRIVALS/YEAR	1972	1973	1974	1975	1976	1977
By Air	4430	6356	6403	6770	9312	11023
By Cruise Ship				44968	33024	28000

(Visitors by cruise ship do not generally stopover for longer than 1 night whereas the average stay for airline passengers is 5-7 days: source, Government Statistician).

1.6 Airline passengers from long distances can arrive in Tonga very rapidly, unwittingly carrying diseases to which the islanders, and others, would be exposed possibly without warning. (The 1977 cholera outbreak in the Gilbert Islands caused some concern in Tonga, and elsewhere in Polynesia).

1.7 Since many of the visitors will frequent various parts of the centre of Nuku'alofa, it is held that there must be a case for securing that area in terms of public health - notably by removing the risks created by the spread of septic tank contents during flood periods.

1.8 (Elsewhere in this Paper will be found proposals for increasing the number of septic tanks, in/out of the town centre. A by-product of this step will be an increase in sludge volumes and the consequent overloading of the existing sludge disposal facilities at Tukutonga, facilities which are already inadequate. Thus, there will be a need for improved sludge treatment. Disposal units, which are proposed herein, create an opportunity to include enlarged facilities and adequate means to treat town sewage, in addition to sludge. Whether or not sewerage is to be provided, the proposed sea outfall will be necessary for the expanded/improved sludge units as an alternative to the present unsatisfactory method of sludge disposal).

1.9 The weakness in the foregoing argument is that the International Dateline Hotel, where most visitors will doubtless stay, is omitted from the future sewerage scheme. This is intentional and is supported by the following points -

(a) as shown elsewhere, the hotel represents a high hydraulic load[1]; it contributes a comparatively low pollution load,

(b) the present arrangements - including chlorination[2] - are seen to be reasonably satisfactory, at least for the foreseeable future,

(c) there would be practical difficulties in pumping the hotel flow into the proposed rising main alongside Vuna Avenue (and the alternative of double pumping with storage/balancing capacity would be inappropriate).

1.10 For the above reasons, then, the hotel is excluded from the first-stage sewerage proposals. A later programme should provide formal facilities, but it is difficult to justify adequate provisions at the present state of conditions.

1.11 Existing flush toilets in the town centre use mains water and doubtless a case could be made for the continuation of this practice. However, if the proposed embryo sewerage system is seen as a realistic scheme then the future would see an extension thereof, in due course. Thus there would be an increasing use of mains water.

1.12 Now the treated water supply relies on groundwater sources, which in Tonga are finite. Clearly it is undesirable to use this supply for the water-carriage method of drainage. Clean, treated water for flushing would be a misuse of a valuable natural resource and its use would perhaps jeopardize development in future years and endanger the supply for the increasing population.

1.13 Thus any water-carriage drainage scheme should look elsewhere for its supply.

1.14 The use of seawater is proposed[3] although this practice entails certain dangers. The most noteworthy is the risk of cross-connexion with the potable water system. On the other hand, this will be a limited hazard since any unauthorised access to a water main is illegal, although connexions elsewhere would be possible.

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[1] most of this originates from baths/showers and housekeeping, not from toilets.

[2] the effluent from the hotel septic tanks is chlorinated before discharge to the ocean.

[3] a similar proposal is currently being implemented in Betio, Gilbert Islands, by the Australian Govt Dept of Housing and Construction.

1.15 In any event it is proposed to incorporate the flushing network into the Tonga Water Board undertaking thereby reducing the risk of cross-connexion and misuse.

1.16 Seawater flushing will require a pumping station for abstraction from the ocean, a rising main, storage reservoir and distribution network.

1.17 To balance supply and demand, storage of seawater will be required and the proposals include a service reservoir, either on Mount Zion, maximum height 53 ft (16m) rSD, or alternatively an elevated tank.

1.18 A network of seawater distribution pipes will be included. These will follow closely the lines[1] of potable water mains and branches. For ease of maintenance, proper identification and co-ordinated pipelaying, the whole seawater system must become the responsibility of the Tonga Water Board.

1.19 Sewers will be laid to serve the selected area, draining to a central point whence the flow will be pumped to a site at Tukutonga for treatment - sedimentation and gravity discharge to the ocean. The site will also contain sludge digestion facilities sufficiently large to accept septic tank contents.

1.20 Sewage treatment will consist of sedimentation, for the removal of most of the suspended matter. The effluent will be admitted to the ocean, by means of an outfall pipe discharging into deep water at the edge of the reef.

1.21 Sludge removed will enter a digestion stage, designed to accept also septic tank contents from the town. Processed sludge will be released to drying beds where the separated liquor will be removed for re-treatment, the dried sludge being used for landfill on site and elsewhere as required.

1.22 The foregoing outlines the nucleus of a formal drainage system for the central area of the town. It has certain shortcomings, notably its lack of flexibility, although this is caused by the poor available surface gradients.

1.23 The present proposal for seawater flushing could be criticized on, inter alia, installation and running costs vis-a-vis availability of freshwater. Tonga Water Board officers confirm that adequate water resources are now available and can be made available for an increased population for some time. Indeed, investigations are in hand for developing new groundwater sources and there is no reason to suspect that sufficient resources do not exist.

1.24 Vaiola Hospital has its own wastewater treatment plant. The site is too far from the town centre to permit a gravity connexion to the sewerage system as proposed.

1.25 It would be possible to pump the hospital discharge to the town centre, whence it could be re-pumped to Tukutonga. This would be the wrong step; the disposal of hospital wastes in that way would have to rely on the implementation of the town sewerage scheme. Whereas this scheme is desirable, it is not essential at present while improvements at the hospital have a higher priority rating.

2. Septic tanks

2.1 Outside the central area of Nuku'alofa it would not now be realistic to prepare sewerage proposals.

2.2 It is recommended that all premises, excluding those which may be served by sewers, in the town as defined should be equipped with adequate

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[1] where possible, the seawater pipes should be laid in the same trench as the sewers.

septic tanks of suitable size and of approved construction. (Pit latrines should be forbidden except, possibly, for temporary purposes). The Government should so legislate, and provide funds for the supply of tanks to the public, free of charge.

2.3 It is recommended that the provision of tanks should be made obligatory, for all buildings not otherwise drained, and that the cost of the tanks should be borne by Government - thus ensuring that correct materials and workmanship are used, and that all households benefit, regardless of the occupant's income. This step would be a significant contribution to public health safeguards in the town.

2.4 The supply of septic tanks alone would, however, not fulfil the needs of public health. It would also be necessary to provide surface water drains, as detailed elsewhere, to ensure that floodwaters do not distribute tank effluents - a common occurrence under existing conditions.

2.5 The census of 1976 showed that there were 3043 households in the town (each with an average of 6.77 persons) - it is estimated that there may now be some 3180.

2.6 A sample survey of a characteristic town area, containing 47 dwellings, gave the following results -

Septic Tanks	20
Pit Latrines	3
Pour-Flush Toilets[1]	11

2.7 If these figures are any guide it seems that about 1826 septic tanks are required, if "households" means dwellings, to equip all homes in Nuku'alofa.

2.8 In reality, the figure is likely to be rather less than 1826 because of the likelihood that some families are in shared accommodation. A better estimate would perhaps lie around 1700 - 1750. (The latter figure has been used herein).

2.9 In general, schools/colleges are already adequately served and no significant demand for septic tanks should arise from such premises.

2.10 The tank empyting service of the MoW removed the following loads of septic tank contents in 1977, from -

Talamahu Market	544
Police Department	87
Public Toilets	200
Hospital	214
Government Quarters	104
Private Premises	563
	1712 loads

2.11 Each load represents 750 gallons (3400 l) and so the total volume removed was about 1.28 million gallons (6 Ml).

2.12 The danger with the use of septic tanks lies in the reliance placed upon this type of sanitation system. Septic tanks are useful where sufficient suitable land is available to accept the effluent; such circumstances exist in rural communities, of course, which was the apt description for Nuku'alofa until fairly recently. Now, the town is becoming urbanized with the increase in population and density of development and, in principle, it is wrong to recommend septic tanks as a continuing means of wastewater disposal.

2.13 Nonetheless, in practice there is little alternative to tanks, at the present time, but the authorities must constantly review the situation, as the community develops. In due course, there will come a time when formal sewerage facilities will be required (and can be justified). At that stage septic tanks will no longer be the appropriate method of disposal.

2.14 Whether the full value of the tanks already installed will be realized by then is, at this moment, conjectural. On balance, it is thought that - for some years - there is no real alternative to septic tanks for wastewater disposal, unacceptable as this may perhaps seem to those accustomed to more sophisticated methods.

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[1] now Central Planning Department

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discussion

CHAIRMAN: Mr J M G van DAMME
Manager, WHO International Reference Centre for Community Water Supply

The CHAIRMAN said he had great pleasure in introducing Mr John G Evans whose paper was very appropriate for the Conference as he discussed appropriate solutions to the drainage problems of Tonga. Mr EVANS was a partner of Richards and Dumbleton International, Consulting Engineers.

2. Mr J G EVANS said that 1979 was not only the Year of the Child; it was the fiftieth anniversary of Mickey Mouse. In scale his Tonga proposals were "Mickey Mouse" and his paper was perhaps of not very great substance. His firm had been dealing with a small town with a total population of only 22 000 in a country whose population was only 90 000.

3. A major difficulty was the heavy rainfall, which causes surface flow all over the town, the runoff passing to a valley in the centre of the town. Sanitation consisted of septic tanks and pit latrines, and many properties had no latrine at all. When the runoff passed across the town it became polluted with overflow from septic tanks and pit latrines. So improvements in surface water drainage would have a direct bearing on health. Filariasis was endemic, and there was some elephantiasis. Filariasis, although it could be cured, was a serious disease encouraged by the spread of surface water.

4. In September 1977 there was an outbreak of cholera 1500 miles from Tonga, and the epidemic had spread from as far as south-east Asia. Formerly when people came to Tonga by sea the incubation period was in line with the journey time. Now there was a proposal that jumbo jets should come to Tonga, and there was a very encouraging tourist industry in the Island. This led to a very real danger to health unless something was done urgently about the polluted surface-water problems.

5. There was reasonable collaboration in dealing with the problem. Initially the British government had sent out two men to investigate. Help was also received from New Zealand and Australia and there was talk of WHO assistance, but the United Kingdom made the greatest financial contribution.

6. Mr EVANS's main proposal was for surface water drainage in trenches filled with coral aggregate. Very little information was available regarding velocities to be expected in such drains and Mr EVANS asked for data from other parts of the world.

7. Slides were shown of a map of Tonga and of Nuku'alofa, from which it was seen that many streets were parallel with the ocean. The natural slope of the ground was towards the lagoon, where the tidal amplitude was less than in the ocean. The average family size was 6.77 persons and such septic tanks as existed were undersize by U K standards. Surface water flooding after rain was well illustrated and some houses were built on stilts.

8. The CHAIRMAN said that Mr EVANS had given a very inspiring talk about a very inspiring subject.

9. Mr W A GILLINGHAM asked whether the proposed outfall of the drainage system was to be below the water level in the lagoon. Mr EVANS said that there was some danger of water backing up in the drainage system because the outfall was to be set at 3.25 feet above datum and it was thought

that the water level in the lagoon rose occasionally to four feet above datum. However, although the British had been on the Island for forty years, there were no available levels of either land surface or water level.

10. Mr M Z KARIM asked for a further explanation of the town map and Mr J F JACKSON asked for more information about the duration and depth of the sheet flow, and also the nature of the sub-soil. Mr EVANS said his visit had been during the dry season so he could not speak from personal experience of the rains. There was no record of rainfall intensity, but he understood that the sheet flow built up very quickly. It also dispersed quickly, partly because of a high evaporation rate: the relative humidity was about 92%. The percolation rate of the soil was variable. There was some good soil which was fertile with quite high percolation. Most of the ground was coral going down to 8000 feet and the top crust of humus varied in thickness. There was a great deal of deteriorated coral.

11. Mr JACKSON said the problems Mr EVANS had described were very similar to those at Nassau, although the topography was more varied than Tonga and there was a ridge running from east to west. Heavy tropical storms caused problems to the south of the ridge where 70 000 people lived in crowded conditions. All plots had pit latrines and it was difficult to find land without a pit latrine. A basic water supply had been installed and there were borholes every hundred yards or so. These were some forty to fifty feet deep and accepted surface flow, which dispersed very quickly. All rubbish was put down the wells, and the sewerage system discharged to boreholes.

12. Mr EVANS said that in Tonga conditions were different. Parts of the town were so low-lying that there was standing water all the time. In Tonga there was a good water supply system from a well field - or at least it was good until a pipe was broken. Then the water supply became polluted. There was water under the whole island; a local tradition was that God supported the island in his hand and might take his hand away allowing the island to sink.

13. Mr S D PRADHAN asked whether consideration had been given to the level of the town by using coral fill, were there any plans to reclaim part of the lagoon. Mr PRADHAN also asked for details of the 32% increase in population. Mr EVANS said that the well-off people did raise the level of their plots. The town was economically mixed, with no ghettoes, and a poor person's plot, without filling, was likely to be next door to a rich man's plot. Consequently the poor man had flooding from rain falling on his neighbour's plot as well as on his own. There were plans to reclaim part of the lagoon, but it was polluted from all sides. A major factor in the increase of population was the demand for education. Tongans were very ambitious for their families and many came from the outer islands so that children could go to school in Nuku'alofa, which was the focal point for education. There were 14 000 school children in the capital. Many people stayed with relatives on first arrival.

14. Mr D V ALLEN asked whether there were proposals to lower the level of the lagoon by the construction of control works at the entrance. Mr EVANS said that a Dutch consultant had recommended lowering the lagoon level by eleven feet, but this would have had the effect of lowering the groundwater level, and there would then be no water for trees and crops. Mr ALLEN asked what would be the effect of lowering the lagoon level by two or three feet. Mr EVANS said that advice from a hydro-geologist would be needed, but he thought any artificial lowering of the lagoon level would have a detrimental effect on trees and agriculture. Mr ALLEN suggested that it might be possible to dredge the entrance to the lagoon and Mr EVANS replied that this would be a delicate operation.

15. Mr R TRIETSCH asked what was the correlation between capital expenditure on the drainage scheme per person and the average income. Mr EVANS said that "income" was difficult to determine in Tonga. Every man over the age of sixteen had a legal right to 8¼ acres of bush land. There was a subsistence economy, with families producing their own food. Even those living in towns did not need money for food, and when cash was needed for other goods, people sold coconuts. The maximum wage allowed for a labourer was equivalent to US $20 per week. All capital expenditure was covered by foreign aid. Unfortunately foreign countries did not pay for recurrent costs, and so there was a tendency to choose schemes with high capital and low recurrent costs.

16. Mr J F JACKSON asked what problems had arisen from the development of the town. Mr EVANS said that the increase of population was partly due to immigration from the country and other islands and partly due to natural increase - the number of children per family was high. Improvement of health had a cumulative effect and people were living longer, but at present there were few old people about. His abiding memory of the people is their happiness; he thought they were a race apart.

17. Mr G S CANSDALE asked about the salinity of the lagoon. Was it changing and how much sea water entered? He also thought it would be disastrous to put dirty water under the island and mentioned the result of doing this in Hawaii, which had a similar coral formation. Mr EVANS said that the lagoon water was saline, but the salinity varied. There was little past experience to go on, as there had not even been a basic levelling of the town. Some research had been carried out recently but the results were not known.

18. Mr JACKSON gave more information about what he had found in Nassau in the Bahamas in 1971. Most of the wastewater was discharged underground. Boreholes up to a thousand feet deep had been dug in the cavernous limestone. There was a freshwater lens under the island and some interchange of water.

19. Mr Jozsef BUKY was also familiar with the problem of Nassau, and suggested that the disposal of wastewater in deep shafts which extended below the fresh water was satisfactory. Problems arose when there was over-exploitation of fresh water and a consequent increase of salinity.

20. Mr Len HUTTON said that a study of the groundwater in the Bahamas was in hand and a report would be published in about a year's time, by the UNITED NATIONS. This study was particularly concerned with the water quality and pollution in urban areas. Water supply was particularly important in the Bahamas which had an influx of a million tourists a year, all exerting a high water demand. Water in the Bahamas was the most expensive in the world. Mr EVANS said that rainwater catchment tanks were common in the West Indies.

21. Mr ALLEN asked how much the improvement in water supply had contributed to the drainage problem. He referred to Sharjah in the Persian Gulf where the demand for a piped water supply had led to a wastewater disposal problem. Mr EVANS said that in Tonga the rainfall amounted to 68 inches a year and there was comparatively low use of piped water. Water from rainwater tanks was often used for personal washing. Consequently the piped water supply had only a minor influence on the drainage problem.

22. Mr G S HOYLES asked whether the open channel drainage system would encourage the exposed pools of groundwater to be collected and carried to the lagoon. Mr EVANS said this would be avoided by making the channels of concrete.

23. Mr GILLINGHAM discussed the need for providing drainage throughout the area rather than the politically desirable drainage of the central area. Mr EVANS said that his proposals covered this point - all roads would be drained to channels or to open-joint thick-wall concrete pipes.

24. The CHAIRMAN thanked Mr EVANS for his enthusiastic and entertaining presentation.

the WEDC GROUP

ANDREW COTTON, KENDRICK ELLIS, LEN HUTTON, BILL MOFFAT, GEOFF MORTIMER and JOHN PICKFORD

collaboration for appropriate technology

INTRODUCTION

All technology should be appropriate (1). Highly advanced, sophisticated and extravagent equipment may be most appropriate for a space-ship. For developing countries appropriate technology is that which maximises the use of plentiful resourses and minimises the use of scarce resources (2) or 'technology which provides the most socially and environmentally acceptable, economically efficient services to the consumer at least social cost'(3). 'Technology must take into account such factors as economics, social structure, the availability of skilled manpower, climate, energy sources and materials'(4).

The WEDC Group in the Department of Civil Engineering at Loughborough University of Technology exists to study and disseminate knowledge and ideas about water and waste engineering for developing countries. It is therefore concerned with the whole of the water cycle and with solid waste and atmospheric wastes. Because the Group is wholly concerned with developing countries it places particular emphasis on aspects of technology which are peculiar to developing countries, and on the factors which determine what is most appropriate. In the past 'too much emphasis has been placed on the direct transfer of technology . . . and not enough on the creation of local conditions which enable technologies to be absorbed'(4). The local conditions for absorption of appropriate technology depend upon individuals and organizations, and it is essential that individuals and organizations should collaborate if there is to be a beneficial application of technology.

The need for improved provision of water and sanitation has been postulated in numerous documents and there is abundant statistical evidence of the deficiences (eg, 5). Figures are merely indications of the magnitude of developing countries' problems - the solution to the problems involves an understanding of a whole range of activities, of which we have selected a few for detailed consideration.

DEVELOPMENT OF WATER SOURCES

Assessment of yield from a reservoir, stream or river requires information on flows. This information comes from gauges (stream or rain) that have been sited by accident or by advanced planning, if any gauge exists at all, In many cases the data are inaccurate and/or incomplete. Yield estimates made from data obtained from stream gauges giving totally inaccurate estimates of low flow are not uncommon in developing countries. Designers/consultants often have little or no control over setting up the network of gauges or over the accuracy of data. When they do become involved in design it is too late to do anything. Better collaboration could improve this by

1. advanced planning to gauge potential future surface water sources -
2. use of suitable gauges that are simple, reliable and easily maintained -
3. a system for collecting and storing the data, and for maintaining gauges - and
4. a system for partial analysis of data to check accuracy and also for identifying the need for other gauges.

Many water supply schemes are designed from short records of flow, which leads to a rough estimate of yield. It would be better if the designer/consultant could reappraise his design after a few years when more data are available.

Surface water supply schemes rarely remain static as population expands and ways are investigated of fully utilizing many water sources. This requires a reappraisal of existing schemes at regular intervals. There are many advantages of allowing the designer and the operator of the reservoir etc to take the original design and investigate ways of increasing the yield possibly by conjunctive use as in India where the total yield from a number of reservoirs supplying a city was reconsidered.

GROUNDWATER LOCATION BY GEOPHYSICS IN A DEVELOPING COUNTRY

Groundwater surveys are frequently recommended as a preliminary to groundwater development. Much time and money can be wasted if the correct methods are not applied from the onset of the survey, or if geophysics is used when it is not cost-effective.

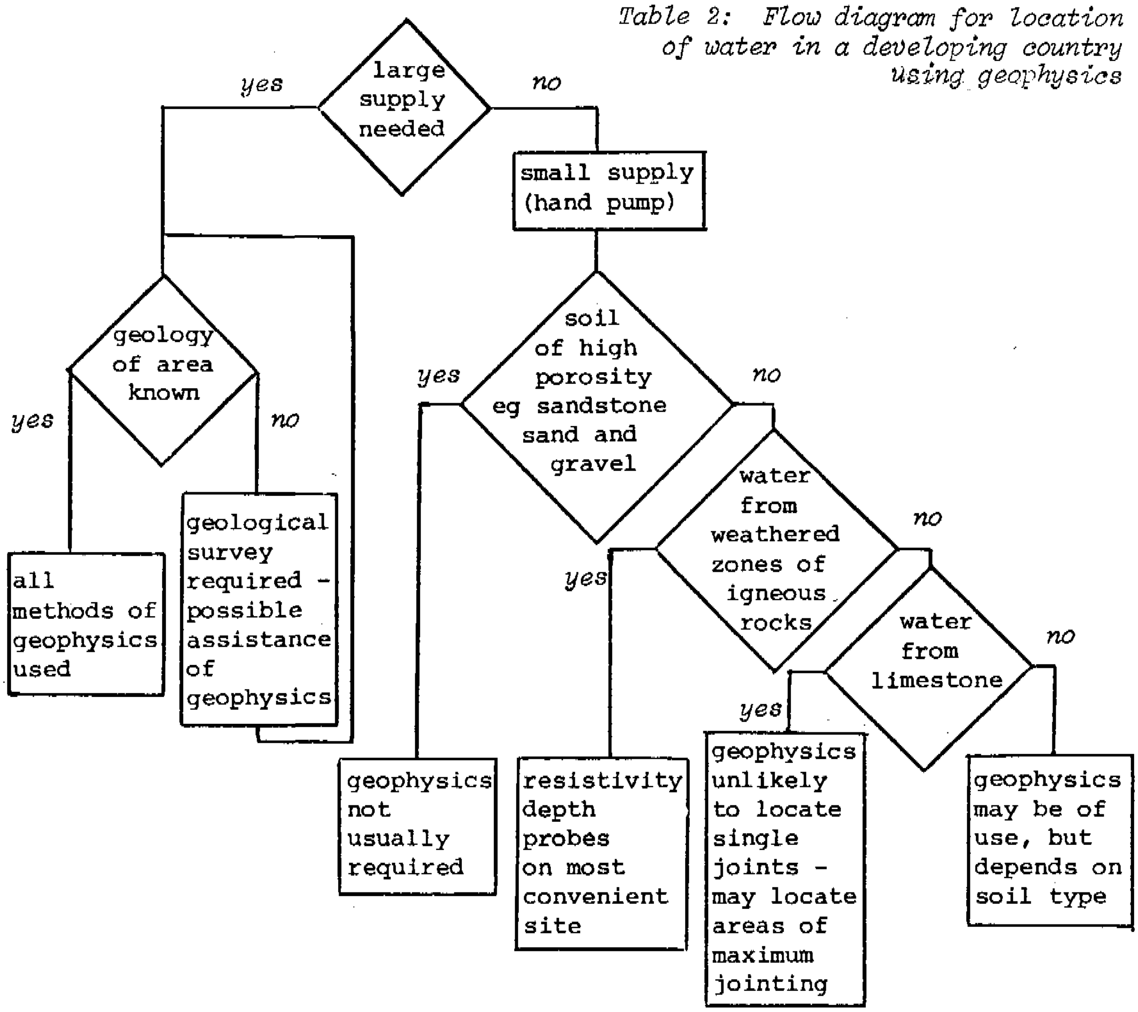
There is little published guidance on the selection of geophysical techniques for groundwater surveys in a developing country. In this situation the search for groundwater supplies can be divided into two simple classes: those which are to be exploited by hand pump and those which are to have an electric or diesel driven pump, header tanks and distribution. In the first case the volume of supply is much less important than its convenience to the demand, whilst in the latter the volume of water available is obviously important. The four geophysical methods commonly considered are set out in Table 1. Of these resistivity is by far the most commonly used, since it is the only method which actually detects water.

Table 1 Geophysical methods available

Method	Application
Resistivity	Most commonly applied method. In favourable conditions will define: a. presence/absence of water b. level of water table c. dissolved content of water
Seismic	In favourable conditions will define: a. water table b. large scale structures which may contain water Only of use for large supplies
Magnetic	Suitable if igneous dykes control the occurrence of groundwater
Borehole logging	Defines water and rock properties inside boreholes

Table 2 is a flow diagram showing the problems in which resistivity can best be applied. The essence of this is that for a hand pump supply geophysics is frequently not an economic search method especially if geological knowledge is available.

Table 2: Flow diagram for location of water in a developing country using geophysics



Interpretation of geophysical field work is the most difficult part of any survey. With modern equipment the field operation of the instruments is simple and can be learnt in a few days. Thus a field geologist can supervise a number of teams in charge of less qualified people operating instruments. For small supplies, once the 'feel' of an area has been obtained, field interpretation of the geophysics is often adequate. More sophisticated methods, frequently using computer techniques, are necessary when the meximum yield is required.

GROUNDWATER POLLUTION : THE NITRATE PROBLEM

Although groundwater provides the most satisfactory source of drinking water for the majority in developing countries, shallow wells are easily contaminated. Study of the nitrate concentration in groundwater can be used to gauge the extent of pollution.

In developing countries a common trouble is poor well construction or maintenance which allows polluted surface water to infiltrate down the sides of wells and boreholes. This can be cured by appropriate engineering techniques, but it is often necessary to obtain the collaboration of health personnel to convince users of the dangers. Where there are sewers, leaks result in groundwater pollution; but there are few sewers (leaking or otherwise) in developing countries. Where rainfall is abundant, leachate from refuse tips may increase the nitrate concentration; but scarcity of rainfall rather than its abundance is most common. Agriculture contributes to the nitrate load: the use of fertilizers is increasing and intensive stock rearing can be a problem in developing countries. Stock need water and the area around wells is often overgrazed and bare so that wastes are not decomposed before infiltrating to the water table.

Inappropriate sanitation is a cause of groundwater pollution. For example in some Botswana villages there is a rapid movement of nitrates and bacteria through weathered granite from pit latrines. Analysis of several borehole water samples showed deficiences in anions when anions and cations were balanced. Nitrate was suspected as the missing anion. Nitrate had not been determined regularly up to that time (1974) because no easy accurate methods were known.

Subsequent studies by the Geological Survey Department showed high nitrate values in the groundwater supply in many villages of eastern Botswana. Gross fecal bacterial pollution of groundwater occurs from pit latrines. A transit time of less than four hours was recorded between a pit latrine and a water supply borehole 25 metres apart, using a lithium chloride tracer. The static water rest level was six metres below surface and pumped water level about 15 metres below surface. The steep hydraulic gradient is thought to have induced the rapid movement of the tracer through the weathered basement rocks.

The high nitrate content of these boreholes is the end product of the breakdown of nitrogenous wastes from human or animal sources since fertilizers are not used extensively in Botswana. The nitrate is an indicator of pollution. The presence of nitrite is another indicator of very recent active pollution. The pit latrines in Mochudi village were shown to cause a massive build up of nitrogenous material in the surrounding soil and weathered rock; nitrate leached from this contaminated soil is postulated to be the cause of the high concentration in the local groundwater. It is unlikely that the pit latrines will be moved or replaced so the contaminated boreholes should be abandoned and new contamination-free groundwater sources provided for the village.

A new development in the field testing of water supplies enables on-the-spot determinations of nitrate, nitrite and ammonia to be made.. Merck of Darmstadt, West Germany, have recently developed test strips for the semi-quantitative analysis of nitrate, nitrite and ammonia. The strip is dipped into the water and if nitrate is present a red-violet colour is produced on the sensitised part of the strip. After two minutes the colour developed is compared to a colour scale printed on the side of the container and the amount of nitrate is read off.

The test strips enable simple and rapid semi-quantitive determination on site and can be used by relatively untrained staff. An on-site assessment of the likely sources of pollution can be made immediately and demonstrated visually to local officials and health workers. The use of test strips allows the field worker to screen water samples and indicates whether special samples need to be taken for more accurate laboratory analysis. The approximate cost is £4 for 100 strips contained in an aluminium can. At 4p per determination the cost is negligible compared to the field worker's transportation costs. The strips have a field life of about one year.

Other field test kits available for nitrate determinations are produced by Lovibond (UK) and Hach (US). Several colorimetric procedures for nitrate determinations have been tentatively approved in the United States, but in developing countries some of the recommended chemicals are often difficult to obtain and operation of the methods requires trained staff, glassware, waterbaths and a spectrophotometer. The use of nitrate ion specific electrodes is increasing and electrode methods are in common use in UK and US, but they must be used in the field with great care by technically competent staff.

More and more women in developing countries are being persuaded by advertising and by contact with other cultures to abandon breast feeding and to feed their infants with dried milk products. There is a greatly increased risk of methemoglobinaemia in infants where the milk feed is mixed with high nitrate waters. The WHO working group on health hazards from drinking water recommended that for infants below six months of age nitrate levels in excess of 5o mg/l should be considered unacceptable.

WATER AND WASTEWATER TREATMENT

The level of technology installed in water and wastewater treatment plants should be appropriate to the situation and the society involved. This does not necessarily imply the installation of the simplest and cheapest techniques. Although it is of importance that treatment works should be both low-cost and simple the criterion of reliability must always be paramount. It is as ethically wrong for designers to install cheap systems that do not work as it is to install expensive systems that cannot be worked.

There is no simple method for deciding which processes are appropriate in any given situation and which are inappropriate. The selection of the appropriate water or wastewater technology depends upon the quality of the source water or the strength of the wastewater. It depends upon the quality of the required potable water or the standard of the effluent. It depends very largely upon the money available. It depends even more on the availability or otherwise of trained technicians and skilled labour. Power supply, pay, level of management, cost of land and many other factors influence the selection of treatment processes.

It is however possible to compile a list of factors which most influence the choice of processes if they are to be truly appropriate in a particular locality. These factors will certainly include -

1. the money available for works construction -
2. the availability of a reliable power supply -
3. the level of competence of local skilled or semi-skilled labour - if any available -
4. the standard of the local technician training establishment (if any) and the standard of its product -
5. the level of pay available to technicians (and others) in the public sector as opposed to private employment -
6. the possibility of direct oversight of the operating plant by an experienced professional -
7. the competence of the local administrative organization -
8. the future availability of spares and chemicals -
9. land costs and land availability - and
10. the quality of the water or wastewater to be treated and that of the potable water supplied or of the effluent.

All too rarely are all these factors adequately considered before water and wastewater treatment plants are designed. Often in developing countries there are sophisticated water treatment facilities, usually incorporating chemical pre-treatment and rapid sand filtration and necessitating a constant and appreciable dosage with chlorine. In these situations slow sand filters could so frequently not only be more effective and reliable, but be more compatible with the local level of technical and administrative ability.

Chemical treatment is, at the least, a waste of money when the dosage rate is decided by an unskilled operative relying on experience and intuition. Rapid sand filtration of polluted source water is inappropriate if a continual supply of chlorine for final disinfection cannot be guaranteed. It is unfortunately common to find a water treatment plant which, for one reason or another, has run out of chlorine. This is not such a danger in those situations in which slow sand filtration is employed. It can be a disaster if the all-too-common rapid sand filter is used. Consideration must be given to the competence of the local administration set-up when a selection of water treatment processes is being made. It is pointless to operate a chemical pre-treatment unit if a continual supply of chemicals cannot be assured. It is pointless to incorporate pumping machinery for which spares may not be available in the future; and if a continuous supply of chlorine is not guaranteed then the provision of slow sand filters must be considered as an alternative to rapid filtration.

The conventional progression of coagulation flocculation, rapid sand filtration and final chlorination can possibly be as appropriate to a developing country as to a developed country, if only there is a simple laboratory provided with a technician capable of determining both the coagulant dose and the chlorine residual. On occasions neither of these is available. On other occasions there will be a laboratory provided and this will be supplied with the latest analytical apparatus, but without technicians either to operate the equipment or maintain it. It is also by no means unusual to discover sophisticated items such as sludge level indicators and automatic flow recorders installed in such works, although these will usually not be working for lack of maintenance.

The inappropriateness of provided treatment units may be the result of the lack of experience of the designer in local conditions. It is suspected that it is fairly common practice to transfer directly a successful design from a moderate climate to a hot climate situation without consideration, in detail, of how it may operate in the different environment. Particularly the effect of increased temperature must be considered. This will increase both the rate of the biological and chemical reactions. It is thought that this direct transfer of designs can result in a particular and peculiar weakness in rapid sand filtration installations. It is suspected that the backwash regime can be 'lifted' directly to the hot climate scene without regard for the effect of different water temperatures. With the rise in temperature the viscosity of the water is lowered and the result is a reduced hydraulic shear and consequently a decrease in washing efficiency. This can, it is considered, be a factor in the creation of deep cracks in some sand media that represents a danger of floc breakthrough.

On the wastewater side there is often resistance to the installation of stabilization ponds. While stabilization ponds must remain the obvious first choice for wastewater treatment over much of the developing world it must also be appreciated that there are situations in which they are not appropriate. Ponds are not appropriate if there is not sufficient land available. They are not appropriate if an effluent free of algal burden is required. They may not be appropriate if a moderate level of technical competence is available. However, not always is a decision for or against stabilization ponds taken for rational or, at least, rational technical reasons. Frequently municipal pride will demand a more sophisticated approach to water pollution control. There is a known situation in which the existing percolating filter works is not operated beyond the primary settlement stage due to the lack of technical ability of the operatives. Yet in this situation despite the obvious appropriateness of stablization ponds the involved government department and the consulting engineer are cooperating in the construction of a far larger filter works -- and this without provision for the adequate training of staff.

The ultimate in inappropriate design must be in a large city in Africa where municipal pride and credulity together with the designer's ignorance and/or cupidity has resulted in the construction of a sophisticated activated sludge treatment plant incorporating pre-aeration, massive pumping, aerobic sludge digestion, centrifugal sludge thickening and sludge sterilization using quick-lime. Not surprisingly the plant is beyond the control of the local work force, the power costs are staggering, the sludge accumulation cannot adequately dealt with and the works can be detected by smell at the distance of more than a mile. (The consultant was not UK!)

The selection of the incorrect technology in any situation may be for a complexity of reasons. It may be, as already suggested, the result of municipal pride in modern, sophisticated processes. It may be the result of inappropriate conditions linked to the grant of foreign aid. It may be due to lack of experience, but perhaps the following list summarises the factors that can so frequently lead to the incorrect choice of technology.

1. The conservative nature of both municipal or national authorities and of some consulting engineers -
2. the lack of experience of some consulting engineers in developing countries -
3. the ease with which designs appropriate to moderate climatic situations can be translated, inappropriately, to a hot country situation -
4. municipal pride in the installation of sophisticated treatment works -
5. the frequency with which external aid is 'tied', and results in the employment of a design firm on account of its nationality rather than for its experience - and unfortunately
6. the unethical practice of a small minority of firms of consulting engineers which appears to place capital cost and hence income above the suitability of the plant designed.

The provision of the appropriate technology for the water industry in developing countries is far more common than one often appreciates. The appropriate does not advertise itself. The inappropriate is obvious to all. Yet inappropriate designs are not rare and can be the result of ignorance on the part of the expatriate designer as of the local authority. The design of water and wastewater projects for a developing country is a most specialised subject and the need for this specialisation arises as much from the social and physical environment as from the complexity of water treatment. Education of professional engineers, both from the third world and from the developed world, in the very special demands of hot developing countries is the only true answer to this problem.

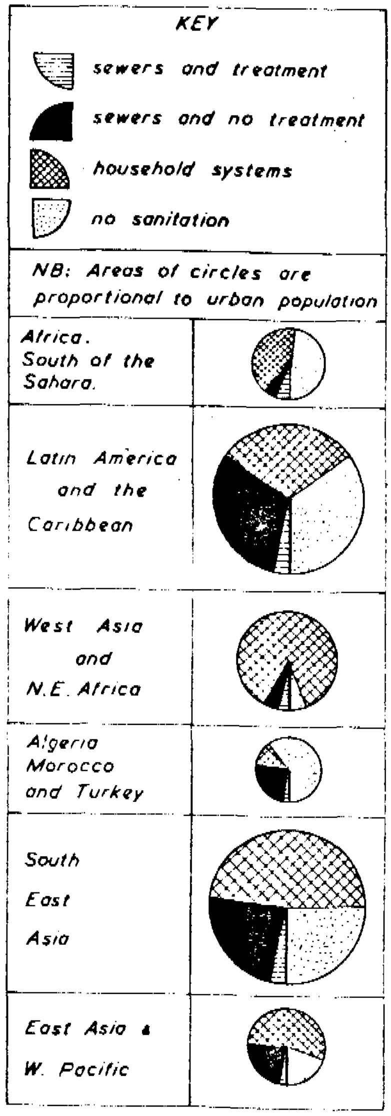
Beyond the need for education is the need for collaboration between all those associated with the demand for, the operation of, and the payment for any water or wastewater treatment works. This will mean collaboration between those designing and those designed for, as to the type of plant required, but also collaboration with the organization responsible for the training of personnel and with the organization that will administer the completed project.

It is pointless designing in the need for spares or for a continuing supply of chemicals unless those ordering them fully appreciate the necessity for a continual supply, and possess the ability to organise it. Collaboration is essential between the design organization and the national, or local, technician training school to ensure that the correct skills are taught to the required level to those who will be operating and maintaining the plant. Frequently technicians of a sort are available but without adequate knowledge of essential processes. The collaboration, if possible, of the employing authority is further required to ensure that suitable wage levels are maintained for skilled amd semi-skilled labour so that it is not immediately lured away to work in private industry. Should there be no local training scheme then it is of importance that the consulting engineers should provide, or arrange to have provided, training of an appropriate level for the technicians to be employed. Finally collaboration between client and consultant is essential to ensure that with the one or the other, or preferably with both, there are professional engineers experienced in the demands of a developing country situation. By all these means it is possible to apply that level of technology which is most appropriate for the local situation.

WATER AND SANITATION FOR THE POOR MAJORITY

There has been an amazing change in the outlook of the World Bank, WHO and many national governments in a very short time. A few years ago conventional 'western' views of water and waste were transferred with little modification to developing countries: only first-class water should be supplied and this water should be used to remove human excreta and sullage in sewerage systems to treatment works or long sea outfalls. These views were supported by international bodies, governments of aid-giving countries, governments of developing countries, and by professional advisers trained in a western way. And so there are 'water and sewerage boards' for countries and regions with no sewers; for several cities aid paid for sewerage master plans, superceded by another a few years later - but no sewers; where sewers have been constructed they often only benefit a small fortunate minority; and in cities where the well-off sprinkle their lawns with potable water throughout the dry season the majority of the population struggles to get a daily tinfull of doubtful quality each.

Now, as far as most developing countries are concerned, it is recognized that this technology is completely inappropriate for the poor. The poor are the majority - the majority of countries and the majority of people. Most poor people in developing countries live in rural areas without reasonable access to safe drinking water or adequate sanitation, and in the towns and cities the present provision of water and sanitation is insufficient. For example, in south-east Asia in 1970 less than 5% of the urban population had a continuous piped water supply. The diagram shows how few urban people have sewers and sewage treatment, represented by horizontal hatching. The aim of the Water Decade is to give adequate water and sanitation for everybody, and this can only have the slightest chance of fulfilment if 'adequate' is interpreted in terms of 'something is better than nothing'. The main theses of the 'new' policy are that access to and quantity of water are at least as important as quality; appropriate sanitation should be provided rather than universal sewerage and treatment; and improvement should be incremental - or capable of implementation in stages.



An early step in the new direction was the publication of "Drawers of water'(6), which examined in detail the water situation in a mainly rural area in East Africa. The change in outlook for both water supply and sanitation has been supported by people in a variety of professions, including engineers, geographers, economists, planners, sociologists and administrators (for example 7 - 10), reinforced by the investigations of geologists, biologists and chemists.

Concurrently two wider changes have influenced the provision of water and sanitation. Aid is now directed specifically to poorer communities instead of assuming that the benefits of industrial development would trickle down and there is a world-wide interest in appropriate or intermediate technology.

The popular conception of appropriate technology is hardware - bullock carts with greased bearings and the like. There have been a number of attempts to devise simple equipment for water and sanitation, such as NEERI's porous pot chlorinator and nightsoil wheelbarrow. However, whether or not gadgets like these are used has little effect on the overall provision of water and sanitation for the hundreds of millions who need it. Improvements to hand-pumps, standpipes and pit latrines have received more attention and have greater potential benefit, but they do not tackle the root causes of the existing deficiences.

Dealing with rural water supplies Pacey(11) sets out criteria for appropriateness under the following headings.

TECHNICAL APPROPRIATENESS
functional - fitness for purpose
environmental - hydrological conditions: avoidance of environmental damage
health and sanitary - disease date: water quality, quantity and availability

SOCIAL APPROPRIATENESS
community - felt needs and stated preferences: scale in relation to community size and organization
work - organization of labour force (whether self-help or paid)
consumer - changes in water carrying and water use patterns
education - interest in health, hygiene and other development
maintenance - organization, administration, village/government responsibilities, spare parts supply, training, record-keeping

ECONOMIC APPROPRIATENESS
resource - utilization - capital and labour intensity - imports, fuel consumption - scale economies
production - time/energy saving and volume of water available for productive purposes

For excreta disposal Winblad (12) suggested a similar set of criteria: *ecological, health, nuisance, cultural, operational* and *cost*.

These lists alone do not cover all that should be considered for appropriate schemes. For example, for functional appropriateness the purpose of a project has to be defined, and this is likely to involve other criteria. Mention of education and training indicates that change in the external conditions is possible. Appropriate solutions may include the provision of education/training and allow for the improved inputs resulting therefrom.

Examination of the lists of criteria indicates differences between industrial and developing countries in the level of technology and particularly in the factors to be considered in devising technical solutions. The groups of people who collaborate are different. In industrial countries civil engineers work with mechanical, electrical and chemical engineers, chemists, biologists, geologists, and financial, legal and administrative experts. Planning of appropriate sanitation or rural water supply schemes in developing countries depends on appreciation of the behaviour of people who are to use the water and sanitation, and familiarity with local endemic diseases and of the institutions which can or could support the schemes.

People in developing countries are much more varied than in industrial countries. In Britain the health, diet, water use and personal habits of the vast majority of the population are pretty much the same - everyone has a bath or shower with running hot and cold water and everyone sits on a water-flushed loo. Contrast this with most poor developing countries. Alongside people with flushing wc's and bidets in tiled bathrooms are those who defaecate on the roadside. Some people squat and others sit. Some use water for anal cleaning; others use corn-cobs, leaves, stones or cement bags. Some women regard defaecation as a social activity, getting away from the kids to chat before sunrise - for others even obtaining water from a public standpipe breaks rules of religious privacy.

Emphasis on the cultural/sociological appropriateness of water and sanitation is sometimes talked about as if it were new - a feature of the 1970s. Perhaps this is due to the specialization of recent education and professional practice - knowing more and more about less and less. The good practical and non-specialist civil engineer of former generations knew the local situation and realized that failures were often due to lack of appropriateness. A nineteenth century book (13) notes that "the history of sanitary experiments on a large scale in India has already furnished several striking instances of schemes 'that ought to have worked but wouldn't', and in each case it has turned out that something, or several things, had been taken for granted, without any warranty whatever". In this book there are many examples of ways in which local conditions influenced technology, such as in the municipality of Cawnpore (now Kanpur) where a meeting was held to discuss decoration for cast-iron standpipes. It was decided to use dog's heads for European and Mohommedan quarters, and horse's heads for the Hindus.

Coming up-to-date, a successful rural water supply operation is reported from Latin America, where a lady anthropologist was put in charge of the national programme. A survey of all villages with over 2500 population indicated which communities already participate in self-help ventures, have the greatest enthusiasm for water and show greatest promise of effective maintenance. These villages are the first to be provided with a water supply.

An example of community participation in sanitary improvement can be seen at Patna in Bihar, India, where a voluntary association operates a number of public latrines and organizes the conversion of scores of thousands of dry latrines to pour-flush units. The public latrines include washing facilities and have paid attendants who charge the equivalent of 0.25p to users. The latrines are clean and well-maintained. The basis of construction, operation and maintenance is a voluntary association whose success depends on the enthusiasm of individuals. An important factor in both the household latrine conversions and the public latrines is control of financial aspects.

Lack of money was cited as the greatest constraint to provision of water and sanitation in the 1970 WHO survey(5). Low budget allocations for recurrent costs are often given as the reason for the breakdown of projects, especially where the construction was paid for by aid or borrowed money. There is need for collaboration between engineers and economists. Costs are just as related to the local situation as any other aspect of appropriateness. However, figure-fiddling alone may lead to conclusions which need review by a practical engineer.

A ten-word summary of the essential requirements for successful provision of water and sanitation for the poor in developing countries might be ALLOW FOR LOCAL CONDITIONS AND FOR THE NEXT TWENTY YEARS.

Looking ahead implies consideration of operation and maintenance, and examples abound of schemes which have failed to achieve their design performance because they were not operated and maintained properly. The designer did not allow for local conditions in the next year, let alone twenty years ahead. There is no such thing as a simple and easily maintained water treatment plant (11), so the best water supply for the future is one which needs no treatment, or only storage. Hundreds of thousands of hand-pumps have been provided for rural water supply schemes, and there are innumerable reports of failure. An effective professional maintenance programme has been organized in some places - like the northern Ghana project reported by Robert Bannerman. Elsewhere more reliance has been placed on the local people, as in Tamil Nadu, India, where a villager appointed 'caretaker' attends a short training course and is issued with a certificate to prove it.

Nearly everywhere in the Third World there are complaints about a shortage of trained technicians. Perhaps this is partly because in the past too much attention has been devoted to the transfer of technology from industrial countries, and this has influenced ideas about the role and training of sub-professionals. 'Bare-foot technicians' may be the answer. Forget about City & Guilds and ONC or equivalent, with their insistence on an adequate mathematical background and a proper scientific understanding of the work. Perhaps the whole grading system needs revision. At one level very short courses or on-the-job training can prepare the bare-foot technician to work with the local community on a limited range of jobs - or even just one job. This in turn requires standardization. (Incidentally, one of the greatest obstacles to standardization in many developing countries is donors' practice of only giving their own products.) The bare-foot technician requires simple instruction sheets or manuals in which diagrams are preferred to words and nomograms and tables replace calculations. At the next level (bare-foot engineers ?) whose primary function should be to provide the conditions under which the technician can operate: to train them, prepare instructional material, and to be at hand to deal with situations where the standard solution does not work.

Higher up the scale the requirements of the professional (the engineer with shoes ?) are much wider in scope than those provided by present training and education, even of the kind outlined by Professor Diamant. The professional should be a collaborator, a selector, a leader and a doer.

a. He (or she) needs to collaborate with doctors, engineers, community workers, sociologists, geologists, administrators and the rest, and therefore must be familiar with their work and jargon and must sympathize with their aims.
b. An important part of his/her work is making choices - selecting which alternatives are the most appropriate - and so he must know about the alternatives, know their advantages and disadvantages from every point of view, and know the local people, their resources and their limitations.
c. He must lead a team, all the time realizing that the contribution of others, barefoot or not, is important.
d. Perhaps most important is a determination and ability to do - to provide water and sanitation, and keep systems working, in spite of all difficulties and opposition.

The old-fashioned PWD district engineer often did all these things in a wider sphere, being involved in a range of activities from building dams to providing bungalow curtains. Public works can provide the most appropriate training for water and sanitation professionals, where the objective is clearly to provide and maintain public services. Unfortunately civil engineering, like other disciplines, has been influenced by two changes which need to be reversed to get the right emphasis - increased specialization and increased sophistication.

If the world's poor are to be provided with water and sanitation there must be a collaborative input from many fields and a realization that providing the most appropriate schemes requires as much, or greater, intelligence and ability as using computers to analyse intricate details of high technology. Lord Rutherford said, "We have no money; therefore we must think." This often sums up the appropriate approach to water and sanitation.

DISCHARGE OF WASTEWATER

Where sewers exist or can be appropriately provided there is inevitably a problem of disposal of the wastewater. In coastal regions and towns situated on tidal rivers it is possible to make use of the large supply of oxygen and minerals contained in tidal waters, which can dilute and oxidize untreated effluent discharged directly to the receiving water. Much care is required in suitably sizing a discharge point, and collaboration and exchange of information between engineers and fishery resource workers is essential.

Discharge to the sea is wasteful of two valuable resources, the water itself and its organic load. In water-scarce areas (coastal or otherwise) consideration should always be given to the reuse of wastewater - usually for irrigation but possibly for industrial or even domestic supply. Exceptionally the cost of sewerage may be justified by the utilization of sewage.

Public health dangers must receive the greatest attention whether sewage is discharged to a river or for irrigation, and whether it is treated, partially treated or untreated. Collaboration between sewage works designer, the local medical staff and agricultural experts is obviously important. The greatest advantage of waste stabilization ponds over conventional treatment of sewage is the ponds' much higher removal of faecal micro-organisms including pathogens. When river water which receives sewage effluent is consumed untreated downstream the most appropriate parameter for design might well be *E.Coli* removal rather than BOD, suspended solids or nitrogen.

CONCLUSIONS AND QUESTIONS

We have dealt with a few aspects of water and waste engineering to indicate what is appropriate. We could have discussed other topics such as water distribution or refuse collection, with similar conclusions. Compared with the UK or other industrial countries, the third world uses a wide range of technologies, most of which can be appropriate in certain circumstances. Determination of what is most appropriate for particular local conditions at a particular time demands an input from a variety of specializations and therefore calls for collaboration greater than that required in industrial countries. However, as part of the limitation of resources in developing countries there is in most places a shortage of specialists and a shortage of skilled people at all levels. Two consequences are suggested. One is that in order to provide appropriate water supplies and sanitation the third world professional requires more training, more ability, more understanding of others and more dedication than in developed countries, and must be willing to consider a range of options. The second consequence is that the technology must be capable of being put in effect in the particular local conditions, which requires it to be simple and acceptable by the local people.

Some questions for discussion

1. In listing factors to be considered in deciding what is most appropriate have we omitted important ones?
2. Are there situations where the appropriate solutions are so clear-cut that there is no need to consider alternatives?
3. What types of organization are appropriate for ensuring continuing service (keeping rainfall and streamflow records, providing chemicals and spares, repairing broken pumps, desludging aqua-privies etc)?
4. In what ways can the widely-reported shortage of trained technicians be overcome? Is too much attention given to teaching technicians *why*, when all they need to know is *how*?
5. How can information about appropriate techniques (like nitrate testing paper) be widely disseminated?
6. Is practical civil engineering the best training for the team leaders?
7. How can professionals learn to consider a wide range of options rather than slavishly following text-book rules?

We suggest that one appropriate answer to question 7 is *by attending WEDC courses!*

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discussion

CHAIRMAN: Mr J M G van DAMME

The CHAIRMAN explained that this paper would be introduced by all the members of the WEDC Group, each of whom whould talk about some aspects of appropriate technology which he found interesting. The WEDC Group itself was an example of collaboration as the individual members were two civil engineers, two chemists, a geologist and a chemical engineer turned civil.

2. Mr John PICKFORD said all technology must be appropriate. Simple rules and simple methods were often most appropriate. For example, in the U K an old rule of determining the size of a culvert was to send a man on a horse to ride round the boundary of the catchment as fast as he could. The time he took in minutes was the diameter of the culvert in inches. Too often so-called modern technology was dominated by science and computers. Complicated formulae were often derived which produced an answer to three or four significant figures but depended on data with an accuracy of plus or minus fifty per cent!

3. When dealing with water and waste in developing countries the text-book answer might not be the best. All kinds of factors had to be taken into consideration. Many of these factors were not technological. There was the attitude of the population served and their ability to construct and maintain any works. Operation and maintenance was vitally important, and technology to be appropriate must take account of the next twenty years as well as the immediate situation.

4. Mr W S MOFFAT said he was interested in the application of geophysics in the appropriate sense for the location of ground water. If a relatively small supply is required, geophysics is not necessary. By a small supply Mr MOFFAT said he meant a hand pump supply. As an example in granite - using resistivity 24 boreholes selected with an average yield of 1280 gph; using resistivity with a restriction on the site position 8 boreholes selected with an average yield of 780 gph; by eye 30 boreholes selected produced an average of 400 gph, i.e. suitable for hand pumps.

5. For small supplies if the geology is suitable you do not need to use geophysical techniques. Mr MOFFAT then showed resistivity instruments costing £1000 - £2000. Skill is needed to operate it, thick bush ground slows down the survey and water is needed. For large supplies geophysical techniques have considerable advantage in locating the site with the greatest possible likelihood of success. Appropriate application of geophysics can save money.

6. Mr L G HUTTON said that when water had been found a sample was often sent to a sophisticated laboratory for analysis. However, tests in the field were often more appropriate. Colour discs were available for estimating the salinity and the concentration of various pollutants. Conductivity meters can be used to estimate salinity. The temperature was also important. Water obtained from a borehole might seem good because it was cool but as it became warmer it would not taste so good.

7. Contamination of ground water was

often important and Mr HUTTON showed slides illustrating the pollution of an aquifer in eastern Botswana where a high nitrate level was attributed to intensive stock rearing and pit latrines.

8. A portable nitrate testing method was appropriate for such places. Mercks of Darmstadt in West Germany had developed nitrate testing strips which could be used like litmus paper. Mr HUTTON demonstrated the use of these strips and pointed out the cost benefit.

	Cost of equipment	Cost per test
Spectrophotometers	£1200	8p
Specific ion electrode systems	£900	5p
Colour discs	£30	10p
Merck paper strips	-	4.8p

Perhaps the greatest advantage of the paper strip method was that results were available immediately. With sophisticated laboratory analysis there was often a delay of three weeks or so before results were available.

9. Mr Ken ELLIS said his particular interest was the treatment of both drinking water and wastewater. He was concerned with techniques which were appropriate for the local situation, which were not necessarily the cheapest and simplest. Reliability was the chief criterion. It was not an easy matter to decide which was the most appropriate technique, but the list of factors on page (6-5) could be taken as a guide to enable a designer to come up with a suitable answer in a particular situation.

10. Factor 1 - money available - should take account of the funds available for recurrent costs as well as capital expenditure. In works operation the reliability of the power supply was essential. Power must be available for 24 hours per day. When considering the competence of the local labour force a further factor was the ease with which local unskilled labourers could be trained for more skilled work, which led on to factor 4 - the local training establishment. People with experience overseas would appreciate that often it was relatively easy to obtain experienced engineers. The weakness was so often the availability of technicians. Without technicians it was impossible to operate sophisticated treatment plants, however well the works were planned. The rates paid to technicians in the public service so often resulted in training technicians and preparing them for the job, only to find that they moved away to the private sector.

11. Mr ELLIS thought it was absolutely necessary to have an experienced professional superintendent or manager for all sophisticated plants. The local administrative organisation was often connected with the next factor - availability of spares and chemicals. So often he had found that sophisticated plants were not operating because there were no spares or chemicals. If chemical additives were required for water treatment it was essential that the local administration collaborated with the technical staff by ensuring a constant supply.

12. The quality of the source of water was of paramount importance to both engineers and designers. Of equal importance was to know the standard required for the discharge of treated wastewater; the cost of reducing the BOD from 75 mg/l to 10 mg/l was very great and might not be justified.

13. Mr ELLIS showed slides to illustrate the points he had made. With percolating filters there was often a serious fly nuisance; overgrown waste stabilization ponds were a potential source of mosquito nuisance. One of the most appropriate techniques was the use of aerated lagoon, which was simple, very effective and not over-sophisticated. However, Mr ELLIS pointed out that even this was too sophisticated, for the aerators in one works had ceased to operate. Going from this simple works which had failed, Mr ELLIS showed a diagram of a very costly works incorporating a lot of sophisticated techniques which also did not work. There were sludge centrifuges, lime addition and aerobic digestion. The consultants, a continental European firm, seemed to have chosen the most expensive system they could find.

14. For potable water treatment Mr ELLIS showed a filter in the tropics where deep and potentially very dangerous cracks had developed. One reason for this might have been that the backwash regime was designed for a temperate situation where viscosity was greater than in a hot climate. Mr ELLIS was in favour of slow sand filters but showed a slide of a filter which had failed.

15. Dr Andrew COTTON spoke about discharge of wastewater. Whenever effluent has to be discharged into tidal water the effect of the effluent quality on the receiving waters should be considered. The siting and sizing of discharge pipes were critical. At Bangkok a discharge of waste had resulted in local build-up on the estuary bed. Collaboration with a local fisheries department could result in utilization of a valuable resource of nutrient in effluent. Collaboration with medical advisers was necessary whenever effluent was discharged to a river or stream which was to be used downstream. The bacterial quality of discharges and receiving streams was often of more importance than the BOD.

16. Mr PICKFORD referred to the poor majority in developing countries for whom sewerage and the quality of sewage treatment were completely irrelevant. As the diagram on page (6-8) showed, only a very small proportion of the population in developing countries discharged their excreta to sewers which in turn discharged to treatment works. Water supply alone ruled out sewerage for many - even if statistics indicated a water supply it might only be available as a trickle for a few hours every couple of days. Because of the growth of population there were more people without sewerage every year.

17. As well as providing good sanitation for the fortunate few connected to sewers, means must be found to improve the sanitation of the majority. For them appropriate sanitation must be provided and this involved an understanding of people as well as Technology. What did people want? How can they become aware of the need for sanitation? How can people be motivated to bother about maintenance and repair of water supply and sanitation?

18. There were frequent complaints about the non-availability of technicians for water and sanitation projects. Yet in developing countries old cars were made to work when well beyond their normal working life. Mr PICKFORD suggested that the trouble might be that the wrong type of technicians were being trained - those who knew a lot of technology but could not carry out the necessary work because they were out of touch with community needs. Perhaps 'barefoot technicians' were needed to work with the local people on a limited range of jobs, for which there needed to be as much standardization as possible.

19. Although at the local level much could be done with technicians whose training was limited to simple requirements, at the level of professional technical management a high level of skill and education/training was required. The professional team leader needed to collaborate with a wide range of other professionals and to appreciate the interaction between technology and people.

20. Mr R WILSON said that water diviners claimed to be able to locate groundwater. He wondered if any work had been done on assessing the reliability of this method. Mr MOFFAT said that some tests had been carried out and most diviners had failed to obtain a success rate greater than would be found by chance. In Britain it was much easier to find water than not to find it. The same applied to northern Ghana. In general the sites of wells were not chosen because of presence of water but because of convenience to the users.

21. Mr J G EVANS said that it was clear that geophysical investigation equipment was easy to use but interpretation of the data was not so easy. Mr MOFFAT agreed and said he could teach someone to use the equipment in half an hour but teaching how to use the results took a long time.

22. Mr James HOWARD was increasingly concerned about over-abstraction of groundwater. It was easy enough to find water and take it out of the ground. Recharge was as important as abstraction. Mr MOFFAT said that a great deal of attention was being given to recharge in the UK and other industrial countries and there had been a number of conferences organised by the Water Research Centre and other organisations. In the UK the usual method was borehole recharge, but this was a very expensive process not suitable for poor developing countries.

23. Mr G S CANSDALE asked about the sequence of pumping tests which Mr MOFFAT had used. Mr MOFFAT said he had pumped until the water became clear and then pumped continuously for at least 24 hours to prove the yield.

24. There was some further discussion between Mr EVANS, Mr HOWARD and Mr MOFFAT about the possibility of artificial recharge. It was pointed out that in

the tropics the high sediment load of rivers and streams was often difficult. Boreholes intended for recharge could become completely blocked quite quickly.

25. Mr Jozsef BUKY asked whether remote sensing and satellite photography were valuable in the location of water supplies. Mr MOFFAT said satellite photographs were very valuable. Infra-red photography could also be used. It was very good at locating underground electricity cables.

26. Mr HUTTON said that a great deal of work was going on in the United States and especially in Arizona on satellite images for Groundwater Exploration. However, the work was very sophisticated and required computers to interpret the results of satellite imagery. This was hardly suitable for developing countries.

27. Mr Michael SANE suggested that the industrial component of wastewater was often neglected, although the pollution load was often very great compared with 55 grams BOD per person per day. Two years ago he had designed a plant to treat effluent from a fruit juice factory, an abbatoir and an olive oil plant. The estimates of discharge and pollution load which had originally been provided proved to be completely false. It was necessary to examine the processes within factories before deciding on the design of wastewater treatment works.

28. Mr ELLIS said that in a situation like this it was always important to check any information provided by the client. In any developing country water pollution control started with effective legislation and there must be adequate inspection to ensure that the law is complied with. Mr ELLIS stressed the importance of water conservation in factories, especially in the food processing industry. "Good housekeeping" by strict control of the use of water could often substantially reduce the pollution load. Mr SANE said that the volume discharge in the fruit juice factory to which he had referred had been substantially reduced as a result of his firm's investigations.

29. Mr S CHAUDHRY asked what was the effect of diet and climate on the amount of excreta. Mr PICKFORD had tried in vain to obtain information about variation in solid accumulation in pit latrines and had written to a number of experts in tropical diet. It had been reported that in Rhodesia,Africans defaecate twice a day and Europeans only once. Mr ELLIS said that it was not only the amount of excreta which varied. There were also variations in the BOD/COD ratio, and in tropical sewage there was a high load of pathogens not present in European sewage.

30. Mr BUKY suggested a further factor to be added to those listed by Mr ELLIS. It was the means of recovering the cost of a project. A number of Mr ELLIS's other factors depended on that. For example, if salaries were improved to provide better mangement and better technicians, then the cost would go up. What if there were no means of recovering the operating costs? The World Bank was desperately trying to find a solution to this problem.

31. The CHAIRMAN suggested this was an appropriate time to close the discussion. So much of what was appropriate depended on the ability of people to pay.

open forum

MR K B NYASULU said it was necessary to motivate people into a desire for improved sanitation, but how was this best done?

2. Mr John PICKFORD said that some people were aesthetically disgusted by excreta, but others were inured to the sight and smell of human faeces. Public health education was a crucial factor in building up a will for improvement. A start could be made in primary schools. If people can be made aware that indiscriminate defaecation leads to disease, they will begin to want improved sanitation. People's demands vary. If a community has been used to visiting a common defaecation area they may be happy to have a communal latrine. Mr PICKFORD had recently visited an area in Karachi where there was a walled village within the city. Inside the village there was no latrine. To make sanitation appropriate it was essential to understand the background of the people - their customs, religious taboos and so on. For example in some places a single household latrine is unacceptable because the mother will not defaecate in the same place as her sons.

3. Mr J F JACKSON said that in Sana'a the family latrines were very unpleasant. A survey had been carried out and everyone wanted sewerage. However they were not willing to pay for it. There was, of course, a special case where places depended on tourism. Mr JACKSON also thought that many people who were accustomed to the sight of exposed excreta still had an aversion to it.

4. Mr James HOWARD said that the provision of services could improve the popularity of a developing country for tourists. Poor sanitation and the possibility of outbreaks of serious water-carried diseases counterbalanced the attraction that often did exist. He had once travelled by bus to India. When going through Turkey he had notices that latrines were available in a mosque at every stopping place. Tourists were willing to pay for proper facilities. Quite apart from tourists, local people were willing to pay for the use of properly-maintained latrines. The public latrines in Dacca, for example, were very well used. Mr KARIM confirmed this.

5. Mr NYASULU said that there was a lot of talk about motivation and educating the people through their children, but the problem was more one of persuading adults to see that the facilities provided by United Nations agencies were worthwhile. The CHAIRMAN asked what type of organisation would be needed to educate and motivate people on a massive scale.

6. Mr Jozsef BUKY said this was a problem which the World Bank had recently examined very thoroughly. Preparing a project which was appropriate for the economy of a rural people was a learning process. The answers were not known. There was seldom proper collaboration between, say, the manager of a Water Board and the Ministry of Health, and neither knew much about health education. Some progress was being made: at least officials were becoming aware of the need for community participation and this was now sometimes a condition for a World Bank loan. Mr BUKY suggested that a Nigerian housewife could not be told what to do. It was necessary to find out why she was frightened of using a latrine.

7. The CHAIRMAN repeated that this was a difficult area, but considerable progress had been made in the past five or six years.

8. Mr PICKFORD said that the attitude towards water and sanitation had changed dramatically since the early 1970's. There had already been a change of emphasis towards provision of water supply and sanitation at international and national level. He thought that the reported aversion to improving sanitation had been exaggerated. Much could be done by competitiveness. When one village or other community built good latrines, others

would want to follow.

9. Mr S D PRADHAN said in India massive grants and loans had been provided by the government for rural water supply and sanitation.

10. The CHAIRMAN reintroduced the subject of Technician training, and asked why and how this was being done. Mr Ken ELLIS suggested that the engineer should be the one who knew why and the technician should know how. However, it was not possible to split one thing from another. If technicians were merely taught how they would also want to know why. The CHAIRMAN said he drove a car without knowing how it worked. Why should we be concerned if the barefoot technician did not know why he was carrying out certain tasks to provide water or sanitation?

11. Mr W A GILLINGHAM said that in many places (he gave Saudi Arabia as an example) there were plenty of mechanical technicians. Consequently, the emphasis on simple non-mechanical technology might be wrong. It might be more difficult to find and train a barefoot technician than a motor mechanic to train for the job.

12. Mr Bruce CLEMENS suggested that some of the UN Decade goals seemed to be unobtainable. It would be better to set realistic goals. Mr BUKY said that it was now eighteen months since the Water Conference. In the meantime, several countries had set their own goals. Some Latin American governments had modified the aim from 100% of the population with proper sanitation to 60% of the urban population and 40% of the rural population. He was optimistic and thought this kind of goal could be achieved, even though the expenditure required would be very large. An essential feature of the Decade was the need for national training programmes. Without them there was no hope of achieving the goals.

13. The CHAIRMAN said that it was significant that people throughout the world were discussing how water and sanitation could be provided. With this interest it was possible that by 1990 everyone would have water.

14. Mr M SANE said that there were all sorts of goals. Often political goals were most important. In some countries the political goal was to expand industry and if this could only be done by first increasing the water supply, then water supply became a political goal.

15. Mr D V ALLEN thought that engineers should not be involved in politics, other than in what was required for technical management. Mr CLEMENS did not agree and Mr PICKFORD thought that engineers' primary concern was getting things done, whatever that involved.

16. The CHAIRMAN said that there were three elements which were of greatest importance. One was the need for money: water and sanitation had to be paid for. The second was the need for community involvement. The third was the training of people to carry out the work. He concluded by saying that thinking was difficult, and that was why we have no money.

B Z DIAMANT

e h e studies in developing countries

The introduction of environmental health engineering studies in higher learning institutions in developing countries.

INTRODUCTION

The growing interest in the quality of the human environment in recent years has highlighted the important environmental health engineering role in preserving and maintaining this environment. In the developing countries where environmental health engineers were always very scarce, the need for this manpower has become urgent, due to the recent fast national development trends. In addition to the conventional basic problems of providing safe drinking water and wastewater disposal facilities, new sophisticated environmental problems have risen in recent years, such as prevention of water resources pollution with industrial wastewater and controlling the spread of water-borne diseases in the course of developing large-scale irrigation schemes.

Developing countries have been facing tremendous social, economical and environmental problems during their relatively short period of independence. Industrialization has been generally adopted as the magic solution to the chronic economical and unemployment problems and the growing need for food supplies could be satisfied by modern agricultural development, involving large-scale water resources projects such as hydro-electric dams, river regulation and irrigated agriculture.

The environmental aspects of such sophisticated development projects must be controlled by competent environmental health engineers, if severe environmental deterioration is to be avoided. This risk has not been under-estimated by the authorities in most developing countries ahd while local environmental health engineers were not available to control and eliminate the environmental hazards, reference was made to bilateral and international bodies for assistance. In most cases this assistance, in the form of foreign environmental health engineering experts, has been provided for various lengths of time.

However, such assistance can be considered only as a temporary measure until local manpower is trained to take over and continue the task. This was the reason why all agreements between Governments and the bilateral or international bodies, required and committed the Governments to provide national counterparts to the experts during their stay in the country, so that the former can carry on upon the departure of the experts. These counterparts were required to have basic engineering training, preferably as civil engineers, in order to be able to cope with the technological problems under the guidance of the assisting environmental health engineer. Unfortunately, this basic and logical requirement has very seldom been fulfilled, mainly due to the fact that national engineers were simply not available for this purpose. The consequences were, therefore, very discouraging, in a way that as long as the foreign professional manpower was available, adequate services were provided, but when such left the country, there was no continuation and the whole framework collapsed.

This situation must have been among the main reasons that shifted the emphasis in recent years, from the previous inservice training in environmental health engineering, to direct academical training. This move has been agreed upon and accepted by both the local authorities and the foreign assisting bodies. Stress has been, therefore, laid in recent years on the training of environmental health engineers in developing countries, in higher learning institutions located locally or abroad.

NEEDS AND SCOPE

The scope of environmental health engineering manpower development depends on present and future needs. These needs are directly related to the size of the serviced population, as well as to the general environmental state of the country. The World Health Organisation has recommended the ratio of one environmental health engineer for each 100 000 people living in developing countries*. Accordingly, a developing country with a population of 10 000 000 will need 100 such engineers. The present situation in most cases does not provide even a tenth of this ratio. A massive training programme will have to be stretched over a period of at least 15 years, in order to close this wide gap. This can be performed in 3 stages lasting 5 years each. During the first stage the number of environmental health engineers can be increased from the initial 10 to 20. This manpower will be distributed to provide professional services to the following Governmental, local and private bodies. The distribution is based on approximate estimated needs.

Health Offices	4 engineers
Water Corporations	2 engineers
Public Works Departments	3 engineers
City Councils	4 engineers
University teachers	3 engineers
Private enterprises	4 engineers
Total	20 engineers

The above breakdown can serve as a general guide for assessing the short-term needs in environmental health engineering services in various relevant disciplines in developing countries. Manpower training in future phases will follow, more or less, the same distribution and will include the population growth aspect, according to the above mentioned ratio. National counterparts to environmental health engineering foreign aid projects can be assigned out of any of the above mentioned disciplines.

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* Personal correspondence with WHO H Q, Geneva.

DUTIES AND RESPONSIBILITIES

An environmental health engineer is considered to be at present a civil, or chemical engineer who completed successfully a postgraduate study in environemntal health engineering with a degree of Master of Science. The required training for environmental health engineers has been outlined by a WHO Expert Committee on "Professional and Technical Education of Medical and Auxiliary Personnel"* as follows:-

> "Environmental Health Engineers should possess basic education and training in engineering, followed by at least an academic year's specialised education and training. The latter should include the science of bacteriology, chemistry and human physiology, as related to problems of environmental health engineering interest. Also the principles and practices of engineering analysis, design and operation as applied to works of water supply and purification, sewerage and sewage treatment, the collection and disposal of municipal, rural and industrial wastes, insect and rodent control, the engineering and administrative phases of food and milk sanitation, the sanitation of buildings, including ventilation, air conditioning, heating, plumbing and illumination, housing, industrial sanitation with particular reference to those industrial hazards, the correction of which is an engineering problem, should be considered.... The postgraduate training of the engineer should include adequate instruction in public health, including public health practice, epidemiology, health statistics and health education of the public".

The(British) Institution of Public Health Engineers defines environmental health engineering as "the art, science, technology, profession and practice of designing, supervising, executing, undertaking, advising upon and administering works intended to assist, develop and control the forces of nature, in order to maintain and improve the health of the community"**.

The duties and responsibilities of the environmental health engineer have been described by WHO as follows***:-

> "Environmental health engineers are assumed to have a broad and thorough understanding of the whole range of environmental conditions that affect human well-being, to be well qualified by aptitude, training and experience, to serve as true professionals at the various levels of responsibility relating to the environment in public health and associate organisations and in the upper echelons, to be able to take their place alongside their counterparts in other professions, in assuming responsible administrative duties and other public health functions. In addition, they should possess the skills required to prepare the design and to supervise the construction and operation of sanitary works".

The (British) Institution of Public Health Engineers**** defines the environmental health engineer as "one who among other things is, by education, training and experience competent in this field of engineering and who is particularly concerned with the development of both the built and the natural environment, as they affect the health of the community".

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* Wld Hlth Org.Tech.Rep.Ser.No 28, 1950, Geneva.

** I P H E Regulations, London.

*** Wld Hlth Org.Tech.Rep.Ser.No 47, 1950, Geneva.

**** I P H E Regulations, London.

It is quite clear from the above definitions that environmental health engineering is a high quality and large quantity study that embraces a wide range of environmental fields and requires a great deal of public responsibility. When such study has to be newly introduced in an existing higher learning institution, it will be technically almost impossible to include all various fields of the study at once and priority of fields might be required. In view of existing environmental conditions in most developing countries at present, it is suggested that priority is given to the fields of safe water supply and proper wastewater disposal. This means that when the study of environmental health engineering is newly introduced, only the two priority subjects will be included in the first two or three years of teaching the study, whereas other fields, such as air pollution, food sanitation, industrial hygiene and vector control, will be gradually added to the curriculum in later stages of the study's development process in the institution, as described ahead.

ENVIRONMENTAL HEALTH ENGINEERING EDUCATION

The education of environemntal health engineers in developing countries can be performed locally or abroad. The latter possibility might be less time consuming, when suitable national candidates are given fellowship and sent abroad for studies in an adequate university in a developed country. However, the possibility is quite costly and also risky to a certain extent, because experience has shown that some of the candidates were reluctant to return back home after completing their studies and preferred to stay abroad. But the main disadvantage of obtaining the education abroad lies in the foreign curriculum, that does not always fit the special needs of developing countries. For example, prevention and control of air pollution is a major subject in environmental health engineering curriculums in developed countries, whereas in developing countries this subject is of minor importance compared, say, to purification of drinking water. In local education and training institutions that teach environmental health engineering, the curriculum is designed according to local needs as it is done in the developed countries. It should be noted, however, that some leading universities abroad, have started to design in recent years, modified curriculums for students from developing countries, to meet their special needs. For example, the University of Technology in Loughborough, England.

In view of the anticipated growing needs for environmental health engineers in developing countries, the best long-term solution to this manpower shortage problem will be the establishment of local training facilities.

Local Training Facilities

The local training facilities in environmental health engineering in developing countries can be divided into 3 categories, according to the nature and characteristics of the host institution.

a. Newly planned universities.
b. Existing universities without engineering studies.
c. Existing universities with faculties of engineering.

The establishment of higher learning institutions in developing countries has been an important component in most national development programmes. In establishing a new university, it is easier to start with studies that do not need laboratory services, such as fine arts. However, in view of the urgent need for environmental health engineers, it is important to include for new universities planned in the national development programmes, at least the study of environmental health engineering in the very first stage of development.

Existing universities with functioning faculties of engineering form the best background for the introduction of environmental health engineering studies. Faculties of engineering usually include civil engineering studies, of which environmental health engineering is a branch. The introduction of environmental engineering studies in the university will have to be performed, therefore, through the department of civil engineering.

THE INTRODUCTION OF THE STUDY

Environmental health engineering is a relatively new branch of civil engineering. Traditional civil engineering studies never paid much attention to environmental health issues, which were considered as medical interests. The subject was slightly touched in the course of studies, as far as basic hydraulic matters, such as diameter of piping and capacities of pumps, were concerned.

Introducing environmental health engineering as a separate study in civil engineering, has to be, therefore, carefully and gradually approached.

It is suggested that the introduction and establishment of the study should follow a long-term procedure, which has been already successfully practised, along the following development stages:-

Stage - I : establishment of optional studies.
Stage - II : establishment of compulsory studies.
Stage - III: development of service courses.
Stage - IV : establishment of postgraduate studies.
Stage - V : formation of a department.
Stage - VI : setting up a reference centre.

Optional Studies

Most universities practise optional courses in the final year of studies. The final year student can choose, in addition to his ordinary compulsory courses, an option course from a group of subjects in various fields related to the main study (civil engineering).

The final year student also has to prepare a final project report, on a civil engineering topic. In most cases the student is allowed to choose his topic for the final report, and these topics are, more or less, identified to the optional subjects. Unlike other options which have already been discussed with the students in previous years, such as structures or hydraulics, environmental health engineering is almost entirely a new matter and the optional course will have to be designed accordingly, in particular in respect of new sciences like microbiology of water and wastewater.

The first introduction year will contain only the optional study and towards the second next year, environmental health engineering subjects can be proposed also for the final year research projects. These subjects will, of course, concentrate on the fields of water supply and wastewater disposal only. The optional study and the research project reports in environmental health engineering will compose the first stage of introduction, lasting for two years, towards the start of the second development stage of establishing ordinary compulsory courses in the study.

Compulsory Courses

Based on the experience achieved during the two-year period with the optional course, the study can move now towards its second development stage. It should be noted that the Compulsory Course is not intended to replace the already established Optional Course, but to supplement it. The Compulsory Course should, therefore, be introduced in the study year preceeding to the final one.

The compulsory and optional courses in environmental health engineering, require the services of sanitary chemistry and microbiology laboratories. Preparations for the establishment of the laboratories must start from the very first stage of the optional study. However, since the setting up of such laboratories is time consuming and fund absorbing procedure, temporary use can be, meanwhile, made of the already existing laboratories in the university, in the Departments of Chemistry and Microbiology.

Service Courses

Environmental health engineering embraces the whole of the human environment and, therefore, the study is related to many relevant fields, such as medicine, agriculture, education etc. The study can be, hence, spread over these related fields of study in the university by means of service courses. A service course in a specific subject is provided normally to a related study, where this subject can be supplementary to the main subject of the study. For example, veterinary-medicine students must obtain a certain knowledge in environmental health, in areas related to their major field of study, i.e. abbatoirs and animal wastes disposal. As a supplementary study, it does not justify to employ a special lecturer in the department of veterinary-medicine, to deliver this study. The department of civil engineering can provide in such case a service course in environmental health engineering, specially designed for the needs and the character of the recipient study. The service course is provided at a rate of 1 - 2 hours per week for one or two terms.

Due to the wide scopes of environmental health engineering, it can be applied in the form of service courses, to a large number of related departments and experience has shown that these departments' authorities, in most cases appreciated the need for the proposed service course and readily included it in their curricula. It is important to point out that service courses in environmental health engineering should be provided to the various Departments only on the basis of a fully recognised and scheduled curriculum course, that requires a written examination paper, or be part of such paper. A free "voluntary" course should be rejected, because experience has shown that free courses were considered by students as less important studies, that did not require much attention. This might develop wrong attitudes towards environmental health engineering which is, as a matter of fact, a very important study.

Medicine

Medical students can have the service course within the framework of their community-medicine studies. The design of this service course will include mainly rural environmental health aspects, such as safe drinking water and human waste disposal, emergency disinfection of water and installation of pit latrines, housing and vector control. The programme will include field visits to a water treatment plant and a wastewater treatment plant.

Veterinary Medicine

Many environmental health problems are involved in practising veterinary medicine. The service course for this discipline will be designed to include rural and farm sanitation and in particular the planning of abbatoirs and their maintenance, the disposal of animal wastes and the protection of water resources, as well as special problems involved in the planning and sanitary running of meat packing plants, butcheries and markets.

Agriculture

Modern agriculture has a strong impact on the quality of the environment, in particular in the fields of water pollution control and the use of the large variety of insecticides, which are, in many cases, dangerous to people. This service-course should include, in addition to the above aspects, mainly principles of rural sanitation and problems involved in irrigated agriculture, with fresh water and also wherever applicable, with treated wastewater, as well as the use of organic fertilizers, such as compost.

Town Planning

The efficiency of urban sanitation is determined to a large extent by the adequacy of the town planning for the town or the city. The service course in environmental health engineering for town planning students will include mainly urban sanitation aspects, such as the principles of housing sanitation, design of markets and public institutions, adequate separation of residential zones from industrial zones, by green belts and commercial zones, air pollution principles and causes and topographical considerations to enable proper sewerage systems, population density and noise control aspects. Emphasis should be laid on the importance of preventing the sacrifice of environmental issues for architectural considerations.

Education

The curriculum of education studies has always included a course in so called "Hygiene". This course contained mainly matters of preserving personal hygiene aspects, such as brushing teeth and cutting nails. In view of the severe environmental conditions in developing countries, this limited scope must be widened to include the importance of consuming safe drinking water and using proper human waste disposal means, the transfer of basic communicable diseases such as malaria and bilharzia and principles of food hygiene and housing sanitation. Teachers have a prominent position in the rural areas of developing countries and they are usually well obeyed by the students and their parents. They can obtain, therefore, a strong influence on the quality of the environment in their duty-stations, provided they have the basic necessary knowledge of the subject.

POST GRADUATE COURSES

Qualification in environmental health engineering normally requires successful completion of a post-graduate course in this study, after graduating in civil engineering or in chemical engineering. A post-graduate course can be accomplished by study and last one calendar year, or by research when it lasts two years.

The research course requires the performance of a comprehensive research work on a selected environmental health engineering subject, during a period of two years. The study course consists of a regular study programme accompanied by a final research project.

It is therefore recommended to start the post-graduate development process with a research course as a first stage, followed after a year or two, upon the availability of suitable candidates, by the study course.

The teaching load required for the above mentioned development stages can be summarized as follows. The teaching manpower can be assessed accordingly.

ENVIRONMENTAL HEALTH ENGINEERING TEACHING LOAD

Course	Department	Year	Lessons Per Week		
			Lectures	Lab	Total
Option	Civil Engin.	Final	2	3	5
Compulsory	Civil Engin.	2nd	2	6	8
Post Grad.	Civil Engin.	1 & 2	12	6	18
Service	Medicine	3rd	2	-	2
Service	Veterinary	3rd	2	-	2
Service	Agriculture	2nd	2	-	2
Service	Town Planning	Final	2	-	2
Service	Education	Final	2	-	2
Total			26	15	41

THE DEPARTMENT OF ENVIRONMENTAL HEALTH ENGINEERING

Environmental health engineering is a dynamic and versatile study which embraces a wide range of various environmental fields. As long as the study is part of a general civil engineering curriculum, it will be practically impossible to cover even a small part of the above mentioned fields. However, the wide range of the study, which covers almost all aspects of human life and environment, justifies the establishment of a separate Department of Environmental Health Engineering, as an independent engineering branch in the Faculty of Engineering. Some leading higher learning institutions in various parts of the world have already reached this conclusion and established such Departments. The issue is in particular important in the developing countries, where the services of environmental health engineering are most needed.

THE REFERENCE CENTRE

The establishment of an environmental health engineering reference centre attached to the university will be the final stage of development in the introduction of environmental health engineering studies. This will take place when all previous stages, including the establishment of a functioning department, have already been well operating and practising.

The Reference Centre will have to be recognised as the supreme professional authority in all matters pertaining to environmental health engineering. It is preferable, but not obligatory, to have the Centre located in the University, but it can be erected elsewhere and maintain close links with the University, and in particular, with the Departments of Civil and Environmental Health Engineering. Such a Centre will normally be providing the following services:-

1. Advice. Provision of advisory and consultantship services, performance of professional investigations and assessments based on laboratory tests and analyses.
2. Research. Organising advanced research activities in the various fields of the study, for public and private sponsoring bodies. Assistance in carrying out post-graduate research will be provided to the Departments of Civil and Environmental Health Engineering in the University.
3. Standards. Establishment of national environmental health engineering standards, in line with existing international standards, adjusted to local needs and conditions. Provision of laboratory testing services.
4. Advanced Studies. Planning and performance of advanced and refresher courses for environmental health engineers and related

professionals, in cooperation with the Department of Environmental Health Engineering.

5. Conferences, Seminars and Workshops. Organisation of conferences, seminars, symposiums and workshops on actual environmental health engineering topics, designed for environmental health engineers and related professionals, such as doctors, sociologists, teachers, town planners, biologists etc.
6. Library. Development of an environmental health engineering library and organisation of dissemenation of material for reference and research purposes.
7. Publications. Publication of professional periodicals and books and organisation of a distribution system.
8. Legislation. Assistance in the preparation of environmental health engineering legislations. Provision of advisory services in all matters pertaining to legal matters of the profession and the professionals.
9. National and International Relations. Maintaining mutual professional relations with similar Centres located in or out of the country, for obtaining current exchanged data and experience.

The preparations for the establishment of the Reference Centre, will start in a later stage of the functioning of the Department of Environmental Health Engineering. With the constant expansion of activities in the numerous fields of the study, the establishment of a Reference Centre will be only a normal step forward in reaching a full development of the introduction of environmental health engineering studies in higher learning institutions in developing countries. This development will be, hence, composed of six consecutive stages: the optional study, the compulsory study, the service courses, the post-graduate studies, the development of a Department and the establishment of a Reference Centre. It is estimated that the whole development process will require a minimum period of 5 - 7 years, during which the first groups of environmental health engineers will start to function in the country. In view of the deteriorating environmental conditions in most developing countries, the urgency of the matter is growing steadily and all efforts should be made by the relevant Governments and by the numerous bilateral and international assistance organisations, to promote and alleviate this vital issue, according to the above mentioned recommendations.

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BRUCE CLEMENS

agua del pueblo

CHAIRMAN: Mr J M G van DAMME

The CHAIRMAN explained that Professor Diamant was not available to present his paper on education. However, Mr Bruce Clemens would talk about the work he had been doing in Guatemala.

2. Mr Bruce CLEMENS has worked with Agua del Pueblo (AdP) for the past seven years. AdP, "The Peoples Water Company", is a private non-profit technical assistance institution working in Central America. AdP is a small scale, grass roots organization, based in the rural highlands of Guatemala. AdP provides potable water by collaborating with its beneficiaries - or rather AdP provides the means by which the beneficiaries improve their own water supplies. AdP was founded by a multi-disciplinary team of engineers, social scientists and technicians in 1972. AdP has been responsible for 36 rural potable water supply projects benefitting 35 000.

3. There were 5 reasons that AdP chose to work with rural potable water supply. First and foremost, it was a response to a felt need. Committees approached AdP directly for technical assistance for water supply projects. Secondly, water supply projects are conducive to improvements in community organizations. The entire community must work together and a representative body must be chosen to make decisions for the community as a whole. Thirdly, improvement in water supply directly benefits the most critical target group, namely rural women and children. Another reason for choosing water supply was the visibility of the project, a flowing tap is a concrete testimony to the project. Lastly improved water supply is avowed to improve the public health. However, this last benefit is the lowest on the priority list for the beneficiaries. As a rule the rural inhabitants want water improvements in quantity and accessibility, however they don't perceive the need for potable water.

4. Mr CLEMENS presented Table 1 showing AdP's approach to development, summarizing their work in Guatemala.

5. AdP assists communities with technical expertise, however, the communities must contribute substantially to the capital costs for construction materials through loans and provide all of the skilled and unskilled labour.

6. Mr CLEMENS stressed the integrated nature of AdP's approach. They were not simply concerned with water supply, but attempted to assist the committee in all aspects of community development.

7. One of AdP's most noteworthy projects is the training of paraprofessionals for rural potable water supply programmes. Over the past 5 years, AdP has demonstrated and documented that there is a vocational gap in the personnel structure of the institutions responsible for rural water supply. The gap can be divided into two; a technical and socio-cultural hiatus.

8. The technical gap hiatus exists because there is a substantial number of qualified engineers and a large number of efficient construction contractors and skilled labourers; but there is a lack of qualified intermediate personnel. The engineers are over-skilled, over-specialized and over-qualified for the necessary tasks. On the other hand the skilled labourers are

THE APPROACH TO DEVELOPMENT OF AGUA DEL PUEBLO

OBSTACLES	GOALS	MEANS/PROJECTS
ABSOLUTE POVERTY AND DISTRIBUTION OF GOODS AND SERVICES	IMPROVE LIVING CONDITIONS IN RURAL AREAS	A. RURAL WATER SUPPLY PROGRAMS i) individual projects ii) integrated rural environmental sanitation pilot programs B. OTHER PROJECTS i) disaster relief ii) hydro-electric plant iii) schools iv) clinics
FAILURE OF INSTITUTIONS TO DELIVER DEVELOPMENTAL SERVICES	STRENGTHEN CAPABILITIES OF DEVELOPMENT INSTITUTIONS	A. MANPOWER DEVELOPMENT: BAREFOOT ENGINEERS AND SKILLED LABOUR B. DEVELOPMENT OF PROGRAMMING METHODOLOGY FOR RURAL WATER SUPPLY C. OTHER PROJECTS i) housing studies ii) environmental impact studies iii) irrigation feasibility studies iv) appropriate technologies for rural water supply (IBRD) v) consulting contracts
INABILITY OF RURAL POPULACE TO TAKE ADVANTAGE OF AVAILABLE DEVELOPMENTAL SERVICES	COMMUNITY DEVELOPMENT AND CONSCIOUSNESS LEVEL RAISING	A. FORMATION OF COMMUNITY ORGANISATIONS B. ENCOURAGEMENT OF CATALYTIC COMMUNITY DEVELOPMENT PROCESS C. FOMENTATION OF COMMUNITY INPUT IN ALL PHASES

not capable of planning and designing a safe and adequate water system.

9. The socio-cultural hiatus exists because the engineers are socially and culturally remote from the intended beneficiaries. The engineers cannot understand the needs of the rural population and at the same time the beneficiaries have difficulty in communicating with the engineers.

10. The solution proposed by AdP to fill this vocational gap is the development of rural water promotors (I.T.A.R.'s). ITAR is an anonym for the Spanish: "Impulsor y Técnico de Acueducto Rural"; translated: Facilitar and Technician for rural acuedusts. The ITARs are natives of the rural area trained to organize, plan design, and supervise the construction of rural water supply projects. To date AdP has trained only 4 ITARs using an on-the-job, person-to-person pedagogy, however, national and international agencies have demonstrated interest in institutionalizing the concept.

11. The work of AdP was extending to other countries in Central America, and with USAID financing, AdP is carrying out a feasibility study for the development of similar country specific programs in El Salvador, Honduras, Costa Rica and Nicaragua.

12. The CHAIRMAN thanked Mr CLEMENS for his most interesting talk and said how good it was to listen to someone who was actually augmenting - and augmenting successfully - a programme to provide water for rural communities.

13. Mr Jozsef BUKY asked for information about the financial arrangements for the programme. He was interested in the source of funds, the allowances paid, rate of interest charged and so on. Mr CLEMENS replied that the cost for personal and operating including technicians salaries amounted to $US 200 000 a year. The funds were obtained from private foundations and donations from the United States, and from the USAID. Funds were also obtained from Church World Services and the OXFAM Foundation. The Guatemala government has also provided some materials.

14. In reply to a question from the CHAIRMAN, Mr CLEMENS said that a great deal of his time was spent obtaining funds.

15. In reply to further questions from Mr BUKY, Mr CLEMENS said that agreements for receiving and repaying funds were signed on behalf of "Village Improvement Companies". The Ministry of Health was also integrally involved. Agua del Pueblo prepared programmes and drew up the agreements.

16. Mr G S HOYLES asked whether PVC pipes used in the programme were imported or made in Guatemala. Mr CLEMENS said the PVC pipes were made locally from material imported from the United States. Galvanized pipes had also been used, and asbestos cement pipes were also made in Guatemala.

17. Mr M Z KARIM said that mention had already been made during the Conference of evaluation of projects. Mr CLEMENS had mentioned evaluation of water supply with other development. Mr KARIM had some experience of such surveys, where a latrine programme had been related to the health of the people. Mr CLEMENS wished he had more time to devote to evaluation of the benefits of the water supply schemes which had been provided. He stated that a recent World Bank survey of AdP projects showed that approximately 85% of latrines were being used. Agua del Pueblo had only been required to make extensive repairs for operation and maintenance of one rural water supply scheme and that was due to the earthquake of 1976.

18. Mr K B NYASULU noted that the communities provided with water seemed to be away from the administrative centres and enquired about the relationship between Agua del Pueblo and the government. Mr CLEMENS said he had worked with the regional governments in the area and site visits were often made in the company of a ministry official. On the other hand they tried to keep government interference at arm's length. Communities had told Mr CLEMENS that the closer Agua del Pueblo got to the government, the further they moved from the local people. Some collaboration with the government was necessary, for the people received some government subsidies.

19. Mr NYASULU asked whether the people were represented by a chief when they first approached Agua del Pueblo. Mr CLEMENS replied that the first contact

with the people was usually with the religious leaders of the villages. A major problem was always trying to get everyone involved.

20. In reply to a question from Mr M Y SINKILONGO, Mr CLEMENS said that communities which were helped with water supply schemes invariably went on to carry out other improvement projects. The villages had approached AdP directly for assistance. This usually meant that they were villages with some communal spirit, and where a representative of the village spoke for the community as a whole.