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2-4 August 1989
Manila, Philippines

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O B J E C T I V E

To share experiences on the latest developments made on rain water cisterns systems technology with emphasis on community involvement.

MAJOR TOPICS

* COMMUNITY PARTICIPATION
* SOCIO-ECONOMIC AND POLITICAL ASPECTS
* INSTITUTIONAL ASPECTS AND POLICY MATTERS
* ENVIRONMENTAL AND WATER QUALITY ASPECTS
* HYDROLOGICAL DATA AND ANALYSIS
* CATCHMENT AND STORAGE SYSTEMS
* DELIVERY AND DIVERSION SYSTEMS
* INTEGRATION WITH OTHER WATER SUPPLY SYSTEMS
* APPLICATIONS AND COST ANALYSIS
* SYSTEM DESIGNS OF RAIN WATER CISTERNS

CONTENTS

Attachment No. 1

An Abstract Submitted to

The Fourth International Conference on Rain Water Cistern Systems

Title: The International Drinking Water Supply and Sanitation Decade (1981-1990)and the Progresses of Rain Water Cistern Systems

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ABSTRACTRACT

Rain water cistern systems have been used for domestic water supply as early as 2000 B.C. in the Middle East. They are developed to suit various life styles of their users in different environmental conditions.

By an unplanned coincidence, the First International Conference on Rain Water Cistern Systems was organized by the write during the beginning of the International Drinking Water Supply Decade (1981-1990). Subsequently, a series of conferences was followed. This paper reviews recent progress in rain water cistern systems' planning, design, development and management in some Pacific and Asian countries. So that their efforts to meet the Water Decade's goal:to provide all people with safe water in sufficient quantity and means to safely dispose of human waste, can be assessed. Proceddings of the 1st, 2nd, and 3rd International Conference on Rain Water Cistern Systems are the main reference sources. Successful case studies are analyzed for the possible application to island countries in the Pacific.

INTRODUCTION

According to Reid (1982) rainwater was stored in cisterns for domestic water supply as early as 2000 B.C. in the Middle East and perhaps, the catchment systems are as old as dugwells in human households. They were built in various forms to suit the needs of the users in different environmental settings with local tools and materials as reported by Ozis (1982), Gordillo, et al (1982), Shata (1982), Crasta et al (1982), Hassanizadeh (1984) and Weiner (1987). This is part of the human effort to support life and to improve their living conditions with a domestic water supply.

Rainwater catchments were reportedly used in regions with annual rainfall of 200 mm or less according to Hassanizadeh (1984) and Weiner (1987). Perhaps rainwater catchment systems should be stressed as a practical method for providing drinking water supply in such zones. The rationale for this can be explained by examining the relationship between rainfall, catchment area, storage capacity, daily water demand and available supply. According to Fok et al (1980, 1982) (Figure 1), if a storm produced 25.4 mm of rain, a catchment area of 200 m^2 would be needed to catch 5 m^3 of rainwater. Or, if a cistern has 41.5 m^3 of water stored and the daily consumption is 0.77 m^3, it would support the demand for 54 days.

The World Health Organization (WHO) reported that over 12 million children die annually in developing countries. A key factor in many of these deaths is the lack of safe drinking water and unsanitary human-excretia disposal. The fact is that two-thirds of the population of developing countries do not have access to safe and sufficient domestic water supplies. And an even greater percentage have no access to sanitary waste disposal. Pathogens in human waste can contaminate water sources causing illness, thus, establishing an unhealthy cycle. In order to break the cycle, the WHO and the United Nations took leadership roles. In November 1980, the United Nations General Assembly proclaimed 1981-90 as the International Drinking Water Supply and Sanitation Decade (IDWSSD). The goal is to provide by 1990 all people with water of safe quality and adequate quantity, and basic sanitary facilities to safely dispose of human waste.

In a united effort to achieve these water decade goals, the World Bank initially estimated the cost at $140 billion (US) and later modified it to $300 billion. For individual countries, financing the UN Water Decade Plan is a major difficulty and finding low cost and appropriate water supply systems technology is also very important. Rainwater catchment systems (RWCS) is one of the low cost technology methods available.

This paper reviews recent progress in rainwater catchment systems (RWCS) based on the 1st, 2nd, and 3rd International Conference on Rain Water Cistern Systems (1982, 1984, 1987) proceedings and other publications. Factors favoring RWCS is first listed and assessed implementation; then, successful cases are analyzed. Finally, possible RWCS adaptation for island countries in the Pacific and other regions are presented.

FACTORS IN FAVOR OF RAIN WATER CISTERN SYSTERMS (RWCS)

Rainwater catchment system is one of many alternatives that can be selected for development. Factors favoring RWCS are listed below:

1. Low construction cost,

2. Private ownership and control,

3. Good water quality as compared to other sources,

4. Easy to construct by the owner with simple technology,

Cost Factor. Financing the International Water Decade Plan is a major problem for developing countries. If the unit cost of developing drinking water supplies is reduced, the likelihood of reaching the water decade's goal increases. Effort must be made to keep the cost low to increase affordability. Figure 2 shows the unit cost of RWCS using different construction materials. Among the materials shown, the Thailand reinforced 2 m^3 concrete jar at $20 US is the lowest cost collector. Figure 2 was first developed by Tuinhof (1979), with data added by Fok and Leung (1982) and subsequently the Thailand jar and tank data by Sethaputra (1986).

Private Ownership Factor. Water supply was traditionally a private system, later changing to the public utility systems of developed and many developing countries. Public ownership of the water supply system has the advantages of providing a dependable supply at a very low price, often below the market value because of subsidy from public sources. This public system works very well in urban areas with high populations to support the tax income needed to operate it. As industrialization intensified, public water supply systems have been adversely affected by increasing pollution as well as ever increasing water demand. As a result, self-sufficiency becomes a new drive in some developed countries. Privately owned individual RWCS supplemental water supply has become popular in the Monterey Peninsula, California, U.S.A. as reported by Fok (1982) and Ingham and Kleine (1982). To be able to free oneself from dependence on the public utility systems is a desire of private citizens.

Good Water Quality Factor. In many developing countries, rainwater is a lot cleaner than water from polluted surface or groundwater sources. Contamination of surface and groundwater sources is a major factor affecting the selection of drinking water supply.

Factors of Ease of Building, Operating, Maintaining, Convenience and Flexibility. If rainwater catchment is selected the owner should be able to construct, operate, maintain and expand the system at low cost. Because this sytem is privately owned, the affordability is the main factor for system's selection.

Considering the favorable selection factors for rainwter catchment system, the RWCS stands out from the other alternatives:

1. Shallow dug well with bucket and rope,

2. Tube well with hand pump, shallow or deep,

3. Fetch or divert water from spring or stream, pond or lake,

4. Public standpipe.

But, according to The International Drinking Water Supply and Sanitation Decade Directory (1981), published by World Water magazine, the general tendency in selecting drinking water supply systems is in the sequence of (1) wells--dugwells, tubewells with handpump; (2) public standpipes and (3) rainwater catchment systems. Perhaps this follows the tradition of public sector practices because most RWCS are privately owned.

The Decade Directory also listed 116 participating countries, including 21 within the Asia and Pacific region, most of which listed their National Plans and Decade Plan. In general, the National Plan guides the development of the Decade Plan. Several countries in this region require water users to share or to pay for the development and maintenance of their drinking water supply systems. Some of these countries stressed that their fulfillment of the Decade Plan depends upon the users' construction and maintenance labor as well as repayment of construction materials through an agreeable financial plan. This is a remarkable policy to motivate self-help in the general public.

Indonesia. In principle, water costs are borne by the water users. Present water charges are too low to meet costs; however, the government will subsidize newly-completed water systems for a maximum of two years. The government will provide a full grant for projects which provide 60% of the total population of a town with safe water of up to 60 liters/head/day; a mix of loan and grant for projects supplying 60% of population with an average of between 60 and 125 liters/h/d; and full loan financing when the average rate of supply is more than 125 liters/h/d.

Pakistan. Central and provincial governments have been the main financers and it is hoped that local government will make more resources available. Fundamental change in pricing policies is needed. Current rates do not even cover operation costs. Government policy is for urban water supply and sewerage systems to be provided on a no-profit-no-loss basis. For rural supplies the target is to recover at least the cost of operation and maintenance.

Philippines. Community participation in policy-making, planning, and operation and maintenance is considered to be the most effective way of ensuring the financial viability of projects. Water districts in larger urban communities, and water associations or cooperatives in smaller communities, will provide water users with the hierarchy to own, manage and maintain their water systems. Social and economic considerations will determine the type of water systems. In general, rural areas will be provided with communal water point distribution systems while urban areas will have individual water connections to households.

Solomon Islands. For urban area water supply, the policy is for consumer charges to cover the cost of construction and maintenance. For rural areas the policy is more flexible but self help, local labor and materials are used where possible. For their Decade Plan, the government contribution is likely to be at 10% of the total costs.

Sri Lanka. The government's policy is to initially provide minimum levels of service. Any services above the basic level will be directly charged. The central government bears construction costs of new systems while local authorities are expected to share the cost of augmenting existing medium or major supply systems. The local authority has to bear the full cost of distribution. Where the communities cannot generate income to pay for their water supply, the central government will provide direct subsidies.

Thailand. The government notes that the large number of organizations involved in rural water supply has made their Decade Plan difficult to form. However, it believes that 60-70% of the rural population could be provided with inexpensive safe water by conversion of exisitng dugwells into sanitary wells supplemented by rainwater cisterns, and equipping small diameter tubewells with handpumps. Financial participation of the population is considered essential for achieving Decade targets. New approaches to financing have been tried and evaluated. Central government's responsibility is for overall planning and programming as well as providing guidance and necessary assistance for implementation. But individuals are expected to participate financially to the fullest extent possible and contribute labor where appropriate. For rural water supplies the government believes that only through such participation will local needs be fulfilled because people are unlikely to put in their own money for inappropriate schemes. Sanitation programs will need full financial support from the central government in the initial stages.

Individual government's policy will have a direct effect on the success of their Decade's drinking water supply plan.

Successful case studies are presented below with analysis of those factors that have contributed to their success.

Successful Case Studies

The Thailand Jar Project - This successful drinking water supply project was a joint effort between the Thailand National Economic and Social Development Board and the Australian Assistance Bureau under the Thai-Australia Village Water Supply Project, and collaboration with the Water Resource and Environment Institute, Faculty of Engineering, Khon Kaen University (Wirojanagud and Chindaprasirt 1987 and Sethaputra 1986).

Prempridi and Chatuthasry (1984) reported that in 1962 the Thai Government started modernizing the country. After 20 year and four five-year plans, they found the rural area, with more than 80% of the population, had not benefited from the program. Their income and education remained low in comparison to the urban population. Therefore, in 1982 at the start of the 5th five-year plan, rural development became the priority. Rural people were assembled to form village councils to plan, implement and maintain their improvement projects with their own resources. The Government provides part of the funds and technical assistance to help the villagers complete their projects. This resulted in the successful Thailand Jar Project in just 4 years.

Prempridi (1982) reported that cement jars are one of several rainwater containers used in Thailand. It is very popular having been used for centuries. There are small factories manufacturing various sizes of cement jars. The Thailand jar project's success is due to the government's assistance policy as reported above, social acceptance of its use, as reported by Appan (1984); and the low construction cost as reported by Prempridi and Chatuthasry (1984) and Vadhanavikkit (1984).

According to Wirojanagud and Chindaprasirt (1987) and Sethaputra (1986), the project's goal is to provide three 2 m^3 cement jars for a family of six persons in rural areas by the end of 1990. There are 3 million families involved in this project; therefore, a total of 9 million jars will need to be built. The following data were used for project assessment:

1. The average rainy season in Thailand lasts from May to September, with 1000 mm total rainfall. Theoretically, only a 1 m^2 catchment area is needed to collect 1 m^3 of rainwater.

2. The water demand for an average family of 6 is 30 liters/day for drinking and cooking. Water is needed from the jars during 200 days/year from the jars. Therefore, a storage capacity of 6 m^3 is required, which translates to three 2 m^3 cement jars per family.

3. Construction materials for a 2 m^3 cement jar are:

   2 1/2 bags of cement (60 kg/bag)
   1/4 cubic meters of coarse sand
   1 1/2 kg of 1 mm steel wire
   1/3 kg of powdered color
   1 set of faucet (valve) and a piece of PVC pipe for jar draining
   1 jar lid made of wood, steel sheet or cement.

Total materials cost is US $20. Construction labor is contributed by the owner/users if they agree to take part in this project.

The government's strategy for implementing the Thailand jar project are:

1. Villagers (users) should be involved in project formulation, development, construction, finance, management and operation. They are given alternatives to the jar project including advantages and disadvantages of each, so that the users can decide whether or not to join the project.

2. The project should be financed with a revolving fund and should begin with a group capable of repaying the materials cost on a monthly basis. This is done at each village so that the revolving fund can be quickly established and its initial participants can serve as models for others following.

3. The government is responsible for supplying tools, jar construction and maintenance training and the initial funding as well as managing the revolving fund.

To implement the project, the government will need to conduct the following preparation and trainings:

1. Preparation of the community--to wage a campaign to make villagers aware of the advantages of drinking water and sanitation. To inform them of the details of the jar project as a cooperative project among themselves and to demonstrate the workings of a revolving fund. The community preparation project itself is a cooperative effort between local district administrators,

the subdistrict working committee and the village working committee.

2. Training--each province is responsible for coordinating the work of related technical agencies, such as the Department of Accelerated Rural Development and the Provincial Office of Department of Health, which train village technicians in jar construction. Subsequently, the village technicians in-turn train other villagers. A simple manual for jar construction which includes many illustrations was published (see Appendix 1). This manual illustrates the need for the teamwork of at least two men for one day. This promotes villagers working together, sharing and communicating with each other, to realize the fruits of their hard work. They will appreciate the leadership of the government officials who provided financial and technical assistance to the project. The positive effects of the Thai jar project are the development of healthier water supplies and better organized rural communities with the experience of working together in community projects to upgrade their living conditions. The whole country will benefit from the teamwork generated spirit of self-reliance.

3. The Revolving Fund--the government is responsible for providing initial funding for villagers to purchasing jar construction materials and for administering repayment of this fund to create a revolving fund. The supervision and management of the revolving fund is a cooperative undertaking between participants, village committee members and subdistrict council members.

   It was found through experience that poor rural villagers were able to repay about $4 (100 bahts) per month; thus, this was set as the repayment rate.

4. The Thailand Jar Project Cost Load on the Government--According to Wirojanagud and Chindapraisirt (1987), the up front government cost will be 470 million baht (about $20.4 million US) to provide the initial revolving fund, train village technicians and provide forms for jar construction to benefit 30,000 rural villages with a population of 18 million. The revolving fund is about 300 million baht ($13 million US) and an expenditure of $170 million baht ($7.4 million US) for training and the jar forms. The Thailand government appears to have developed an outstanding method for providing drinking water to rural villagers with $7.4 million US in just 4 years. Because revolving fund of $13 million US is recoverable, the per capita cost can be as low as $0.42 US! The Thailand Jar Project is now well underway. During 1986, project campaigning resulted in the construction of 1.7 million jars. By the end of 1987, a total of 3 million jars will have been constructed. By 1990, the goal of 9 million jars should be reached.

5. Additional Rainwater Catchment Efforts in Thailand--Drinking water supply for public schools in rural Thailand is also in progress. At a rate of 0.5 liter/student/day for 200 days, a 12 m^3 water volume can supply 120 students. The 6 to 12 m^3 cylindrical rainwater tanks are suitable. Construction manuals for these 6 and 12 m^3 tanks was also published by the Water Resources and Environment Institute, Faculty of Engineering Khon Kaen University, Khon Kaen, Thailand under the sponsorship of New Zealand Government. For a school of 600 students, it will need 5 12 m^3 tanks to provide drinking water to such a school. Materials cost for a 12 m^3 reinforced cement water tank (which uses a similar construction technique for jar construction) is about 2,800 baht ($122 US). Thus, each school needs around 14,000 baht ($609 US) to purchase the construction materials. Estimated construction labor for a 12 m^3 tank is 3 men working for 6 days. Since this is a community public works project, villagers who have children in the school may want to participate in the construction and share the costs. Villagers who have benefited from safe drinking water jar project may have the desire and construction skill to expand their own rainwater storage capacity. This may be true of especially those who participated in constructing the school rainwater tanks.

6. Social and Educational Benefits of the Thailand Jar Project - Social and educational benefits that have been realized from the Thailand Jar Project are:

   a. Rural communities are better organized, villagers learn to work as a team to upgrade their quality of life and create a more harmonious neighborhood.

   b. Village working committees become a social functional unit to solve community problems and to dispense the governments good will.

   c. Villagers practice sanitary public health and learn to protect and conserve their drinking water supply.

Assessments of the Thailand Jar Project - The Thailand Jar Project meets all seven factors favoring the selection of a rainwater catchment system: low cost, private ownership, good water quality, easy to develop, low operation and maintenance costs, convenience and flexibility. The jar is large enough to permit a person to get in for repair and cleaning yet light in weight (450 kg) and round in shape to be readily moved about the house. It is tall and smooth enough to prevent young children from climbing in. Although the service life of the 2 m^3 reinforced cement jar has not been tested, it is expected to last for 30 years or more. In summary, Thailand may be the only developing country to provide safe drinking water supply for every rural household by year 1990.

Indonesia Rural Rainwater collectors Project - According to Aristanti (1986), there had been no water development efforts in Gunung Kidul prior to 1975. In 1976, the Indonesian government began building some brick rainwater tanks to provide one or two tanks per village. However, contractors hired to build the tanks were careless, hence, only 10% of the tanks built are usable. In 1977, Yayasan Dian Desa (YDD), an Indonesian non-government agency, began to work in the Gunung Kidul area, and together with the local community they developed rainwater tanks using local materials. In 1978, YDD, after a number of experiments, introduced the 9 m^3 ferrocement tank design and construction manual to Gunung Kidul. It is low cost, easy to build by villagers, and simple to operate and maintain. However, even with its low cost, the villagers could not afford the price.

Bamboo-cement tank was found suitable for the villagers because they are good at working with bamboo, bamboo is locally plentiful and the cost is 50% less than the ferrocement tank. After several careful trial-and-error experiments, YDD finally produced a standard 4.5 m^3 bamboo-cement tank. (For cost comparisons, refer to Figure 2.) In 1979, the bamboo-cement tank was the most economical rainwater storage tank. However, many of them soon failed due to decaying of the bamboo subject to fungus, termines (white ants) and moisture (wet and dry cycle). As reported by Latham (1984) bamboo as a construction material needs careful selection of mature bamboos and the treatment and placement in cement needs skilled workers. He suggests that more research is needed for bamboo as a construction material in rainwater storage tanks. Latham (1984) also reported that YDD is presently in favor of ferrocement tanks because their reliability is high with a longer service life of 30 years.

Indonesia as the leading country in rainwater catchment development, according to the three papers presented and published in the Proceedings of the First International Conference on Rain Water Cistern Systems. Winarto (1982) reported the policy of the Indonesia's rainwater catchment program; completed with a design criteria, blue print of 18 m^3 ferrocement or bamboo cement tanks, complete detailed gutter, down-pour pipe, inlet filtering, and even a storage gage in their design. They listed the advantage of the system as: it can be built beside the house it is privately owned, it takes only a small land area, water consumption is controlled by the owner, no special catchment area is needed and water quality control is easier. Kerkvoorden (182) and Doelhomid (1982) provided cost comparisons of different construction materials versus the tank capacity (see Figure 2). They reported that construction manuals are provided to local users so that trained technicians can train new users, allowing rapid project expansion. They also reported that the training course and materials are supported by project funds. Later a manual for operation and maintenance was also provided and methods for financing construction material cost to poor participants.

Aristanti (1986) reported that a unique financing scheme was developed by YDD without depending on outside funding. Under an equal sharing system between the owner and the borrower, YDD lends two she-goats to a family needing storage tank. If the two she-goats bear (usually) four kids, two will be given back to the owners (in this case YDD) and the other two will be kept by the borrower. The latter then takes care of the two kids until they are big enough to be sold. This sale money is used to build the tank. The two she-goats will then be loaned to another family and so on. Howver, if the family wants to keep the goats, it is allowed to do so under the same equal sharing system. This means that the family will own a rainwater tank as well as goats. Though it takes time, this scheme is progressing very well.

Another scheme was also tried and was quite successful. Assume a village has 100 families needing rainwater tanks, but YDD can only get funds for 25 tanks, meaning that each group of four families could get only one tank. The agreement with the families is that afer each harvest, the four have to use a share of their harvest to build one rainwater tank until each family has a tank.

According to Ferkvoorden (1982) and Latham (1984), the International Water Supply Consultants (IWACO) jointly with the Indonesian government sponsored the West Java Rural Water Supply Project to provide critical drinking water to 2 million people on the coastal plain. In this project a high-quality rainwater collector with a 10 m^3 storage capacity was designed to serve four households, while a smaller collector with a 2.5 m^3 storage capacity could be used for a single family. A pilot project tested the low cost rainwater collection systems. A construction manual for a 10 m^3 ferrocement tank was published in the Indonesian language which provided step-by-step instructions for constructing a ferrocement tank. Thirty tanks were built in 1979-80, by a contractor. Cost for the 10 m^3 ferrocement tank was $400 US. Up to 1983, IWACO had built 58 tanks in Singakerta serving 150 families in 92 houses. Most of these are ferrocement tanks.

<u>Assessments of Indonesia Rural Rainwater Collectors Projects</u>

1. Social Acceptance - As reported by Latham (1984), in Indonesia, the number of tanks in use may total 10,000 or more. There has been very little apparent commercialization of tank building, so the agencies must train builders (or hire contractors) and provide considerable financial support for almost all tank programs. Moreover, the agencies have to conduct educational programs to convince tank owners that rainwtaer is safer than traditional surface water that villagers have long been accustomed to using. Aristanti (1986) reported that in Gunung Kidul, some tank owners dump buckets of mud into their tanks of clean rainwater to modify the water taste. He also reported that a new local practice of filling the rainwater tanks with pond water was increasing the overall water consumption and was thus causing drainage ponds to dry up even faster than before. This practice has caused additional hardship for those families not having tanks.

   Social acceptance of rainwater collectors needs more study. If 4 families share a 10 m^3 ferrocement tank, the operation and maintenance of the tank is bound to cause problems because it is difficult to maintain a fairness in water usage and up-keep of the tank. Each family owning their own tanks would help to eliminate this friction in many societies.

2. Social Education - As reported by Aji (1986), a post construction survey was conducted in a portion of the West Java Rural Water Supply Project. After 4 years, there were no feedback from th users; therefore, an exploratory survey was conducted. He found water consumption conformed with the designed quota of 0.5 m^3 per person during the dry season, with an average of 4.24 liters/person/day for 100 days. As for tank cleaning, out of 97 tanks surveyed, 85 were cleaned once a year

at the beginning of the rainy season. The 12 others had never been cleaned, 7 reporting that the tanks were not yet dirty and 5 said cleaning was not necessary. As for repair, of 100 tanks surveyed, 55 were in prime condition and 45 had suffered damage. Of these, 38 were slightly damaged (ranging from leaking gutters to broken down pumps), 4 were heavily damaged but still usable (leaking walls) and 3 were out of order due to leaks in their base. Latham (1984) reported tank fixtures such as top cover, filters, overflow pipe's wire screen, storage gage and gutters were missing, disrepaired or damaged. He thought many of these damages were caused by children playing around the tank. Perhaps a social education program may help prevent some of these damages. Water is a life supporting resource; the fundamental respect of water and our environment is within our instinct. The problem is momentary relaxing of our vigilance to protect it.

The Indonesian Rainwater Collectors Project has set an example of how to provide safe drinking water to rural areas. Their approach was well-thought out with step-by-step construction manuals plus the operation and maintenance handbook. Their national policy provided valuable guidance to their Decade Water Plan. The self-help spirit will take root in their rural and urban areas. Their promotion of community participation in government decision-making will bear fruit.

The Water Decade Plan is one of many ways a country's government shows their concern for the citizenry and the success of the Water Plan relfects citizens' support of the government. Collectively, this is a show of love to humanity. There are many successful examples that can be reported, however to save the space, only two have been discussed.

Possible Adaptation of the Rainwater Catchment Systems for Small Pacific Island Countries

The geographical characteristics of small islands are: small land area, high runoff and evaporation, lack of natural storage sites and thin fresh groundwater lens. Many small islands depend on rainwater catchment systems for their drinking water supply. The rainwater catchment systems design have to first consider the size of the catchment area, then in sequence rainfall quantity, storage capacity, daily water demand and protecting the water in storage. Before discussing rainwater catchment system selections, the above five basic design elements are first examined:

1. Catchment area - The rainwater catchment systems owner's roof determines his ability to furnish his water supply which not only limits the quantity of rainwater that he can collect but also controls the quality of his water supply. The roofing material and the attached fixtures plus elements that fall on the roof, all affect the water quality. Fok et al (1980, 1982) had shown how to size it.

2. Rainfall quantity - The patterns of annual, monthly, weekly and daily rainfall provide the needed information of expected rainwater to be collected. Fok et al (1980, 1982) had shown how to obtain them.

3. Storage capacity - The RWCS storage capacity can be determined by considering the probable rainfall veruss the projected water consumption in a given period. Maintenance of some reserve-water in storage is very important for the RWCS owner, because he owns a private water supply system, and should not expect others to help him once his water is depleted.

4. Daily water demand - Water in a RWCS owner's storage is like money in his bank account. If the storage is full, he can use them relatively freely, if the storage falls below half the capacity, the RWCS owner must exercise conservation. In a long run, a RWCS owner, will become a very efficient water supply manager.

5. Protecting water in storage - Water in a RWCS needs protection to prevent quality degradation. Therefore, storage containers should be cleaned frequently, and must be covered to prevent contamination.

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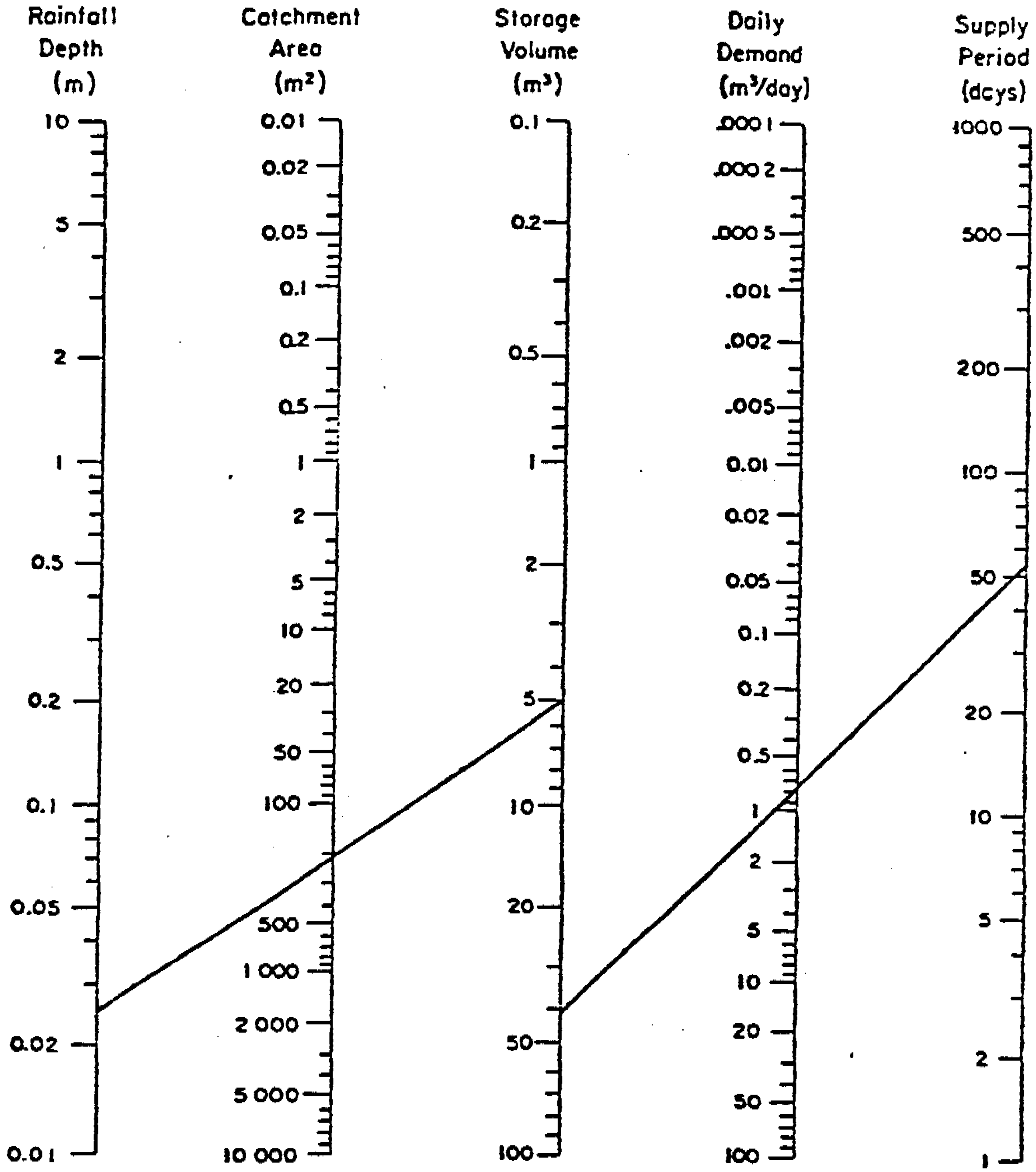

Figure 1. Alignment chart showing relation between rainfall catchment area, storage volume, daily water demand, and available supply period for a rain-catchment system design and management

COMMUNITY PARTICIPATION

PARTICIPATORY STRATEGIES IN WATER SUPPLY (COSTA RICA)

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ABSTRACT

Over the years, International Aid Agencies and government organizations in developing countries have come to realize the importance of community participation in water supply and sanitation projects. In spite of this, important questions such as how to motivate communities, or what contributions and responsibilities should they assume, remain only partially resolved.

From its inception, IRDC's Handpump Programme has encouraged research in this area of community participation, as it considers it an essential component in going from pilot research projects to widescale dissemination of water supply and sanitation technologies.

Between 1986 and 1988, the Centre supported a project in Costa Rica. This project looked into the adaption of the UNIMADE handpump to the Costa Rica environment. As part of this project, a number of participatory strategies (in response to the needs that were being encountered) was developed. These focused on community organization, health and hygiene education, and pump installation and maintenance.

Based upon this experience, these strategies have been adapted to include the participation of villagers as instructors in the social and technical aspects of the introduction and use of water supply technologies in other communities of the country.

INTRODUCTION

Costa Rica, is a small Central American country of 51.000 squares kilometers. At present it has a population of 3 million people. Fifty five percent of the population is rural. The most recent estimates by the Ministry of Health indicate that over 80% of this rural population remains without a protected water supply. Over a third of this populations still draw its domestic water from contaminated wells and rivers.

To remedy this situation, the Ministry of Health began a handpump installation programme about eight years ago. During the first six years, around 1500 American and Japanese cast-iron pumps were installed. However, pump corrosion, importation of spare parts, and the lack of appropriate well drilling equipment severely limited the success of the program.

In 1986, IDRC supported the project "Handpump Technology (Costa Rica)", 3-P-86-0018, to investigate the adaptation of the UNIMADE handpump to the Costa Rican environment. This project was in response to the need expressed by the Ministry of Health to experiment with more efficient and lower-cost handpumps and well drilling techniques. The project, showed that UNIMADE pumps can be successfully adapted to rural conditions in Costa Rica. These pumps being non-corrosive are very well suited for the country. Also, the handpumps installed during this project have been readily accepted by the villagers, thus generating significant interest from neighbouring communities.

The above project also revealed that the existing government handpump programme was very weak in the area of community sensitization, and health and hygiene education. Other problems identified were inappropriate drilling equipment and inadequate well protection measures, specifically in areas where the water table is only inches below the ground surface. Due to lack of drilling equipment in the country, the government often relies on the users to dig shallow wells by hand. Due to inadequate subsurface filtration and the failure to correctly locate wells with respect to latrines, the waters in these wells are often fecally contaminated.

As a follow-up to the "Handpump Technology" project the IDRC supported the present project: " Participatory Strategies in Water Supply".

Building upon the knowledge and experience gained during the last three years, the present investigation is developing, assessing and documenting some of the successful community participation strategies tried in the previous project. These strategies specifically relate to community organization, sensitization, health and hygiene education, as well as handpump installation and maintenance. They were adapted to permit the members of the original project communities to act as instructors and motivators in disseminating relevant information to new project communities.

In addition, we are considering the persistent problems associated with well drilling and construction, a neglected component of handpump introduction programs. During the execution of the previous project, it became evident that the quality of the well was a serious bottleneck. As an alternative to the high cost of drilling and associated difficulties with well construction in isolated rural areas, it is been investigated the use of ferrocement technology in the rehabilitation of existing shallow wells. Preliminary investigations have indicated a potentially successful application of this low-cost, easy to use technology.

PARTICIPATORY STRATEGIES DEVELOPED IN THE PREVIUOS PROJECT

This methodology consisted of a number of participatory strategies, many of which were developed or adapted according to the needs as they arose. These strategies relate to:

i.) initial contact and community motivation;
ii.) community organization (delimitation of priorities and needs,organization and management, approaches to solve community problems,possibilities and limitations).

iii.) sensitization on the need for clean water and improved personal an household hygiene (including participatory activities related to the discovery of the microbial world and its relation to health);

iv.) creation of an organizational infrastructure (water committees) and revolving funds (including legal implications and small business accounting);

v.) training in handpump installation and maintenance and well protection measures;

vi.) implementation and monitoring of the intervention.

Many of the approaches used had never been tried before. Based on the responses observed and on feedback from community participants, these approaches are being revised and tested for integration into a methodology for future replication. Community members who participated in the previous project are being trained as instructors in the various components of the introduction methodology in an attempt to create a team of field workers, from the same communities. It is anticipated that these workers will be able to assist the project team in future technology dissemination projects.

OBJECTIVES OF THE PRESENT PROJECT

The overall objective of this project is to build on the successful community participation strategies developed in the previous project "Handpump Technology (Costa Rica)", and adapt these strategies to include the participation of community members as instructors in the social and technical aspects of the introduction and use of water supply technologies. The project is also investigating the application of ferrocement technology in the rehabilitation of shallow wells.

The specific objectives are to:

a. train selected members of the original communities involved in the project "Handpump Technology (Costa Rica)", as instructors of hygiene education community organization, and small business management.

b. train selected members of the above communities, as instructors in well rehabilitation and handpump installation and maintenance.

c. develop and field test a simple, low-cost technique for rehabilitating shallow wells based on ferrocement technology.

d. field-test a technology introduction methodology by giving training experience to the instructors in a) and b) above, in their own communities as well as in a nearby "new" community.

e. Rehabilitate 50 shallow wells and install 50 handpumps within the three project communities using the methodology indicated in (d).

f. Evaluate and document the effectiveness of the training program and the participatory strategies applied in (d) focusing on knowledge gained and results achieved.

TRAINING OF COMMUNITY INSTRUCTORS

The study site is located to the north east of the country, on the Atlantic north plain, on land parcelled out to the rural people by the Instituto de Desarrollo Agrario, IDA. It is named the Rio Frio region, in the "Cantón" of Sarapiquí, province of Heredia. The project is taking place in three communities: the two communities that participated in the previous project, La Chaves (100 households) and Ticari (150 households); and a new community.

Village instructors were selected for training from the two former communities as they have already acquired valuable experience with the technology and its introduction process in the previous project.

The new community (for this study) was selected on the basis of the interest it has expressed on the technology and its accompanying development process.

The training of community instructors was performed during the first three months of the project. Members from the communities, and from each water committee of La Chaves and Ticari were trained as instructors in hygiene education, community organization and small bussiness management. In addition, a small group from each community was trained as instructors in the rehabilitation of shallow wells and in handpump installation and maintenance.

A the end of the project, we will have at least twelve instructors trained by the project team.

The training of instructors in hygiene education, community organization and small bussiness management was done through a series of workshops.

Topics that were covered in the workshops in community organization and small bussiness management included: what is an organization; how to get organized; management of problems within an organization; delimitation and delegation of functions; how to get the community involved in the process of decision-making; what is a revolving fund; and, accounting for small rural enterprises.

In relation to hygiene education the topics that were covered included: how to identify the main concerns of the community towards hygiene and health; how to conduct educational activities with a community relative to the discovery of the microbial world and its relation to health; basic household and personal hygiene measures; and concrete solutions to water supply needs.

The training of instructors in shallow well rehabilitation and on the installation and maintenance of the handpumps was a parallel activity conducted at the beginning of the project. The training lasted for 2 months and consisted of: new construction techniques in well rehabilitation; principles of ferrocement technology and its application to wells; sanitary prevention and protective measures; handpump installation and maintenance; and, skills on how to train other people. These instructors, under the supervision of the project team, are the ones responsible for well rehabilitation and handpump installation in the villages. They assist families in these villages on how to rehabilitate wells and install handpumps. They also oversee the construction and well protection requirements. With the help of the project team, they also advise community members on the relocation and proper use of latrines (if necessary), and on how to solve maintenance problems.

Prior to the testing of the overall participatory methodology in a "new" community, the instructors try out what they have learned in their own communities. For this purpose, 15 wells are being rehabilitated and 15 handpumps installed in both villages, La Chaves and Ticari.

The new instructors, under the supervision of the project team, will organize workshops in each community for the fifteen recipient families. They will present and explain the project, and teach the families about personal and household hygiene, well rehabilitation and protection, and handpump installation and maintenance. They will also assist each household on the rehabilitation of the well and on installation of the pump.

After training the instructors, the overall participation methodology will be tested in the "new" community, by providing twenty families with protected water supplies (ferrocement wells and handpumps). The introduction process will be implemented by the instructors in consultation with the project team. The instructors will participate in the organization of community workshops and training courses and will be responsible for conducting these. The project team will monitor all workshops and courses and will guide group discussions or the delivery of the courses as needed.

EVALUATION COMPONENTS

In terms of the training of instructors, different levels of evaluation will be conducted throughout the development of the project. During the initial training period on hygiene education, community organization and small bussiness management, the research team assesses the individual's preparation for his/her presentation for knowledge acquired, correctness of information presented, overall organization of presentation, and teaching skills. These exercises indicate if further training is necessary before going into the field. The instructor's knowledge and teaching skill are also being monitored during the field training exercises in their own communities.

The instructors' skills on well rehabilitation and handpump installation are being judged by the quality of their workmanship. Their skills will be perfected before allowing them to teach other villagers. Their knowledge and skills as teachers and motivators will also be monitored throughout the field training exercises and via site visits to households as the wells and pumps are being installed.

In the last month of the project an evaluation workshop (focus group discussion), focusing on the overall introduction process will be carried out in the new community. This evaluation will be done by the members of the recipient community together with the project team and the instructors. The purpose of this activity will be to obtain feedback (ideas for improvement) in relation to the overall methodology used in the introduction process from the point of view of the beneficiaries. An external consultant with experience in anthropology and community development will assist the project team in developing the methodology to be used at this workshop. Variables that will be considered as indicators of success or failure include: level of community organization: modification in perceptions and conduct associated with hygiene aspects; maintenance of the revolving fund; degree of community participation in the process of well rehabilitation; use and cleanliness of latrines: and, maintenance of well surroundings. The perceptions of the communities, in relation to the work done by the village instructors, as well as their importance in project implementation will also be assessed.

CONCLUSIONS

As a result of this project, the research team will have evaluated the effectiveness of a number of participatory strategies involving key social and technical components for a water supply system. The strategies tested and their evaluation will allow the research team to develop an integrated methodology for project replication with other communities in the region. The project will also create a team of village instructors and promoters that will be able to participate in future dissemination projects. In addition, the communities that participated in the previous, and this project, will serve as demonstration models to government policy makers and the leaders of neighbouring communities on the suitability of handpumps and software components required in a technology introduction process, and on the often ignored need for protecting water sources from contamination via appropriate hygiene education and well protection measures.

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REPLACING COMMUNITY PARTICIPATION WITH NGO PARTICIPATION - A NEW APPROACH

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ABSTRACT

Running the Canadian Hunger Foundation (CHF) programme in Kenya, the author has learned that the 'missionary' approach to village water projects by most development agencies in the past has been largely responsible for their very high failure rate. Most NGO's and agencies plan and implement a project, then wrestle with the problems of trying to encourage what they call 'community participation', which seldom succeeds.

The CHF begins by discussing with the committee of a self-help water project group the possibility of their upgrading their embryo project to a business enterprise, in which CHF are temporary joint venture partners. The group registers itself as a Legal Society with enforceable obligations and responsibilities. The project becomes a financially self-sufficient enterprise run on business-like lines. The rules governing commissioning, operation and membership are established in a registered constitution.

With both their contributions (in the form of share capital), and the intergrity of the project safe-guarded by legal means, the willingness of even the poorest community to contribute their time and money is overwhelming. Protected and encouraged by sound business-like arrangements, the community provides equity, all the labour, and significant material inputs. The CHF provides technical training and supervision of construction works, training in book-keeping, in project management, in recruitment, in the institution of checks and balances for the resolution of political problems, etc., and capital in the form of some of the expensive materials. The project is run entirely by full-time employees of the Society.

In the case of the first CHF-assisted project, the CHF withdrew in 1987. By 1989, the group had a healthy bank balance, had expanded their project by 100%, and had even built their own offices. It now serves as a model for water project development all over Kenya. In this project, it is the NGO which participated in the community's project, and not the other way around.

INTRODUCTION

In 1982, the Canadian Hunger Foundation(CHF) carried out a study of village water projects in Kenya to find out why they had such a high failure rate. Many of the projects studied had received donations from development agencies or NGOs which were used for the purchase and installation of material. However, without a sound institutional framework, water would flow only for a short time, much to the bewilderment of the donor, who would not understand why the project had 'failed'. The result would frequently be an evaluation seeking technical flaws, and excluding an assessment of the institutional aspects. Repairs or modifications would then be carried out for the technical flaws, but water would still not flow continuously. Eventually, the donor would become disillusioned and finally resign from the project.

The symptoms of institutional inadequacy were found to be;

- Poor management skills,
- Little or no organisational structure,
- Lack of maintenance skills,
- Absence of a financial plan, of regular income and of administrative controls,
- Absence of a sense of ownership of the water project by the community,
- Difficulty in fostering tangible contribution from the community,
- Ignorance of the skills and resources required to run a water project,
- A 'charity' relationship between funding partner and the community groups.

It was clear that the institutional requirements of village water projects had not received enough attention. All parties concerned had grossly underestimated what was required to make such projects successful and self-sustaining. Hence ,it was apparent that a new approach was required.

THE NEW APPROACH

A new approach to village water projects was developed by the CHF, and translated into a methodology. This methodology embodies seven key components, each of which is fundamental and equally critical to the application of the New Approach. These key components are as follows:

1. Establishment of the project by the community as an independent enterprise, owned and managed entirely by the community;
2. Relationship of supporting agencies such as the CHF as a partner and investor covered by a joint venture agreement (i.e. not as traditional 'donors');
3. Registration of the project in the framework of a legally constituted Society;
4. Establishment of a business-like project management capability in the hands of the Society, with project manager and full-time employees;
5. Establishment of the capacity for the Society to independently address and resolve managerial, political administrative, and technical problems as and when they arise;
6. Establishment of a financially sustainable operation involving the payment of monthly water consumption tariffs;
7. Provision for contributions from each member, to establish a Society share capital fund.

With this approach, the project becomes an example of self-development by the community. It leads to an increase in the community's ability to implement their own development initiatives in other sectors.

The principles constituting The New Approach can be adapted to any water project. In the case of the CHF, they have been applied to community water projects employing rain water chanelled from an intake into pipes, and fed by gravity to the members' village plots, for drinking, livestock and small kitchen gardens.

INITIATION OF THE WATER PROJECT

The typical community water project is a long, complex process spanning generations in the life of the community. From initial inception through its various phases of planning, construction, operation and expansion, it must survive social, political, managerial, technical and financial hurdles if it is to achieve the long term goal of upgrading the quality of life of the community.

The projects assisted by the CHF in Kenya had typically been established twenty (or more) years before the involvement of CHF. All the projects had been planned to operate indefinitely, with major replacements and expansions required at 10-15 year intervals. The plans, drawn up by the Ministry of Water Development (MOWD), were designed to cater for the expected population for the next ten years or so.

At the time of CHF involvement, the projects have not yet 'taken off', due mainly to the lack of suitable institutional arrangements. The point of entry has typically occurred after the community achieves:

- Registration with the Ministry of Culture & Social Services (MCSS) as a self-help group with the intention of undertaking a water project;
- Design of the system is completed as per MOWD criteria;
- Obtaining of the Abstraction Permit, authorising the project to draw water from a source;
- Collection of initial funds;
- Construction of part of the system, however small a part.

Many projects being assisted by NGOs and development agencies may, of course, be quite new and quite small. But it is essential that the idea of the project should have emerged from within the community. In this way it starts life as the community's project, and should never be perceived as otherwise, throughout its life.

The CHF will then proceed through the various steps with the group and work towards jointly developing the water supply system as an independent enterprise, run on sound business-like principles. These steps are set out in the following section.

CHF PARTICIPATION IN A WATER PROJECT

Initial Discussions

The CHF discusses and counsels the group committee over a period of several weeks or months, during which the community conducts a number of public discussions aimed at re-establishing their project with a form legal framework and on sound business principles. Having only registered as a self-help group, the CHF then assists the group to complete the requirements with the Government to become a legal Water Society. During this period, the Society's constitution must be established, which is a long process involving much discussion in the community and with CHF.

Signing of Joint Venture Agreement

A joint venture agreement is signed by both parties covering each party's commitments and responsibilities for the period of participation by the CHF in the Society's project.

Building the Water System

During an intensive period of activity each party contributes towards building the intake, main lines, storage tanks and distribution networks according to the signed agreement and project design. These activities relate to gravity-fed systems. These would be corresponding activities for other types of project, whether cisterns, dams, boreholes or shallow wells. Usually CHF provides some of the material, and supervisory services. The Society contributes a significant portion of materials, all the labour for trenching, pipe laying, back filling and construction of tanks, and pays for all skilled tradesmen required in the water system construction and the salary of a manager and accounts staff, plumbers etc.

Training and Management Support

Concurrent with the construction phase, CHF provides training in technical aspects, bookkeeping and administration, to the staff employed by the Water Society and management advice to the Project Manager and Executive Committee of the Water Society. This phase also continues concurrent with 'Home Connections' following the completion of the construction phase.

Home Connections

Once the basic water system is built, and basic management procedures are in place, the Society can embark on the process of connecting members when the members pay their dues. The dues cover the cost of pipe from homestead to the distribution line, the meters, taps and a connection fee. In the case of large, gravity fed systems, this connection period can take up to 5 years, depending on the number of members, and their particular circumstances, and notably on the number of connecting teams the Society can afford. A connection rate of 1 - 5 members per week is typical on these projects.

CHF Long-term Relationship with the Water Society

The CHF normally reduces their direct participation in the project when the terms of the joint venture agreement have been completed. At this point it is expected that five to ten percent of the members will have been connected and the Society would conduct an official opening, to commission the operation of the project.

Over the period of the agreement the CHF and the Society develop good working relationships. This relationship is not necessarily severed at the time of commissioning the project. The CHF has often been called upon for advice and training support when the Society identifies a particular need. However, even with this extended relationship through maintaining a monitoring role, the participation of the CHF in the water project of any Society is for only a short time period when compared to the long life of the project.

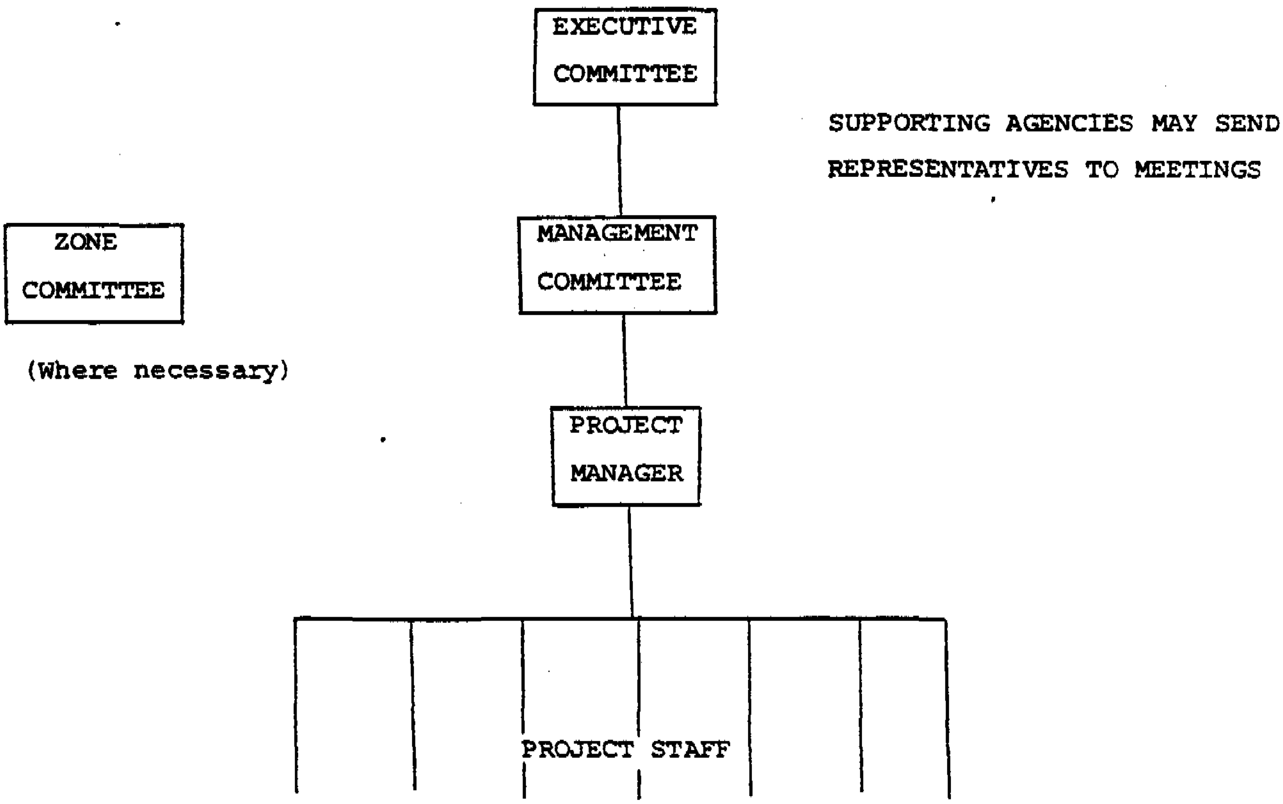
The groups who have their project assisted by the CHF are registered as Water Societies under the Societies Act. The requirements for this registration are very exacting, including security checks on all named trustees and Officials, and thorough vetting of the constitution, particularly as regards to the ownership of the assets and safe guarding of the members' interests.

This aspect of the institutional arrangements is a key factor for convincing the community members of the soundness of the project.

The Society Officials can be held responsible in law for a number of aspects of the affairs of the Society, and this emphasizes the seriousness of the persons responsible for the Society's affairs. It also clarifies the question of who owns and mánages the project. There is no question that the Society is responsible for the project, and for maintaining the required standards. It is then clear that the involvement of participating organizations such as CHF can only be conducted in a formal manner and must be based on appropriate written Agreements.

Typical management arrangements are set out in Figure I below:

Figure I: Typical Project Management Arrangements



Village water projects are typically beset by many problems, whether or not there is a partner NGO or donor involved. Generally, the more successful the project, the greater the variety of problems, because successful projects affect the lives of the entire community directly and everyone comes to depend on it.

Typical problems include financial, (including tariff structures), social. political, planning and expansion, technical, managerial and distribution problems, and combinations of all of these.

The CHF's role is not to worry unduly about such problems, and not to try to solve them for the Society. Instead, the CHF's job is to build up the capacity within the Society to enable it to address and resolve such problems when they arise. This is an important point, and one which is fundamental to The New Approach.

When a problem arises during the operation of an established project, many well-intentioned agencies react by either offering to solve the problem, or show undue concern or embarrasment, or offer money to resolve the issue. All of these reactions can ultimately be the kiss of death for the project, because from that moment on the community does not consider itself responsible for its own affairs. The temptation to 'step in' must be resisted at all costs.

ESTABLISHING FINANCIAL VIABILITY

It is essential that each water project is eventually able to cover all its running expenses and overheads with funds generated by the sale of water. Since connecting members is a gradual process, there is a long period between commissioning the water system and reaching a break-even level. There are, identifiable stages of growth of the project which follow the commissioning;

Stage (i) The stage of initial connections where there are not sufficient consumers to cover monthly running costs,

Stage (ii) The stage during which there are sufficient consumers to cover monthly running costs but not all overheads,

Stage (iii) The stage during which there are sufficient consumers to cover all running costs and overheads, and thereby reach a financial break-even point,

Stage (iV) The stage during which there are sufficient consumers to provide a surplus thereby adding to financial reserves and to expanding these water systems.

As the Water Society progresses through these stages, greater degrees of financial viability are achieved. During stages (i) and (ii), the Water Societies will adopt several practices in order to balance their income and expenditures.

Most Societies will put into practice a combination the following;

- drawing working capital from their capital fund,
- motivating members to pay up their share of capital contributions,
- limiting expenditures on controllable items,
- phasing staff build-up to an affordable level of cost,
- employing connecting teams in balance with the rate at which members are paying for connections.

The CHF experience gravity fed projects is that it takes at least five years following commissioning before all the members are connected. The proportion of connections required to achieve financial viability varies from project to project, and depends on population density, economic levels, and administrative efficiency of project management.

FUNDING A WATER PROJECT

Funding of CHF assisted project is, like the project's own development, a complex process. The group will typically have raised money within the community at the outset of the project, then there will have been a period of dormancy. The Government of Kenya from various sources, will have provided inputs from time to time, but these will not have been combined with solid organizational and institutional arrangements so as to provide a suitable basis for a take-off and progressive development of their project.

The first major financial input comes from the Society members in the form of share capital contributions. This is followed by a massive provision of unskilled labour to trench, lay pipelines and back fill for the entire distribution network including storage and break-pressure tanks.
During this period, the CHF provides the technical supervision required in the systems development, training services and a portion of the materials.

As the project gathers momentum, more members come forward with their share capital subscriptions, building up a substantial fund enabling the Society to meet their contribution of materials and to cover the costs of skilled labour and staff salaries for the implementation of the project. Part of this fund is put towards a reserve working capital which can be used to assist the Society to bridge the period between establishing their staff resulting in recurring expenditures and actually achieving full financial viability. At this point the CHF has contributed around 50% of the total cost of the project, the Society contributing the other 50%. As home connections proceed and members' consumption of water increases, revenues accruing to the Society also increase covering all direct running costs and eventually generating a surplus. At this point the Society will replace their capital funds reserve in anticipation of expanding and replacing their water system. No further contributions would normally be made by the CHF.

It is important to realise that the principles of institutional development of The New Approach can be applied to any community water project, whether assisted by the CHF or not.

CONCLUSION

From the comparative success of the CHF's modest program in Kenya, from 1984-1988, the indications are that The New Approach, with its heavy emphasis on community ownership, business-like management principles and financial sustainability, is very promising, and can in principle be applied to all types of community water project.

During the development and application of the principles of The New Approach, it became clear to the CHF that all parties involved in community water projects in the past had grossly underestimated the magnitude and difficulty of the task of managing such projects. They require very considerable skills, rather like managing a substantial business, with additional issues of politics and social problems with which to contend. Establishing and running even relatively small water projects is a serious and complex business, beside which the technical issues, which are usually dwelt on at length by the literature, are relatively easily addressed.

In the case of the first CHF - assisted water project in Kenya, the CHF withdrew in 1987. By 1989, the group had a healthy bank balance, had expanded their project by 100% and had even built their own office complex. It now serves as a model for community water project development. In its current Kenya Programme, NGO's and development agencies will be invited to send beneficiary group committees and the NGO's own staff to projects being developed in Kenya with the assistance of CHF. These projects are to become live training grounds for visitors and students to see how the principles developed can be applied in practice.

While visiting these projects, visitors are not likely to hear the phrase 'community participation', because it is the NGO participating in the community's projects not the other way around.

STRATEGIES FOR OVERCOMING THE OBSTACLE ASSOCIATED WITH "SOFTWARE" ASPECTS OF RAINWATER CATCHMENT SYSTEMS IMPLEMENTATION.

J.E. Gould

ABSTRACT

During the last decade, significant progress has been made in rainwater catchment systems "hardware", namely in the development of low cost appropriate tank designs and construction techniques. Most of this work has been well documented and is available to fieldworkers throughout the world.

Strategies for overcoming the obstacles associated with the "software" aspects of rainwater catchment implementation have been less well documented. These include ways of tackling a lack of awareness, motivation, organization, skills and resources amongst communities at grassroots level. Approaches to overcoming these obstacles, such as conducting preliminary surveys, promoting awareness and interest in rainwater collection, setting up organizational framework , arranging training courses and developing techniques for raising funds from both within and beyond the community are considered in this paper. Features common to successful project implementation strategies are outlined and case studies from Kenya, Botswana and Thailand are cited.

In the global context, the need to promote interest and awareness in the potential benefits of rainwater catchment technology extends far beyond the need for pure community involvement and includes marketing the technology to government agencies and major international funding bodies. In order to secure the substantial external support needed by poorer communities to subsidize improvements in their water supplies, project proposals have to be presented in a way that donors can manage. Considerable coordination between different projects may be needed to secure this support.

INTRODUCTION

The renewed interest in rainwater collection technologies during the last decade has resulted in a rapid growth in the literature on this topic. To date, however, the majority of articles have been concerned with what we can term the "hardware" aspects of the rainwater catchment systems, namely their construction and design. These aspects of the technology are of course extremely important because without information on appropriate tank designs and clear construction details, communities would not be able to benefit from the accumulated knowledge and experience of others. Since many new tank designs e.g. the Thai interlocking brick design, Vadhanavikkit (1986) and the Botswana ALDEP sub-surface ferrocement design, (see Pacey and Cullis 1986, p96) have not been field tested for a sufficiently long period for us to be entirely confident in their longterm performance, continued research and exchange of information is essential in the future. Problems with the bamboo reinforced cement tank design in Thailand and Malaysia illustrate just how important such flows of information can be. Following the construction of more than 50,000 of such tanks in Thailand alone at a cost of more than US$11 million it was discovered that decay of the reinforcing of the bamboo was leading to failure of a number of tanks, threatening both property and lives, Vadhanavikkit and Pannachet (1987).

Despite the importance of information on the latest developments with regard to rainwater catchment technology hardware, there is a growing awareness that technical information alone is not sufficient for a successful implementation program. A large number of appropriate tank designs are already widely known and have been well documented; such as the ferrocement (Watt 1978), the cement jar and the concrete ring designs (Nissen-Petersen 1982). There are, as a result, increasing demands for information relating to the development of effective approaches and strategies for the widespread implementation of these designs. These are concerned with the social, cultural, administrative and economic aspects of rainwater catchment technology implementation or what may be called the "software" aspects.

Unlike the "hardware" aspects (designs, construction details and computer models for calculating appropriate tank volumes for given catchment areas) which can often be easily modified and replicated anywhere, the "software" aspects of successful rainwater catchment implementation strategies are difficult to replicate in different communities. This partly explains the reason for lack of references to rainwater implementation strategies in the literature.

Although the difficulties and dangers inherent in any approach to try to replicate or transfer an entire implementation strategy from one area to another make it inadvisable, useful lessons can be learnt from the experiences of others. Furthermore, important elements common to most successful rainwater catchment tank implementation projects can be recognised. The most significant of these are listed below:

FEATURES COMMON TO SUCCESSFUL RAINWATER TANK IMPLEMENTATION STRATEGIES

1. Most successful projects have started small and grown slowly, developing and modifying both the tank designs and implementation strategies on the basis of constant self evaluations.

2. Projects which have been predominantly run by local people have a far higner success rate than those run or set up by people predominantly foreign to an area. Frequently, however, outsiders have played important roles as catalysts to stimulate project initiation.

3. Projects which involve the community from the outset in planning, implementing and maintaining the systems have a greater chance of enduring and expanding.

4. Successful projects are generally associated with communities where a real "felt need" for water has been expressed and where this figures very highly on the development priorities for the locality.

5. Projects where the local community have contributed funds, labour and ideas have a much greater record of success than those supported entirely from external sources. It is, however, important that the financial and labour requirements do not place an unacceptable burden on the community, as this may jeopardize project.

OBSTACLES TO PROJECT IMPLEMENTATION

Obstacles to the implementation of rainwater catchment tank projects in common with other projects aimed at improving water supply and sanitation using low cost, small scale, "appropriate" technologies can be identified at a variety of levels.

1. International and National Level:- The main obstacle at this level is due to the reluctance of governments and major international funding bodies to support small scale, scattered projects at the grassroots. Among the many reasons for this are the fact that from an administrative point of view it is much easier to support large scale projects such as major dams which carry with them, prestige and spin-offs such as irrigation and power generating potential. These projects provide most benefits to the politically influential urban middle classes as well as creating employment for skilled labour both from within the country and abroad. Ultimately, economic and political factors determine how significant funding earmarked for so called "development projects" is spent and this often results in small scale rural water supplies figuring low on the list of priorities since the return on investments in this field are neither rapid nor immediately obvious. Furthermore there is often relatively little political capital to be gained from poorer rural

communities which are neither particularly vocal nor influential.

Although, most NGO's do try to target their energy and resources at small scale projects for the grassroots in many developing countries there is relatively little coordination between the numerous organizations working in this field. The result of this is that often considerable duplication is occurring with different groups all "re-inventing the wheel" leading to considerable inefficiency. While, it must be recognized that some projects may be very successful, the total impact of all the projects in the country is less than it might be given more coordination and a greater exchange of information between the various organizations. Given the generally negative international climate within which most NGO's have to operate they are, despite everything, probably still administering development "aid" more efficiently than anyone else.

2. Regional Level:- At the regional level bureaucratic procedures and pressure on limited funds present major impediments to the implementation of projects. One particularly commonly occurring problem which has been observed in Kenya and Botswana is the inefficiency associated with attempts to loan money to individual households to pay for rainwater tanks, McPherson et al. (1984) and Gould(1985), respectively. Considerable time and energy is wasted in attempts to collect repayments and interest on the loans which are frequently never finally repaid in any case.

3. Local Level:- The most common impediments to rainwater tank implementation at the grassroots level in areas where hydrological conditions are such that the technology offers the possibility of substantially improving water provision, are a lack of awareness, motivation, organization, skills and/or resources. Any one of these impediments may be sufficient to prevent a project from succeeding.

Many other obstacles may also exist but they are so varied and numerous that it is only possible to cite a couple of examples here. The future job security of water sellers is one problem which if ignored could result in the failure of any project aimed at improving domestic water supply delivery. In general the alienation of any particular group in a community and a failure to allow them to share in the benefits of a project risks provoking their retribution and even acts of sabortage against the improvements resulting from the project. This has occurred in Tanzania among other places, where newly installed standposts have been vandalized beyond repair by redundant water sellers.

Another example of an unforeseen obstacle to smooth project implementation comes from a rainwater tank project in Kwazulu, South Africa where considerable reservations about the suitability of the technology was expressed by the local community because of fears that supplies might be poisoned by pernicious neighbours. Clearly unexpected problems of this type can only be identified by conducting a thorough preliminary survey during which not only the technical and economic feasibility of the project needs to be assessed but also the social feasibility.

STRATEGIES FOR OVERCOMING THE "SOFTWARE" OBSTACLES TO PROJECT IMPLEMENTATION AT THE LOCAL LEVEL

Any strategy attempting to overcome these obstacles must begin by first identifying to what extent they exist within a given community. This can only be done by means of a comprehensive community survey, which should be done in conjunction with a technical field survey in which data on past rainfall, roof and other catchment areas, distances to improved and unimproved supplies and present water usage, local cost of materials etc... is collected to help in the technical design of the project. The purpose of the community survey is to establish current attitudes to collecting and using rainwater for different purposes, the level of willingness to participate in a project and the ability of the community to pay for, or contribute towards, it. This survey should include structured interviews with community leaders, a questionnaire survey of a significant sample of households and ideally a meeting to which all members of the community should be invited to attend and contribute ideas and opinions.

Some of the most common problems experienced at the local level and possible strategies for overcoming them are listed below:

1. Lack of awareness and or interest in rainwater catchment technology.

This obstacle can be overcome through a campaign to increase education and knowledge about the potential benefits of RWCS through:-

i) Local media
ii) Leaflets, posters, etc.
iii) Persuading community workers, teachers, agricultural extension workers to promote the technology
iv) Arranging for community members to visit a neighbouring RWCS project
v) Constructing demonstration tanks.

Negative attitudes towards the perceived taste or quality of rainwater might be overcome by inviting members of the community to taste rainwater collected in a demonstration tank.

2. Lack of motivation and determination to support a RWCS project.

This problem sometimes occurs in communities due to previous negative experiences with self-help projects or where payment or food has previously been provided in exchange for labour in communal projects. To overcome this obstacle it is necessary to convince the community that the benefits afforded by the project outweigh the costs. Similiar methods to those used to overcome a lack of awareness can be adopted to achieve this. If the whole community can not be persuaded to support the project it may be worth initiating the project with the members of the community who are supportive in the hope that others will join once the benefits have been recognized. If it is not possible to motivate more than a small portion of the community to support a project this may indicate either that an improved water provision is not a significant "felt need" in the community or that other more urgent problems require priority. In both cases it may not be advisable to attempt the implementation of a RWC project under such conditions.

3. Lack of an effective organizational and management framework

Ideally if an effective organizational structure already exists within a community, such as a Village Development Committee which has experience of previous projects and commands the respect of the local people, it is advisable to build on this existing organizational framework when introducing the RWC project.

If no such organizational structure exists a committee will need to be established. If a project is to stand a good chance of success it is essential that the committee is made up of well respected members of the community with no vested interests related to the project. Ideally they should be elected by the community.

4. Lack of skills to construct the Rainwater Catchment Systems

In order to overcome the problem of a lack of necessary skills, a training strategy will be required. This may involve setting up a specific training course or having an on going training program where "apprentices" work with skilled tank builders for a period of time until they have acquired sufficient skills to work independently. Since the technology involved in RWC projects is generally simple, training local people in the necessary skills should not be a major problem. Ideally, however, existing skills within the community should be utilized to the full and local builders and plasterers should be encouraged to attend training courses. It is essential that the training program is extremely thorough and that following this training period tanks are only built by those with some experience and that work is very carefully supervised. The failure of even one system in the early stages could jeopardize the future of the whole project.

One further problem which needs to be recognized is that sometimes, once local people have acquired a marketable skill such as ferrocement tank construction in a region where there may be a growing demand for this product, they may be tempted to set up independently of the project or seek work elsewhere.

5. Lack of resources to finance the project

This is the most common reason given by individuals and communities for not being able to proceed with the desired Rain Water Catchment System (RWCS) implementation scheme. In some cases this may not be entirely true. Often resources may be used for consumer durables, such as motor bikes or radio/cassettes, which are considered more desirable. Frequently, however, very few funds are available to individual households to finance improvements. In either case a mechanism needs to be found to raise the necessary funds for implementing the rainwater catchment systems. A number of different options are available, these include:-

(i) Revolving funds: This is where a group of householders, for example 12 make a monthly contribution equivalent to 1/12 of the sum required for constructing the rainwater tank and guttering. Then each month for a year the households in the group receive in turn a system. It is essential that work does not begin until all the money for the first tank has been collected. For this method to succeed it is essential that all the group members trust each other and it may be worthwhile drawing up some sort of contract. The advantage of this method is that it involves the community directly in the project and often leads to rapid uptake of the new systems. It also guarantees the builder a steady supply of work whilst spreading the cost of the tank over a managable period. In poorer communities the implementing agency may need to subsidize part of the cost of the system.

(ii) Grant/Down-payment: In this case the recipient household makes a down-payment as their contribution to the cost of the system and the implementing agency covers the rest of the cost.

(iii) Payment in full or in kind: Better off members of the community may be in a position to meet the full cost of a RWCS unassisted. Others may be able to pay if they can be persuaded to sell off surplus livestock or might be provided with a system in exchange for providing labour to an income generating venture associated with the project.

(iv) Loan/Repayment: This method is best avoided except in cases where an individual householder has the ability to pay but where money is tied up in livestock and can be released only when any are sold or where funds will only be available after harvest time for example.

In all of these cases the recipients of the RWCS's may be able to help reduce the overall costs by contributing labour and materials eg. sand, water, hardcore etc...during the construction period.

OVERCOMING "SOFTWARE" OBSTACLES AT THE REGIONAL, NATIONAL AND INTERNATIONAL LEVEL

At the International level and to a lesser extent at the National and Regional levels the obstacles to gaining unreserved support for a global effort to significantly improve water supplies across the world are enormous. The failure of the International Drinking Water Supply and Sanitation (IDWSS) Decade to even approach achieving its objectives bears witness to the magnitude of the problem. Although efforts must continue to try to bring about a positive political climate worldwide, supportive of a more serious approach towards global grassroots development, it seems imperative that local communities will have to do their best to improve the situation alone, with relatively little external assistance for the time being.

Where the government has lent support to local initiatives in Thailand, and to a lesser extent to a few individual projects in Botswana and Kenya progress has been rapid. Much more effort needs to be made to encourage regional and national governments to support RWCS projects and to try to attract significant funding from major international donors to support these efforts. One possible route to this objective might involve efforts to coordinate the activities of the many NGO's and scattered community projects trying to implement RWC technology. Obviously a coordinating body would be needed. This body could then put forward a joint project proposal on behalf of all of the members of a consortium. In this way more time and resources could be focused into producing an extremely thorough and comprehensive proposal for substantial funding thereby reducing the administrative load on both individual prpojects and the donor agency.

CASE STUDIES

The following case studies are all examples of successful projects visited by the author which have all involved their respective communities from the outset and have all had some degree of government or foreign donor support. The descriptions focus on the key positive elements of the projects which have helped to lead to their success and it is hoped they might each in a different way provide models for other projects.

1. BOTSWANA: The ALDEP ground catchment tank project.

This project was initated in 1979 and is currently administered by the Ministry of Agriculture. It consists of the construction of 10-20 cubic meter sub-surface ferrocement tanks which use traditional mud and dung plastered threshing floors as a catchment apron. These are located on scattered homesteads throughout the country and provide an invaluable water supply to their semi-nomadic occupants who farm the remote districts on the fringe of the Kalahari throughout the rainy season. During the last decade several hundred of these tanks have been constructed. The key to the success of the project has been the fact that it started small and has grown steadily. The design was thoroughly tested, redesigned and extensively field tested in a major pilot project. Both the technical design and the implementation strategy has been constantly evaluated and improved. For example, problems in administering loan repayments in the original system for financing the tanks led to the replacement of a loan/subsidy scheme with a downpayment/subsidy scheme in which a 15% downpayment by the tank recipient was matched with a n 85% grant from the Ministry of Agriculture. The project was supported with significant funding from foreign donors and used Botswana's substantial network of Agricultural Demonstrators, not only to promote the technology throughout the country, but also to administer and monitor the project. More detailed accounts of the project giving information on many of the specific problems encountered and how they have been overcome are given by Ainley(1984) and Gould(1985), (1987).

2. KENYA: Machakos Diocese Rainwater Tank Programme

This project was initiated in 1983 and is being coordinated by the local Catholic Diocese Development Office. The project covers the whole of Machakos district and is assisting groups each consisting of 10 households to set up revolving funds for financing concrete ring tanks built to a locally developed design. A third of the cost of the tanks was initially covered by the local Development Office supported by a foreign donor. The rest had to be met by the group members using the revolving fund. The recipients of tanks provide materials and unskilled labour to help to reduce costs. The project has now become completely self financing and around 3000 tanks between 4.5 and 15 cubic meters have been constructed. The success of the project is due, in part, to the effectiveness of the setting up of revolving fund groups for financing the development and motivating other groups to do likewise.

3. THAILAND: Jar Construction Program

Although this project has only been running since 1986 it is by far the most successful rainwater tank implementation program in the world, having resulted in the construction of around 4 million 2 cubic meter wire reinforced cement jar tanks by the early 1989. The success of the project has been mainly due to the active participation of grassroots communities supported by local and national government agencies, universities and non-governmental organizations.

A number of key elements each vital to the enormous success and widespread replication of the program have been identified by Wirojanagud and Chindraprasirt(1987), these include:

1. The preparation of the community and their involvement from the outset in both financial management and construction.

2. The use of revolving funds to help householders raise the necessary money to cover the costs of materials for the tanks.

3. The close partnership of government and community. This is reflected in the assistance of the government in providing tools and in establishing a revolving fund of 10,000 Baht (approx. US$350) for each village to help subsidize villagers contributions. Villagers in return were expected to contribute their labour free of charge and pass on skills learnt on government training courses to others.

The relatively small size of the jars (2 cubic meters) and their low cost 550 Baht (approx US$20) for materials has made them affordable to the masses. Although an average family requires 3 tanks to provide sufficient domestic water to last throughout the dry season, additional jars can be added to the first when further funds become available.

If current rates of tank construction continue it seems likely that the goal of the IDWSS Decade may be attained making Thailand one of the few developing countries to achieve this. It is estimated that by the early 1990's, 9 million tanks would have been constructed.

A project to introduce larger 11 cubic meter ferrocement tanks has been running concurrently with the jar program and has been administered by the Population and Community Development Association (PDA) since 1980 with assistance from a variety of foreign donors.

CONCLUSIONS

Despite the unfavourable international climate which has resulted in a serious lack of support for small scale rural initiatives, low cost water supply technologies including RWCS's can have a considerable impact at the local level if an appropriate approach is adopted.

The success of any strategy aimed at introducing the widespread inplementation of rainwater catchment tanks into a region depends on a number of key conditions.

1. Suitable hydrological conditions.
2. An appropriate affordable system design.
3. A real felt need and desire for rainwater catchment technology by the people.
4. A successful survey of the technical, economic and social feasibility of the project.
5. An effective implementation strategy with effective management, training and sufficient financial support to ensure successful tank construction can proceed unimpeded.
6. A positive and supportive policy towards the program by the national government and major donor agencies.
7. The existance of a dynamic individual or organization to act as a catalyst to set the implementation program in motion and to motivate participants.

The first two of these conditions are physical factors relating to the hardware of the rainwater collection systems. The rest are what can be described as software factors and as experience has shown, although less immediately obvious, these may be equally inportant in determining the success or otherwise of any project. It is, therefore, imperative that policy makers, planners and project coordinators give at least as much of their attention to the "software" side of RWCS implementation as to its "hardware".

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THE USE OF LOW-COST, SELF-HELP RAIN WATER HARVESTING SYSTEMS FOR COMMUNITY WATER SUPPLY IN SOUTHERN KENYA

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ABSTRACT

The Mutomo Soil and Water Conservation Project has helped implement a wide range of water harvesting systems for the improvement of community water supply in the semi-arid Southern Division of Kitui District, Eastern Province, Kenya.

Several rain water cistern systems have been developed which harvest runoff water from rooftops, roads, compounds, springs and exposed bedrock. These compliment larger communal runoff water harvesting systems such as rock catchment dams, earth dams and shallow well/sub-surface dams. They are low-cost, appropriate technologies involving a high-level of community participation in planning, construction and maintenance. Artisans selected from the local community and trained and equipped by the project have combined with women's and other self-help groups to install rain water tanks at most schools and public buildings in the Division.

The paper focuses on the approach adopted by the project in implementing rain water harvesting systems in a marginal, rural, semi-arid area with a predominantly subsistence economy. Some general recommendations and conclusions are summarised from the experiences at Mutomo from 1982-1987 and the five standard tank designs adopted by the project and ranging from a seven cubic-metre tank system costing US $157-168, to an 78 cubic metre excavated tank costing US $690-870 inclusive are described.

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INTRODUCTION

Around Mutomo in the semi-arid Southern Division of Kitui District in the Eastern Province of Kenya some 200 km east of Nairobi, the 100,000 inhabitants of the region have very few natural perennial sources of water. With an average annual rainfall of roughly 500 mm and extremes of 237 and 1471 over the last 14 years, some form of water collection and storage is needed to even out the spatial and temporal variations in water supply that place excessive burdens on the rural people attempting to secure their daily water supply. The Danida-funded Mutomo Soil and Water Conservation Project (MSCWP) has helped implement a wide range of rain water harvesting systems for the improvement of community water supply. These range from seven cubic metre household rain water cistern systems to 2,000 cubic metre rock catchment dams built with communal labour by self-help groups supported by the project. Successive review missions have requested that the experiences and successful methods developed for construction and maintenance of water points be passed on to a wider community outside the Mutomo area (Danida, 1984, 1987). In answer to this, the authors of this paper have produced a comprehensive manual on rain water and runoff harvesting soon to be published by the International Reference Centre for Community Water Supply and Sanitation (IRC).

In keeping with the objective of the conference to share experiences in rain water cistern system technology with emphasis on community involvement, this paper presents some of the community aspects of the MSWCP. In particular it focuses on the kind of approach that needs to be taken when using rain water harvesting techniques to develop community water supply in marginal, rural, semi-arid areas of Africa where the subsistence economy is dominant and technological and financial resources are limiting. For 90% of the population around Mutomo, incomes are below US $15 per month. Although there are few financial resources, there is a local tradition of mutual cooperation in labour activities, with the pooling of resources to accomplish tasks exceeding the capacity of individuals. These are self-help groups known locally as Mwethya groups. They are mostly made up of women since many adult males leave to become migrant workers in urban areas. Consequently, the project has concentrated on the development and implementation of low-cost, self-help water harvesting systems. These allow the bilateral aid from Danida to be combined most effectively with the locally available resources of self-help labour to improve the water supply through the mobilization of community groups and the training of local artisans in the manufacture of systems and their components. Provided here are a few of the conclusions and recommendations derived from the MSWCP experiences and some general details of the rain water cistern systems adopted by the project and their costs.

The complete manual (Nissen-Petersen and Lee), from which some of this paper is derived, provides a description of the semi-arid environment in Africa, the role of rain water harvesting and its improvement over traditional water supply systems, the methodology of setting up a rural development project with its water component based on water harvesting, site selection and design criteria for a range of cisterns, dams and sub-surface water stores, and the training and management of artisans and organisation of self-help groups to carry out construction. For the various water harvesting systems the authors provide individual construction guides which include quantity surveying and costing details, siting considerations, site preparations, building instructions, quality control and maintenance instructions.

DEFINITION OF RAIN WATER HARVESTING AND ITS PURPOSE

Rain water harvesting involves the collection, concentration and storage of rain water that runs-off a natural or man-made surface area. It has two main functions. Firstly, it is a method of smoothing out fluctuations in the available water supply through time by storing water during times of plenty for use when it is scarce. Secondly, it is a method of evening out the variations in space providing water in areas where it is limited. This may be due to the lack of surface water storage features such as natural ponds or lakes which allows the surface run-off to leave the area as river-flow, or due to the low overall volume of water which quickly infiltrates into the ground. Water harvesting can also be used to provide alternative water sources in a more convenient pattern, for instance closer to population centres or quality farmland. It may be used to supply water of a higher quality where alternative traditional water sources such as rivers or lakes constitute a health hazard.

When designing and implementing rain water harvesting systems in underdeveloped areas where a subsistence economy predominates, it is imperative that the appropriate combination of supply area, collection and storage method be selected so that the water requirements of a particular user group can be satisfied efficiently at minimum cost. A rain water harvesting system should possess the following features:

- initial investment cost should not be too high to prevent user uptake of the technology or the construction of a sufficient number of water-points using project resources and local labour,
- the system should be built using appropriate methods and materials, i.e. the materials should be cheap and locally produced or readily available,
- the system must correspond with what people want, in locations they desire and find most convenient to use. This ensures their vital cooperation in construction, regular use and management, and therefore a satisfactory long-term return to the investment.

In addition, it is desirable that the system should:

- direct the rainfall inputs into the storage structure with minimum losses or waste,
- should be constructionally sound without over- or under-capacity,
- should require little operational inputs in terms of maintenance or spare parts and should not degrade through time resulting in water loss and water quality deterioration,
- the total costs of supply and storage should not be in excess of the value of the water provided over a pre-determined period,
- the system must provide water at a quality the user group finds acceptable, irrespective of any external standards.

TRADITIONAL RAIN WATER HARVESTING

Rain water harvesting is a common traditional water source in the Southern Division around Mutomo and compliments alternative sources such as local water holes, seasonal rivers, springs and shallow unlined wells. It usually takes the form of rudimentary rooftop harvesting involving stationing pots, pans and other vessels beneath the eaves of a house to catch runoff water from the rooftop during rainstorms. Whilst it is a simple exploitation of an obvious local resource, it is often not taken to its logical conclusion of building gutters and a large single storage tank that could provide sufficient water for the complete dry season if carefully managed. The major reasons for this are:

- the lack of resources, both financial and technical, to construct a larger harvesting system,

- the poor local perception concerning the full resource potential of the household rooftop site,

- the inability of user to calculate the amount of water that runs off,

- the inability of the user to judge the households consumption needs relative to the quantity of water that could be harvested,

- the perception of the environment as arid and therefore having insufficient rainfall to support the family,

- the temporary nature of some building structures or materials not warranting permanent harvesting fixtures,

- the poor suitability of the house design to support a larger harvesting system.

By providing technical support, financial assistance and organising communities to work together, rooftop and other water harvesting systems designed for more communal use were developed by the local people and the MSWCP.

THE MUTOMO SOIL AND WATER CONSERVATION PROJECT APPROACH

Given that little experience had been previously gained in the implementation of large-scale grass-roots approaches adopting low-cost, self-help solutions to semi-arid water supply problems, a flexible, multiple-level approach was adopted.

Target Groups

A number of different scale targets were quickly identified and included:

- family/private individuals who would own and use a rain water harvesting system exclusively,

- a small group such as a self-help group, church-congregation, school or other organised group who would use the system under joint ownership restricting use to members,

- a complete community/village who would use the system as a common resource and with open access.

Additionally, women were recognised as a major force in agricultural and environmental development, a fact which is true for many rural arid and semi-arid (ASAL) regions. The project decided to especially focus attention on women's groups and their needs. These related primarily to reducing the journey time and distances required to carry daily water supply to the home (often in excess of 10 km round-trip), freeing more time for food production, firewood collection, and child care.

Rain Water Harvesting System Types

Relying on a single type of rain water harvesting system such as individual household tanks is not a feasible strategy for areas like the Southern Division where the development project must provide basic infrastructure, existing water points are almost solely un-improved traditional systems and the majority of the population cannot afford to finance water point construction without significant economic and social change within the local economy. The required approach is that some households or institutions could be helped to develop individual systems whilst a more favourable distribution of larger, perennial communal systems could be developed with the assistance of larger self-help groups.

Every additional water harvesting system provides more convenient local water, a major need of rural families. They help reserve the larger sources, which may be the only points providing a permanent source in the driest years, for times when drought conditions result in the small or medium scale systems drying up. Thus a safety net is provided. In the wettest years, local small and medium scale water points will provide sufficient water and expenditure on water collection and transportation will be a minimum. In the driest years, the time until people must resort to relying on the few large-scale water points will be lengthened keeping average journey times and round-trips short.

Throughout the Southern Division, there is considerable potential for development of a wide range of different types and scales of rain water harvesting system types. Classifying the landscape into three main components, water sources were identified for exploitation;

- hilly/mountainous areas with extensive rock outcrops and potential for spring development, rock catchment construction and local groundwater exploitation by shallow wells,

- lower-level hills and slopes with wide stream beds and some isolated rock outcrops and potential for shallow groundwater exploitation, rock catchments and a variety of tanks,

- shallow slopes and featureless plains with potential for deepened and earth-dammed water holes, ground tanks filled from roads and raised and ground tanks by houses and compounds.

A range of different water point types are necessary to exploit the full potential of the landscape: rock catchments, shallow wells, sub-surface dams, sand-dams, earth dams and water tanks. During 1982-87 the local people and the MSWCP together constructed 191 water tanks, 103 rock catchment dams, 126 shallow wells combined with 10 sub-surface dams and 15 sand-dams, 12 earth dams, 3 spring protections, and 8 tube wells. Development of more water tanks was attempted when the MSWCP complemented its community-scale operations by beginning a pilot scheme subsidizing private individuals 50% of the materials and skilled labour costs to build 60,000 litre ground-tanks. However, this did not get the approval of the Danida review committee at the start of 1986 and was phased out in favour of providing ground-tanks to all schools in the region. By the end of 1987, the total potential water capacity in these various man-made water systems was estimated to be 722, 680 cubic metres, which accounting for two rainy seasons, losses to evaporation and sub-surface seepage gives an estimated 670 million litres of water for human and animal consumption.

RAIN WATER TANKS USED IN THE MUTOMO PROJECT

Tank Construction Costs and Maintenance

Five standardised tank cisterns were adopted for construction by the MSCWP ranging from a seven cubic metre raised ball tank to a 78 cubic metre extended ground tank. Local people with only basic skills were trained to be artisans and to carry out the technical aspects of construction whilst supervising the recipients of the harvesting system (school parent groups for instance) in providing the required labour and in after-care and maintenance. The ground tanks can be fed by runoff either from roads, rock surfaces, compounds, rooftops or feeder pipes from highland spring protection systems. Raised and extended tanks are generally fed from rooftops, the smaller ones from houses and the larger ones from schools and public buildings. The costs of each tank with and without self-help labour is listed in Table 1.

Table 1 - Tank Construction Costs

Ground Tanks	Labour		Materials		Total	US $/litre
22 m^3	self-help	20.0	free	51.0	71.0	
	artisan	22.5	purchased	32.0	54.5	$0.002
		42.5		83.0	125.5	$0.005
60 m^3	self-help	80.0	free	104.0	184.0	
	artisan	55.0	purchased	290.0	345.0	$0.0064
		135.0		394.0	529.0	$0.0088
78 m^3	self-help	100.0	free	83.0	183.0	
	artisan	75.0	purchased	613.6	688.6	$0.0087
		175.0		696.6	871.6	$0.0110
Raised Tanks	**Labour**		**Materials**		**Total**	**US $/litre**
7 m^3	self-help	0.0	free	11.5	11.5	
	artisan	25.0	purchased	132.0	157.0	$0.021
		25.0		143.5	168.5	$0.023
21 m^3	self-help	40.0	free	23.5	63.5	
	artisan	60.0	purchased	410.9	470.9	$0.022
		100.0		434.4	534.4	$0.026

(The costing of labour and materials is based on Kenyan prices as of January 1988 converted from Kenyan Shillings at an exchange rate of 17 Shillings:1 Dollar)

The free material costs refer to sand, gravel, rock ballast, and water that can all be collected locally and brought to the construction site by the self-help labour as their added contribution to the cost of the rain water harvesting system. The commercial costs are kept low by manufacturing many of the components locally such as guttering and gutter hangers. Polytechnics were issued with equipment and students trained as contractors, providing a boost to local employment and the economy. The two US $/litre figures give the construction costs per litre for the system with self-help contributions (upper figure) and with no self-help contributions (lower figure). These investment costs are only incurred once per system and with each successive year of use, the costs of providing water obviously decrease. Maintenance is usually self-help with expenditure confined to bitumen paste or mortar water-proofing.

Without proper maintenance all water constructions will deteriorate. Lack of care results in the need for a minor repair, this is neglected and results in the need for a major repair and then finally the system becomes beyond repair. At Mutomo, motivating people to take responsibility and maintain a structure involves getting the concept of preventative maintenance across. In much of Africa, the concepts of prevention and maintenance are not present, only those of breakdown and repair. Something has to stop working completely before action is taken. As a primary means of prevention, construction projects were all developed to adopt standardised, maintenance-free designs involving minimum machinery with moving parts, construction techniques similar to those existing in the area and to include the users in construction and maintenance training. Where relevant, specific maintenance people were taught how to fault find, diagnose problems and undertake remedies for the type of water point they constructed, on the understanding that if serious faults develop, project personnel should be contacted to come and effect repairs.

The Five Standard Tank Designs

The five standard tank designs are:

22 cubic metre ground tank

This tank is a family-size perennial system that could be used for drinking, irrigation of a garden plot, or livestock watering. It is an excavated hemispherical tank that is most commonly fed by runoff from a road, but could also be fed from a rooftop area, compound, or small rock outcrop. The quality of the water is lower than in the raised or extended tanks of the same size. If the tank is full at the start of a six month dry season it would provide between 100 and 124 litres per day depending on the losses to evaporation.

60 cubic metre ground tank

This ground tank is an excavated hemispherical tank capable of holding 60,000 litres of runoff water. Because of its large size it is most suited to collecting water from a compound, road or rock outcrop. It could also be used in conjunction with a large roofed area. However, for this, the slightly more expensive 78 cubic metre extended ground tank is recommended. The quality can be improved by constructing an effective silting tank and building a roof for shade. A full tank at the end of a rainy season prior to a six month dry season would supply 300-330 litres of water per day depending on the amount of water lost to evaporation.

78 cubic metre ground tank

This tank is most suited to harvesting water from large roofed areas such as schools, churches, meeting halls, or larger private homes. It is an excavated hemispherical tank with a 60 cm raised cylindrical extension and a 30 square metre roof of iron sheet. It can be used successfully as a storage tank for spring protections and gravity pipes. The quality of the water is higher with little sediment and low levels of organic pollution due to roofing. When fed from a rooftop, if the tank is full at the start of a six month dry season it will provide 433 litres per day with little loss to evaporation.

7 cubic metre raised tank

This tank is suited to a small family dwelling with a small roof area of galvanised iron sheet. In some cases it can also be used with thatch if an effective method can be found to hang gutters and catch the runoff water off the rooftop. It is a raised spherical tank with a volume of 7,200 litres. If the tank is full at the start of a six-month dry season it will provide 40 litres of water per day with little loss to evaporation. Because the water consumption of people with water next to the house in ASAL regions is generally 10-20 litres per capita per day, the tank will not last a complete dry season if water use is not carefully controlled or additional water supplied from alternative sources during all or part of the dry season.

21 cubic metre raised tank

This tank is the most suited to harvesting water from large roofed areas such as schools, churches, meeting halls or large private homes. It is a raised cylindrical tank made from ferrocement and modified to cut construction costs to half that of a conventional tank with a volume of 21,000 litres. A cylindrical ferrocement tank is strong, durable and often cheaper than tanks made of bricks, blocks or galvanised iron. Because it is roofed, the quality of the water is very high with little sediment and low levels of organic pollution. If the tank is full at the start of a six month dry season it will provide 116 litres per day for the length of the dry period.

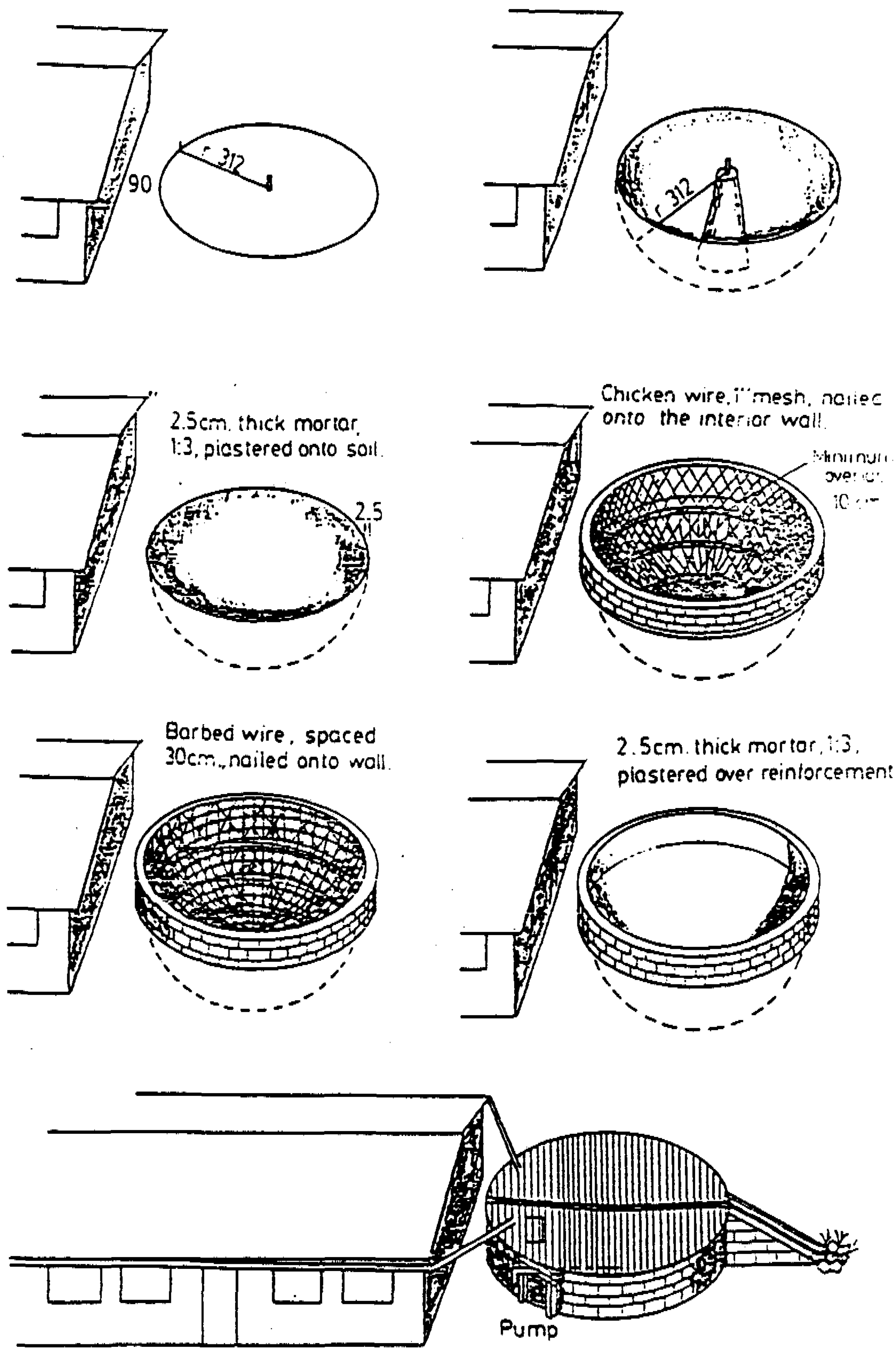
Example - The 78 Cubic Metre Extended Ground Tank

As an example, the quantity surveying and costing details of the 78 cubic metre ground tank are included in Table 2 and followed by a series of annotated diagrams showing the various stages of construction. The full details of site preparation, construction and maintenance are given in the rain water harvesting manual written by the authors which will soon be available as an IRC Technical Paper.

Table 2 - Quantity Surveying and Costing for 78 Cubic Metre Extended Ground-Tank

	US $
Labour requirements:	
Excavation, 4 labourers x 10 days x $1.0	40.0
Construction, 2 artisans x 15 days x $2.5	75.0
Construction, 4 labourers x 15 days x $1.0	60.0
Total Cost of Labour	175.0
Material Specifications:	
Tank-	
2,400 kg of cement (48 bags x $5.0)	240.0
3 rolls of chicken mesh, 2.5 cm x 90 cm x $17.5	52.5
2 rolls of barbed wire, gauge 16 x $30.0	60.0
20 kg of nails, 6.35 cm (2.5"), x $0.5	10.0
30 metres of thin polythene sheeting x $0.25	7.5
15 tonnes of sand, clean and coarse, x $3.0	45.0
6 tonnes of cleaned stones x $3.0	18.0
4,000 litres of water (20 drums x $1.0)	20.0
Roofing-	
325 cm of galvanised pipe, 3.75 cm (1.5") with flat irons	17.5
77 metres of timber, 10 cm x 5 cm (4" x 2") x $0.7	53.9
15 corrugated iron sheets, gauge 30, 3 m x $5.5	82.5
7 Metres of chicken mesh, 2.5 cm x 90 cm x $0.5	3.5
4 kg of nails, 10 cm (4") x $0.5	2.0
4 kg of roofing nails x $1.0	4.0
Guttering (for a 22 m long roof)-	
36 triangular lengths of 180 cm, gauge 26 x $1.0	36.0
26 skirting lengths of 180 cm, gauge 26 x $0.75	19.5
60 hangers for triangular gutters, 3 mm wire x $0.1	6.0
16 metres timber 10 cm x 2.5 cm (4"x2") for downpipes x $0.5	8.0
4 kg of roofing nails x $1.0	4.0
1 kg of clot nails x $0.7	0.7
2 kg of Bitumen Paste x $3.0	6.0
Total Cost of Material	696.6
Full Cost of 78 Cubic Metre Tank	**871.6**
Savings Through Self-Help:	
Excavation, 40 labourer days x $1.0	40.0
Construction, 60 labourer days x $1.0	60.0
15 tonnes of sand supplied from local sources	45.0
6 tonnes of stones supplied from local sources	18.0
4,000 litres of water drawn from local or project sources	20.0
Total Possible Savings	183.0
Reduced Cost of 78 Cubic Metre Tank	**688.6**
Construction cost per litre without self-help	$0.0110
Construction cost per litre with self-help	$0.0087
Approximate purchase cost per litre in Mutomo village	$0.0070

Diagram 1 - Stages in the Construction of a 78 Cubic Metre Extended Ground Tank



CONCLUSIONS

A Flexible Approach

The project has shown the need for a flexible approach to water supply improvement through the development of both temporary and permanent, small and large-scale water sources. A complete range of potential resources exist within most semi-arid environments from large catchment to small rooftop harvesting systems. Different systems should be developed and recognised as having different exhaustion periods. Where water is limited and seasonal, a strategy should be adopted that encourages groups to keep certain points in reserve, e.g. using traditional short-lived points first, then small reservoirs, then large reservoirs, then wells. It is clear that in such a climatically and socio-economically marginal region, rain and runoff water harvesting may only provide a partial solution to the local water supply problems. The population is growing, the annual variation in rainfall is extreme and the potential for developing universal individual household systems is limited. Additionally, choices must be made between quantity and quality and both must be balanced against cost. The project developed relatively cheap household ground-tanks, the water quality of which is poor in terms of turbidity, organic matter and the potential for faecal and other biological contamination. However, the cost compared to a similar-size raised and roofed tank in which the water quality is much improved is nine times lower if self-help labour and local materials are used in construction. Since the traditional water sources for most of the population are highly contaminated, are often seasonal, and require the users to travel long distances each day, the project felt it appropriate to concentrate its activities primarily on quantity and availability whilst aiming to improve quality wherever possible.

Community Participation

Prior to any major work undertaken, it is essential to encourage people's understanding, preparedness to participate, and acceptance of their required commitments. In the Southern Division, this is done through village meetings called 'barrazas' and through training and extension efforts. The process is aided by the Kenyan District Focus system in which local people play a role in deciding where and what developments should take place. In areas where communities are dispersed and few large-scale development projects have previously been established, communication and motivation are vital. Lines of communication need to be opened between the project and the community and key diffusion points for the introduction of improved or new methods of securing daily water supply must be identified. These include the existing self-help groups, community leaders such as tribal elders or local chiefs, schools and other institutions, and local innovators such as farmers who introduce improved farming techniques and who are natural choices for the demonstration of household rain water cistern systems. A key recommendation for any other grass-roots project that seeks to promote water harvesting, is that the project itself must be seen to be supported by this water supply technology. All project staff houses should have rain water cistern systems, as should offices and workshops. In the vicinity of the project base, all available catchment water harvesting systems should be developed (a good opportunity for training artisans prior to their use in the community) to provide water for construction projects. In this way, confidence can be generated in the community that the technology is successful and that the aridity of the climate and uncertainty of the rainfall is not a barrier to the development of more reliable and safe water supplies.

The Need for More Systems

Reviews of the MSCWP found that in absolute terms, the impacts of the water supply developments had resulted in women having more time to spend on the land as their daily traveling distances and times were reduced for a large part of the year. Water had been brought closer to roughly 60% of the population and lasted longer into the dry season at all locations. This is illustrated by the fact that since 1982, the cost of a 20 litre jerrycan of water sold in the village had fallen from 9 Kenyan shillings to 3 in the driest part of the year. However, many more rain water harvesting and other water point systems need to be introduced to improve conditions for the 40% of the regions population still relatively unaffected by project activities and further improve conditions for the rest. The ratio of perennial points to those that regularly dry up must be increased either by increasing the number of small points and hence reducing the load on each point, or by providing strategic large water points wherever possible. The latter is difficult to achieve unless a large number of self-help groups within a given area can be successfully organised to build large, communal resources.

ACKNOWLEDGEMENTS

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Table 2 and the figures in Diagram 1 have been taken from the manuscript of a forthcoming joint publication by the International Reference Centre for Community Water Supply and Sanitation, The Hague, The Netherlands and Danida, Copenhagen. Parts of this paper has been based on sections of this publication and thanks must go to them and Mr. Jan Teun Visscher and Mr. Kurt Morck Jensen for their cooperation.

The contents, interpretations and recommendations given in this paper are those of the authors and cannot be assumed to represent the official views or policies of Danida or the various Kenyan authorities with which the authors worked on the Mutomo project.

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RAINWATER CISTERN SYSTEM TRAINING THROUGH COMMUNITY PARTICIPATION IN NEPAL

By

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Abstract

The rainwater cistern system concept is still new to the Kingdom of Nepal. To promote this concept a training program was conceived by the Office of Peace Corps/Nepal. This paper aims to share and disseminate a ferrocement tank construction and rainwater catchment system training through community participation conducted successfully in July 1988 in the Jana Prakash Primary School, Pokhara, Nepal for U.S. Peace Corps water supply volunteer engineers and their coworkers/counterparts.

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Introduction

Out of approx imately 1.8 million population in Nepal, about thirty percent have access to clean drinking water. With 2.6 percent population growth rate, the Kingdom of Nepal faces enormous challenges to provide potable drinking water to all its population by the year 2000 as its aim through the new minimum basic need program initiative. The Government of Nepal continues its efforts to utilise its available resources and there is an emphasis on community particiation in this program as it directly involves and benefits women and children of Nepal and their health.

Clean safe drinking water is a basic need. It is a prerequisite to improved health and standard of living. The rain in the Kingdom of Nepal which falls in the rainy season for a period of about 4 months is ample, hence the concept of rainwater cistern system is therefore very applicable. However, this concept is still very new to the people of Nepal. An introduction of this rainwater cistern system is therefore called for.

In order to achieve this goal, the Office of Peace Corps/Nepal Rural Conduction Program took the initiative by conceiving a training program on "Ferrocement Tank Construction and Rainwater Catchment System" for its Peace Corps volunteer engineers and their counterparts from their respective district posts from eastern to far western region of Nepal. The program was geared towards the community participation in the hands-on experience training, maintenance and use of the system. It was hoped that this training could serve as a starting point for the use of rainwater cistern system in the Kingdom of Nepal.

Preparation for Training

It was planned that the training should be conducted at a community centre such as a school with the problem of drinking water and the community should be willing to participate. During the feasibility survey, it was found that Shree Jana Prakash Primary School near Pokhara was a suitable site.

Prior to the training, the Peace Corps/Nepal had sent a team to survey and arrange necessary logistical support. The survey revealed that Pokhara is a good location with quite a number of building material suppliers which served as an assurance for additional materials and tools if needed during the training. The contact with school committee also indicated that the school community was very receptive to the rainwater system for their school and the community participation could be assured.

A training team of four was selected. The lead trainer was a well-known researcher in this field of rainwater catchment from Khon Kaen University. Two assistant trainers were selected from the experienced Peaces Corps volunteer engineers . The fourth member was an administrative assistant from the Office of Peace Corps/Nepal.

The training team went to Pokhara four full days before the start of the training. These four days were very essential as a thorough survey of the availability of material and decision on the types of ferrocement tank and gutters to be constructed had to be made. Materials and tools were acquired and brought to the school and preparatory work including sieving and cleaning of sand and gravels was done in this period.

Details of Training

The training was for seven Peace Corps volunteer engineers and their seven counterparts (2 engineers and 5 overseers) from 7 different districts and regional offices. One additional Peace Corps volunteer who stationed at the school also participated in this training. It was known to the lead trainer before hand that the trainees were engineers and skilled technicians. The training was thérefore designed to have maximum interaction among the trainees and to share experiences of all the participants. Training consisted of theory, practical and experiential learning, group discussions and presentations. The design and construction work was designed such that maximum input were from the participants. This was achieved by having the participants involve in group discussion, express their ideas and suggestions and finally had the ideas and suggestions tried in the actual construction within the constraint of the available materials, tools and engineering soundness. The details of the training schedule is given in appendix A. List of hand-outs is given in Appendix B. The pictorial display of the training is shown in Appendix C.

For actual training, it was observed during the first day of the training that some of the Nepalese counterparts did not have full command of the English language and had some difficulties in following the discussion. In the following days, some of the discussion and presentation were done in Nepalese language. The Peace Corps volunteers were also encouraged to explain to their counterparts in Nepalese. All these were done in order to get the full benefit of the training and get everyone to participate and express their opinions.

One of the objectives of this training was to start the ferrocement rainwater tank and catchment system in Napal. This training was a good start. In order to make the training more meaningful, the lead trainer had a suggestion that the participants should compile a construction manual on ferrocement rainwater tank as a result of the experience gained from this training. This manual could serve as a starting point for construction of the ferrocement tank and catchment system in Nepal. This idea was well received by the participants.

The training was planned for 10 days with one rest day on day 7. This rest day was a reserve for additional work if required. The training schedule was arranged such that some background informations such as objectives, knowledge on rainwater containers; ferrocement technology; ferrocement rainwater tank were discussed during the first 1 1/2 day. On the afternoon of day 2, design of the rainwater tank and catchment system to be constructed was discussed. The actual construction work started in day 3 and continued until the final day. The discussion on rainwater catchment was in day 8 and the maintenance and caring of the system and cost estimation were in day 9. The work on manual was in day 9 and 10. The wrap up and evaluation were conducted in the last session of the final day.

On the first day, right after the introduction the participants had to work in two groups and made the presentation on the objectives of this training. This was to get the participants involved in the training as soon as possible. Also in the first 1 1/2 day, the participants were presented with the experiences in ferrocement tank with the presentation of publications, slides, VDO and pictures. This helped convince the participants of the lead trainer competency and also helped the participants familiarize with the construction work.

The discussion and adoption of the design of rainwater tank were put in day 2 so that construction work could start as early as possible so that ample time could be left towards the end of the training if additional work was needed. This was considered likely to happen as the power tools could not be used because the school had no electricity and the construction work could be further delayed by the monsoon. This early start of construction work proved to be very beneficial as a lot more time was required during construction and discussion owing not only to the above reasons but also to the input and ideas from participants that needed to be discussed and tried out in the actual construction which was very crucial to this participatory training.

Two 12 cubic metre ferrocement tanks, rainwater gutter and feeder pipes were constructed as a result of the training. Two types of wire mesh viz. woven wire mesh and chicken wire mesh were used to construct the tanks. This was done in order to compare the cost, construction design and ease of construction. A drafted outline of the construction manual on ferrocement rainwater tank and collection of rain water was also completed.

The help from the school community was excellent. They were very enthusiastic about the rainwater system for their children. They provided skilled and unskilled labor and participated in the discussion of the various aspects of construction and in the actual construction.

After the training, the personnels from Peace Corps/Nepal have made several visits to the school to check on the utilization of the tank and to give additional advice. The school community (approximately 500 people) is now using the water from the tank for drinking purposes. The quality of the water from the tank was tested along with existing tap water and tank water was free from contamination as opposed to tap water.

Conclusion and Recommendation

All of the participants worked very hard for the whole 10 days. It was quite amazing to see them work both in the discussion and on the actual construction. The participants indicated that the objectives discussed in day 1 were obtained. The lead trainer was very satisfied with the training and the Peace Corps/Nepal though that excellent training was achieved. Overall, it could be concluded that a good training program was accomplished.

To promote a rainwater cistern concept a training program through community participation is very appropriate. Listed here is the summary of recommendations:

1. Good organization, logistical preparation and support are needed.

2. Close contact between the training team and the community is very essential to get the full participation of the community through the entire training program.

3. For the actual training, the length of training of 10 days is suitable as lengthening of the training would run the risk of losing enthusiasm and interest of participants.

4. The construction work should start as early as possible in order to have some spare time towards the end of training.

5. Some discussion and presentation should be done in the local language to get the counterparts and community participate and feel at home.

6. A manual compiled by the participants is also recommended as it would serve as a starting point and the participants are proud of their work. The manual when completed should be translated to the local language and distribute to related local government agencies.

7. Additional visit by the training team to consult with the community about the utilization of the facilities is also recommended.

Acknowledgement

This training program was conceived by the Office of Peace Corps/Nepal Rural Construction Program. The funding was provided from the Small Project Assistance and the Office of Training and Program Support Peace Corps/Washington D.C.; Peace Corps/Nepal; and the school committee. The school committee provided about 20 % of the total cost; Peace Corps/Nepal provided participants travelling cost, per diem and lodging; and the rest was provided by SPA/OTAPS. Their contributions are greatly appreciated.

A lot of hard work was done by the Peace Corps/Nepal staff and the participants, their contributions are acknowledged.

Appendix A: Training Schedule

Day 1:

Opening introduction

Opening remarks by Associate Director, Rural Construction Program, Peace corps/Nepal; all participants introducing themselves, describing their experiences on ferrocement rain water tank and their expectations; discussion of logistical support, training norm and training schedule; group discussion of training objectives.

Rain water containers

Discussion of rainwater containers with regard to type, size, shape, construction material and technique; distributing hand-out No's 1,2 on details of various types of cement based rainwater tank; slide presentation on various types of cement based rainwater tank construction and testing; VDO presentation on jar and mortar tank construction.

Ferrocement technology

Discussion of various designs and construction of ferrocement rainwater tank; distributing of hand-out No.3 on ferrocement technology.

Day 2:

Ferrocement rain water tank

Discussion of various designs and construction of ferrocement rainwater tank; distributing of hand-out No's 4-7 on various types of ferrocement rainwater containers; slide presentation of construction of ferrocement rainwater container with the aid of formwork (or mould); displaying of photographs and manuals No's 8,9 on ferrocement rainwater construction.

Adoption of design

Discussion and decision on the designs of two ferrocement rain water tanks to be built with available materials i.e. chicken wire mesh and woven wire mesh; group discussion and work on the chicken wire mesh tank and woven wire mesh tank.

Day 3:

Continuation of group work on the design and construction of the two tanks; discussion of the two tank design and construction to get everyone familiar.

Construction

Group 1: Woven wire mesh: preparation of foundation and first part of reinforcement cage (skeletal steel and wire mesh), pouring of concrete base.

Group 2: Chicken wire mesh: preparation of foundation and reinforcement cage.

Day 4 :

Group discussion

Review and discussion of the previous day work, positive and negative points with suggestions.

Construction

Group 1: finishing of reinforcement cage; core wall plastering.

Group 2: finishing of first part of reinforcement cage; pouring of concrete base; gutter work.

Day 5:

Group discussion

Review and discussion of the previous day work, positive and negative points with suggestions.

Construction

Group 1 : finishing of core wall plastering.

Group 2 : reinforcement cage : skeletal steel, wire mesh, binding wire and spacers; gutter work.

Day 6:

Group discussion

Review and discussion of the previous day work and plan for today's work.

Construction

Group 1 : gutter work; inside wall plastering.

Group 2 : finishing of reinforcement cage; core plastering.

Day 7:

Construction

Finishing of outside wall plastering of woven wire mesh tank and finish of core plastering of chicken wire mesh tank.

Day 8 :

Group discussion

Review and discussion of the previous day work with suggestions; discussion on today's schedule and the remaining days.

Rainwater catchment

Discussion on availability of rainwater, rainfall data, roof area, roof and gutter coefficiency, water requirement for household and school.

Construction

Gutter work , feeder pipe , scaffolding and formwork for roof concreting of woven wire mesh tank inside wall plastering of chicken wire mesh tank.

Day 9 :

Maintenance and caring

Discussion on caring during and just after construction; normal usage; concrete curing; first filling of tank: crack development and repairs; rainwater replenishment and tank hygiene.

Cost estimation

Group work on cost estimation of the two tanks, material list and material estimation.

Manual

Discussion on objectives and contents of the construction manual of ferrocement rainwater tank; manual development.

Construction

Wall plastering of chicken wire mesh tank; gutter work, scaffolding and formwork for roof concreting of chicken wire mesh tank.

Day 10 :

Group discussion

Review and discussion on the construction of gutter, scaffolding and formwork for roof concreting with suggestions.

Manual

Presentation of outline of the manual, drawing, material list, construction steps, list of tools.

Construction

Finishing of roof concreting, gutter, feeder pipe and accessories.

Wrap up and evaluation

Summary of the training course; comments on the training from the participants; evaluation.

Appendix B: List of Hand-outs

No.1 : Details of various types of cement based rainwater tank taken from
CHINDAPRASIRT, P; HOVICHITR, I and WIROJANAGUD, P. (1986) "A Study and Development of Low Cost Rainwater Tank" Research Report, Faculty of Engineering, Khon Kaen University, Thailand. PP.4-8.

No.2 : "Calculated Stress in Thin-Walled Cylindrical Water Tanks" taken from
WATT, S.B. (1978) Ferrocement Water Tank and Their Construction", Intermediate Technology Publications Ltd, London, Chapter 15.

No.3 : Ferrocement Technology taken from
PAUL, B.K. and PAMA, R.P. (1987) "Ferrocement" Ferrocement International Centre, Asian Institute of Technology, Bangkok, Thailand. Chapter 2 and 3.

No.4 : "KKU-Ferrocement Water Tank Construction Manual" taken from
VADHANAVIKKIT C. and PANNACHET, Y. (1987) "Construction Manual of Ferrocement Rainwater Tank", Faculty of Engineering, Khon Kaen University.

No.5 : "Standing Ferrocement Water Tank Construction Manual" Technology Support Section, Eastern Africa Regional Office, Nairobi, Kenya.

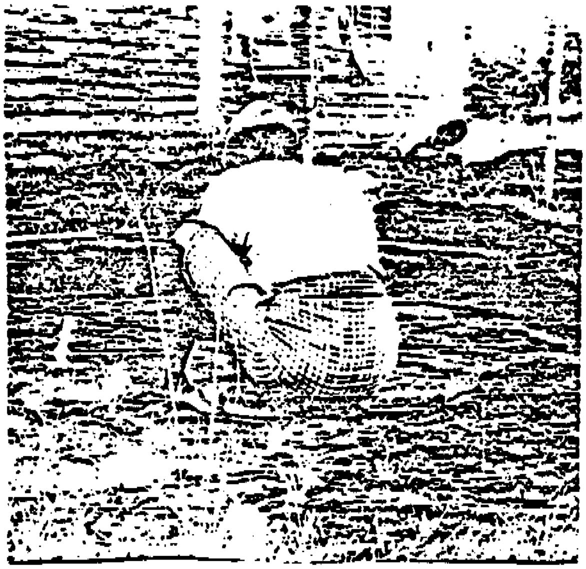
No.6 : "Demonstration Tank Built without Formwork: $6m^3$ Capicity, U.K." taken from
WATT, S.B. (1978) "Ferrocement Water Tank and Their Construction", Intermediate Technology Publications Ltd, London, Chapter 11.

No.7 : "A Low Cost Rainwater Tank",
CHINDAPRASIRT, P; HOVICHITR, I; and WIROJANAGUD, P. (1987), Proceedings of the 3rd International Conference on Rainwater Cistern Systems, Faculty of Engineering, Khon Kaen University, Thailand, Paper E2.

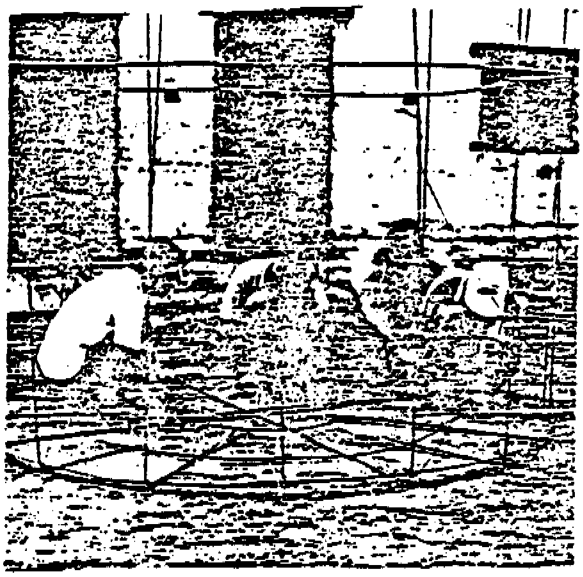
No.8 : "Construction Manual of Mortar Jar"
Thai-Australia Village Water Supply Project and Office of Water Resources Developement, Faculty of Engineering Khon Kaen University, P. 10.

No.9 : "Construction Manual of Wire Reinforced Mortar Tank"
CHINDAPRASIRT, P. et al (1986) Water Resources and Environment Institute, Faculty of Engineering, Khon Kaen University, P.14

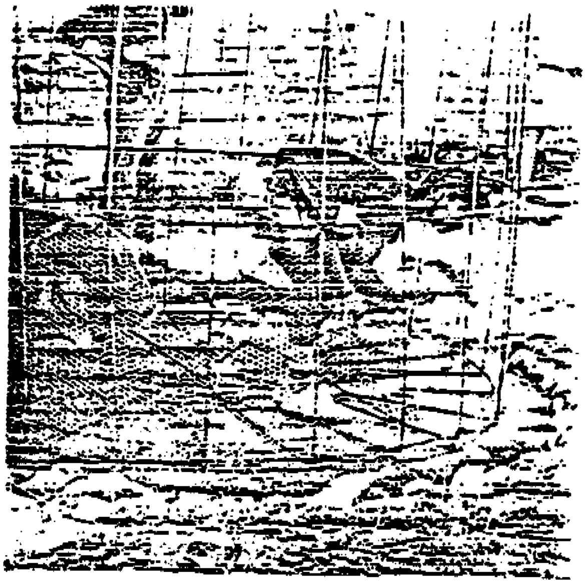
Appendix C: Pictorial display of
ferrocement tank training



1) Foundation preparation

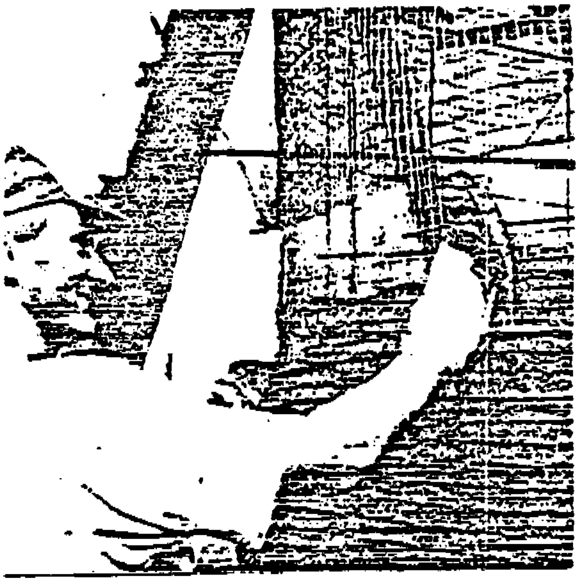


2) Reinforcement cage assembly

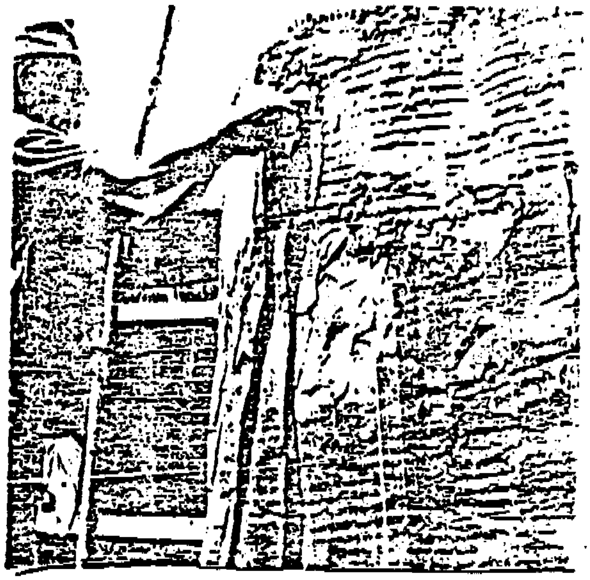


3) Construction of base

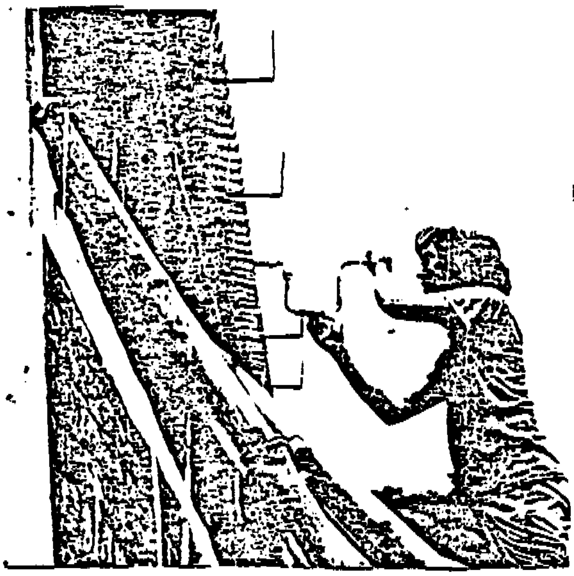
4) Group discussion



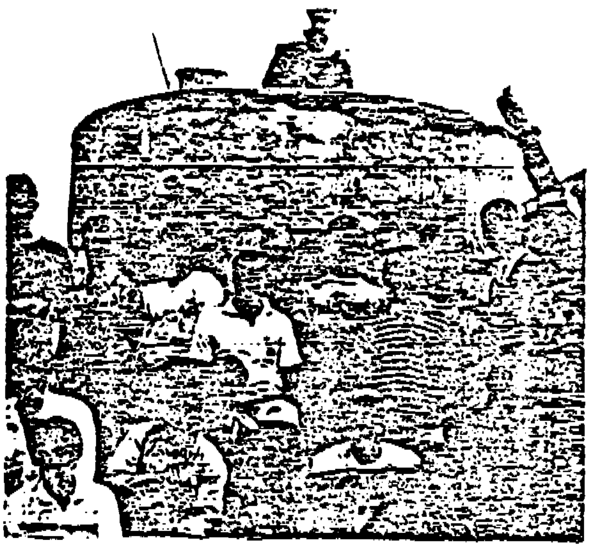
5) Core wall plastering



6) Wall plastering by villager



7) Gutter work



8) The tank and the gang

COMMUNITY PARTICIPANTS IN DRINKING WATEP SYSTEM: PROJECT EXPERIENCES OF WOMEN DEVELOPMENT SECTION MINISTRY OF PANCHAYAT AND LOCAL DEVELOPMENT, NEPAL

Uma Pradhan

I. Country Background

Nepal is a sovereign and mountaineous Kingdom situated between the two big countries People's Republic of China and India. The country in the south, east and west is bordered by India and the North by Tibetan region of People's Republic of China. It is more or less rectangular in shape with 845 kilometers in length and an averages of 200 kilometer in breadth. The total area of the Kingdom is 147181 Square Kilometers. Topographically, the country is divided into three distinct regions, the Tarai in the South, Hill regions in the middle and high land of the Himalayas ranges in the north. The altitude varies from 500 ft. in the south from sea level to 29,00 ft. in the north. Of the total land, only 20% is cultivable and the rest being mountaineous and barren. Its economy is basically agrarian and subsistence prevails in economic activities. Accessibility is limited, 35 percent of the population has to walk about three days to reach a motorable road. Administratively, the country is divided into 5 regions, 14 zones and 75 districts. Each district is divided into Ilaka, town and village panchayat and urban centres. The total population of Nepal is around 16 million with an annual growth rate of 2.6 percent.

II. Drinking Water System in Nepal

In 1976 eighty one percent of urban population and five percent of rural population had access to piped water. The urban population is small (6.4 percent in 1981) and concentrated in the three cities of Kathmandu valley it accounts for about 40 percent of the total urban population in 1981. A little more than 10 percent of population in the country had access to such system in 1976. At present scarcity of piped water is increasing in the urban areas where as no significant progress has been made in the rural areas because most of the annual investment has gone in maintaining the past projects.

Inspite of the country's huge potential of water resources, more and more of the population have to face the problem of or minimal amounts of drinking water to be fetched lap distance. Studies have shown that the average travel time for fetching drinking water has been increasing. Women are the victims of the problem of collecting water because of their ascribed role in the domestic spheres of activities. Sometimes they spend as much as five hours in fetching water.

III. Programme and Basis to tbe adopted for Providing Drinking Water Supply Facilities to all by the Year 2057 B.S.

The Royal Command delivered by His Majesty The King envisages to fulfill the basic needs of the people which includes safe drinking water supply facility to all the Nepalese by the Year 2000. This colossial task does not seem possible only through the endeavour of His Majesty's Government in the context of our country with a limited resources. In this advent people's participation is excessively expected. Keeping in view of this, the concerned Ministry has adopted the following strategies related to the water supply:

1. In the Rural areas of the Terai (plain area) His Majesty's Government provides required construction materials in grant to the users for installation of Tubewell aimed to supply water for 150 persons and make the user groups sole be responsible for installing handpump and its maintenance.

   However, in the densely populated business centres in the Terai area where the water is to be supplied by the pipe with the installation of deep tubewell, is implemented only ensuring the availability of cash and people's participation.

2. The procedures to be followed while implementing drinking water project in the rural areas at the district level follow as:

   (a) In the initial stage i.e. before the implementation of the project, 5% of the total estimated expenditure of the project is to be deposited in cash by the concerned community and also assure to make available people's participation equivalent to 5% of the total estimated expenditure during the project implementation.

(b) If the user groups deposit 5% of the total estimated expenditure in cash, the rest 95% is provided by His Majesty's Government.

(c) In case if the cash contribution from the community is not possible, it is necessary to provide peolle's participation generally equivalent to 10% of the total estimated expenditure during the implementation of the project.

3. District Assembly will not approve those projects which do not fulfill above mentioned procedures. Even though, such projects are approved by District Assembly, His Majesty's Government manages not to include it in the programme. Excepting Foreign Aided Central level projects related to constuction, rehabilitation and extensions in urban areas, financial resources is mobilized by adopting the following policies:

(a) His Majesty's Government provides 50% of the total cost on loan, 30% of the total estimated expenditure is grant and remaining 20% is to be fulfilled by the internal source of the Town Panchayat including people's participation for the implementation of the new projects, which are in fact implemented by the Town Panchayat itself. Town Panchayat is fully responsible for repair and maintenance required during post implementation of the project.

(b) In ase of rehabilitation and extension of the existing water supply systems, His Majesty's Government provides 50% of the total estimated expenditure, and 5% through internal source of Town Panchayat and mobilization of people's participation.

(c) In case of any district level projects whether it is implemented by the grant of His Majesty's Government or by the Foreign aid, the policy of mobilizing people's participation is to be followed.

IV. Repair and Maintenance

The strategies adopted for repair & maintenance and use of completed projects follow as:

1. Water Supply User's Committee is formed and mobilized right from the

beginning of the project implementation phase for each water supply project.

2. The ownership of the water supplu project is handed over by His Majesty's Government to the User's Committee of the concerned Panchayat. Accordingly, the User's Committees formulate their internal working plan and policy in line with the Decentralization Act. The User's Committee makes decisions regarding fixing water charges, collecting water charges and taking actions to those who do not comply with rules, work policy Act and Laws.

3. The policy of developing talent in the national level on imparting training to the personnel required for repair and maintenance of completed water supply and sanitation projects, water supply and sanitation technicians and for maintenance of taps and tubewells.

4. In the urban areas the local Town Panchayat is given responsibility of the project maintenance, operation etc. including the authority of fixing water charges, collection of water charges etc. His Majesty's Government provides the required technical support and technical training to the personnel of Town Panchayat so as to fulfill the task responsibly.

5. The Revolving fund is set up for major repair works with the deposit of 1% to meet the possible major repair works in future. At the time, if handing over the project to theUser's Committee is to be done, an agreement is reached between the User's Committee and HMG/Nepal indicating the responsibility of each other in regard to cash and type of major repair works to be carried out.

6. The technical evaluation of the completed projects is done by a team from the Ministry and Department, accordingly certification is made for each completed projects. The quality of technical evaluation of the project itself serves as a base of evaluation on performance of technical personnel.

V. Bried Description of the Women Development Programmes

Of the total population of Nepal women constituting nearly 50 percent of the population, approximately 6% contribute to the total labour force in agriculture. The time allocation data compiled by the study on the Status of Women in Nepal (1980) reveals that the intensity of labour input by females is 50.2% in domestic production and they work for 10.4 hours a day.

The main mandate of Women Development Section of the Ministry of Panchayat and Local Development is to promote women's participation in the mainstream of development. The first time in the history of planned development of Nepal, Sixth development plan (1980 - 85) included a few pages highlighting the importance of the participation of women in development. The concern shown by International Women's Year created a realisation of for the nedd to enhance women's participation in development in Nepal. Accordingly initiation of many programme/projects, with a special focus to women materialized since 1980 in Nepal. Women Development Section (WDS) was established in the year 1980 in the Ministry of Panchayat and Local Development (MPLD) under the Training Research and Evaluation Division (now it is in the Planning, Integration and Women Development Division) with main purpose of closing the existing gap between the rural women and available services and expertise with the development agencies. WDS seeks to enhance women's ability to generate both subsistence and market income. In this advent, WDS has been implementing a series of village level programmes and patronising projects aiming to avail resources to women's resource. It has been undertaking various activities which will promote integration and participation of Women in Development.

Long Term Objective of WDS

1. Create the awareness in the society that women are not merely the objects of social welfare but a potential contributor in total development process of Nepal.

2. Carry out/implement the programmes so as to eradicate if not minimize the prevailing rampant illiteracy- ignorance, poverty, dogmatism inhibiting the women to participate in development process.

3. Implement the programmes so as to increase the productivity of women in order to harness the production potentialities which in turn adds to national economic objectives- in direction to achieve the long term objectives of WDS are to:

-Raise the incomes of poor rural women, thereby enhancing their status in society and improving the welfare of their families. This would be done through a combination of credit for income-generating activities, training and community development related activities.

-Involve the communities in the development process.

-Integrate women into the regular delivery system of credit and technical support services.

-Establish self-relient women's groups to enable them to initiate and undertake productive activities and develop the capacity of the WDS to ensure that the women's interest are duly reflected in the development policies of the country.

Regarding institutional framework, WDS makes use of existing financial and institutional infrastructure to provide support to the programme rather than creating parallel infrastructure and resources which often leads to marginalization. In doing so, WDS performs a leading role in coordinating the agencies involved. The Commercial Banks have been providing credit to the women's group under Priority Sector Credit Schemes. In order to provide extension services to women's group, line ministries and other intitutions have been involved.

Achievements by December 1988 Reveal the poor women hitherto deprived from institutional credit and support services, have now access to these. So far, 3293 women in 924 groups have been provided credit ammounting Rs. 95,62,993 for livestock raising, crop and vegetable production and cottage industries. Similarly 187,006 people have been benefitted from the provision of drinking water facilities, child care centre, family planning, afforestation, smokeless stoves, trail construction and repair & construction of small bridges, community hall and drinking water projects etc. In the same manner, 12,970 women have been imparted functional training in order to improve their skill in the areas of income generating activities e.g crop production, livestock, health and veterinary care etc. Number of people benefitted from improved drinking water system has been 34411 (women 8334, men 6107, children 17970.) The most outstanding achievement besides the above tangible outcomes could be seen in the increased self-confidence of the rural women involved in the programme and their delight in it, increased aspriation in social and economic change, rising level of participation in the development of the world they live in and increasing decision making status in their family and community affairs.

VI. Drinking water programmes in Production Credit for Rural Women (PCRW)

Implementation process of improved drinking water system adopted by WDS under its PCRW Programme involve two steps and are as:

1. The first step, is to carry a survey on possible drinking water projects i.e hand pump, reservoir, tank construction, pipe-line tubewell etc. Through community leaders, Women Development Officer invites a meeting to form a committee. In the meetings, the objectives, analysis of the methodology, budget and the importance of community participation are the points to be discussed. Once the community accepts the project, the communities become very active in launching the further activities. In the meeting, the community selects a drinking water committee to make responsible for the inplementation, supervision, maintenance of the project.

   They decide in selection of the place where drinking water tap, hand pump, or tubewell are to be installed.

2. The second step follows with the construction, installation of hand pump, pipe line etc.

   In order to enable the people to carryout the project orientation on the technology and technical information is given to the users. For this purpose training is organized involving both women and men on the theory and practical operation of the project, sanitory requirements and measures to avoid water contamination.

In relation to the construction of the reservior tank, tube well and the installation of the hand pumps, all the work is done by the members of the community. Men, women and children provide the voluntary labour to construct the tank and the ground level concrete works i.e cement, bricks, pipe etc.

The installation of the hand pumps is also done by the community. Technical supervision and facilities is given by WDS at this stage.

A monthly meeting is held involving community to monitor the stage of the project.

The User8s Committee Members report their daily activities. In the PCRW Project, communities are involved in all stages of development of projects right from the concept, planning, construction to operation and maintenance in absence of this built-in mechanism, the communities will think of themselves as bystanders in the process and look upon Government as solely responsible for providing and maintaining their basic community level services. Now the stage is such that the themselves recognize the importance of improved Water Supply and Sanitation and accordingly take steps to improve the services.

In these few years of the efforts of WDS, community participation has been accepted as an essential ingredients in the formulation and implementation of projects. As a result, there has been a notable achievements in the efforts to promote community participation in all 44 PCRW projects.

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FERROCEMENT RAIN WATER CISTERN SYSTEMS TECHNOLOGY: A CASE STUDY ON THE DAC EXPERIENCE OF BARANGAY AGCABUGAO, CUARTERO, CAPIZ

Wilfredo Abejo/Wilfredo Amper

ABSTRACT

Development Assisting Center (DAC), as a wholistic approach to community development, aims to enable people to manage their own development within the context of Christian love and community concern.

The experience of the people in Agcabugao, Cuartero Capiz in adopting the technology of a FerroCement Rain Water Cistern Systems tank yielded significant learning in the process of effective technology infusion. The project also encouraged the community's involvement in each stage of planning, implementation and evaluation.

This case study focuses on the following key factors that served to facilitate the effective process of technology transfer and community involvement:

1. the facilitative role of the change agent in the person of the Community Development Worker.
2. a people-based development process which facilitated the effective problem solving, mobilization of resources leading to the attainment of the goal.
3. a need-based project, ensuring maximum community support and involvement.
4. maximization of local resources plus a strong network with other agencies as a contributing factor in project success.
5. introduction of simple technology allowing for an easy process of adaptation in the community, and
6. recognition of the significant role that women play in development.

FerroCement Rain Water Cistern Systems Technology within the DAC Experience of Barangay Agcabugao, Cuartero, Capiz

I. Background

Agcabugao is a community of 110 household with an average family size of 5 to 7 per household located in the hilly terrain of Cuartero, Capiz. The town of Cuartero is about 40 kms. away from Roxas City, the provincial capital of Capiz. Agcabugao is located 7 to 8 kms. distant from the Poblacion of Cuartero.

In its five sitios/clusters namely Bakahan, Ilawod, Luho, Ilaya and Proper, the main source of income is rice farming largely from rainfed areas. Around ninety percent of farmers in this community are small landowners having at least one hectare of farmland on the average. The minority are landless peasants who provide skills and labor for agricultural production.

Low production, high cost of chemicals and inorganic fertilizers, poor roads, lack of a local credit system that exacts low interest rates from farmers, plus a host of other socio-economic, political and other problems have plagued local farmers for years. This has made people in Agcabugao feel indifferent and apathetic towards any development endeavor locally initiated whether by the government or other agencies.

Strong cultural values have greatly influenced the people's attitude of resignation. The people only have a clear sense of community spirit during fiestas, political activities and other local events. Other than these, people continue to live with a feeling of helplessness. At present, they do not believe they are capable solving their problems much less develop their community.

II. History

The people in Agcabugao expressed their interest in organizing themselves and undertaking the development process partly because of the positive effects of a pilot Development Assisting Center (DAC) project which started in nearby Bun-od. which started in 1983.

With the entry of the Community Development Worker (CDW) in Agcabugao in 1986. a group of interested barangay residents started to emerge through formal and informal meetings with the CDW. This initial working group went through the process of problem identification. prioritization. analysis. selection of a problem. planning and implementation of the seed project. The seed project selected was construction of sanitary toilets. It took almost 7 months of community organizing before the construction and installation of the toilets. This project benefitted 55 involved families in the community. To date. about 40 people comprise the community core group all of whom were initially part of the working group.

As part of the process that the community people together with the core group underwent. they identified health training as an urgent need in the barangay. The baseline data which the core group (CG) gathered showed incidence of water-borne endemic diseases which actually affected 90% of the residents - mostly their children. The people's main source of drinking water is an open dug well. A very small percentage draw water from few springs and jetmatic water pumps in the barangay.

The built-in training component of the DAC. which is based on need. has raised people's consciousness not only in the area of health. but also in agriculture and income generation projects (IGP). value formation (spiritual nurture) and networking. The DAC model emphasizes people's sharing of ideas. concepts and experiences.

The DAC concept is that people in the community can and must take responsibility for their own future. Hence. things are not done for the people: the people are encouraged to develop their own potential for problem solving.

III. Infusion Process: Adopting New Technology

Based on the experience of the people in Agcabugao, the following were considered as the critical factors in facilitating the process of infusion and adoption of new technology in response to a specific felt need.

1. Community Development Worker-Facilitator of Development Process

   Integration of the Community Development Worker in the community. Since the CDW worker lived in the same community which she sought to serve, she was able to build a trusting relationship with the local people. Informal sharing and discussion heightened people's awareness of their problems in the community. This also opened opportunities for discussion of possible solutions. The CDW met with the people in their context whether at home, on the farm or in social gatherings. Respect and trust began to build. A group of concerned and interested people formed a working group which later became a core group. This core group facilitated the development process in Agcabugao.

   Crucial also in the role of the CDW as change agent, was her own facilitating skills. The CDW, herself a Civil Engineer, earlier completed a seminar/workshop on the technology of FerroCement Rain Water Cistern Systems tanks. This was piloted in the Capiz province and hosted by the Capiz Development Foundation, Inc., a locally-based private development agency. The provincial government, thru its Provincial Planning and Development Office (PPDO), is responsible to monitor the transfer of this technology at the barangay level. In recognition of people's capacity to manage their own development, the CDW served as an enabler or facilitator in the entire development process.

2. People-based development process facilitates effective problem solving and mobilization of resources.

   The people-based development process facilitated problem solving, mobilization of resources and attainment of the articulated goal. After a series of both formal and informal meetings with the community people, following the initial sanitary toilet project, the people started to respond to other health problems. This eventually led to a discussion of the lack of potable water in the community. Baseline data were gathered by the CG as to the seriousness of this problem. Trainors were then tapped from the local Rural Health Unit to raise people's awareness of the importance of potable water. These training sessions were well attended by the community people as CG members facilitated the dissimination of information to others.

In the planning phase the CG identified the urgency of the problem of unsafe drinking water affecting 150 school children of Agcabugao Primary School. Options identified were to 1) Utilize a spring water system. 2) Install jetmatic pumps. and 3) Adopt the ferrocement rain water cistern systems technology shared by the CDW. From their training. other measures for proper storage of drinking water were shared and discussed.

The CG members. who were themselves active leaders of the school's Parents Teachers Association (PTA). identified the need to put up a ferrocement rain water tank on the school grounds to benefit the school children. The PTA coordinated with the Barangay Council who in turn linked up with the provincial government and CDFI for the supply of construction materials and a grant of technical assistance.

The PTA together with the CG. faculty members. and the CDW met with all affected parents of said primary school. The group expressed support in solving the problem identified by organizing themselves into several committees. Prior to actual project construction. the goal. plans and strategy were claimed by the community as theirs.

3. Need-based project ensuring mass support.

Involvement of community people from the beginning of the problem identification and planning stage enabled them to respond to their own problem.

After arranging for the material and labor necessary for the completion of the project. the work schedule was formulated by the people. Parents worked by grade levels. i.e.. parents of Grade I students worked on the first day. Grade II on the second and so on until the fourth and last day. By the end of the fourth day. the 10.000 cubic-liter ferrocement tank was completely finished.

The proper use and maintenance of the tank was discussed and agreed upon by the people. Guidelines for its use were formulated and accepted by everyone.

Primarily. the tank will benefit the school children. During summer when water is scarce. the community can draw water for drinking from the tank.

4. Maximization of Local Resources and Networking with Other Agencies

The four-day construction period started daily with a one-hour period of technical trainig by the CDW. The rest of the day was devoted to actual construction of the tank.

The community provided labor and all the needed locally-available resources. Fathers were directly involved in the construction. Mothers and youth joined hands in food preparation. Food was prepared locally. Four sacks of rice came from a private donor agency involved in a "Food for Work" program. School funds paid for the needed gutter for the water tank. (See Table I)

Effective planning and mobilization of the community accounted for the impressive accomplishment of constructing the ferrocement rain water tank in only four days.

TABLE I

PROJECT COST
(Agcabugao FerroCement Tank)

Community Counterpart	Government	Private
Core Group/PTA * bamboos * tools * labor * food * networking	Provincial Planning & Devt. Office (PPDO) * technical assistance	Capiz Development Foundation, Inc. (CDFI) * construction materials * tools * technial training
Youth * labor	Brgy. Captain/ council * networking	United Nations - World Food Program * food for work (4 sacks rice)
	Rural Health Unit (RHU) * trainings on health	World Vision * CDW technical asst./skills * welding expense P30.00 only
	Primary Elem. School * gutter	

Following the construction the provincial government through PPDO and CDFI gave the people of Agcabugao a special commendation for their successful community undertaking.

The completed water tank not only serves its purpose but other projects are now underway resulting from a deepened awareness of the potential for further community development. In the other areas, the core group continues to initiate holistic development efforts that respond to the real needs of the community.

5. Simple technology allows easy process of transfer.

The technology employed in the construction of the ferrocement water tank was readily adopted by the community with technical assistance from the CDW. Though ferrocement technology was unfamiliar, the people were encouraged to attempt it by the simple instructions and step-by-step procedures provided. After the completion of the tank they took pride in seeing that they were able to accomplish the construction.

One possible limitation presented by the ferrocement water tank is the need for galvanized roofing from which the catchment gets its supply of water during downpours. Since the only structure in the barangay which had a galvanized roof was the primary school this was the location selected. It was a good location to showcase the new technology since the primary school is the center of community interaction.

"Starting where the people are" should be our guiding principle not only in technology transfer but in all development work.

6. The role of women in development

The composition of the Agcabugao Core Group is 95% women while the same serve also as the PTA Officers and active members.

In this specific project alone, the water tank was fully supported and endorsed by the women who were also the interested mothers. Their children's health is, of course, a priority to mothers. Fathers who are often busy in the farm rarely have the time to attend formal meetings. But women related to their husbands all the technical input, concepts and ideas discussed in meetings and even facilitated the involvement of everyone in the household including youth and children in any possible development undertaking.

Thus, as this water tank was under construction, it became evident that the women played a key role in organizing and involving the community for this undertaking. Virtually all residents took part, even the children who ran errands. Fathers were directly involved during the actual implementation and expressed support for any future development plans for the good of the community.

IV. Impact on People's Lives

* The relationship among community people was strengthened.

* Consciousness raising by way of training helped people see their problem as solvable and enabled them to plan for solutions.

* Sharing roles in development among community people, government and private agencies contributed to the success of the development undertaking at both the micro and macro level.

* The people's goal, sense of ownership, dignity and worth was viewed as a significant product of the people-oriented development process.

* The value of cooperation, sharing, honesty, and resourcefulness were strengthened and reinforced by the spiritual input given by the CDW.

* The wholistic approach to development recognizes the importance of value transformation and re-orientation as part of the process.

* By building on people's small successes, they will continue to internalize the development process as they embark on bigger plans in the future.

* The radiation effect of the community's development efforts will also be a means to challenge others and to raise the awareness of nearby communities concerning development and to effect change in their lives.

V. Recommendations

1. The need for more simple. appropriate technology that maximizes the use of locally available resources can be adopted by communities according to their NEEDS. Indiginous resources should be maximized.

2. Local Community Development Workers both private and governmental should avail themselves of technical training that will broaden their experience in facilitation of options for the community to select from.

3. A constant sharing/discussion/interaction during the project undertaking is critical to the adoption of new technology. Networking should be enhanced and strengthened.

4. There should be a deeper study and analysis of how to maximize the role of women and their significance in contributing to development.

5. In order to insure the sustainability of the project there should be a built-in education process that orients people to the proper use and maintenance of the product of their labor. This will make them feel responsible for its long use.

6. For any technology transfer to be mass-based and supported by the people. it should be done within the context of a development process. where people are the main actors. decision-makers. and shapers of their future.

The successful completion of the Agcabugao ferrocement rain water cistern systems tank illustrates the potential of community-based action. With proper technical organization. technical expertise. planning. thorough networking and timely execution such projects may not only meet an immediate need but also set the community on the road to further development in the future.

AN ABSTRACT

COMMUNITY PARTICIPATION AROUND THE FERROCEMENT RAINWATER COLLECTORS: THE CAPIZ EXPERIENCE

by Jessica Calfoforo Salas, Ed.D.

This paper is presented to highlight learnings on community participation from the experience of the Rainwater Collection Project: Philippines sponsored by the International Development Research Centre (IDRC-Canada) and implemented by the Capiz Development Foundation. The experience is significant because inspite of prevalent poverty in this province, certain communities were able to demonstrate the value of participation in acquiring benefits from a new technology: the ferrocement rainwater collectors. The experiment started with 30 ferrocement rainwater tanks built in 3 pilot areas and, 3 years later, 300 rainwater collectors spread throughout the province without any program for technology dissemination.

Several sad and happy episodes in community participation were studied. This paper presents story summaries about 3 communities whose group life and growth were facilitated by the need for water and the concern for rainwater collectors.

The experience underlined the different roles played by people's organization, the rainwater catchment technology, health and sanitation practices, participation of women, livelihood and income, and extension to other group projects; in community building.

Elements of learnings were found in: (a) participation, an abstract process, was expressed by rainwater tanks in a concrete fashion (b) basic need of man -- water in this instance -- can either become a railying ground for cooperation or a source of frustration and despair (c) intervention in terms of awareness exercises, leadership formation, self-reliance schemes, skilled facilitators, and carefully planned program of implementation and follow-up is necessary (d) continuing education helps sustain interest and level of awareness (e) countervailing cultural factors, not carefully studied and handled, can affect the process of intervention.

Further to this experience tells of the need for fusion (partial though maybe) of perception about and feelings toward the situation, problems and aspirations in life. This fusion of perception could be brought about by fusion of group expectation and what may actually happen. A repetitive experience in this fusuion could perhaps bring about a higher degree of unity of perception which could lead to cooperative work.

COMMUNITY PARTICIPATION AROUND
THE FERROCEMENT RAINWATER CATCHMENT SYSTEM:
THE CAPIZ EXPERIENCE

INTRODUCTION

Capiz is a province in central Philippines whose economy is basically agriculture but the incidence of poverty is one of the highest in the region. In 1985, the estimated the region's poverty incidence of 73.2% was the second highest in the country. (National Economic Development Authority, 1985). As in the other parts of the country, Capiz receives low government input for social services relative to the need of the province. This is particularly true with water. The province today has only 2.73% only of its rural household served with faucet community water system. (1980 Census of Population and Housing, NCSO). Seventy nine per cent (79%)of the water sources still come from dug wells where potability is never questioned nor ascertained by the rural folks. (1980 Census of Population and Housing,.NCSO)

In 1984, a research on rainwater catchment system using ferrocement tanks was initiated and funded by the International Development Research Centre (IDRC) Canada. In this project, 30 rainwater tanks were to be established in a pilot-scale basis with specific emphasis placed on community involvement and participation. Details of this pilot project are described elsewhere (Appan et al, 1989). However, without any purposeful dissemination plan, the number of tanks increased from the experimental number of 30 tanks to 300 tanks to date.

What has caused such phenomenal increase? Some groups have requested private donors to assist them build ferrocement tanks for the children at school, for the health centers in the villages and for households.

In some villages, small groups were formed around the ferrocement tank with peopole sharing water and sharing labor for the tank's maintenance. In some places, the tank is seen as a conspicuous edifice in contrast to a background of nipa and bamboo houses surrounding it. But such edifice is a monument of the cooperative work the group has undertaken and a symbol of life -- drinking water --for the people.

While it is not, in all cases, that the ferrocement tank assumed such high value, (except probably for the poor who could not afford to have one unless acquired through group self-help efforts), it is worthwhile examining how and why did this level of participation occured.

This paper presents a summary story of three different group- lives around and with water tanks. An assessment of the elements of community participation found in these studies is presented to give an idea of its profound impact in implementing such systems.

CASE 1

MALOLOC AND ITS WATER SITUATION

Maloloc is a rural village nestled in a mountainous area 15 kilometers from Roxas City, the capital of Capiz. The common source of income of these people is farming. The village has four sitios or area divisions. Two out of these four have very serious water problem. In the whole village, only one artesian well was operational. The main sources of drinking water were open shallow wells in the barangay and in the next village. During the rainy season, water covered the open well which were frequently dug in between the rice fields. Water pumps served some households which could afford them.

The People's Organization.

The people's organization at Maloloc started in 1986. The main motivating force which led these people to join the group, as expressed by them in one focus group interview, was their desire to give their children a good future. According to them, they had no fixed source of income and they were unable to send their children to school. They also considered that by joining the organization, they could be able to find some of the solutions to their existing problems.

The community workers of the Local Resource Management (LRM) Program implemented by the Capiz Development Foundation, gathered the villagers into a barangay assembly to discuss about the situation of their village, their problems, and how they could possibly work together to find a solution to their problems. The villagers agreed to attend a series of meetings. Soon, ten community organization volunteers were selected out of the many who were willing to serve the organization, to undergo a two-week long intensive training in leadership and the officers of the organization were elected by secret balloting. After the officers were elected, the group planned to embark on a project. The first project they chose was a communal garden, the produce of which was to be sold to provide income to the organization.

Conflicts.

In the process of struggling for group cohesiveness, some conflict with the barangay officials occurred. The village officials were apprehensive of the community activity going on, wherein they were not the leaders as it was not customary in the past. The group then decided to undertake an activity to respond to their most serious need which is the lack of water supply. For this project, the village officials were asked to get involved.

Building of ferrocement rainwater tanks.

The group's decision was to use the ferrocement rainwater catchment tank. The village officials looked for resources for the ferrocement tanks. The catchment units were then built for the school, for the health center and for individual households desiring to own one, as the members provided labor. This was the beginning of a cooperative and harmonious relationship between the organization members and the village officials.

The role of women.

Building a tank is a process which necessitated cooperative work. Volunteers, men and women, were trained in ferrocement. This team, composed of 10 to 11 persons, then moved from one site to another to build the tanks.

Most members are women inasmuch as the men have to stay in the fields or to work as laborers. Even in constructing tanks, The women enjoyed a new kind of work which is constructing water tanks, although they had to ask the men to help them carry heavy materials and do laborious job such as mixing sand and cement. When asked whether their new found preoccupation in the organization created trouble in the family, the women answered that they explained to their husband what they were doing. In most instances, the husband would be appreciative.

The activity of building tanks reinforced learning on cooperation because of the concreteness of the output of teamwork. As soon as the ferrocement water tanks were built, the organization continued to periodically inspect and maintain the tanks and the catchment parts.

Extension to Other Projects.

Seeing cooperation at work, the group continued to embark into other projects. They put up a cooperative store which buys and sells to the members, merchandise basically needed like food items, fertilizers, and other household necessities.

The organization likewise learned to be sensitive to the needs of its members. The village was a recipient of a low-cost housing program after two typhoons devasted the province in 1987.

The housing units were given to the organization and the group decided to give it to those who were in dire need, the poorest in the village, even though they were not members of the organization.

Participation continued in this small village as seen in the regular meeting held where some members have to walk for two hours from their sitio (a unit of a village) just to attend the meeting.

A socio-economic survey.

In one focus group discussion with the members, one question was asked: "What is a community?"

The following were the translated responses of the villagers:

Ana: "Wholeness in the village."

Jose: "The whole barangay consulting each other, thus knowing what the whole problem is all about."

Sasing: The people in the barangay takes part and cooperate in all activities of the barangay."

Belding: "This barangay cannot be called a community if people are individualistic. While we work for our families, we should also work for our community."

Mila: "There is community because when the barangay captain calls for a "bayanihan"(cooperative) activity and the men could not come, the women work to take the place of men."

CASE 2

THE SMALL ORGANIZATIONS AT BARANGAY CULASI

Barangay Culasi is almost five kilometers froms the city of Roxas. It is along the shoreline. The place is accesible to various means of transportation like the "jeepneys" and the "tricycles". The roads are cemented and well kept. Houses are very close to each other and mostly made of light materials.

Activities at Culasi.-

The people of Culasi are hardworking people. Men, as well as women, indulge in livelihood activities. The main sources of income for the people are fishing and handling cargo at the port. It is in this village that the Roxas Port is located and where ships from Manila, Romblon, and Masbate, dock. The coordinated efforts of husband and wife working side by side for the upkeep of their family is very noticeable. People are hard working and they love their work. The average monthly income is P1,000 a month. Work, however, is at peak when ships are coming and that is not everyday. People still enjoy interacting with each other.

Water Facilities.

Near the modest port complex of the province is a schoolhouse for children and right at its front yard is a 10,000 liter tank which the Parent-Teachers Association owns. The tank was to provide drinking water to children in the school, the members of the organization and some of the villagers. The women members built this ferrocement tank three years ago.

At Culasi, water is usually sold in cans. A water tank of 4,000 liters which costs P4,000 is usually owned by middle-income households. The big water tank at the school provided not only free water to the school children but also savings to the members and other villagers who would have bought water from other tank-owners. The income of the organization is used to support the maintenance of the tank, and the wide roof and gutter of the school building and other special projects for children.

Along the seashore, still at the Village of Culasi, there are four other small water tanks owned by four different groups having six to eight members. While the tank is attached to the roof top of the house of one member, members of the group share water and help clean the gutters and tanks for maintenance. More often, water is also shared with non-members when they could not obtain water from other sources, which is usually a shallow open well.

Need for Cooperation in Use of Water.

Why the unusual cooperation for water? A look at the water situation of the village is disheartening. Drinking water is normally bought at P2.00 to 5.00 for a 4-gallon container. Only the middle-income families could afford to put up a galvanized or a concrete tank to collect and sell drinking water. Shallow wells are dug but water is saltish. It can only be used for washing and bathing. Water from wells are salty. In areas off the shorelines, water is colored red and heavy with mineral content. Only few deep wells can be dug because of a stone or rock base beneath a few feet from the surface soil.

Sanitation Facilities.

Those who can afford to dig open well use water from this source or washing, cleaning, and sometimes drinking if rainwater gets expensive. These wells were not subjected to examination by the city health office. In many instances, children suffer from stomach pain which is easily dismissed as one of those ordinary discomforts.

The surroundings of this barangay, looks clean but only few families have sanitary toilets. The people utilize the sea as the public toilet. The neighborhood has no central garbage dumping area. The garbage truck comes once a week to collect garbage. Oftentimes the people could not wait that long and garbage has to be dumped into the sea.

Culasi is basically a clean barangay but one reason why people cannot build toilet is that wells for washing are found in almost all households along the shore and houses are located very near each other. People are aware of the harmful effects of unlcean water, but there is no less expensive source of potable water. One has either to buy rainwater, or boil water which costs the same.

Group Interviews.

During the group interview, participants were asked of their concept of community participation. Many expressed that they can do many things if given opportunity. This untapped potential can be utilized not only for their ownselves but also for others. They claimed that their concern for each others was exhibited through their participation in the water project.

Women's Participation.

The women took the frontline again during the training for ferrocement technicians. According to them, they have learned so much during the training which usually is only for men. They said that they have learned to recognize sizes of iron bars, mesh wire, and even how to mix cement. The husbands or the men in the group also recognized the importance of the participation of women. Besides, the women were happy that they were involved in the construction because they felt that they were part of the group. They set aside other household jobs just to be able to assist during construction. They were very proud that they were partners of their husband in community development.

CASE 3

THE BASIAO SMALL FISHERMEN AND LABOR ASSOCIATION

Twenty six kilometers from the Capiz Provincial Capitol, is a fisherman's village sprawling along the coast of a white beach. As one approaches the barangay, one can feel the cool breeze coming through the mountain. The view of the barangay at the foot of the mountain breaks the long trail of rolling hills and green bamboo plants.

The village has a total land area of 100 hectares divided into six sitios. However, only 5 public vehicles, the "jeepneys" can take the route to Basiao because of bad roads.

Livelihood.

Ninety per cent of the people in this village depend their livelihood on fishing. Fishing boats are just anchored along the shore. At nighttime, flickering lights from fishing boats at work look like a carnival at sea. People are very industrious and they work day and night, even in stormy weather, whenever opportunity needs them. For lack of capital, the villagers still remain poor.

Water Situation.

For the whole barangay, only two water pumps are the sources of fresh potable water. During summer, all the residents, totaling 1,904, get their water supply from these two pumps. Other villages, such as those coming from Culasi or from other islands still come to get their water from these pumps and the water is sold by the owner of the land. The story goes that the government installed the water pump, but the landowner claimed it to be his own since the pump is on his land!

Drilling wells on the rock is very expensive and the water from shallow wells is salty as sea water sips in. Hence, people resort to rainwater catchment tanks, aluminum tanks, concrete tanks and others. There are 40 open wells and 25 pumps in the village which are used for washing.

Formation of Association of Fishermen.

As this association was formed, the people decided to build their water tank. Three communal ferrocement tanks were built for the association members, for the chidren at the school, and for the health center of the village.

The group's growth was surrounded by problems but the people persisted and their group cohesiveness only get stronger. The first problem they met with was when they decided to put up an artifical reef for Lapu-lapu, a special kind of fish. The association wrote to one large Corporation in the country and asked if their used tires be given to them to be made into an artificial reef. This corporation willingly obliged and sent them the used tires. The fishermen and the womenfolk, especially, made these tires into some structure and painstakingly brought them out near one small island and plunged them into the sea, four fathoms deep. The fishermen were very optimistic that Lapu-lapu will breed in these rubber structures -- their artifical reef -- and this will help them improve their living condition. One day, however, the fishermen found out that their artificial reef was bombed by one of those dynamite fishermen even before they were able to make their own harvest.

Dynamite fishing compounded the problem of this village and this new organization got its first challenge. In a group interview with the officers of the association, the officers presented their problems and how they struggle for a solution as a group. Dynamite fishing, for example, is not a simple matter to be solved by the system of having fish wardens because it is related to politics and sea piracy. The village also has problems of sanitation 40% of the households use open toilet and 20% do not have any. The midwife, who was present during the discussion reported that the latest "Operasyon Timbang" showed that 107 children in the barangay were in the first degree malnourished stage; 45 children, second degree; and 5, third degree.

Rationale of Committment to Organization.

The officers were asked why should they continue working for their organization in the face of poverty and very difficult problems they face. The immediate past president of the association responded, "We have invested so much of our time and emotional commitment to this organization. We cannot afford to let it fail." The seriousness in the face of the other officers echoed the sentiments of his group.

At the nearby chapel stood a communal tank of rainwater filled to the brim and carefully covered with plastic sheet. It was mid-summer, and here, 10,000 liters of rainwater stood untouched. One member explained that the water is scheduled to be rationed next week, just before the "fiesta".

The people's organization at Basiao is one kind of organization which clearly grow strong as it is challenged by problems.

LEARNINGS FROM COMMUNITY PARTICIPATION IN THE CAPIZ EXPERIENCE

Development of participatory groups is not an easy straight line to construct. To some, the fastest way to group cohesion is through a maze of critical problems and even failures, as in the case of Basiao, while some groups needed continuing activities for awareness and team building.

One unique feature of these groups at Capiz is that they revolve around water which is a basic need of man.. To some groups, the structure of the ferrocement rainwater catchment unit which the groups and individuals have acquired through participatory effort, stood as a monument of their cooperation and group work. Everyday, that edifice reminds them of what they have gone through and of who they are. To some groups, however, the huge tank reminded them of their failure.

The serious need for water in this aprovince became a rallying factor for group work. In other parts of the province, however, this serious need became a source of frustration which created adverse attitude towards the program.

Effective training, continuous leadership formation, encouragement of volunteriism, and exercises in valuing for teamwork resulted in the formation of strong groups. Interpersonal communication used for organizing proved effective in many cases. These are in the form of person-to-person approach, household visits, informal group discussions, and formal village assemblies.

Skilled facilitators or community workers are required. They implement a well-thought plan of entry to the barangay and have their activities monitored and analyzed. On the other hand, inadequate input and unclear scheme of follow-up activities resulted in the disintegration of some otherwise potential groups.

Situations and alternatives were presented to the community members. These alternatives were clearly understood by the members and this enabled them to arrive at a rational decision.

Continuing education on the potability of water and health practice is also crucial for valuing the water system.

Many individuals could not see the need to be organized. Organizing is not seen as a pirority activity. To bring awareness, several activities may be used. The seminars and training for community volunteers used at Capiz are only one of the several techniques available for raising awareness.

Formal and informal leadership at Capiz were strengthened by the introduction of the project. There were places where these types of leadership were already strong. Effective leadership facilitated a strong organization and project implementation. On the other hand, the lack of a continuing mechanism for community interaction and cooperation because of weak leadership leads to group disintegration. In many villages, the formal leadership of the elected village officials proved ineffective. Sometimes, informal leaders could not emerge because of restraining political and cultural forces.

The existence of problems proved as effective catalyzers which heightened group cohesion. This was because of:

a. frequent meetings and discussions about the problem

b. support from other institutions and groups, within or outside the village

c. high consciousness of responsibility amongst leaders and members

d. volunteerism considered as investment of time, energy, and effort into the organization.

e. expectation of a concrete benefit from the organization

f. Unrealized expectation of benefits from the organization meant loss of invested time and effort to members.

BEYOND THE EXPERIENCE

A visit or a new experience is often translated into a new insight. Oftentimes, color, shapes, and numbers are forgotten, but the meaning remains.

The three cases cited were unique in their own way. The first was a large organization in the community, yet members see problems and solutions in unity. The second case was a village with several small groups engaged in participatory activity. It worked as well. The third group is assailed by problems but is still getting strong.

The common element in the three experiences is fusion. To a certain degree, individuals in a group share the same perception and share the same feeling. The extent by which individuals share the same perception and feeling determines the degree of participation in a group. This could be applied to looking at the situation, at the source of the problem, or at their aspirations in life.

Another dimension of unity could be the fusion of expectation and realization. What do group members expect of each other and of their group? Are these expectations realized? The closer the two, the less varied will be the perceptions of group members. This is an insight beyond this experience which perhaps future activities and other scholars could take a look at as the world learns more and more about community participation.

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SOCIO-ECONOMIC

AND

POLITICAL ASPECTS

RAINWATER USE IN BANGLADESH-- A CASE STUDY IN DACOPE UPOZILLA

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ABSTRACT

This study describes the present system of rainwater collection and storage facilities, the socio-cultural and economic aspects of rainwater use.

During the months of October to November, 1987, a three-week case study on rainwater use was conducted in Dacope, Khulna, a coastal region of Bangladesh. Since the area is located very close to the Bay of Bengal, both ground and surface water contain undesirable level of salinity. Drinking water was an acute problem in the area. Normally, people of Dacope use water from pond, canal/ditch, river, tubewell or rainwater, depending on the availability. The study reveals the fact that a large number of people of the area has been drinking rainwater. People drink rainwater in the rainy season. But in the off-season they hardly drink rainwater because of lack of proper storage facilities. Roof discharge was a common method of rainwater collection. Gutters ,made of G.I. sheet, bamboo, betel nut tree and bark of banana tree had been used widely for rainwater collection. People store rain water in large earthen vessel. They periodically maintain the quality of stored rainwater using burnt snail shell.

The survey also indicated that about 75% of rainwater consumers preferred to have large storage facility although most of them could not afford it. Cost of rainwater collection was found to be Tk 0.29 per litre, which was the lowest among all water sources. An appropriate rainwater storage facility may solve drinking water problem in the area.

INTRODUCTION

Bangladesh is located between latitude 21 N to 26.5 N and longitude of 88 E to 93 E (Fig. 1). The country is blessed with high to very high rainfall in monsoon (Talukder 1982). Rainfall starts from the month of April and lasts up to October with 95 percent precipitation. Besides ground water, there is abundant water supply in ponds, rivers and canals in the rainy season. These surface water sources are not usually suitable for drinking. Nevertheless, a large number of people especially citizens of rural Bangladesh has been drinking water from these sources. They drink contaminated water because of the unavailability of pure water nearby. As a result, significant number of people die each year or suffer from water borne diseases. About 85% of the total population of the country has problem with drinking water and general sanitation conditions. The problem is very serious in the coastal belt (southern part) of Bangladesh where both surface and ground water contain high level of salinity. About 18% of total population live in this coastal area (Statistical Year Book of Bangladesh 1983). Furthermore, the problem of drinking water is also acute in other parts of the country, such as, hilly areas, forest areas etc. The problem intensifies during dry season and flood time. Drinking water for human consumption should be easily available, clean and free from contaminations. People living in coastal and hilly Bangladesh have been collecting rainwater as a better source of drinking water since the time immemorial. But no specific study report on the use of rainwater for drinking purpose in the region was available. Therefore, an attempt was made to investigate the rainwater use, socio-economic aspect, and the scope of developing the rainwater catchment facility in the country. A case study was conducted in twelve different villages of Dacope upozilla of coastal Khulna in Bangladesh. The objectives of the study were:

1. To study present system of rainwater use and storage systems.
2. To study the socio-cultural and economic aspects regarding the use of rainwater and water from other locally available sources.
3. To perform a comparative cost analysis between rainwater use and the use of water from other available sources.

METHODOLOGY

The study of rainwater use was conducted in twelve selected villages in Dacope upozilla of Khulna district of Bangladesh. After a series of discussions with a sociologist, an engineer and an economist, an appropriate questionnaire was prepared to collect primary data. The selection of sample from each village was based on the cluster sampling technique. The villages in the study area usually consists of 2 to 3 "para"s. "Para" is a local name of a distinct cluster of households within a village. A sampling unit, in this case a single farm household, was selected randomly from each "para" to produce the study sample. Finally, within each selected household, the family leader was chosen to be the interviewee. Key individuals included in the interviews were the village school teacher, members of village committee, common labourers, different categories of farmers and non-farmers. A total of 36 farm households were interviewed from 12 different selected villages. The primary data as collected through questionnaire was compiled and analyzed to draw valid conclusion.

Present Condition of Water Use

In general, the inhabitants of Dacope upozilla use water from the following sources.

1. Pond
2. Canal/Ditch
3. River
4. Tubewell
5. DPHE-UNICEF sand filtered facility and
6. Rainwater

Table 1 shows the present condition of drinking water facilities in twelve villages in Dacope. About 49% of tubewells was found to be out of order (Department of Public Health Engineering 1986). Furthermore, 41% of remainings (workable tubewells) was not using because they discharge water with undesirable level of salinity. On the other hand, 45% of DPHE-UNICEF sand filtered facilities was found to be idle. Fig. 2 indicates the consumption of drinking water in different seasons. In the rainy season largest group of people preferred to drink rainwater, on the other hand, most people used to drink water either from pond or tubewell in the dry season.

1. Pond : Pond water had been using in many villages for drinking purposes as well as fish culture and cattle feeding. They were usually encircled wrth big and small trees. The water in the pond was normally not pure and considered hazardous for human health. People usually drink pond water without necessary pre-treatment. However, only a few people treat pond water before consumption. The pond water remains soft between the period of May to September and then gradually becomes salty in rest of the period of the year. In Dacope upozilla headquarter, reserved pond water was pumped to over head tanks for water supply in local offices.

2. Canal or ditch : Almost all the villages have canal nearby or small ditch within the house premises. Ditch water was used for washing utensils and canal water was used for taking bath. Canals or ditches were also used for fish culture. The villagers construct open toilet on the canals. As a result, canal water becomes contaminated. It was also reported that a few villagers collected water from these canals for drinking purposes because they were a bit lazy to fetch water from other distant water sources.

3. River : Normally, river water in the area contains high level of clay particles and salt. Most people living near the bank of the river have no other alternatives but to drink river water. People living in the area were very poor and they lived under thatched roof. Salinity level of river water goes up during dry season.

4. Tubewell: The installation of shallow tubewells was successful only in limited areas. Table 1 indicates that about 41% of workable tubewells remained idle because they discharged water with undesirable level of salinity throughout the year. About 49% of total tubewell was out of order.

5. DPHE-UNICEF sand-filtered-facility : A joint program with the Department of Public Health Engineering (DPHE) and UNICEF was undertaken in Dacope and the nearby areas to provide better quality of drinking water. This program included establishment of a sand filtered tank of 2m × 2m × 2m size. A reciprocating hand pump pumped water from a pond to the tank containing sand and coarse aggregate. The function of the tank was to filter the water rather than store it Several discharge tapes were connected near the bottom of the tank where people got filtered water.

Since ground water contains undesirable level of salinity, the hand pump took water from a large pond instead of ground water. The salinity level of DPHE-UNICEF sand filtered water gradually increased in the dry season. As a result, people somewhat became reluctant to drink the water.

6. Rainwater : It was reported that during rainy season (May to September) villagers harvested rainwater for drinking and washing purposes. Some people collected and stored rainwater for the whole year and others stored it for couple of days to several months, depending on their economic conditions. During rainy season local roads become muddy and unsuitable to walk. At that time people cannot walk to fetch water from other sources. Normally, villagers collect rainwater both for drinking and cooking purposes

RESULTS AND DISCUSSIONS

Rainwater Collection and Storage

This study revealed that the rainwater have been used for drinking purposes since the time immemorial at the coastal district of Khulna in Bangladesh. Most people used to drink rainwater in the rainy season but a few household consumed rainwater throughout the year (Table 2). The storage capacity ranges from 32 litres to 5376 litres. "Motka" and "kalshi" were the only popular rainwater storage facilities available in the area. Roof discharge was a common method of rainwater collection. Gutters made of C.I. sheet, bamboo, betel-nut tree and bark of banana plant had been using widely in the rainwater catchment system (Fig. 3). Some household who have no C.I. sheet or tile roofs also collected rain water for drinking purposes. They used a rectangular sheet of polythene paper, a bed sheet, a clean "saree", an inverted umbrella or a mosquito net under open sky (Fig. 4) as a rainwater collector.

"Motka" was usually used by rich people and for long term storage. These were semi-permanently placed inside or outside the house depending on the motivation, education of the household members the quality of stored water also vary. The author who visited the study area found two households of Mollick bari in the village of Sutarkhali, Dacope so enthusiastic that they stored rainwater in large "motka" for year round consumption. They took out water with a pre-cleaned small pot and kept the "motka" closed all the time. Sometimes they also supplied water to their neighbours whenever necessary. They developed a technique to maintain the quality of the stored water and treated it using locally available material. The authors found the quality of the stored water highly satisfactory. They put snail shells in several layers; in between the two layers, cowdung, straw or rice husk were placed. Rice rusk was spreaded over the setup and the lot was burnt gradually. The burnt shell was collected and used to maintain the quality of stored rainwater. They put certain amount of burnt shell into the "motka" containing rainwater at least once a month. It is believed that the calcium or its compound of the burnt shell is the main element which purifies the water. This method was found to be very effective but was practised by a couple of households only. However, most households having limited storage capacities found difficulty in maintaining the quality. Mosquito larvae and other insects developed within two weeks in the stored rainwater. A special kind of fish locally know as "koi","sing" or "magur" was allowed to grow in the stored water which in tern ate the larvae of mosquito and other similar insects. "Koi" (Anabas Testudinews), "sing" (Heteropneutes Fossils) and "magur" (Clarias Batracnus) are common fishes available in Bangladesh. On the other hand, fish discharges its own excreta in the water which again deteriorated the quality of the drinking water.

Some consumers drink rainwater simply by filtering the water. Few families treated water using chemicals such as alum, lime or water purifying tablets. Sometimes people found frog, toad and dead body of rodents, lizards, cockroaches etc. in the stored rainwater. This was due to their improper storage practices.

Social Aspects of Rainwater Use

Besides drinking, people also consumed rainwater for other purposes, such as cooking, bathing and washing of clothes. Some households used rainwater for cooking purposes. They also reported that vegetables, pulses or rice cooked by rainwater tasted better. Several conscious users pointed out that since rainwater contains no essential minerals necessary for human body, it is not good for continuous consumption. However, some people drink rainwater only because it tastes better.

During rainy seasons, road becomes muddy as a result of continuous rain fall. It is hard to go outside the house to bring drinking water. Therefore, people prefered to collect and drink rainwater during rainy season within their houses. Some villagers become physically resistant against the health threatening agent usually present in the pond water, river water and canal water. Thus, it was difficult for them to realize the difference between pure water and impure water. In other words, people hardly differentiated the effects of drinking pond water, rainwater, river water or tubewell water. However, some people did realize the benefit of drinking pure water. Table 3 shows the percentage of households using different sources of drinking water in Dacope, Khulna.

About 75% of rainwater consummers prefered to build better and larger rainwater storage unit for private use. Only economically solvent households which possess more than 5 acres of land showed their interest of building such a facility. However, farmers possessing less than an acre of land preferred to have a drinking water storage unit for community use. Most of the rainwater consumers assumed that it is the responsibility of the government to provide pure water to the villagers. Only a limited household wanted to get bank loan with a very low interest rate to establish a drinking water storage facility by their own provided that the process of getting bank loan be simplified.

Fig. 2 reveals the fact that the seasonal variation had a significant effect on consumption of various sources of drinking water. About 35.5% households (the largest group) had been drinking rainwater in the rainy season but in the dry season the figure fell down to 2.4%. About 2.4% households had been drinking rainwater throughout the year. This was due to unavailability of rainfall in the dry season and the lack of proper storage facilities. Table 1 indicates that a significant number of hand tubewells were not using because of the tubewells discharged undesirable level of salinity. On the other hand, about 45% of DPHE-UNICEF sand filtered facilities were not using or working properly, because of lack of proper maintenance and salinity problem.

It was observed that women and young ladies in the society had a significant role in collection of drinking water. The society assumed that collection of drinking water was solely a woman's job. Man collected drinking water only under exceptional circumstances. Sometimes women went down to distant places to gather drinking water with a "kalshi" on their laps.

Table 4 shows that the education level had also a significant effect on water consumption. People consuming DPHE-UNICEF sand filtered water, hand tubewell, rainwater, pond water, river water and canal/ditch water had 7, 6.13, 5.8, 5.46, 2.87 and 1.0 years of formal education, respectively. This indicated that educated or motivated people prefered to drink quality water.

Cost of Different Sources of Water

Table 5 shows a cost comparison of different types of water sources in Dacope upozilla. The cost was calculated on the basis of a consumption rate of 3 litres per person per day for a family of 7 members. Cost of drinking water storage facility, labor cost for collection, repair and maintenance costs and installation cost, wherever appropriate, were also considered. The per litre cost of providing better quality of water through hand tubewell, DPHE-UNCEF sand filtered facility and rainwater catchment method were found to be pretty close to each other (Table 5). The Table 5 indicates that the better quality of drinking water may be supplied from rainwater. Rainwater catchment method was found to be more ecinomic than the DPHE-UNICEF sand filtered system.

SUMMARY AND CONCLUSIONS

1. The result revealed the fact that the people in the area have been drinking rainwater since the time immemorial.

2. About 35.5% households have been drinking rainwater in the rainy season. On the other hand, 2.24% household drinks rainwater in the off-seasons only. This indicates that people will be willing to drink rainwater in the off-seasons too if appropriate storage facilities are established.

3. People who got thatched house could use a polythene sheet or a clean piece of cloth as rainwater collector.

4. Member of households should be properly motivated to maintain the quality of stored rainwater.

5. Regarding rainwater consumption, no significant of unwillingness between male and female, rich and poor, educated and uneducated person was found.

6. Rainwater do not have any essential minerals for human body, thus necessary additives (minerals) should be added in the drinking water, time to time.

7. The existing rainwater catchment method was found to be more economic than the DPHE-UNICEF sand filtered facility.

8. Proper collection and storage of rainwater could solve the drinking water problem where there is a serious problem for drinking water. An appropriate rainwater storage could be built to supply water upto the end of the dry season.

9. The rainwater could be supplied through plastic bottles during flood in Bangladesh. The further research in the Department of Farm Power and Machinery, Bangladesh Agricultural University, Mymensingh is in progress to design a suitable rainwater storage structure for rural people of Bangladesh.

ACKNOWLEDGEMENTS

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TABLE 1 Present Situation of Drinking Water Facilities in the Villages of Dacope

Name of village	Condition of hand tubewells					Condition of DPHE-UNICEF Sand Filtered Facilities			Pond ownership	
	Total no. of tubewells	No. of tubewells out of order	No. of tubewells in good working condition			Total No	No in good working condition	No unused	No of Public pond	No of Private pond
			No. used	No. unused because of salinity	Total					
Sutarkhuli	8	3	2	3	5	2	1	—	3	3
Anandanagar	4	2	2	—	2	—	—	—	—	—
Satgharia	—	—	—	—	—	—	—	—	—	
Khatail	4	2	2	—	2	2	1	1	—	1
Khona	3	1	—	2	2	1	—	1	1	1
Baruikhali	4	3	1	—	1	2	1	1	—	2
Chunkuri	18	9	8	1	9	1	—	1	3	3
Batbunia	1	1	—	—	—	—	—	—	1	1
Sahaberabad	3	2	—	1	1	—	—	—	—	7
Srinagar	3	2	—	1	1	1	1	—	—	2
Ramnagar	3	1	1	1	2	—	—	—	1	1
Burirdoba	2	—	—	2	2	—	—	—	—	2
Total	33	26	16	11	27	9	5	4	9	23

Source : -1984 office of Sub-Assistant Engineer, Public Health Government of Bangladesh, Dacope, Khulna & during inspection.

TABLE — 2. Rainwater Collection and Storage Scenario in Village of Dacope.

Number of households (persons)	Total rainwater storage capacity for drinking purposes only		Type and number of storage facilities (Type-number)	Method of rainwater collection (Type)
	for rainy season use (litres)	also for off-season use (litres)		
6	90	—	A—5	I
9	—	5376	D—4 C—8	I
6	—	4224	D—6	I
5	96	—	A—6	I
8	64	—	A—4	I
22	640	—	C—2	I
6	192	—	B—1 A—5	I
5	128	—	B—1 A—1	V
12	576	—	C—1 B—2	I
5	128	—	B—1 A—1	IV
5	32	—	A—2	II
16	960	—	C—3	I
7	288	—	B—2 A—3	III
6	724	—	C—2 A—4	I
20	384	—	B—3 A—2	V
9	—	1280	C—4 A—2	I
7	80	—	A—5	II

Storage facilities :

Type A = a 'Kalshi' of 16 litres

Type B = a 'Matka' of 120 litres

Type C = a 'Motka' of 350 litres

Type D = a 'Motka' of 750 litres

Method of rainwater collection :

Type I = roof discharge through G.I. Sheet

Type II = roof discharge through tiles

Type III = roof discharge through straw

Type IV = Polythene Paper under open sky

Type V = Bedsheet/ saree under open sky.

TABLE 3. Percentage of Households Using Different Sources of Drinking Water in Dacope, Khulna

Villages	Water source											
	Pond		River		Canal/ditch		Rainwater		Hand tubewell		DPHE-UNICEF Sand filter	
	Rainy Season	Dry Season	Rainy Season	Dry Season	Rainy Season	Dry Season	Rainy Season	Dry Season	Rainy Season	Dry Season	Rainy Season	Dry Season
Sutarkhali*	—	20	—	—	—	—	40	13.47	—	6.6	6.6	13.33
Anandanagar	25	25	—	—	—	—	—	—	25	25	—	—
Satgoria	—	—	—	—	—	—	—	—	50	50	—	—
Khatail	—	—	—	—	—	—	14	—	—	28	29	29
Khona	10	8	8	—	16	16	26	—	—	16	—	—
Barolkhali*	—	14	—	—	—	—	—	—	14	14	29	29
Chunkuri	14	14	—	—	—	—	14	—	29	29	—	—
Batbunia	25	25	25	25	—	—	—	—	—	—	—	—
Shaheberabad	11	28	17	22	—	—	22	—	—	—	—	—
Srinagar	11	10	—	—	—	—	23	—	11	11	11	23
Ramnagar	—	20	—	—	—	—	40	—	20	20	—	—
Burirdoba	16.5	16.5	—	—	—	—	34	—	16.5	16 5	—	—
Mean	14.75	34.08	8.32	7.80	2.66	2.66	35.50	2.24	27.58	36 00	12.60	15.72

*Note : October to April is cosidered dry season.

TABLE 4 Average Year of Formal Education of Heads of Households Consuming Different Sources of Drinking Water in Dacope, Khulna.

Pond water	Rainwater	Canal/Ditch water	River water	Hand tubewell water	DPHE-UNICEF sand filter
5.46 (5.2)*	5.80 (5.86)	1.0 (1.41)	2.87 (3.41)	6.13 (4.99)	7.0 (7.0)

* The figure in the paranthesis indicates standard deviation.

TABLE 5 Comparative Cost of Different Types of Water Sources in Dacope, Khulna.

Types of water source	Average water cost, Tk/litre
1. Pond	0.254
2. River	0.045
3. Canal/Ditch	0.045
4. Rainwater :	
a. Roof discharge	0.290
b. Open sky catchment	0.300
5. Hand tubewell	0.285
6. DPHE-UNICEF sand filtered facility	0.321

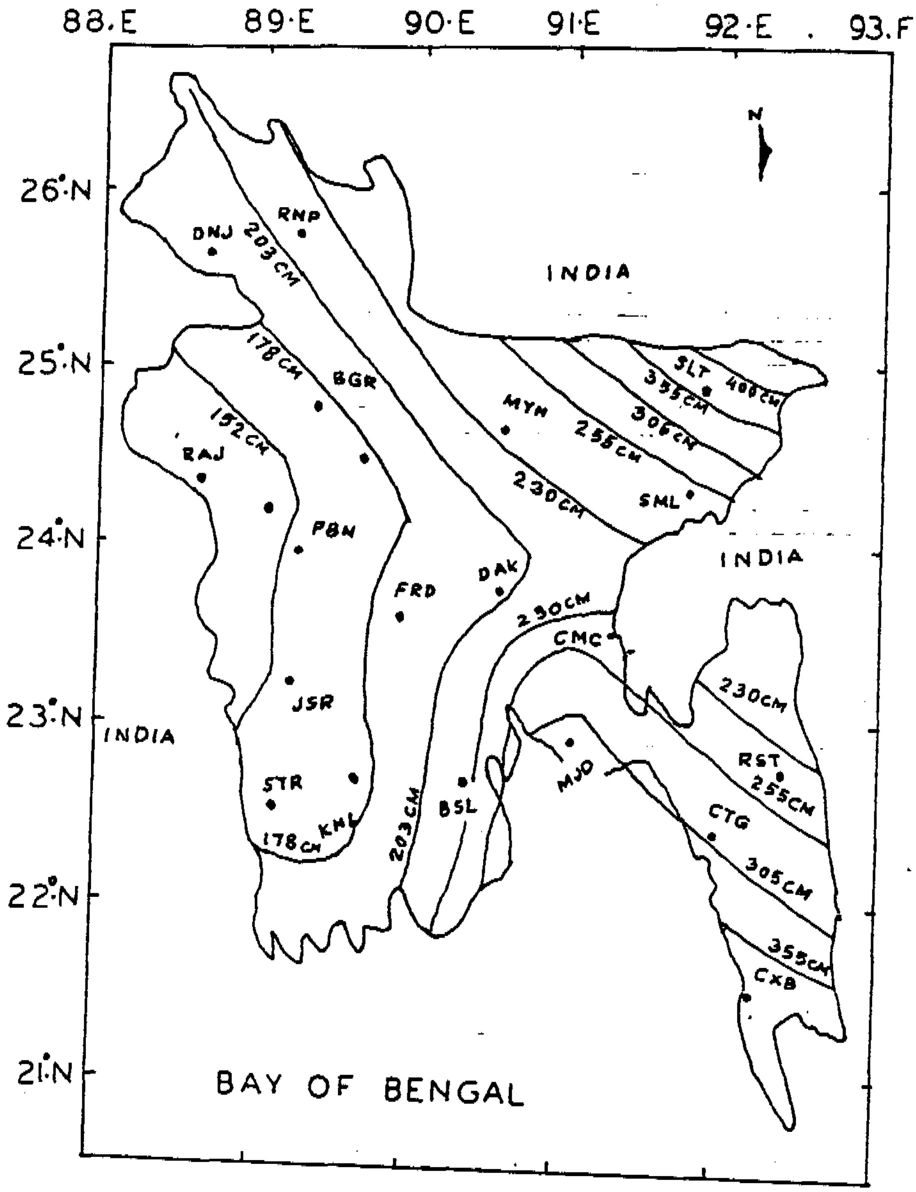

FIG. 1 GEOGRAPHICAL LOCATION OF BANGLADESH SHOWING NORMAL ANNUAL RAINFALL.

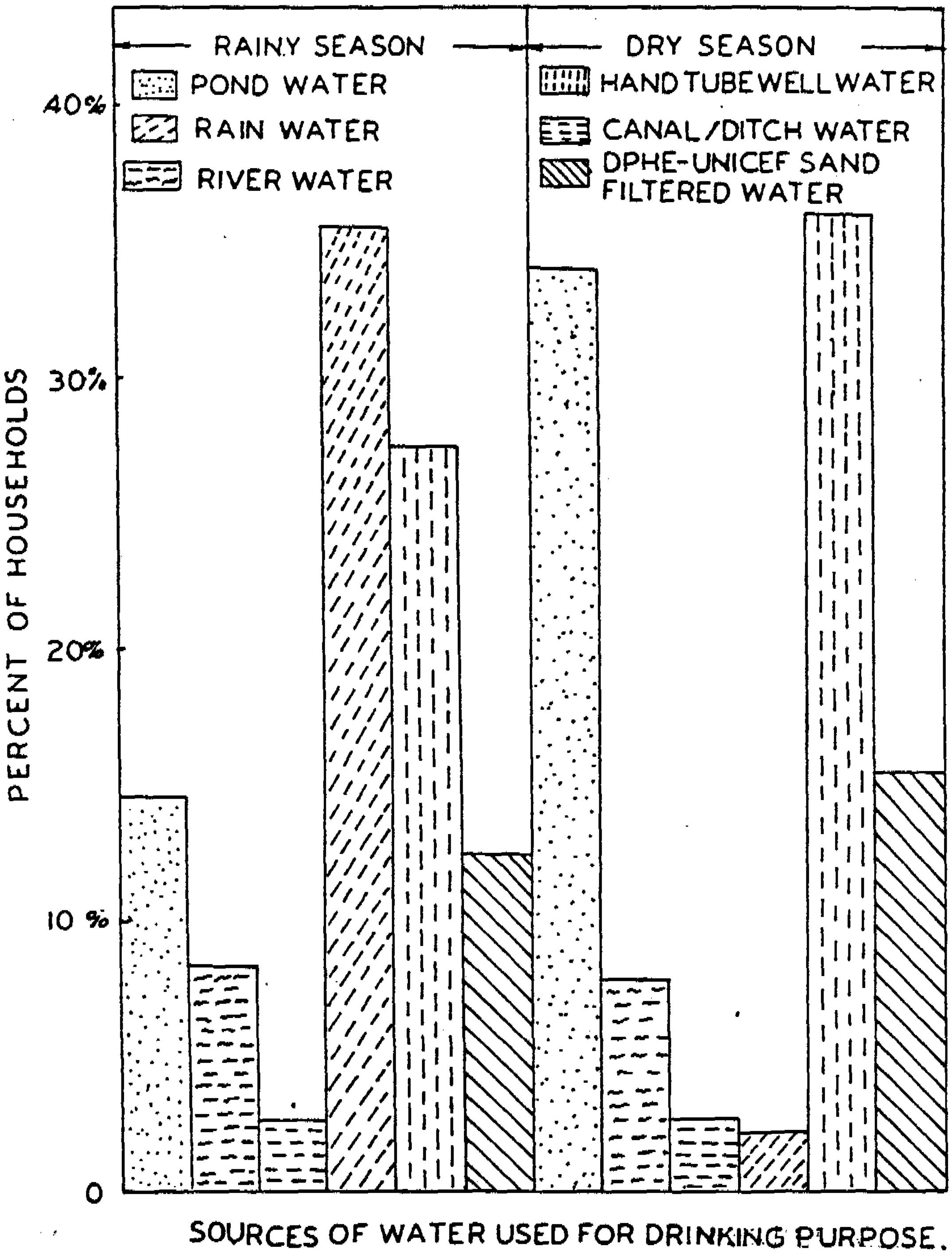

FIG. 2 CONSUMPTION OF DRINKING WATER BY HOUSEHOLDS IN DIFFERENT SEASONS.

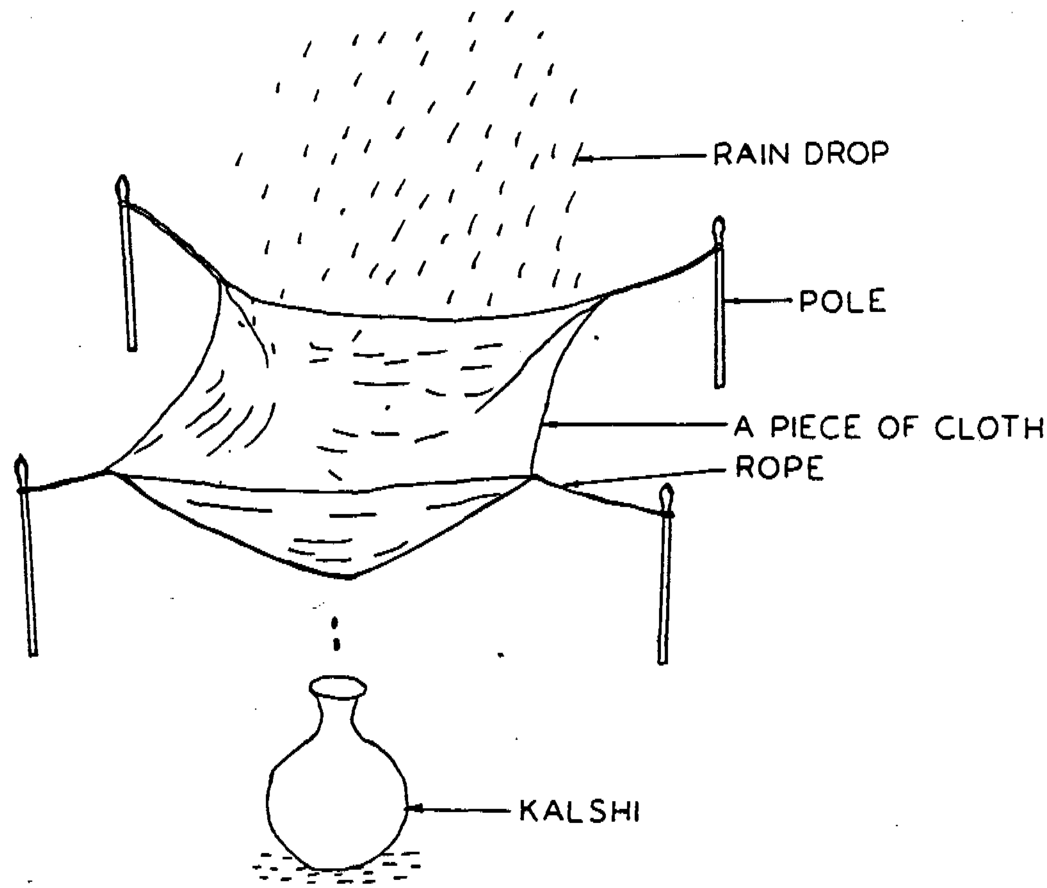

FIG. 4 A SCHEMATIC DIAGRAM OF A RAINWATER HARVESTING SYSTEM USING A PIECE OF CLOTH.

WATER SUPPLY AND WATER USER BEHAVIOUR: THE USE OF CEMENT RAINWATER JARS IN NORTHEASTERN THAILAND

Nongluk Tunyavanich and Kevin Hewison*

ABSTRACT

The supply of drinking water in the rural areas of Northeastern Thailand has long been a problem. From the early 1980s the Thai government has attempted to ameliorate the problem through the promotion of 2,000 litre cement rainwater storage jars.

This paper, based on research conducted in two provinces of the Northeast, and over a four year period, examines a number of issues related to the government-sponsored jar programme, and villager acceptance of this new technology. These issues are: jar acquisition and ownership; construction quality; use of jar water; rainwater collection systems and access; water quality and cleanliness; taste preferences; increases in storage capacities; and current water shortage problems.

It is concluded that the government programme, while having its problems, has been largely successful, with the drinking water storage capacity of thousands of villages having been greatly improved. Villagers are now drinking relatively better quality water for longer periods during the year. Villager acceptance of these facilities has improved. The next step is to ensure that the full health potential of the jar programme is achieved. Recommendations about this and other issues are included.

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INTRODUCTION

Background

The Northeastern region of Thailand, which is subject to long dry seasons and unreliable rainfall, has been, since the early 1950s, a major target area for government water resources development programmes. These programmes were accelerated during the counter-insurgency period of the sixties and seventies as the Communist Party of Thailand was strong in this the poorest region of the country (SAIYUD, 1986).

Even so, by the early eighties various surveys showed that many villages in the Northeast still lacked adequate and safe drinking water throughout the year. For example, the *Masterplan for Rural Water Supply and Sanitation* indicated that only 14 percent of the population had access to such supplies (at five litres per capita per day) in 1983 (ASIAN INSTITUTE OF TECHNOLOGY [AIT], 1985: III-34).

Therefore, over the course of the fifth and sixth five-year National Economic and Social Development Plans (1982-91), and coinciding with the International Drinking Water Supply and Sanitation Decade, the government intensified its efforts to solve the Northeast's drinking water problem. A major vehicle in this was to be the humble rainwater jar.

The jar programme

Traditionally, villagers in the Northeast have stored rainwater for consumption in small clay and ceramic jars (20-240 litres). Usually, however, this water is exhausted by the dry season, and villagers obtain their drinking water from shallow wells and ponds. Realising the social acceptability of rainwater (vis-a-vis groundwater from tubewells), and the potential of rainwater catchment as increasing numbers of houses used metal roofing, a small band of researchers had been experimenting with the construction of large-capacity (2,000 litres) cement jars. The earliest report we have been able to locate, from 1977, suggests that large-capacity cement jars are indeed a very recent technology (AMNUAY, 1977).

It was found that rainwater collection was, in fact, cost-effective, and that jars were simple to construct and low-maintenance. In addition, the quality of the water was generally better than that from shallow wells and surface facilities (AIT, 1985: III-46; THAI-AUSTRALIAN VILLAGE WATER SUPPLY [TAVWS] PROJECT, 1985: 47-54). The government, through the Department of Health, had already been promoting cement jars in designated poverty areas (NONGLUK et.al., 1985), and it was decided to massively expand this as a national rainwater collection programme. This programme aimed to provide five million large-capacity cement jars in rural areas by the end of 1987, which meant that, at one jar per household, daily drinking water of three litres per capita would be achieved for the whole country. To meet this mammoth task, a careful implementation programme was devised, with the Northeast being a major target area (FACULTY OF ENGINEERING, KHON KAEN UNIVERSITY et.al., 1987: 23-25).

In the end, because of the campaign format and the top-down nature of bureaucratic programmes, implementation did not follow the community participation approach originally envisaged. Nevertheless, millions of jars were purchased, distributed or constructed. From a situation in 1983 where large-capacity cement jars were so uncommon that they were not usually enumerated in surveys, by mid-1988 there were 8.9 million jars throughout the country (GOVERNMENT OF THAILAND, 1989: 33). In the Northeast, the programme was equally widespread -- for example, in Mahasarakham province, where there were about 80,000 jars in use during the 1986 dry season, by May 1987 there were 213,000 (HEWISON, 1987: 9-10).

Earlier reports indicated that some villagers suspected the quality of jar construction, while many others objected to the taste of water stored in cement containers (NONGLUK et.al., 1985). Given the recent extensive promotion of cement jars, and the wider experience of villagers in the use of these cisterns, this paper will summarise the results of two recent studies which have re-examined the use and acceptance of cement jars, and the changing attitudes of villagers (HEWISON, 1987; NONGLUK et.al., 1989).

Sources of data

The two studies which are the basis of this paper were both completed for the Thai-Australian Northeast Village Water Resource Project. That by Hewison was completed in mid-1987, based on a sample of 85 households in one district of Mahasarakham Province, covering twelve villages in five sub-districts. The second, conducted in Yasothon Province, was researched by a team led by Dr. Nongluk Tunyavanich of Mahidol University. It surveyed 300 families in seven villages from five districts.

THE USE OF CEMENT JARS

Jar Acquisition and Construction Quality

Acquisition

During the 1986-87 period in Mahasarakham, the most common method of acquiring jars was through the Rural Employment Generation Programme (REGP) or some other government project. Fully 90.8 percent of households with cement jars reported that these were the sources of their jars or of support for their acquisition. In Yasothon, two-thirds of people reported purchasing jars, but almost all of these were at reduced prices due to government project support. Most people acknowledged the central role of officials in encouraging them to acquire jars, although the most commonly stated reason (40 percent of respondents in Yasothon) for acquisition was to increase water storage capacity.

In Mahasarakham, conversations with villagers revealed that the bottom-up potential of the jar programme was not fully realised. The jar campaign meant that villagers believed that they had little choice but to request jars under REGP. This seriously undermines a central REGP objective, which is to develop the efficiency of Tambon (sub-district) Councils and increase participation in the planning process (VANPEN, 1986: 10-13).

The various governmental promotional and support programmes to encourage the acquisition of drinking water storage jars, especially the use of village development funds, were not so successful in Yasothon. Even though a majority of people were aware of such funds, various problems concerning the administration and management of them tended to discourage their use. Nevertheless, jar ownership has increased markedly.

<u>Ownership</u>

In the Yasothon study, various socio-economic and behavioural factors (such as the level of education, income, occupation, water shortage problem, and taste preference) were analysed statistically, but were not found to be significantly related to the ownership of cement jars. However, a significant relationship was found between ownership and experience of having attended training about drinking water and sanitation. Those households which had sent someone to attend government-sponsored training sessions (e.g. as sanitation craftsperson, health volunteers, etc.) tended to own more large-capacity cement jars than those households with no experience of training. In addition, as might be expected, people from households with cement jars were more likely to drink water stored in cement containers than those without such jars. Likewise, people from households with cement water containers or planning to have them, or where household members had attended training about water, have a more positive attitude towards drinking water stored in cement containers than those who have no experience of training, those who do not have cement containers, and those who did not plan to have them.

Construction quality

The quality of jar construction has not always been good, and seems to vary according to location, the agency involved, and over time. For example, in 1987, 36 percent of surveyed villagers in Mahasarakham reported either breakages or leaks. However, in 1988, only 16 percent of respondents in Yasothon reported similar problems. Many interviewees, in both study areas, reported that they were still not satisfied with the quality of jars.

Water Use

Utilisation of jars varies between the wet and dry seasons. In Yasothon, for instance, almost 80 percent of the jars were used to collect and store rainwater during the wet season.* This was not the case during the dry season.

* A further 16.7 percent had not begun to use their jars, but stated that they intended to do so.

While jars do not require large amounts of rainwater to fill them, almost a quarter of villagers surveyed in Mahasarakham reported that at the end of the wet season their jars were not full. At the same time, 43 percent of these people stated that they did not have sufficient storage capacity for the whole dry season. This was confirmed in Yasothon, where only 47.7 percent of households stated that they had rainwater left for drinking in the dry season, and that empty jars were generally not replenished from other sources. Large-capacity jars are reported by villagers to be too big to replenish, and the task is too difficult. It can be concluded, therefore, that the majority of large cement jars are being used to store drinking water only when there is rainwater to catch -- mainly during the wet season.

One reason for this pattern is that jar water is not always rationed, and nor is it used exclusively for drinking (see Table I). More than a third of households report using the water for drinking, cooking, washing clothes, and bathing.

TABLE I

USES FOR JAR WATER, KAE DAM DISTRICT, MAHASARAKHAM

Use	Percentage of Households Reporting Use
Drinking water [a]	87.9
Water for cooking	79.5
Washing clothes	36.1
Bathing	33.7
Washing dishes	7.2
Have jars but do not use them	2.4

[a] 9.6 percent of surveyed households reported that they have jars but do not drink from them.

Nevertheless, water storage capacity has been increased markedly. In the Yasothon study villages, a census of total water storage capacity was made in 1984 and 1988. This showed that the average household drinking water storage capacity had increased from 783 litres to 1,818 litres, an increase of 132 percent. In Mahasarakham, where only large-capacity jars were considered, the estimated average household storage had increased from about 460 litres in 1985 to almost 5,000 litres by mid-1987. That these increases were due to large-capacity jars is striking evidence of the success of the government campaign.

Once stored rainwater is depleted, villagers inevitably return to shallow wells -- 82 percent in Mahasarakham, and about 70 percent in Yasothon. However, the impact of the jar programme can be seen in Yasothon, where villagers reported using rainwater exclusively for 4.2 months in 1984; by 1988, this figure had risen to 5.5 months. Another indicator of change was the number of people drinking rainwater during the dry season, which increased from 2.7 percent in 1984 to nine percent in 1988. This suggests that in other areas, where the programme has been more widespread -- in the surveyed villages in Yasothon only 44 percent of households had large-capacity cement jars -- the impact will have been even more significant.

Access and Collection Systems

Health authorities have recommended that jars be constructed with taps, drainage plugs, and lids. If these are present, then the risks of contamination from the roof and unhygienic handling practices can be minimised (AIT, 1985: III-46). In the Mahasarakham survey, however, it was found that 72.3 percent of jars did not have taps, and access to the water was by bucket (35.8 percent) or siphon hose (34.9 percent). Villagers have been shown to be concerned about taps: in the Yasothon survey, the vast majority of respondents in 1984 (86.7

percent) and 1988 (97 percent) agreed that a tap improved the convenience of jar use. However, villagers have also reported problems with taps -- they are difficult to repair; children play with them and waste water; and dogs and ducks will lick the tap, thus discouraging human use.

Lids were found to be in wide use in the surveyed district of Mahasarakham, with 88.5 percent of jars having some form of cover. It seems that even with this high coverage, however, there may still be problems. For example, villagers complained of increased mosquito infestation. There is no conclusive evidence that this is related to the use of jars, although it is possible that the increased availability of water within villages may be adding to the breeding places for some varieties of mosquito. An examination of a small sample of jars (undertaken by non-specialists) indicated that jars with lids are less susceptible to larvae infestation than those without lids (HEWISON, 1987: 17). As a result of concerns about mosquitos and for filtering debris from water off the roof, netting of jars has recently been recommended by the Department of Health.

After taking water from jars, nine out of ten respondents reported decanting it into smaller containers. Villagers do this in order to improve the taste of the water, for convenience of access within the household, and to keep drinking water cool. In doing so, however, they increase the risks of bacteriological contamination through handling (PINFOLD, 1988).

One very significant advantage of jars over more traditional water sources is their convenience. For most North-eastern villagers the collection of water is an arduous and time-consuming activity, often carried out by women and children (NAPAT and GORDON, 1987: 339, 351; NONGLUK et.al., 1987:54-57). Collecting water from ponds and shallow wells will often involve a trip of several kilometres, collecting, and pushing or carrying up to 120 litres of water at a time back to the house. Jars, situated next to the house, are clearly more convenient. In many villages this convenience factor is even more important as the majority of working age people will leave their homes in the dry season in search of paid labour elsewhere (KOSIT and SOMCHAI, n.d.). This leaves just the old people and young children in villages for long periods of time -- the convenience of jars has obvious advantages for them.

Cleaning and Water Quality

In the Mahasarakham survey, almost 90 percent of villagers stated that they cleaned their jars. Indeed, a physical inspection indicated that, in general, jars were clean, with only some instances of mosquito larvae infestation, algae, or debris (in one case, a child's plastic revolver!). It seems that villagers do have a concern for the cleanliness of their jars. In both Mahasarakham and Yasothon it was noted, however, that cleaning could be a problem as someone had to climb inside the jar, meaning that it had to be completely emptied of water.

Prior to the implementation of the jar programme, it was feared that rainwater would be contaminated by debris from the roof collection systems (AIT, 1985: III-23). Indeed, only about a third of people in Mahasarakham indicated that they cleaned their roof catchments. But, it was also found that most villagers (94 percent) ran off the first rains, thus flushing the system. This probably reflects the traditional practice of allowing water to run off thatching a number of times prior to collection -- more than a third of villagers reported running off more than one rainfall.

Despite this pattern of apparent concern for cleanliness, and a feeling amongst villagers that water in cement cisterns is generally clean (in Yasothon in 1988, 93 percent of respondents stated this), problems of quality remain. Water quality technicians have reported that while the physical and chemical quality of samples collected from jars meet the 1971 WHO drinking water criteria in 90 percent of cases, for bacteriological quality, in fact only 29 percent meet the criteria (GOVERNMENT OF THAILAND, 1989: 39). This latter figure is surprising, as other studies have shown quite different results. For example, a study based on 489 samples in the Northeast indicated that 67 percent did not indicate faecal coliforms exceeding an MPN of 2.2 per 100 ml. This result was very close to that achieved for cement rainwater tanks (TAVWS, 1985: 10). Another, using just 80 samples in the Northeast, found that 41.25 percent showed less than 10 MPN total coliform bacteria per 100 ml., and 57.5 percent with less than 2 MPN faecal coliforms per 100 ml. (PHICHIT et.al., 1987: 23, 26).

There are two confounding factors in this picture of water quality. First, recent studies have shown that the bacteriological quality of water improves markedly with only short periods of storage, as bacteria die-off (WATER RESOURCES NEWS [in Thai], Vol. 1 No. 4, 1989; SUWANNI, 1988). Second, it can be logically assumed that where villagers were previously abstracting water from <u>public</u> sources known to have a high propensity for bacteriological contamination -- surface water facilities and shallow wells -- the move to <u>private</u>, household-level facilities reduces the risk to public health.

Further investigation of water quality is thus necessary, but criteria for tropical countries which are achievable (with emphasis on <u>E.coli</u>) should be used (HELMER, 1989; MALIK, 1988). In any case, it has been shown that whatever the quality of jar water, by the time it is decanted several times prior to consumption, handling contamination will occur (PINFOLD, 1988). Thus, efforts by health authorities to chlorinate jar water are a waste of time, money, and effort, and are doomed to failure:

hygiene education is the only appropriate vehicle in overcoming this problem.

Taste

As noted above, the taste of water stored in cement jars was an issue when the jar programme was initiated. The results of the two Yasothon surveys in 1984 and 1988 showed similar results, with about three-quarters of respondents choosing rainwater as the "tastiest" water (see Table II).* However, when the choice was between rainwater stored in cement containers and shallow well water, significant reductions in taste acceptability were noted, with only about two-thirds of people choosing the stored rainwater. Nevertheless, the responses indicated that the percentage of people who would choose rainwater, whether stored in cement containers or not, had increased marginally between 1984 and 1988. This is probably due to the fact that more people have experience in drinking water stored in cement containers (up from 55 percent in 1984 to 71.4 percent in 1988).

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* This is not necessarily typical of the whole Northeast. A number of studies have shown that the preferred drinking water in many areas of the northeast is shallow groundwater. For example, ORAPHIN and AMARA (1986) have shown this for their study area.

TABLE II

OPINIONS ON THE TASTE OF SHALLOW WELL WATER AND RAINWATER, YASOTHON PROVINCE, 1984 AND 1988

Opinion	1984 Percent	1988 Percent
Rainwater is "tastier"	73.9	75.8
Shallow well water is "tastier"	13.2	13.5
No taste difference	12.9	10.7
Total	100.0	100.0

While the comparison of attitudes in 1984 and 1988 towards drinking water stored in cement containers encountered some methodological problems due to the changing situation in the study villages in Yasothon, some significant results were achieved. It is clear that more people now have a more positive attitude to drinking water stored in cement containers. Only one-fifth of respondents had a positive attitude in 1984, but by 1988 this increased to almost one-third. The number of people who were neutral also decreased from 70 percent in 1984 to 60 percent by 1988. Many of those who were neutral in 1984 had changed to being more positive in 1988. Again, the reason for the change would seem to be that more people now have experience with cement containers (see Table III).

For taste, it was found that while in 1984 48.9 percent agreed that rainwater stored in cement jars was "tasty", by 1988, this had decreased to 36.7 percent. Similarly, when presented with the statement: "Rainwater in cement jars is not 'tasty'", 69.4 percent agreed in 1984 and 66 percent agreed in 1988. This data is not conclusive. In 1984, only small numbers of households had cement jars and about half of the respondents said the water stored was "tasty". In 1988, almost half of the households had cement jars, but the percentage of people who thought the stored water was "tasty" was lower than in 1984. This may reflect the fact that those who had cement containers in 1984 were more receptive to water stored in this manner -- they were the "pioneers". However, by 1988, ownership was more widespread after vigorous government promotion, and thus there was a much wider cross-section of opinions to be assessed.

TABLE III

COMPARISON OF ATTITUDE TOWARDS DRINKING WATER STORED IN CEMENT CONTAINERS, YASOTHON PROVINCE, 1984 AND 1988

Attitude	1984 Percent	1988 Percent
Negative	10.3	7.3
Neutral	70.0	60.0
Positive	19.7	32.7
Total	100.0	100.0

This is confirmed by the fact that the percentage of people who stated that they would never drink rainwater stored in cement cisterns or who found the taste "sour", "bitter", or in some way "bad", had been reduced from 14.6 percent in 1984 to just five percent by 1988. Similarly, by 1988, almost half of the respondents felt that water stored in cement jars was as "tasty" as that stored in ceramic jars. Indeed, by 1988, cement jars were the preferred kind of cistern (see Table IV).

TABLE IV

DESIRABLE TYPES OF DRINKING WATER STORAGE CISTERN, YASOTHON PROVINCE, 1984 AND 1988

Type of container wanted	1984 Percent	1988 Percent
Small clay and ceramic jar	13.2	14.4
Big cement jar	19.3	36.1
Cement tank	41.0	18.7
Combination of above and zinc tank	11.4	1.0
Nothing	15.0	29.8
Total	100.0	100.0

It became clear, both in Mahasarakham and Yasothon, that the unpleasant taste associated with cement cisterns was generally restricted to newly constructed facilities. Once they had been used for a season or more the "cement" taste was much diminished. Some villagers even developed methods which they believed hastened this process. These included washing the inside of the new jar with vinegar, and rubbing it with banana leaves or lime skins; some even threw a handful of clay from their favourite shallow well into the jar, to give it an "earthy" taste.

These results indicate a clear tendency -- rural North-easterners are coming to see rainwater stored in cement containers as convenient and acceptable for drinking. More households now have and use the facilities and less people have negative opinions towards water stored in cement containers.

Storage capacity

As villagers have now been drinking rainwater for a far longer period than in 1984, increased storage capacity is to be expected. In Yasothon it was found that households now have more water storage containers of various types. More than 40 percent had six or more ceramic jars (capacity 160-240 litres) in 1988 compared to only 25.4 percent in 1984. The percentage of households with large cement jars also increased: only 3.9 percent of the households had these in 1984, but 44 percent had such containers in 1988. Cement tanks saw only a slight increase, from 3.1 percent in 1984 to 4.3 percent in 1988. This is probably due to the higher investment required for tanks.

As noted above, there have been huge increases in rainwater storage capacity in the surveyed areas. The reasons for such big increases in water storage capacity, as noted by participants in focus group discussions, was that there were now many agencies campaigning for all the households to have big cement jars. This, coupled with the convenience factor, means that households which could afford jars quickly acquired them for their households.

Water shortages

As water storage capacity has increased, stored water for drinking has lasted longer. Thus, more people respond that they no longer have water shortage problems. In 1984, 29.6 percent of households in Yasothon stated that they did not have a drinking water storage problem, but by 1988, 37 percent believed they had sufficient drinking water. Nevertheless, the majority of people still thought they had a drinking water shortage problem, even if the number of households who said they had a "severe" shortage problem decreased considerably (see Table V).

TABLE V

IDENTIFICATION OF DRINKING WATER SHORTAGE PROBLEMS IN THE HOUSEHOLD, YASOTHON, 1984 AND 1988

Level of problem	1984 Percent	1988 Percent
Severe problem	20.7	13.0
Moderate problem	33.3	22.7
Little problem	16.4	27.3
No problem	29.6	37.0
Total	100.0	100.0

In Mahasarakham, where the jar programme had been even more extensive, only about five percent of respondents said they had insufficient jar capacity. Conversation with villagers showed, however, that many felt that 4,000 litres (two jars) was not sufficient, and that 6,000 litres was more realistic.

CONCLUSIONS

This paper has briefly summarised some of the findings of recent studies concerning the use of large-capacity cement water jars in Northeastern Thailand. The focus has been on user behaviour and attitudes.

It is worth noting that, in spite of management problems, its top-down campaign nature, and the lack of community participation, the government's jar programme has generally been quite successful. By the government's own measures -- jar counts -- the increase in the number of jars in rural areas has been remarkable. While villagers in the North-east do not always agree that drinking water is a major problem, and would prefer to improve agricultural water supplies (ORAPHIN and AMARA, 1986), there is an acknowledgement that the introduction of jars has improved their drinking water situation. Indeed, most villagers would now prefer big cement jars to any other drinking water storage facility. And, they are drinking rainwater for longer periods than in the past. In addition, it seems that villagers prefer to purchase the ready-made jar, rather than have them constructed in the village.

Villagers remain, nonetheless, critical of some aspects of the programme. They continue to object to the cement taste of jars, although this seems to be greatly reduced with time. They are confused by the lack of coordination amongst the various government agencies, and the lack of quality control in jar construction. Importantly, while agreeing that their situation has improved, most villagers still note a drinking water shortage. This means that they must continue to utilise water which is more prone to bacteriological contamination -- shallow wells and surface water facilities.

There remain some aspects of jar use which may be of significance for health. First, villagers generally do not ration water in the dry season. Hence, they return to less sanitary sources. Second, many jars do not have taps, meaning that water abstraction can lead to bacteriological contamination. Third, water from cement jars is usually transferred to other containers prior to consumption, thus increasing the chances of contamination (PINFOLD, 1988). Nevertheless, it should be admitted that jars are now (and potentially) a more sanitary source than the traditional alternatives, and villagers generally agree that the water is "clean".

It does not appear that there are many social or demographic factors which indicate a propensity to acquire cement jars. Those factors which seem significant are: (i) economic development -- it appears that as the general level of economic activity increases, villagers are less willing to spend time collecting water; (ii) convenience -- people like the ease of access to jar water; (iii) knowledge -- those people who have attended some kind of training related to water supply are more likely to own cement jars; and (iv) experience -- those people who already have cement jars are likely to acquire more.

RECOMMENDATIONS

1.0 The jar programme should continue to be emphasised in the Northeast.

1.1 Health education should have a high priority in order to motivate villagers to acquire adequate drinking water storage capacity.

2.0 It is crucial that the potential health benefits of increased jar ownership and use be maximised. Hygienic water user behaviour, both at the jar and within the household, is the only appropriate strategy.

2.1 A study of the behaviour of cement jar users should be completed in order to find appropriate ways to more fully and hygienically utilise jars.

2.2 Further studies of the bacteriological contamination of jars should be completed, using E.coli as the appropriate criteria. Chlorination should be avoided wherever possible.

2.3 A careful investigation of the relationship between large-capacity cement jars (and, hence, greater quantities of water within villages) and mosquito populations is required.

3.0 All agencies working towards the promotion of village drinking water provision should implement their activities using broadly similar methods, so as to avoid confusion among villagers. Stress should be put on quality control and pricing of facilities so that there will not be great variations between agencies. Community participation should be further promoted, especially in large-scale programmes. Village and sub-district decision-making should be encouraged by government agencies.

3.1 The trained village sanitation craftspersons should be utilised to their full potential for the provision of village drinking water. Opportunities for them to use their skills should be promoted (e.g. by having more cement jars made in the village). This would also be a way for other villagers to participate and construction quality might also be better controlled. This should only done if it can be shown that a useful role for craftspersons can be defined.

3.2 If the village development fund is to be used to promote household water provision, the administration and management of the fund should be improved, and villagers should have a better understanding of the funds and their operations.

4.0 Taps, lids, nets, and drainage plugs should be standard features of all jars, whether ready-made or village constructed.

5.0 Since the majority of villagers still rely on shallow wells for drinking water, some attention should be given to socially, culturally, and hygienically appropriate methods by which this water can be used.

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THE PLANNING, DEVELOPMENT AND CONSTRUCTION OF A TYPICAL RWCS PROJECT USING THE TOTAL CONCEPT: A CASE STUDY IN THE PROVINCE OF CAPIZ

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ABSTRACT

Following the first International Conference in Hawaii in 1982 and a Regional Seminar in Khon Kaen, Thailand in 1983, the establishment of Rain Water Cistern Systems (RWCS) in developing countries seems to have acquired a new lease of life. One of the locations with most potential and, most important of all, the right attitude was the Province of Capiz in the Philippines. A preliminary field investigation in 1985 helped to confirm that there was a dire need for potable water in this area. Besides, it helped to identify the critical sizes of tanks required and the most appropriate material to be used. The Government of the Province of Capiz came out with a proposal that not only ensured proper participation and self-help of the villagers but also incorporated an excellent system of repayment of capital. Thus, the first set of trial RWCS was introduced with the help of the International Development Research Centre (IDRC), Canada in 1986. Following this, the movement gained momentum as there was public acceptance leading to better cooperation amongst the people. To date, not less than 500 tanks have been constructed and are serving the people of Capiz very well. This intense RWCS project, when completed, can be claimed to be one of the largest of its type in the world.

INTRODUCTION

Rain Water Cistern Systems (RWCS) have been in existence about 5000 years ago in Sumeria (Durant 1954) and in Venice (Clark et al 1977), which depended on such systems for 1300 years for its water supply. The major motivating factors for such systems have been the primary need for drinking water and the suitability of such systems due to the lack of other sources. There has been a rejuvenation of such systems in recent times because they are being highly organised, taking into consideration the selection of the most appropriate locations, the use of technology that has been brought down to the level of understanding of villagers and their purse strings and, most important of all, self-help methodologies. These factors have made RWCS a more attractive and economically viable proposition, particularly to those in developing countries. Such an approach has been successfully adopted in Thailand (Hayssen 1986) and this system has been recognised and recommended with modifications as the "total" system (Appan and Lee 1987). The RWCS project in the Province of Capiz has largely followed this "total" approach and, when completed, is well on the way to being one of the biggest such undertakings.

THE CHOICE OF CAPIZ AS A RECIPIENT FOR AN RWCS PROJECT

The Province of Capiz is one of the four provinces in the Panay Island which lies in the half of the Philippines (See Fig 1). Capiz has an area of 2633 square kilometres. It has a population of 490,000 out of which 86.5% live in rural areas.

Though there is an average rainfall of about 1700 mm (Appan 1985), the coastal municipalities faced difficulties in obtaining drinking water due to:

a. Availability of only brackish water
b. Insufficient good quality water for drinking.

In case of those living in upland areas, during the dry season, there is extreme scarcity for drinking water. During the drought of 1983, villagers had to walk considerable distances to obtain water of dubious quality from streams and open wells.

Though rainwater is available in sufficiently large quantities in Capiz, the traditional method of collection and storing was haphazard, the number of households practising rainwater collection was small and the water collected often insufficient. Recognising these problems of insufficient potable water, the Provincial Government in Capiz proposed to test and study the potential for an organised RWCS.

A case was made up to the IDRC, Canada and approval was given in 1985 for the construction of 30 RWCS in three selected locations.

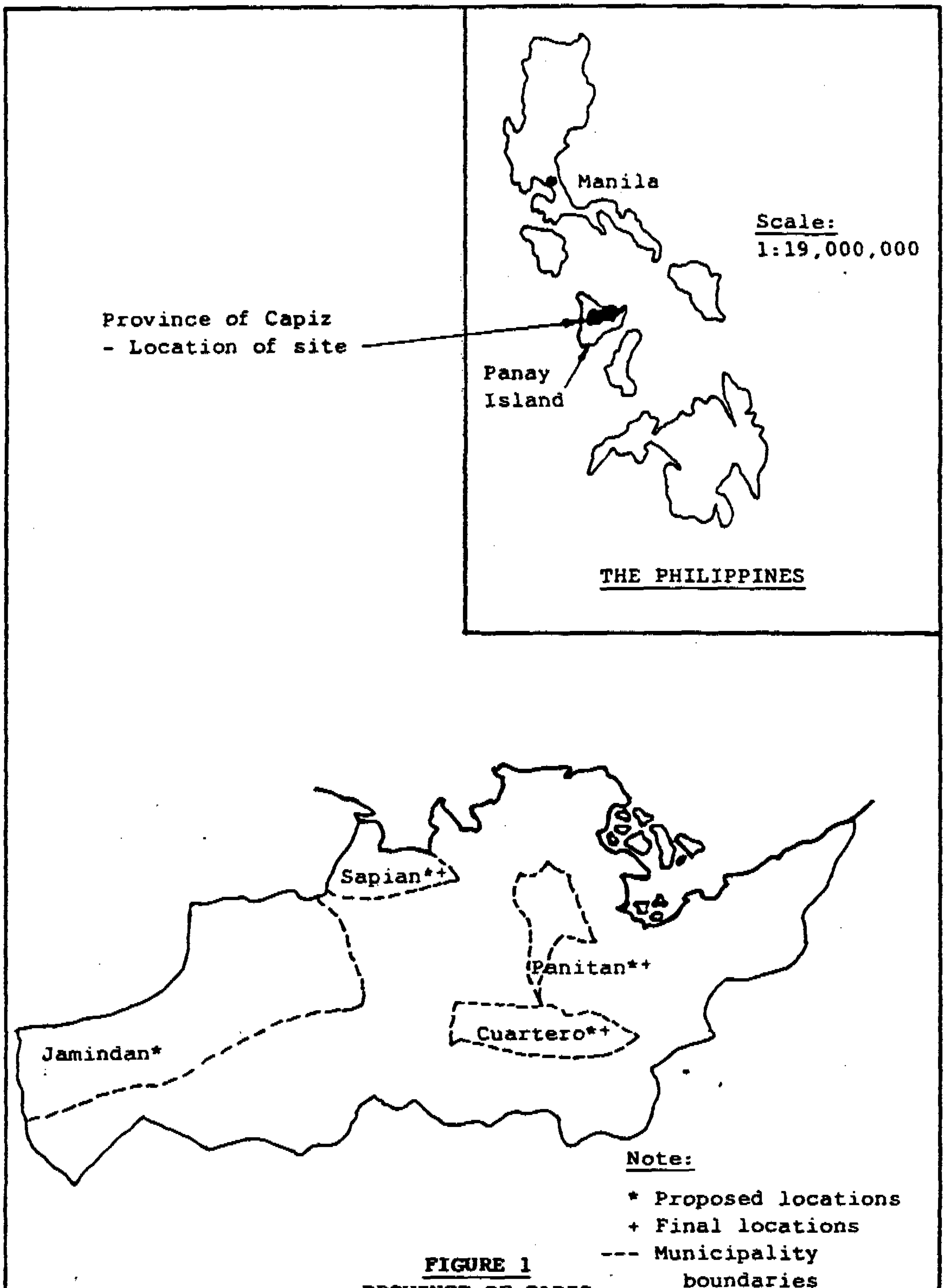

FIGURE 1
PROVINCE OF CAPIZ
PILOT LOCATIONS - PROPOSED AND FINAL

THE TOTAL APPROACH AS APPLIED TO CAPIZ PROJECT

The need to pursue an an integrated approach for establishing a successful RWCS on a project basis has been recognised, practised and institutionalised in Thailand (Hayssen 1986). Basically using this approach, some concepts from the Indonesian practice in the Jogjakarta area (Aristanti 1986) and incorporating some modifications, a "total" approach has been recommended (Appan and Lee 1987). In such an approach, the sequence of steps to be taken have been well-defined (see Fig 2). The order of events in this flow chart has taken into consideration the community's basic requirement of the community for potable water, the status of RWCS technology in the target project area, the establishment of a few RWCS at pilot project level and selection of monitoring stations, the study of the people's attitudes and responses, the potential for expansion and finally an appropriate financial model for repayment.

Since the proposed project in Capiz has largely followed the total approach, the stage-by-stage process will be recounted as follows:

1. Existing RWCS in the province of Capiz

The traditional method of collection, storing and usage appeared to be haphazard and inadequate. The roof of a house was used as catchment and the runoff was trapped in household jars, galvanised sheet iron tanks etc., The number of households practising rainwater collection was small and the amount collected was often insufficient to last through the dry periods. On the whole, though rainwater is available aplenty, it had yet to be exploited in an organised, hygienic and efficient manner.

2. Selection of Pilot Locations

Three study areas were chosen (see Fig 1) each of them representing different topographical characteristics in terms of accessibility to drinking water. Some details of these locations are given in Table 1.

Table 1
Characteristics of Pilot Locations

Municipality	Population	Type of Area
Panitan	27,631	Lowland
Jamindan	25,562	Upland and mountainous
Sapian	18,753	Coastal plain

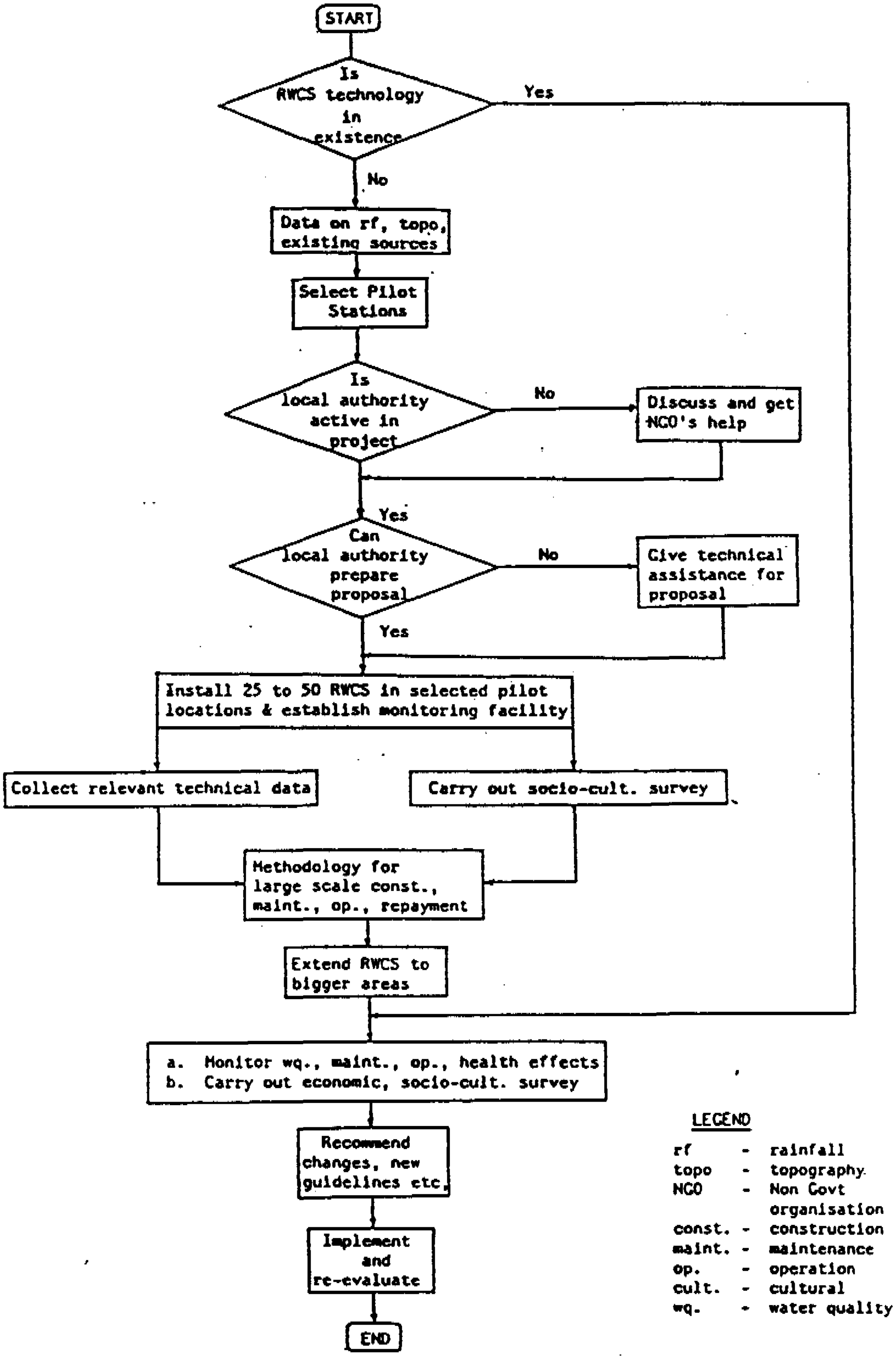

FIGURE 2 : FLOW CHART FOR A TOTAL APPROACH

In the Panitan area, the shallow wells tended to dry up during summer and the villagers had to draw water from distant sources. In Jamindan, though there was sufficient water in the streams during the dry season, the villagers had to travel a long way to get to the water source. In the case of Sapian, the water was generally brackish and was not accepted by the people.

The three locations represent almost 30% of the Province of Capiz and were considered to sufficiently represent the different prevailing conditions in the whole island.

3. Proposal for Establishing RWCS in Capiz

The provincial government of Capiz was very enthusiastic at the prospect of supplying drinking water through this project and came up with a comprehensive proposal. Their research project had the primary objective of introducing RWCS to the rural inhabitants and to investigate the operating characteristics and social acceptability of such a system as a low-cost source of potable water.

The specific objectives to be attained were:

a. Prepare the three municipalities to build, install and maintain 30 units of RWCS.

b. Construct and maintain 10 Ferrocement tanks in each of them.

c. Develop and conduct a non-formal course on construction, installation and maintenance of Ferrocement rainwater tanks for recipients of tanks.

d. Establish one monitoring station in each of the three municipalities to record rainfall, water-use patterns and rainwater quality.

e. Develop and test several self-supporting repayment schemes.

f. Monitor the villagers' acceptance and perception of the program, maintenance of the completed tanks, quality of water stored and the repayment scheme.

4. Preliminary Work

Planning of the necessary initial work was based on experience accrued in similar projects in other developing countries and an understanding of the nature and characteristics of the prospective recipients ,the residents of the Province of Capiz. Some of the preliminary work carried out was as follows:

a. Selection of monitoring stations: Based on field investigations (Appan 1985), appropriate sites (see Fig 1) in the following villages were chosen in the pilot locations:

Agkilo	(Municipality of Panitan)
Guintas-Milan	(Municipality of Jamindan)
Maninang	(Municipality of Sapian)

In each of the above locations, a rainfall recorder and a water-level recorder, both having continuous recording facilities, were recommended to be installed. Also, water samples were to be collected and tested mainly for appraising bacteriological content.

b. Transfer of relevant technology from neighboring countries: At the commencement of the project in 1986, two researchers from the project team in Capiz were sent to Thailand and Indonesia. The methods adopted in Thailand for establishing RWCS are as well known (Hayssen 1986)as their extensive use of Ferrocement and other indigenous materials (Vadhanavikkit et al 1984). Besides, the Indonesian experience on rural water supply using appropriate technology has also been well-publicised (Aristanti 1986) The two researchers spent two weeks in both the countries and acquired on-the-job training in relevant aspects of establishing RWCS and in the explicit use of ferrocement for constructing water tanks.

c. Socio-cultural survey and support: Another aspect of the Capiz project was the need for the project team to inform the residents of the project, to obtain their support and solicit their active participation. As such, meetings were organised and held with the residents.

A household survey was also carried out to obtain information on household or demographic characteristics, annual income and expenses, water consumption per day and general water-use habits. Such information helped largely in selecting the most appropriate households to participate in the project. A salient factor for selection was the willingness of the villagers to undergo training on tank construction and contribute labour to construct their own tanks.

d. Research on construction of Ferrocement tanks: The tremendous potential for establishing RWCS in Capiz and the proposed large numbers to be ultimately built warranted a design that was easy to construct, economical and durable. The tanks should be constructed by locally available or trained skills and, preferably, local building material. Besides, there was the need to ensure that under no circumstances should the pilot set of 30 tanks be subject to any form of failure as it would have an adverse effect on the acceptance of RWCS in its present form (Appan 1985).

Accordingly, a study was undertaken to propose a ferrocement tank design and detailed construction techniques that would ensure durability and long service life. Two sizes of 5 m^3 and 16 m^3 were chosen, analysed, constructed and tested. The relevant methods of construction and details were made available to the potential user. (Lee et al 1986).

To make sure that the principles of design and techniques of construction were well understood and there was appropriate transfer of technology, two of the project researchers from Capiz also acquired the necessary information and training in Singapore so as to implement the system in Capiz.

5. Socio-cultural approach and installation of 30 units of RWCS in pilot locations

Very early in the project, it was realised that the initial groundwork in community organisation was a crucial factor to achieve the objectives. Prior to the commencement of construction aspects of the project, the necessary contacts and arrangements had to be made with local officials and influential people at barangay (village) level.

As for the actual construction, the general idea was to propagate the concept of learning-by-doing and strengthening the training component by community organisations. This strategy resulted in getting the people involved and there was active participation in the construction activities.

During the construction stage, the project team lived in the site area so as to establish a better rapport with the recipients and obtain their active support. This was done with the sole objective of ensuring that the village groups involved would acquire the skills for constructing, installing and, subsequently, maintaining the tanks on their own. Besides, such an approach would also help to ensure the structural soundness of the tanks and the social acceptance of RWCS in rural areas.

A few changes were made in the original location and sizes of the tanks. It was decided that instead of Jamindan the municipality of Cuartero be selected for installation of RWCS. Besides, the smallest tank size was changed to 6000 litres and it was also agreed that a few tanks of 16,000 litres be sited in schools having more than 240 pupils and teachers.

Actual construction of the units, 10 in each of the final target pilot locations, started in the coastal area followed by the lowland and upland villages. Each of the locations had the same number of RWCS as detailed in Table 2.

Installation of the tanks was completed in early 1988. The only minor delay in the construction schedule was due to flooding in the location of aggregates.

Table 2
Details of Tanks in (revised) Pilot Locations

Size of Tanks	Number
6,000 litres	8
10,000 litres	1
16,000 litres	1

6. Collection of relevant data and socio-cultural survey after completion of project

Following the completion of the 30 units of RWCS, constant monitoring has been carried out in the three monitoring stations with respect to the rainfall pattern. From all the 30 tanks, water samples were collected and analysed to appraise the bacteriological purity.

The status of the tanks, in terms of structural aspects, was also monitored during this period of time and only some minor seepage has been observed from the sidewalls. There have also been no leakages in the base slabs or the joints and there has been no case of tilting of the tanks.

From the regular monthly water sampling programme carried out for the tanks, it was noted that not less than 25% of the samples indicated a positive presence of Coliform Group of organisms. However, based on questionnaire, conversations, visual observations and regular visits, no common illnesses, ailments or diseases appear to have been propagated by the use of the RWCS.

Based on a field visit and subsequent report (Appan 1989), it was noted that in the pilot location area, the RWCS installed were not utilising their full potential regarding roof catchment though quite a lot of overflows were observed. Also, locations of the tanks needed looking into so as to ensure that there was no contamination to the rainwater being collected.

There are plans now to carry out a more comprehensive socio-economic survey to appraise the use of RWCS in Capiz.

7. Repayment Scheme

When the initial proposal for constructing 30 units of RWCS was made, it was suggested that several strategies for repaying the cost of the tanks would be developed and tested. These included training of recipients in cooking, tailoring, dressmaking,compost-making etc, so that the skills acquired would enable them to generate more income which could go towards repayment of the tank. Alternatively, surplus rainwater could also be sold. The amounts collected were to constitute a core fund which could be used to expand the program.

However, during the initial construction stage of the project, the beneficiaries were convened to solicit their suggestions on the repayment scheme. They were very much in favour of engaging in hog-raising where the project authority provides the piglets and basic training on how to care for pigs. This proposal is very much akin to the Indonesian "two she-goat" policy (Aristanti 1986) which gave excellent results.

In Capiz the recipients were required to pay for the construction materials of the tank on an installment basis over a period of three years. This scheme has proved to be very popular and effective. At present they have the capacity to pay on a monthly basis and also after the harvest time.

8. Extension of RWCS project

During the period of the construction of the 30 units of RWCS, the construction procedures were so adaptable and the cost so minimal that many people began to construct their own tanks. Besides, UNICEF has also sponsored the building of some units. Thus, the total additional number of RWCS built is in the region of 500. However, the capacity of most of these tanks is 10,000 litres.

Proposals are now under way, in collaboration with the IDRC and CIDA (Canadian International Development Agency) to disseminate the acquired ferrocement technology to a much larger group and extend the number of tanks by a further 600. Health education and community organisation elements will also be built into the proposed project activities to ensure that the RWCS introduced will have the desired impact of providing safe drinking water and, in the process, improve the health of the people.

DISCUSSION AND CONCLUSIONS

1. Most of the operations outlined in the "total" approach have been carried out as proposed. However, the flowchart does not sufficiently reflect the degree of participation of the benefactors, the sense of well-being amongst the community members when they are helping one another, the sense of achievement when they have built their own water storage facilities and , in many cases, the acquisition of new construction skills. Most important of all, the whole operation which is geared for the people of Capiz, is considered to be effective through the "Halaran" - the God-centred approach to development. The noble motives and the high degree of goodwill and faith thrown in for the successful implementation of RWCS projects in Capiz augur well for the future of such systems.

2. In the actual execution of the project, the financial model plays an important psychological role. The feeling that the tank is not being doled out and has to be paid for has a positive impact on the benefactors. This is mainly to maintain the beneficiary's self-respect and capacity for self-reliance. Besides, there should be greater care taken in the construction of the tanks and the maintenance of the tanks should also be of a higher order especially when payments are still being made.

3. The system of repayment should preferably be worked out when the pilot-scale project is being planned and executed. It will then be possible to better identify those participants who are genuinely interested and willing to get involved in the project.

4. From observations made and tests carried out in the pilot plant locations, it was noticed that there is potential for some of the collected rainwater to get contaminated. Hence, siting of the tanks has to be done with care.

5. The results of the water analysis in terms of bateriological purity have to be viewed with trepidation as 25% of the samples indicated high Coliform counts. It has been suggested that the possible routes of contamination are unclean roofs and/or guttering, unclean water tanks, poor collection and handling practices. But, there is no need for alarm as there has definitely been no case of reported ailments or sickness by imbibing the collected roofwater.

However, it would appear that from previous examinations of roofwater quality, there have been instances of higher than allowable Coliform counts (Waller et al 1984, Bunyaratpan and Sinsupan 1984). This issue of high Coliform counts need not, perhaps, be viewed in the same light as identical values obtained from surface runoff sources. In the case of surface runoff, the potential danger lies in human contamination whereas in the case of RWCS, which have roofs as their catchment areas, this is quite unlikely.

6. The tank volumes chosen for the project in Capiz were constrained by limited field data. From an analysis of the demand patterns available at present, it would appear that the 6,000 litre capacity tanks appear to be oversized. With available data on rainfall and pending data on water-usage patterns, it could be worthwhile reappraising the sizes of the 6,000 and 10,000 litre tanks.

7. RWCS units are being constructed in Capiz at a very rapid rate with and without appropriate control with regard to structural accuracy and safety. As more and more tanks are being built, not necessarily with proper supervision and control of the design and construction, there is the possibility of structural failure. At this point of development of RWCS, it should be timely to introduce measures in the form of bye-laws or regulations to

ensure that the different types of RWCS units being designed and constructed are structurally safe.

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INSTITUTIONAL ASPECTS

AND

POLICY MATTERS

EDUCATING CIVIL ENGINEERS ABOUT RAIN WATER CISTERN SYSTEM

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ABSTRACT

Water supply is a topic covered by all civil engineering curricula. Civil engineers must know how to plan, design and implement piped water supply to the community. Rain water cistern system has received little or no attention in most civil engineering curricula than more technically oriented centralised pipe water supply system.

Especially for developing countries where most of the population still lived in remote rural areas, rain water is a vital high quality though low volume source of water supply. Rain water cistern system may not be the best water supply system but it definitely is the cheapest and most viable alternative for most undeveloped and developing countries.

A unique four-year civil engineering curriculum was drafted for Universiti Sains Malaysia to be offered at the undergraduate degree programme in the 1989-90 academic session. This environmentally inclined curriculum will among other things emphasise the less sophisticated technologies and rain water collection system is one of them.

INTRODUCTION

Traditional civil engineering curricula has basically been concerned with public works and is mostly design oriented based on modern sophisticated technology. They had little or no emphasis on cheaper and lesser quality alternatives that are sometime more appropriate for some countries. Modern civil engineering education should be geared to the needs and aspirations of the respective countries.

Rain water cistern system is increasingly used both in developing and developed countries. In most developing countries, rapid urbanisation has forced some of the populace to resort to other sources for water supply and rain water has increasingly been used to supplement public water supplies. Meanwhile in underdeveloped and developing countries, the use of rain water is particularly applicable in rural areas where piped water supply system is non existence.

WATER RESOURCES IN MALAYSIA

Malaysia is a country endowed with abundant rainfall that is unfortunately unevenly distributed both chronologically and geographically. As a result, various parts of the country are occasionally afflicted with floods and water shortages. Annual rainfall in Peninsular Malaysia, Sabah and Sarawak are 2420 mm, 2630 mm and 3830 respectively. Compared to a world average of 973 mm, Malaysia has about 2½ times the world's annual average precipitation.

In 1985, it was estimated that 93.1% (5,502,899) of urban dwellers and 57.6% (5,687,584) of the rural populace in Malaysia has access to piped water supply. For a country with 60% rural population, the real problem seems to be in the rural areas where nearly half of the populace is still without piped water supply. The government estimated that by the year 1990, 96.5% and 72.8% of urban and rural dwellers respectively will be supplied with piped water supply.

Realising the fact that it costs far less to provide clean water and sanitation than the price paid for its shortages, the government implemented other alternatives to piped water supply by constructing wells and rain water cisterns. Between 1981-85, 5600 wells equipped with hand pumps and 420 wells with direct supply to households were constructed. In the same period, about 14,300 rain water cisterns were constructed mostly in remote areas in Sabah and Sarawak. Rain water cistern system is especially applicable in remote areas where population densities are too low for reticulated supplies to be economically justified.

CIVIL ENGINEERING CURRICULUM

The Civil Engineering Curriculum drafted for Universiti Sains Malaysia was geared towards the needs and aspirations of developing countries similar to Malaysia. Currently, five of the seven institutions of higher learning are offering civil engineering education. The civil engineering programmes differ widely from university to university, and the level of practicality for local conditions likewise varies depending upon the philosophy set by the individual institution.

Table 1 shows the basic structure of the curriculum. The curriculum is based on the unit system. One unit is equavalent to 14 hours of lectures, tutorials, seminars or laboratory works. A total of 146 units is needed for graduation. As in other curriculum, this one has core courses in structures, strength of materials and fluid mechanics which led to applied courses in steel, concrete and timber design, infrastructure and building services design and foundation design. The last decade saw the advent of computers as design aids. Some computing papers are also included for this purpose.

The vast expansion of civil engineering knowledge in recent years have forced engineering institutions to broaden the curricula. The core content of this curriculum is similar to any other civil engineering curricula from any other institutions. This paper will mainly highlight the inclusion of less sophisticated technologies like the rain water cistern system in the curriculum.

		FIRST YEAR	SECOND YEAR	THIRD YEAR	FOURTH YEAR	UNITS
COMPULSORY COURSES	First Semester	Mathematics I (4) Computer Programming I (2) Material Science (3) Engineering Mechanics (3) Surveying I (3)	Engineering Workshop I (3) Mathematics III (3) Structural Theory I (4) Soil Mechanics I (3) Engineer In Society I (2)	Engineering Workshop III (6) Structural Design II (3) Geotechnics (3) Public Health Engineering I (3) Transportation & Traffic Eng. (3)	Project (4) Foundation Engineering I (3) Hydraulics and Hydrology (4) Water Resources Engineering (3)	
	Second Semester	Mathematics II (4) Computer Programming II (2) Strength of Materials (3) Construction Material (3) Geology (3)	Engineering Workshop II (3) Structural Theory II (4) Structural Design I (4) Fluid Mechanics I (3) Highway Engineering (3)	PRACTICAL TRAINING (18 WEEKS)	Project (4) Building Services Engineering (2) Construction Management (4) Engineer in Society II (2)	112
UNIVERSITY REQUIREMENTS & ELECTIVES		General Physics I (3) Environmental Studies (2) Electrical Technology (3) Surveying II (2) Chemistry (2) Biology (2)	Metallurgy (3) Mathematics IV (3) Islamic Civilisation (4) Languages (10) Co-curriculum (6)	Computer Programming III (2) Conservation (2)	Public Health Engineering II (3) Advanced Hydraulics (3) Water Resources Management (3) Advanced Hydrology (3) AND OTHER SPECIALISATIONS	34
				TOTAL UNITS FOR GRADUATION		146

Table 1 : Civil Engineering Curriculum

The first year and part of the second year, the programme is devoted to giving students exposure in the basic sciences, mathematics, computer programming and basic engineering principles. A very broad understanding of the pure sciences including biological chemistry is stressed initially since the basic processes and operations of most civil engineering systems are controlled by other than just physical mechanisms. Courses in the third and final years are geared towards application of theories and are problem solving in nature.

Application of less sophisticated technologies are highlighted where ever appropriate. In infrastructure, apart from rain water cistern system, other less sophisticated technologies include the treatment of wastewater using pit privy, latrine and septic tank and the treatment of rain water using crude sedimentation and filtration techniques.

RAIN WATER CISTERN SYSTEM

One of the common definition of engineering is that "it is the art of harnessing the forces of nature for the service of man". Rain water cistern system is a method of harnessing rain water to fulfill one of the greatest needs of society, that is, for survival and to safeguard public health.

In the curriculum, rain water cistern system is discussed at length in the course Public Health Engineering. The main bulk of the content of this course is the application of engineering principles to solve environmental oriented projects such as the various unit processes design in water and wastewater treatment plants and solid waste disposal system.

The topic on rain water cistern system starts with a brief introduction on the current water resources situation in developing countries and stresses its needs to supplement public reticulated supply. This course basically outlines the major steps and basic considerations in planning and developing a rainwater harvesting project. The first thing an engineer needs to know is the rainfall pattern in terms of temporal and spatial characteristics. These include the relationship of rainfall, roof area, tank size and the household demand from which the optimum tank size can be determined. The potential and availability of rain water supply as well as its realibility monthly needs to be evaluated as well.

A brief introduction to the rain water quality is necessary in the course so as to safeguard public health. In this respect, the course also discusses the water quality assessments of rain water in the atmosphere, roof catchment and storage tanks. Several of the important parameters include alkalinity, hardness, chloride, iron, nitrate, pH, temperature, colour and coliform bacteria.

For a project of this nature to be successful, community participation is vital. This course also discusses ways and means to assess a community's willingness and ability to support a rooftop catchment system and also to conduct an inventory of local skills, materials and techniques.

The next important step is construction of the tank and gutter. The various materials that can be used for tank construction discussed are ferrocement, bamboo, brick, interlocking mortar-block and non-cement based materials. Techniques to size the gutter and tanks are also highlighted. A major part of the course is also allocated for tank sizing. Parameters taken into account are the relationships between roof and tank size, rainy and dry seasons, and yield and consumption.

Last but not least, some socio-economic factors are also discussed briefly. These include the attitude and acceptance or non acceptance of the consumer towards the system. The advantages and disadvantages of the system are also highlighted in comparison to a full reticulated system.

CONCLUSION

The collection of rain water as a water source has an increasingly bright future. This fact is further reinforced if builders especially civil engineers have full knowledge of its use, importance, suitability and capable of designing and constructing the system. Application of less sophisticated technologies such as the rain water cistern system therefore need to be part and parcel of a civil engineering curriculum.

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THE WASH RAIN WATER NETWORK

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Abstract

The Water and Sanitation for Health Project has established a Rainwater Harvesting Information Center (RHIC). RHIC has developed bibliographic and organizational databases to establish a rainwater network and organize literature pertaining to rainwater harvesting. There are nearly 300 documents in the literature collection and 277 organizations and individuals in the rainwater network. A questionnaire has been distributed to network members to obtain information on rainwater research and projects. One issue of a newsletter entitled "RAINDROP" has been published and distributed also.

The WASH Rainwater Harvesting Information Center

INTRODUCTION

The Water and Sanitation for Health Project (WASH) is sponsored by the U.S. Agency for International Development. WASH provides AID Bureaus and Missions with technical services to support its drinking water and sanitation projects. In 1984, WASH established a specialized information center to create a rainwater network. The purposes of the rainwater network are to:

- gather and disseminate information from a variety of sources;
- provide for a creative cross fertiliztion of ideas among researchers and others;
- establish a mutual learning/sharing process through personal contact among network members.

INFORMATION CENTER

The Rainwater Harvesting Information Center (RHIC) collects and disseminates information. The Information Center contains nearly 300 reports, articles and books on rainwater harvesting. A specialized thesaurus was created to index the rainwater literature, and a bibliographic database was developed on dBASEIII+. The database, which is named RAINCOLL, allows for searches and retrieval of documents by keyword, author, title, country and language. In 1984, a literature search was done on the major environmental and engineering databases. This search retrieved only 5 citations pertaining to rainwater harvesting. The rainwater thesaurus and RAINCOLL were created to fill this void in the literature.

RHIC also maintains an organizational database to record and monitor information on rainwater projects and research. There are 231 organizations listed in the database. 70% of the network members are from developing countries. Enclosed is a graph which shows the geographic distribution of network members. Approximately one-half day per week and $15,000 per year is dedicated to maintaining RHIC. A 1988 evaluation stated that the very limited budget and staff support resources have been used with laudable efficiency and productivity.

In addition to maintaining bibliographic and organizational databases, RHIC responds to information requests and disseminates reports and information packets. RHIC recently provided comprehensive literature searches and information for rainwater research projects in India and Bangladesh. RHIC has published and distributed one issue of a newsletter entitled

"RAINDROP." A sample issue is included in Appendix 1.We hope to distribute 2 or 3 additional newsletters within the coming year as well as publish an annotated bibliography and a directory of rainwater network members.

RAINWATER NETWORK

The network presently consists of 277 organizations and individuals from 80 countries. 76% of the members are from developing countries in the African, Asia/Near East, and Latin American regions. A graph of the geographic distribution of network members is shown in Figure 1.

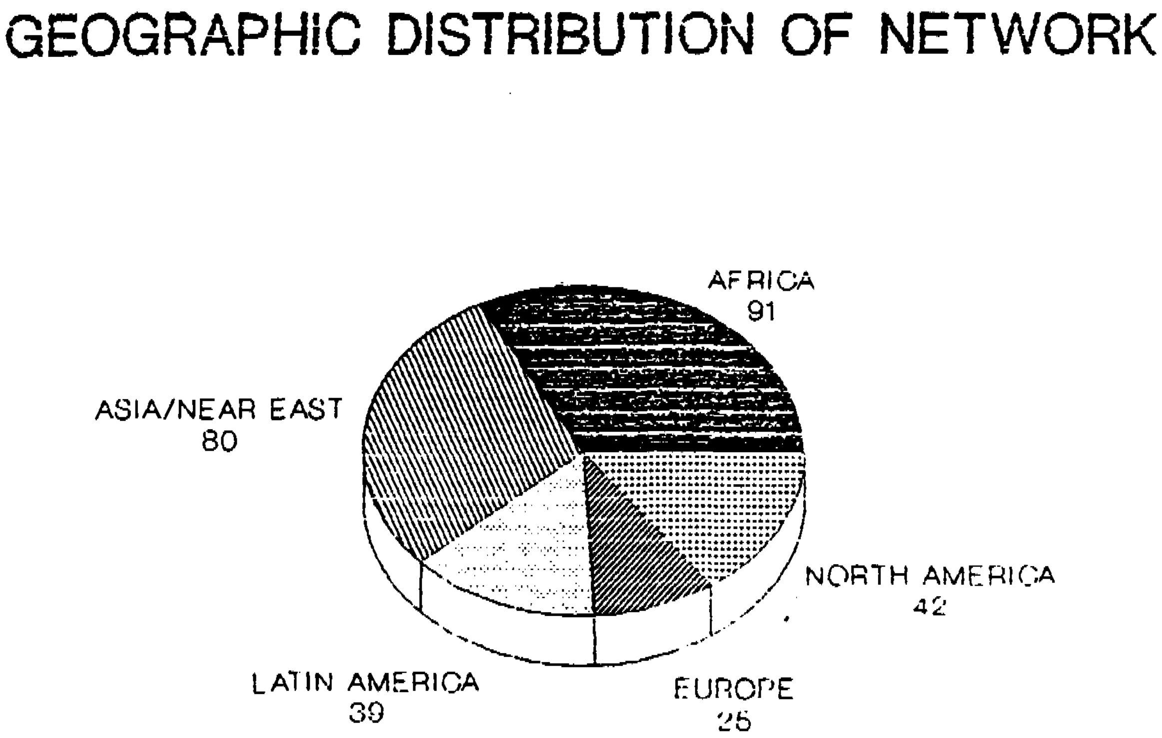

Figure 1

In December 1988, a questionnaire was distributed to network members. The questionnaire requested information on the interests, projects, and needs of network members. As of April 1989, 58 or 25% of the network members had responded to the questionnaire. A follow-up questionnaire to those who did not respond was distributed in May 1989. A sample of the questionnaire is included in Appendix 2.

The 58 organizations that responded are involved in a wide range of rainwater activities. A summary of their activities is included below:

Area of Involvement	Number of Organizations
Research/Field Trials	31
Training	31
Community Participation	29
Construction of Cisterns	28
Project Evaluations	24
Develop Training Manuals	21
Financing Projects	18
Other Areas of Involvement	3

The 58 responses also included information on recent or proposed rainwater projects. These are:

Bangladesh - Bangladesh Agricultural University. A research project "Rainwater Catchment for Rural People of Bangladesh" will be starting soon with IDRC support. The objective of the project is to develop and demonstrate an appropriate rainwater catchment system.

Botswana - Botswana Technology Centre. The Centre plans to investigate failure of ferrocement tanks. A new manual will be written on ferrocement tank repair techniques.

Colombia - Convenio Colombo-Holandes. This organization plans to implement rainwater catchments into future primary health care projects.

Haiti - United Nations Development Programme. UNDP has recommended rainwater cisterns in the limestone mountainous areas of Haiti.

Kenya - AMREF. AMREF will be investigating simple tank sizing techniques.

Kenya - Diocese of Meru. The Diocese plans to promote 1000 liter and 2500 liter cement tanks for people who live in semi-arid areas. Women will be trained in the construction of the 1000 cement liter tank.

Malawi - UNICEF. UNICEF is investigating low cost cisterns and collection of rainwater from thatch for household water supply.
Nepal - WaterAid. WaterAid may undertake pilot projects in rainwater harvesting.

Papua New Guinea - Department of Works. The Government is conducting an investigation of replacing corrugated iron tanks with ferrocement storage tanks. It is estimated that the PNG government spends 1 million U.S. dollars per year to maintain the corrugated iron tanks.

Philippines - Philippine Center for Appropriate Technology. PCATT would like to incorporate rainwater catchment in the design of low cost housing.

Tanzania - Swedish International Development Authority. SIDA has recently started funding small scale rainwater catchment projects in Tanzania. Community participation plays an important part in these projects.

Zaire - Southchurch Missionary Support Workshop. This group has recently started demonstration projects with concrete water tanks. The feasibility of cement roof tiles is underway.

Zimbabwe - Manicaland Development Association. A training centre is being established in the south of Mutare. Training in ferrocement construction and water harvesting techniques will be given a high priority at the centre.

International - World Bank. The World Bank is proposing a research study to prepare a state of the art paper on rainwater harvesting. This may lead to possible case studies of successful rainwater harvesting projects and to the development of future guidelines for World Bank involvement in rainwater harvesting.

Other respondents described projects which have been underway for some time. Examples of these are:

Brazil - EMBRAPA. EMBRAPA has constructed 5000 cisterns in northeast Brazil. Several short courses were also organized to train extensionists.

India - Integrated Fisherfolk Development Project. A number of Arab Muslims collect rainwater from October to November. Water in cisterns is purified by dropping red hot iron into the cisterns.

Kenya - Action Aid. This organization has assisted in the construction of rainwater tanks for schools and womens groups in 5 regions. 2 staff members train the community and local artisans.

Kenya - Machakos Diocese. The Diocese introduced watertanks for roof catchments in 1983. 1500 tanks were built within 3 years. Presently, the program is financially self-reliant.

South Africa - University of Natal. A research program on artificial catchments and roof catchments was conducted from 1982 to 1986. Artificial catchment surfaces were found to be too expensive compared to other options such as boreholes. Roof catchments, however, were found to be a cost effective alternative and are used extensively in areas where metal roofs are available.

CONCLUSIONS

The Rainwater Harvesting Information Center has taken the initial steps in establishing a network and organizing information on this topic. The evaluation of RHIC recommended that the information center assume a more active role in promoting and disseminating information. Specific recommendations include:

1. Publish 3 issues of "RAINDROP" or a similar bulletin at least three times per year.

2. Publish at least 3 articles per year in relevant international journals.

3. Provide technical and organizational support to the on-going rainwater harvesting conferences.

4. Encourage research and documentation on the role of women in rainwater harvesting.

5. Encourage research into the role and benefit of rainwater harvesting during the rainy season when groundwater supplies may be contaminated.

6. Evaluate the Togo Water Project to assess the level of community organization and the level of guinea worm infection before and after the construction of rainwater cisterns.

7. Promote economic analysis of rainwater harvesting in its varied applications to demonstrate cost/benefit and cost/effective relationships.

8. Exploit the potential applications of the RAINCOLL database by incorporating it into international databases such as AGRICOLA, AGRIS, or NTIS.

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Appendix 1

Sample Issue of RAINDROP

WATER AND SANITATION FOR HEALTH PROJECT

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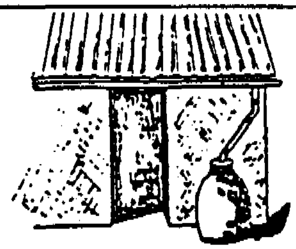
RAINDROP

Rainwater Harvesting Bulletin

Vol 1. No. 1 November 1, 1988



Distributed to the Rainwater Harvesting Network. To join, contact WASH.

WHO IS RHIC?

The WASH/Rainwater Harvesting Information Center, now known as RHIC, was created in 1982 as a part of the USAID-funded WASH project. The objective of RHIC is to increase the availability of potable water supplies to rural areas through the promotion of appropriate, low-cost, self-help rainwater harvesting technologies. RHIC's major activity is information dissemination. The Center's RAINCOLL database is accessible to Network membership and to the general public.

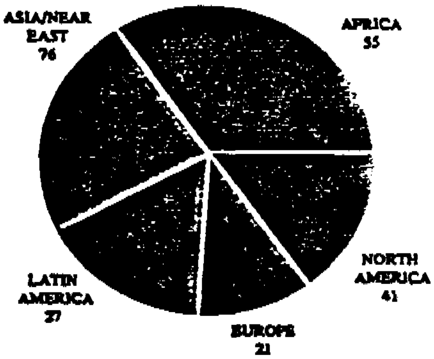
HOW THE NETWORK WORKS

In Kenya, there are nearly one hundred community-based, cistern construction projects scattered across the countryside. Recently, two such projects were promoting ferrocement cistern construction, yet were unaware of the activities of the other. When both responded to the previous Network questionnaire, showing striking similarities of their activities, RHIC put the two in contact with each other, resulting in useful sharing of experience and skills..

The Network database is intended to serve the Network members, and access to its data is available to any member. If, for example, you work with ferrocement cisterns and want to know the names of other projects who have similar experience, contact Dan Campbell at RHIC with your request, being as specific as possible as to the information you are seeking.

WHO IS THE NETWORK?

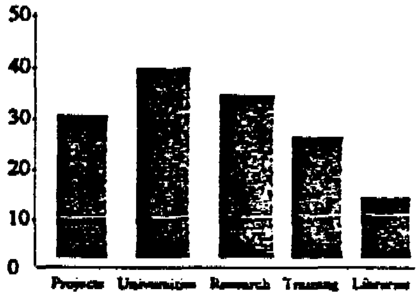
The RHIC Network membership currently includes 231 individuals and institutions from more than 25 countries. These members are involved in a range of Rainwater Harvesting (RWH) activities from grass-roots project implementation to university-based research. The names, addresses, and any other pertinent information received from the Network members are set up on a computer data base for retrieval by contact person, organization, country, RWH activities, reports issued, etc. The Network membership has increased from 74 in 1986 to the present total. Membership is open to any individual or organization who wishes to join, and has no dues or fees. Seventy percent of Network Members are from Less Developed Countries, representing eleven different languages.



SOURCE: RHIC NETWORK

Of the 231 Network Members, 103 have provided information concerning their RWH activities. Of those, the distribution of known Network Membership activities includes: 30 recent or on-going community-based rainwater projects; 39 university-based members; 36 RWH research and development activities, organizations, or individuals; 28 organizations that have conducted RWH trainings, of whom twenty requested copies of the WASH/Rainwater Harvesting Training Manual; and 12 library or documentation centers that feature RWH documentation.

Types of Organizations in RHIC Network



SOURCE: RHIC NETWORK

One of the goals of RHIC is to increase the number of Network members and distribution of RHIC technical information and the RAINDROP bulletin. The enclosed questionnaire requests that you supply RHIC with information about your activities. You are also invited to help expand the Network membership by giving the names of other individuals and institutions whom you would suggest be included as Network members. The information you supply about your organization's RWH activities will help RHIC to focus its technical assistance services to best meet the needs of the Network members. We look forward to learning more about your activities, which will benefit all Network members.

EDITORIAL

NETWORK PRIORITY!

RAINWATER INFO CENTER EXPANDS

The USAID-funded WASH Rainwater Harvesting Information Center, now known as RHIC, is broadening its scope. As before, RHIC's objective is to increase availability of potable water supplies to rural areas through the promotion of appropriate, low-cost, self-help rainwater harvesting (RWH)water supply systems. The goals for expansion of RHIC services are to: expand Network membership, increase technical information dissemination, and focus RHIC's technical assistance services to the areas of highest demand. As a means of meeting each of these three goals, RAINDROP is being published on a trial basis. Its objective is to provide practical, field-oriented technical information and support to RWH activities.

RHIC's major information dissemination activities are 1) distribution of WASH reports and training guide, 2) response to requests for technical information and technical assistance, and 3) correspondence with the RHIC Network members to link them with similar RWH projects, and to inform the Network of new developments in rainwater harvesting.

RAINDROP can report on important RWH technology developments and issues, project profiles, provide a guide to current information resources, and review new publications and articles. RAINDROP can also facilitate communications within the Network 1) by reporting and building on Network members' knowledge and skills from hands-on experiences, and 2) by identifying and responding to the Network's common concerns, technical issues, and information demands.

One objective of RAINDROP is to actively encourage exchange of information within the Network so that members can benefit from each other's experiences. This could include reporting on member's successes in a range of RWH activities—including project implementation, field trials, extension, self-help community organization, etc.

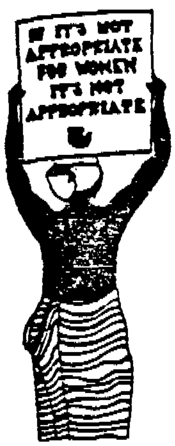
Another of RAINDROP'S objectives is to focus on under-documented areas and issues, relying on the Network membership as well as its own technical expertise to improve the documentation on selected issues. In addition to the priority focus on women's role in RWH in this issue, upcoming priorities could focus on taking a new look at cost-benefit evaluations of RWH, community organization, and extension techniques for RWH.

We are excited about RAINDROP and the role it could play in promoting rainwater harvesting around the globe. You can help by letting us know how we can serve your needs. Your ideas and reactions to RAINDROP will be very welcome and could play a critical role in the scope and frequency of RAINDROP. You can also contribute by sending to RHIC any relevant project reports, construction plans, photos, or even better, contribute an article to RAINDROP. We look forward to hearing from you.

WOMEN'S ROLE IN RAINWATER HARVESTING?

It is a fact that women provide nearly all of the labor in supplying drinking and household water to their families, although very little has been written about their role in rainwater harvesting (RWH). In a survey of all publications and documents known to the RHIC RAINCOLL database, almost no such information is on record. Simple logic would lead us to conclude that it is critical to integrate women in RWH at every level from project planning, training, and extension, to technology research and design. Why then has so little been written on the topic?

RAINDROP's priority is to use the Network's participation to improve the documentation on this important topic. To do so, send documents such as project reports on how your own RWH activities involve women; a description of how women have reacted to RWH technologies; the changes which may have occurred to their work and labor demands due to RWH; or any related documentation that could be useful to other Network members. These documents will be reviewed for possible inclusion in the RAINCOLL database, and some could be excerpted or abstracted in potential future issues of RAINDROP.



STILL MUCH TO LEARN

by J.E. Gould
Kent, United Kingdom

Like so many great inventions, the strength of rainwater catchment technology lies in its simplicity. During the last decade renewed interest in this ancient form of water supply has resulted in its budding revival. Engineers and practitioners have developed new and appropriate designs which have spread rapidly in many areas. Inevitably, mistakes have been made along the way. It is not a simple challenge to find low cost solutions. The now abandoned bamboo reinforced rainwater tank program in Thailand, Malaysia, and Indonesia provided valuable learning experiences for us all. As the result of both failures and success, reliable and well-tested designs have emerged such as the ferrocement tank, the work reinforced cement jar, and the concrete ring tank designs. Others, such as the interlocking brick cistern developed in Khon Kaen, Thailand and the the quick form cistern from Togo are still being tested, but seem to offer promise for the future.

Despite the great strides which have been made in improving and developing the design and construction of rainwater tank hardware in the last ten years, much needs to be done to develop the "software" to market and promote this technology. Software, in this context refers not only to developing appropriate implementation strategies at grassroots level which enable individual families, groups of householders and whole communities to help themselves, but it is equally important to market the technology to government agencies (both at local and national levels) and to major international funding bodies.

Critics of rainwater catchment technology often cite the high economic costs of rainwater tanks vis-a-vis alternative improved water supply technologies. This comparison is wholly misleading, however, since rainwater tanks are often used where such alternatives are not viable. More research needs to be done comparing the costs of rainwater harvesting with other forms of supply in those regions where due to remoteness, poor groundwater, or lack of suitable surface water supplies, rainwater collection may be viable or is already widely practiced.

Further research also needs to be done in assessing the benefits due to the vast savings of time and energy derived from rainwater tank implementation. Improvements in health resulting from the replacement of distant, frequently contaminated water sources by rainwater tanks which provide a water source at the point of consumption also warrant further investigation. Findings in these critical areas of research need to be widely disseminated to encourage appropriate RWH technology implementation.

Successful and well-tested approaches to rainwater tank implementation at the village level also need to be more widely publicized. Although it has to be realized that every community and, hence, every project is unique and thus there is never any guarantee that an implemenation strategy which succeeds in one area will necessarily succeed in another. Much effort has been wasted in the past, reinventing the wheel, by projects isolated from the outside world. It is time to start learning from others' mistakes and benefitting from their successes.

An example of one traditional idea from Kenya, which has spread elsewhere is the adoption of forming revolving fund groups to help individual households raise the money to install their own cistern. The system is simple: a group of families, for example ten, would each make a monthly contribution to a central pool equivalent to one tenth of the cost of the rainwater tank. Each month one tank would be built and within less than one year, the whole group would have rainwater tanks, the cost of which would have been spread over ten months.

Real progress has been made in developing rainwater catchment tank designs during the last decade. If the full potential of this very promising technology is to be fully realized during the next decade, however, those promoting it need to learn how to secure support for its implementation at local, national, and international levels. The priority for improved domestic water supplies while high at local levels, remains depressingly low at national and international levels. Nevertheless, in Thailand the impact of a succerssful rainwater tank program resulting from cooperation at local, national and international levels is clear. By 1987 more than 3 million tanks had already been constructed and it is confidently predicted that by 1990, around 9 million tanks will exist, helping to make Thailand one of the few developing nations, which may to come close to achieving the goals of the International Water and Sanitation Decade.

INFORMATION RESOURCES

Collection and Storage of Roof Runoff for Drinking Purposes: A project Supported by the International Development Research Centre. By the Faculty of Engineering, Khon Kaen University, 1984. Consists of 4 volumes, which include: Hydrolic Studies, Studies of Rainwater Quality, Construction Materials—Techniques and Operational Studies, and Socio-Economic Studies. Contact Khon Kaen University, Faculty of Engineering, Khon Kaen (40002), Thailand for ordering information.

Proceedings of the Third International Conference on Rain Water Cistern Systems, 14-16 January 1987, Khon Kaen, Thailand. Contains 40 papers that were presented at the conference. Papers are divided into the following areas: History; Planning; Design; Policy and Planning; Technology: Water Quality; and related topics. Available from Khon Kaen University, Faculty of Engineering, Khon Kaen (40002), Thailand. Price $40.00.

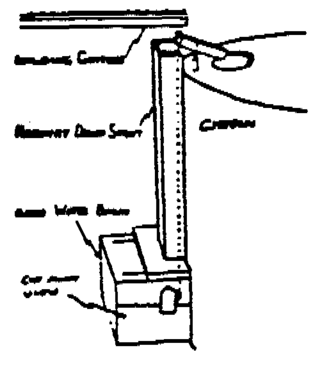
A Workshop Design for Rainwater Roof Catchment Systems: A Training Guide. Technical Report No. 27. By D. Edwards, K. Keller, and D. Yohalem. WASH, 1984. Manual for conducting a 2-week workshop for local project promoters in rainwater systems. Available from WASH, 1611 North Kent Street, Room 1001, Arlington, VA 22209, USA.

Rainwater Harvesting: The Collection of Rainfall and Runoff in Rural Areas. By Arnold Pacey with Adrian Cullis, 1986. Intended for rural development workers; software issues—including how to design and implement schemes in appropriate ways for rural communities. Using material from a wide variety of sources, it explains the importance of social, economic, and environmental considerations in the planning of rainwater projects. Chapters include: Technical perspectives, Water—livelihood and organization, Data collection and design criteria, Rainwater tanks and technical assistance, Design for drinking water systems, Traditions in runoff farming, Replication in runoff farming, and rainwater economics and future prospects. Available from IT Publications Ltd, 9 King Street, Covent Garden, London, WC2E 8HW, England. £5.95.

TECHNOLOGY NEWS

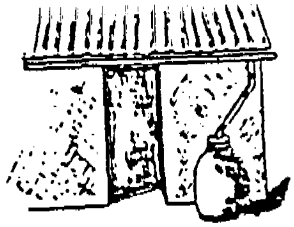
FOUL FLUSH DIVERTER

When raindrops fall to the earth they are generally clean and safe to drink. However, when they fall on a dusty roof and wash down the roof carrying accumulated leaves, dust, bird dung, etc., those first several dozen liters of rainwater are not hygienic for drinking. A system called a "foul flush diverter" channels the first dirty rainwater out of the cistern. One system which has been used with good results was developed in Togo by the USAID-financed Water Project. It is a low-cost, relatively simple foul flush mechanism which has equipped more than 250 cisterns built by the Togo Project. As a part of the overall hygiene system, the Project recommends cleaning the cistern annually with bleach and covering the cistern fill hole with screen to keep out small animals and debris.



In Togo, foul flush diverters were made in a central workshop by village metal workers and then transported out to the construction sites. The exact placement and adjustment of the diverter must be adapted to each site. The necessary materials include: 3m of No. 8 and 2m of No. 6 re-enforcing rod, a 60cm piece of sturdy gutter material, a plastic jug, and a small catchment basin which could be made of masonry, a half barrel, or a large clay jar. The short diverter gutter is balanced on a No. 6 rod pivot. The diverter gutter channels the rainwater either into a flush basin or into the cistern. During the flush mode, as the basin fills, the plastic jug float rises with the water level. The float, lifted by the rising water level in the flush basin, tips the diverter gutter to the other side of the balance, thus channeling the rainwater into the cistern. The collected foul flush water can be used for household purposes other than drinking, and must be emptied before the next rain to permit proper functioning of the foul flush system.

For further information, contact Dan Campbell at RHIC. If you have experiences with other foul flush systems, RAINDROP invites you to contribute drawings and a brief description which would be adequate to duplicate the design elsewhere.



NETWORK RESPONSE FORM
RAINDROP EVALUATION

1. DO YOU FIND RAINDROP USEFUL? PLEASE COMMENT.

2. IF YOU WOULD LIKE TO RECEIVE FUTURE ISSUES OF RAINDROP, WHAT KINDS OF INFORMATION, TOPICS, ANALYSIS, TECHNOLOGIES, ETC. WOULD BE USEFUL TO SUPPORT YOUR RAINWATER HARVESTING ACTIVITIES?

REQUEST FOR FREE WASH RAINWATER REPORTS

The following WASH reports have been published. To obtain copies, send name, address, and selection to: WASH Operations Center, 1611 North Kent Street, Suite 1001, Arlington, Virginia 22209, USA.

1. Technical Report 11. *The Role of Women as Participants and Beneficiaries in Water Supply and Sanitation Programs.* Available in French, Spanish, and English.
2. Technical Report 27. *A Workshop Design for Rainwater Roof Catchment Systems: A Training Guide.* 1984
3. Field Report 115. *Training in Rainwater Catchment for SANRU-86 Village Health Workers and Peace Corps Volunteers.*
4. Field Report 163. *Training Workshop on Rainwater Roof Catchment, San Julian, Bolivia.* 1986. Available in Spanish and English.
5. Field Report 172. *Project Design and Extension Training in Cement Stave Rainwater Cistern Construction in Togo.*

NAME ______________________________
TITLE ______________________________
ORGANIZATION ______________________________
ADDRESS ______________________________
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Appendix 2

WASH/RHIC Network Questionnaire

WASH/RHIC NETWORK QUESTIONNAIRE
OCTOBER 31, 1988

1. NAME OF ORGANIZATION____

2. ADDRESS____
____

3. TELEPHONE NO.____________________TELEX NO.____________________

4. HEAD OF ORGANIZATION____

5. CONTACT PERSON if different from above____________________________

6. TYPE OF ORGANIZATION (can check more than one)
   ___ Private voluntary organization
   ___ International organization
   ___ University Affiliated
   ___ Governmental Organization
   ___ Religious Organization
   ___ Other____________

7. WORKING LANGUAGES (check all that apply)
   ___ English ___French ___Spanish ___Arabic Other____________

8. IF YOUR ORGANIZATION HAS EVER DONE WORK IN COUNTRIES OTHER THAN THE ADDRESS ABOVE, PLEASE LIST THOSE COUNTRIES AND BRIEFLY DESCRIBE THE ACTIVITIES.
____
____

9. AREAS OF INVOLVEMENT IN RAINWATER PROJECTS (check all that apply)
   ___ cistern construction
   ___ project financing
   ___ community participation
   ___ project evaluation
   ___ training in rainwater catchment
   ___ development of training manuals, guides, etc.
   ___ research/field trials
   others

10. CONSTRUCTION MATERIALS USED (check all that apply)

CISTERNS
   ___ bamboo
   ___ fired brick
   ___ cement
   ___ ferrocement
   ___ metal
   ___other____________________

ROOFS
   ___ corrugated roofing
   ___ clay tile
   ___ thatch
   ___ sisal
   ___ cocofiber
   ___other____________________

11. PLEASE PROVIDE A BRIEF DESCRIPTION OF RAINWATER ROOF CATCHMENT PROJECTS WHICH ARE CURRENTLY UNDERWAY IN YOUR ORGANIZATION. (include the number of cisterns built, objective of field tests, number of field staff, training sessions, community organizations involved, etc.)
____
____
____
____
____
____

12. DO YOU HAVE PLANS FOR FUTURE OR EXPANDED RAINWATER HARVESTING ACTIVITIES? (please give brief details)

____

____

____

13. FROM THE FOLLOWING LIST OF TECHNICAL ASSISTANCE SERVICES, PLEASE CHECK THOSE WHICH ARE MOST NEEDED BY YOUR ORGANIZATION'S RAINWATER HARVESTING ACTIVITIES.

___ Technical Information on RWH Technologies
___ Project Planning and Design Assistance
___ Cistern Design
___ Gutter Design
___ Training Design/Trainers
___ Low Cost Roofing Technologies
___ Water Hygiene
other____

14. HAS YOUR ORGANIZATION RECEIVED FUNDING FROM ANY OUTSIDE SOURCES TO SUPPORT ITS RAINWATER HARVESTING ACTIVITES?

____ YES ____ NO

IF SO, WAS THE SOURCE
____ LOCAL GOVERNMENT
____ BI-LATERAL OR INTERNATIONAL AID
____ PRIVATE OR VOLUNTARY ORGANIZATION
____ RELIGIOUS ORGANIZATION
OTHER (please describe)____

15. HAS YOUR ORGANIZATION PUBLISHED ANY REPORTS, BOOKS, NEWSLETTERS, ETC. ABOUT RAINWATER HARVESTING, ROOF CATCHMENTS, CISTERN CONSTRUCTION, ETC. (If yes, please list the titles. If the RHIC Database does not already have a copy of the document, if possible, please send a copy, and it will be reviewed for addition to the RAINCOLL DATABASE).

____

____

____

16. DOES YOUR ORGANIZATION HAVE A COLLECTION OF DOCUMENTS OR A LIBRARY ON RAIN WATER ROOF CATCHMENT SYSTEMS?

___ YES ___NO

_________Approximate number of publications

17. PLEASE LIST THE NAMES AND ADDRESSES OF ANY INDIVIDUALS OR ORGANIZATIONS INVOLVED IN RAINWATER HARVESTING WHO YOU RECOMMEND BE INCLUDED AS MEMBERS OF THE WASH RAINWATER HARVESTING NETWORK?

____

____

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____

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THANK YOU FOR TAKING THE TIME TO COMPLETE AND RETURN THIS QUESTIONNAIRE.

ENVIRONMENTAL

AND

WATER QUALITY ASPECTS

QUALITATIVE ASPECTS OF RAINWATER USE IN THE FEDERAL REPUBLIC OF GERMANY

Beate Klein
Martin Bullerman

ABSTRACT

An extensive research has been made on qualitative aspects of the use of rainwater for closet flushing, gardening irrigation and washing machines.

The quality of the roof water run-off was analysed using 20 parameters at 15 gaging stations. The selection of the parameters depended on the demands of drinking water in the F.R.G. The measurements were carried out during the period of 1988/89. They showed systematical connections between water quality and roof materials, site facts, meteorology as well as the seasons. The quality of the run-off water was estimated regarding the mentioned uses. Conclusions for the design and operation of rainwater systems are deduced from the results.

1. INTRODUCTION

The research on the qualitative aspects of rainwater uses has been made in the Federal Republic of Germany in 1988/89 (Bullermann et al. 1989). The rainwater shall be used for closet flushing, gardening irrigation and washing machines. In addition, the use of rainwater is possible in the industrial field. The research had in particular the following objects:

a) To determine impact of roof characteristics on the water quality and to judge existing roofing material.

b) To define the impacts of geographical factors of location in an industrial nation like the F.R.G.

c) To examine impact of the first run-off on the water quality.

d) To register meteorological and seasonal aspects of impact on the quality of roof water run-off.

Gagings have been taken at 15 objects (real roofs) at 8 different locations. The buildings' locations were distributed all over the province of Hessen. The gaging stations were sited at highways in overcrowded areas, close to industrial areas, as well as regions of intensive agriculture. Thus diverse negative aspects of impact on the water quality were aimed to be registered.

Gagings concerning roofing materials were made at roofs plastered with tiles slate, concrete pan and bitumen. In addition the gutter materials were registered in order to keep their influence distinct. The gagings of the impact of roofing materials were taken at objects with similar conditions. Thus impacts of location were eliminated, and equal precipitation was guaranteed.

For the analysis, average samples were taken referring to one precipitation event. To register the average samples, a special sampler had been developed (s. Fig. 1). In order to register change of concentrations of single substances during the run-off from the roof, flow-proportional samples were examined. Therefore, samples were taken in short intervals directly from the run-off at the beginning of a precipitation event.

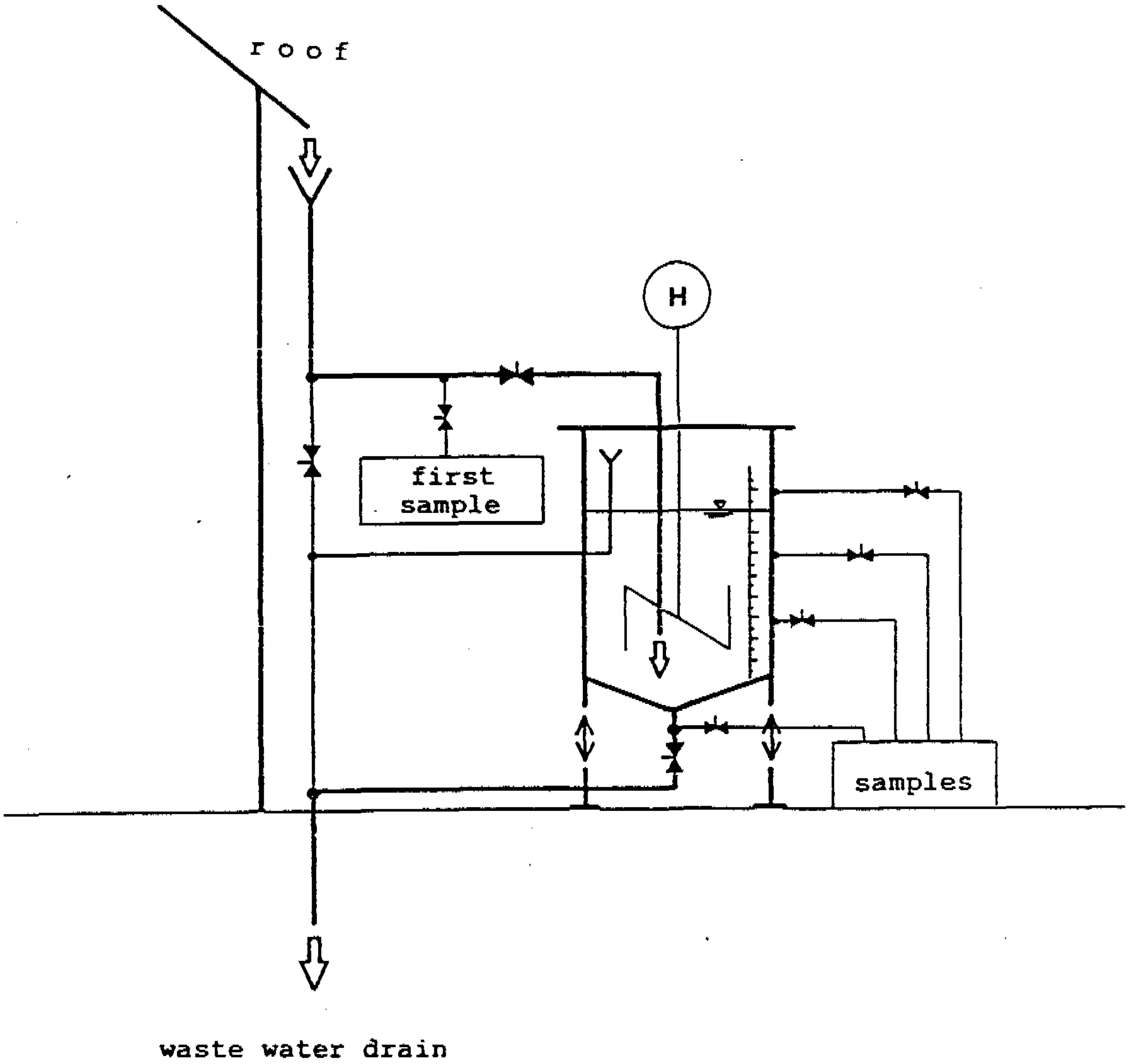

Figure 1: Rainwater sampler

At the beginning of the gaging programme an orientating investigation phase was made, during which a large range of potentially relevant substances was analysed (s. fig. 2). Selection was made according to the German drinking water standards (Trinkwasserverordnung, 1986). After first results out of that phase, a standard investigation programme was developed. In addition, further parameters of importance for judging the roof water run-off were selected.

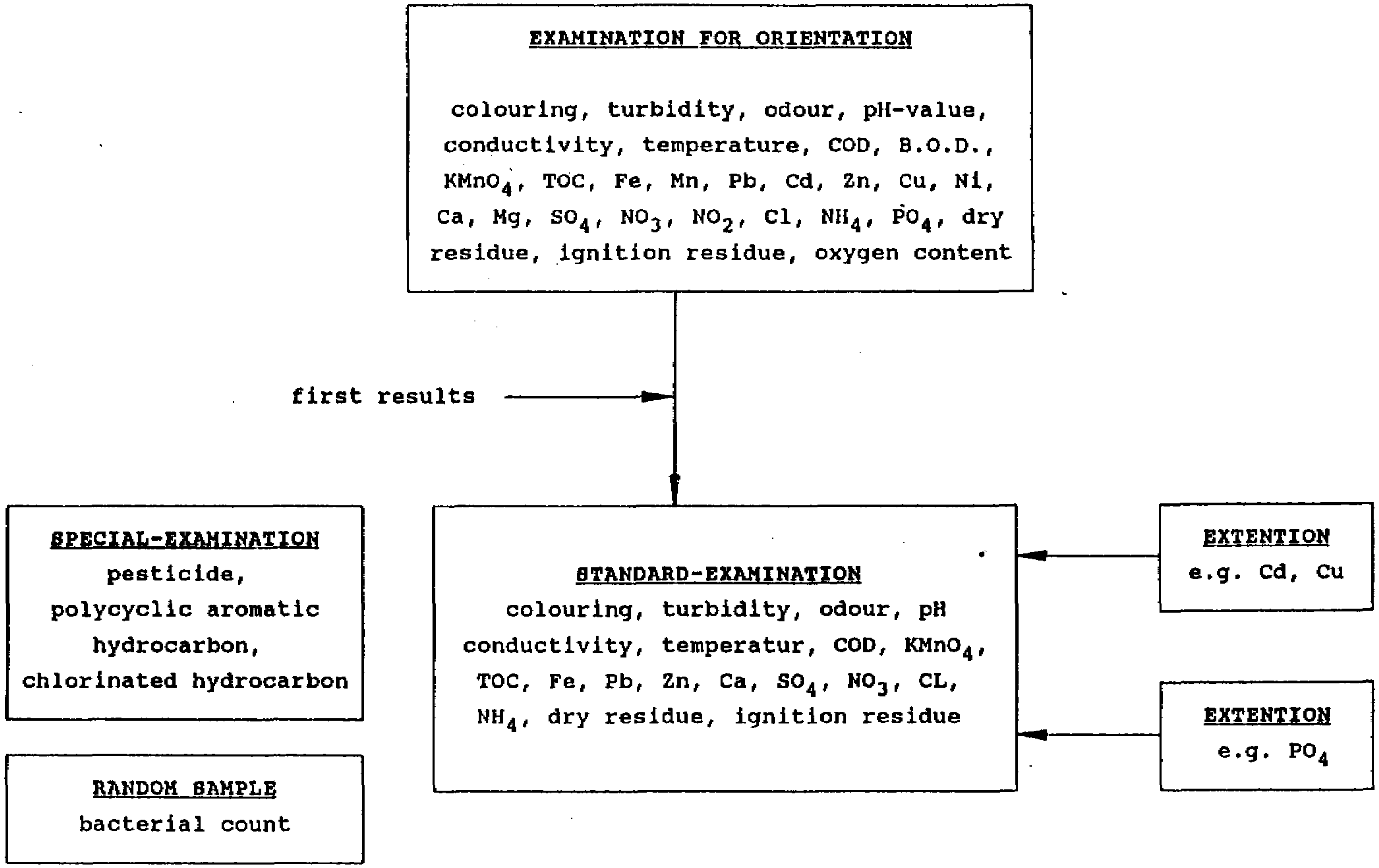

Figure 2: Examination-parameter

Roofing Materials

The research of impact of roofing materials showed that nearly all chemical parameters depend on the materials. Thus the pH-value is determined above all by roofing material. While the pH-value in the run-off of concrete pan- and slate roofs as well as of bitumen roofs with crushed stone or gravel is regularly higher than pH 7, it gets lower with roofs of chemically inert material, going down to values of pH 4.

The total pollution of roof water run-off is evidently higher with old concrete pan roofs and bitumen roofs, as those materials are partly chemically non inert and because of higher deposition rates on rough roof surf aces, than e.g. with tile roofs (s. Fig. 3).

The lowest total pollution is shown by bitumen roofs with gravel, as gravel has the effect of a filter.

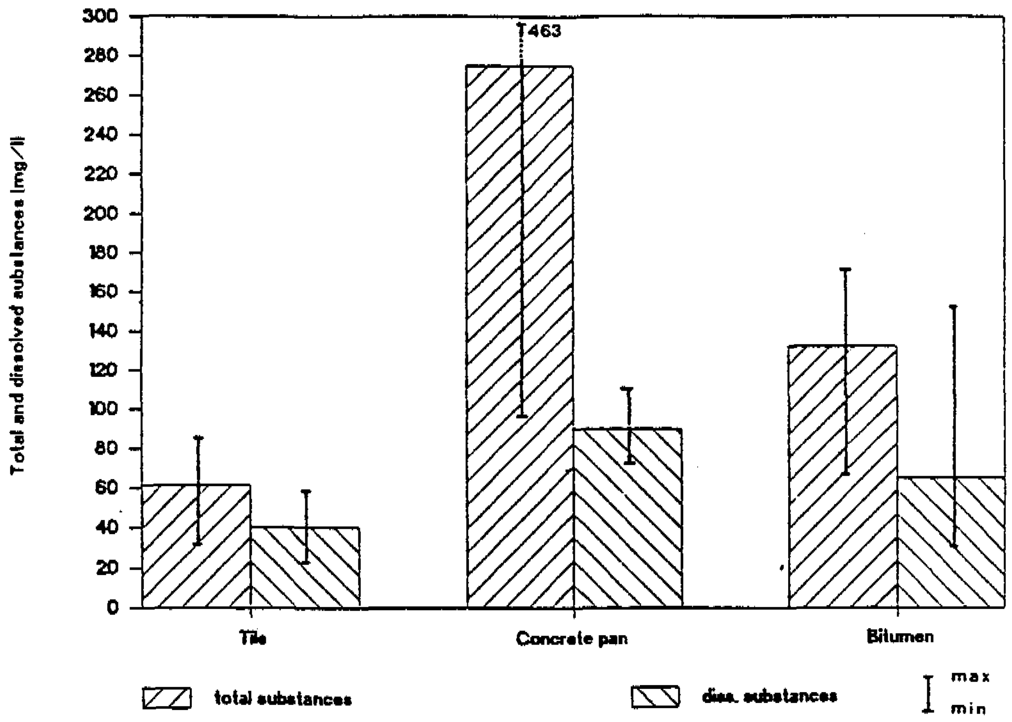

Figure 3: Average, maximal and minimal concentration of total and dissolved substances in the run-off of tile- and concrete pan roofs, and bitumen roofs

The organic load of roof water run-off at bitumen roofs is evidently higher in contrast to other roofing materials, which is above all due to precipitation of organic acids (s. Fig. 4). The content of heavy metal in the run-off of old disintegrated concrete pan roofs with rough surface is evidently higher in unfiltered samples than with materials of smooth surface.

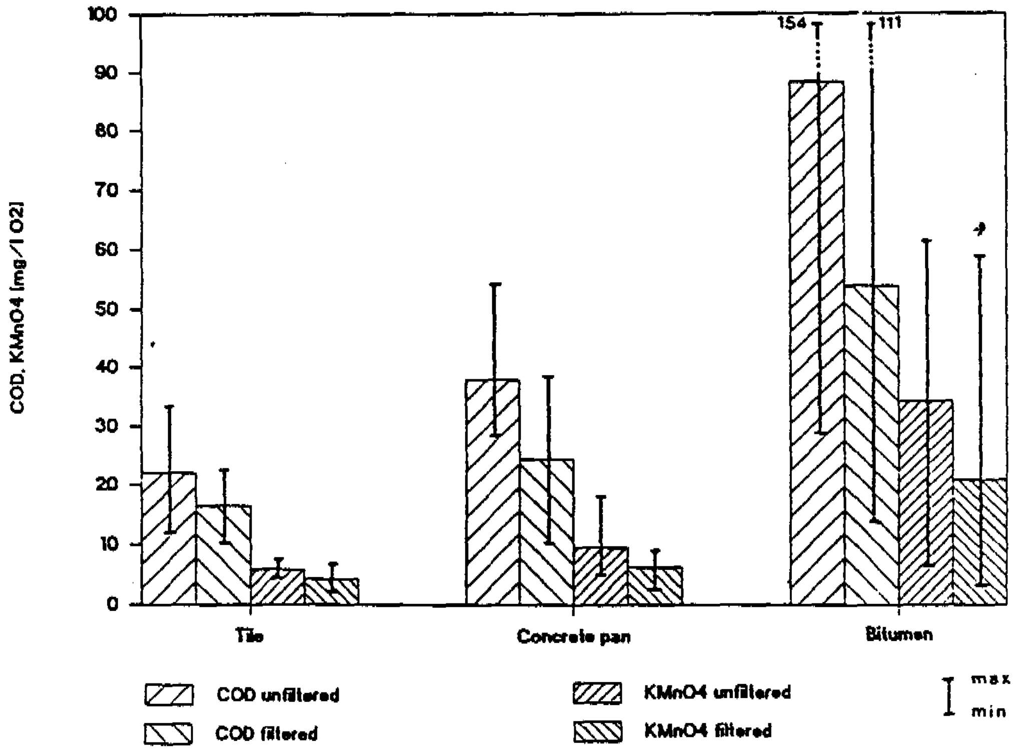

Figure 4: Average, maximal and minimal COD and $KMnO_4$ concentration in the run-off of tile- and concrete pan roofs, as well as of bitumen roofs

By determined setting- and filtration processes concentrations of nearly all parameters can be reduced to a vast extend. This indicates a high individual proportion of all substances. Regarding iron, that effect is shown in Figure 5.

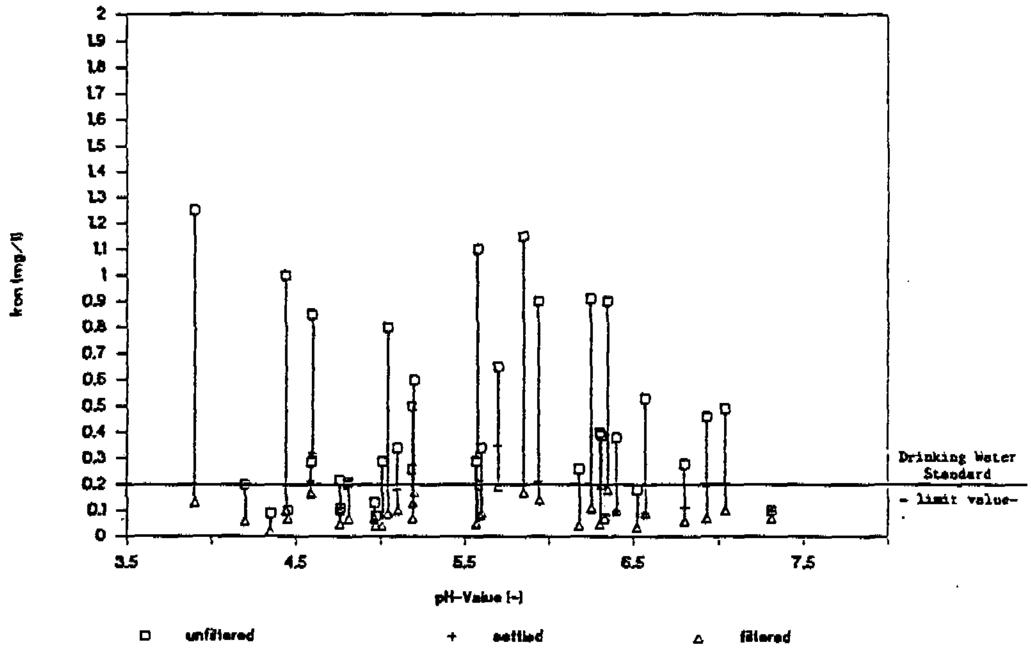

Figure 5: Concentration of iron in unfiltered, settled and filtered roof water run-off samples of tile roofs

Factors of Location

Beside roofing materials the most evident impact on roof water run off quality is brought about by conditions of location. At locations which are big-scale loaded, that is to say in areas far from emissions as well as in sub-urban regions of overcrowded or loaded areas, referring to all examined parameters there occurred generally low concentrations in roof water run-off.

In most cases values have already been lower than the current limits according to "drinking water standards" even in the non-settled roof water run-off samples (s. Fig. 6).

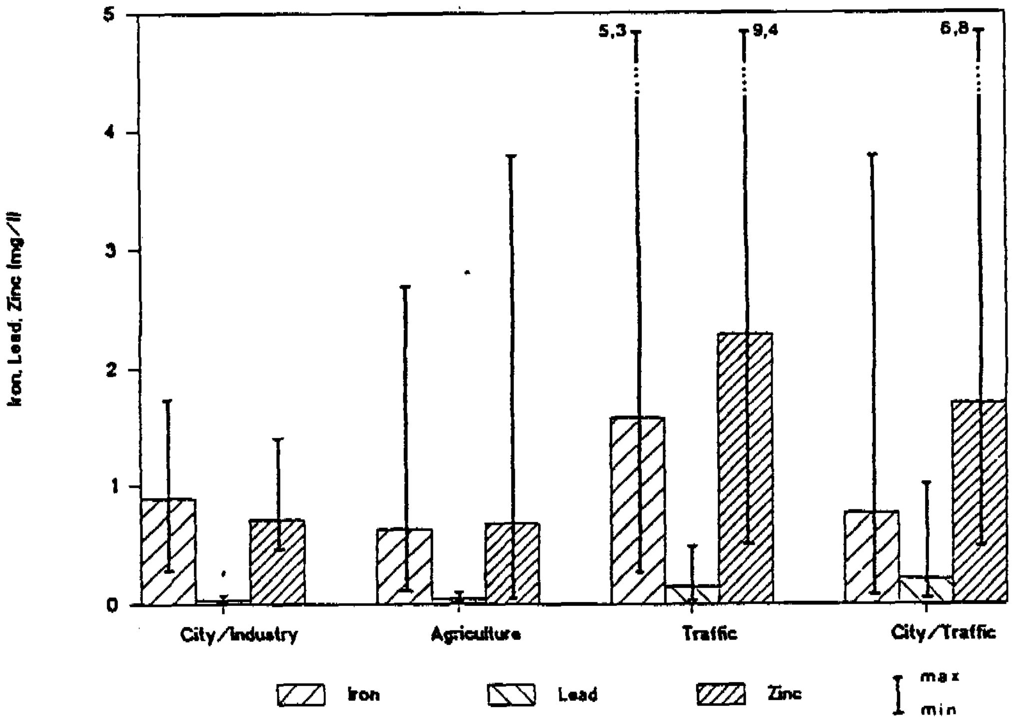

Figure 6: Average, maximal and minimal iron-, lead- and zinc concentrations in unfiltered roof water run-off at different locations (roofing material: concrete pan)

Due to small-scale load factors, respectively by addition of several negative aspects, evidently higher concentrations of all parameters may occur. For instance at locations very close to highly frequented roads a higher load of roof water run-off containing acid formers (sulfate < 150 mg/l, nitrate < 52 mg/l) and heavy metals (lead < 1,0 mg/l, cadmium < 0,06 mg/l, copper < 0,9 mg/l, zinc < 9,4 mg/l) as well as higher organic load was detected. In residential areas of high density with a lot of small-scale load factors, particularly with heavy metals, there occurred higher concentrations in roof water run-off.

First Run-off

For investigations concerning the first run-off, four events of rain have been examined after long arid periods.

Table I: Meteorological conditions of precipitation events registered for the first run-off

No.	dry period (h)	total height of precipitation (mm)	average precipitation rate (mm/h)
1	23	1.8	0.8
2	260	5.9	1.6
3	343	7.2	0.9
4	343	7.2	0.9

The researches regarding the first run-off have shown that at all events of rain concentrations of substances in roof water run-off are evidently reduced within the first 1,0-2,0 mm, and that by increasing height of precipitation a dilution of roof water run-off occurs. It is just the pH-value that proves to be relatively constant during precipitation events. The COD content was evidently reduced during the first millimetres of precipitation after increased values at the beginning.

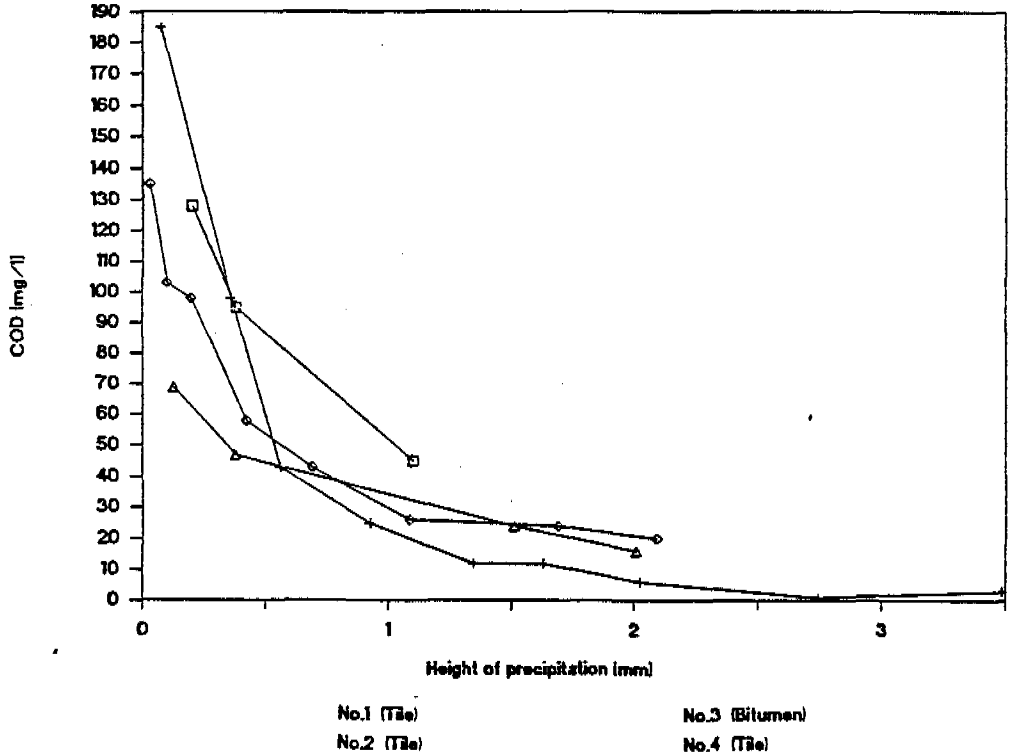

Figure 7: Courses of concentration of COD content in roof water run-off at different precipitation events (No. 1-4, s. Table I)

Concerning heavy metals by the example of lead in Fig. 8, the decrease in concentration in the first 2 millimetres of precipitation is pointed out.

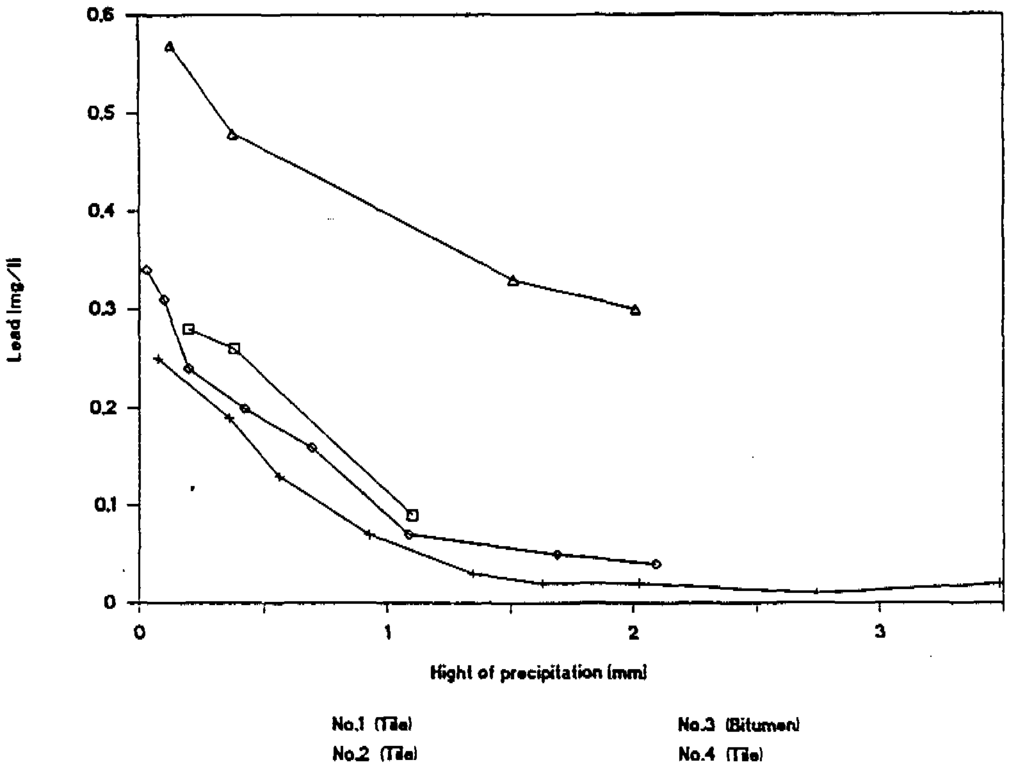

Figure 8: Courses of concentration of lead content in roof water run-off at different precipitation events (No. 1-4, s. Table I)

By taking away the first 1,0 to 2,0 mm of precipitation, an improvement of mixed water load can be reached.

But for the use of closet flushing, gardening irrigation and washing machines the water quality is sufficient after the first settling and/or filtration, even with the high polluted "first run-off". Besides the quantity of usable water decreases considerably (up to 20 %) without storing the first run-off, and no additional technical installations are necessary.

Meteorology and Season

Regarding meteorological factors, with all examined parameters no clear or just a low dependence of load on the unfiltered roof water run-off, could be remarked.

The total load of roof water run-off shows off a gentle increase during spring and summer. The impact of seasonal factors became most evident concerning organic macro-pollution. Particularly if trees or bushes were standing near the roof, in spring and early summer, an increased amount of small blossoms, pollen and seeds was noticed in the container. Correspondingly the COD content was raised in spring and summer.

3. CONCLUSIONS

The present investigations result in the following conditions for design and operation of rainwater systems.

Roofing Materials

- All common roofing materials, such as tile, concrete pan, slate, bitumen, plastic material and metals are appropriate for the use of roof water run-off.

- Smooth materials like tile, slate, metals, and plastic materials are of positive impact on the total load of roof water run-off. Therefore, as to new buildings those materials should be used with preference.

- In few years only, with concrete pan an increasing deposition of dust as well as a growth of moss and lichen, has to be expected due to the rough, partly disintegrated surface. That leads to an increase of sludge in total, and particularly in spring and summer to more organic load in the cistern. This has to be taken into consideration for the operation of rainwater systems in the long run.

- The colour of roof water run-off from bitumen roofs is often yellowish. In the long run that can affect the results of washing. For irrigation of lawn and closet flushing the run-off of bitumen roofs-especially of those with gravel (= pre-filtration) - can be used without hesitation.

- As to metal roofs (iron, aluminium, zinc, lead copper) and metal gutter and down piper (zinc, copper) an increase in metal content is to be expected in roof water run-off.

Coarse Filter

- In front of cistern intake there is to be planned a coarse filter - independent on location - at all rainwater systems.
- Its function is to hold back substances (leaves, blossoms, moss etc.) that might affect the plant's operation by clogging, deterecration or decomposition processes in the cistern.

First Run-off

The first run-off of the roof water at the beginning of a precipitation event generally makes the quality of stored and used water worse. The worsening of the quality of roof water run-off is of no importance for the types of the mentioned utilisation. Thus there is no need for a first run-off.

Cistern

- The cistern should be placed in the ground or in cool rooms (e.g. cellar), in order to prevent processes of digester gas and bacteria growth. To avoid algae growth it should be protected from light.
- Due to its hardness roof water run-off is particularly aggressive towards concrete at low pH-values (< 5,5). Having tile and bitumen with sand as roofing materials, plastic tanks should be preferred because of the frequency of low pH-values. In the case of concrete cisterns then, there should be provided a sufficient cover of the reinforcement with concrete.
- By settling processes the concentration of many substances in roof water run-off is reduced considerably. Therefore a settling compartment has to be planned in the cistern.
- A simple possibility of cleaning the rainwater cistern is to be planned, particularly to remove sludge.
- The intake into the cistern (rainwater and possibly drinking water intake) have to be installed in a way, that already settled substances are not whirled up.
- The delivery tap of the cistern has to be sited about 10 cm above storage ground. Thus it is guaranteed that no sludge stored on the ground will be drawn.

Fine Filter

- Usually a fine filter is not necessary for reasons of quality after coarse filtration in front of cistern and settling in the cistern.

- At locations which are evidently extremely high loaded (e.g. with high dust depositions close to cement factories) the necessity of a fine filter has to be examined individually.

- Should a fine filter be necessary or considered as desirable, a mush size larger than 100 μm has to be chosen. With smaller mush sizes the danger of bacteria growth is clearly higher.

Material of Pipe Lines and Pumps

- Due to its chemical composition roof water run-off is not able to form an effectively protective scale in pipe lines, so that a damage caused by corrosion is to be expected in the long run using metalic working material. For that reason plastic material should be used for the pipe line network of rainwater systems. Regarding the pumps, high-grade steel or plastic material should equally be used.

Servicing

- For the perfect operation of a rainwater system regular servicing, respectively cleaning of coarse filter, of cistern and of the potentially existing fine filter has to be ensured.

- The coarse filter has to be serviced especially in spring and autumn, because of the increase of leaves, blossoms etc. during those seasons.

- Emptying and cleaning of cistern should at best take place once a year. It is appropriate to execute cleaning when the cistern is empty in summer.

- Back-washing, respectively cleaning of potentially present fine filters is recommended twice a year in case of loaded locations and with concrete pan roofs. Otherwise one cleaning process per year is sufficient.

Locations

- In general, apart from few exceptions all locations are appropriate for utilisation of roof water run-off for closet flushing, washing and irrigation of lawn, after the above described treatment of water.

- Very close to highly frequented roads, increased concentrations of polycyclic aromatic hydrocarbons in roof water run-off are possible. For that reason utilisation for washing and irrigation of useful plants is not recommended.

- At extremely loaded locations such as city-centres, very close to highly frequented roads, industrial plants, power stations or similar things, the total pollution of roof water run-off is generally increased. The necessity of a fine filter has to be investigated in such cases, respectively washing machines should not be connected. Possibly more frequent servicing of the rainwater systems turns out to be necessary.

4. ACKNOWLEDGEMENTS

The research shows that the quality of roof water run-off in high industrial and overcrowded nations like the F.R.G is suitable for closet flushing, gardening irrigation and washing machines. However, certain conditions concerning design and operation of rainwater systems has to be observed. With that the use of rainwater could make an important contribution to the necessary economization of drinking water.

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Qualitative Aspects of Rainwater Use in the Federal Republic of Germany

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CISTERN WATER SYSTEMS
IN THE U.S. VIRGIN ISLANDS

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ABSTRACT

In the U.S. Virgin Islands, cisterns are commonly used to collect rainfall and provide domestic water supplies. Since the rainfall varies considerably between different points on the islands, a simple formula is proposed that uses the average annual rainfall and roof area to compute cistern storage requirements. Alternative construction materials are discussed which might be less expensive than the conventional reinforced concrete cisterns that are usually built in the Virgin Islands. The results of recent water quality studies indicate that in many cases, cistern water does not meet the Safe Drinking Water Standards. Better cistern maintenance and disinfection procedures are necessary to provide good quality water for drinking and other domestic purposes.

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INTRODUCTION

The United States Virgin Islands consist of three main islands (St. Thomas, St.Croix and St.John) and a number of smaller islands located approximately 1800 km east southeast of Miami. The three larger islands constitute a total area of about 35,000 ha. The topography of St. Thomas and St. John consists of rugged and steep terrain, while St. Croix has some rolling land as well as steep hills. The U. S. Virgin Islands have approximately 110,000 residents, of whom, more than 95 percent live on the two islands of St. Thomas and St. Croix (Virgin Islands Dept. of Commerce, 1986). Because of the steep slopes, remotely located housing developments, and limited fresh water supplies, the public water distribution system serves only a small part of the island area. It is therefore necessary for homeowners to provide alternative sources of water for their domestic use. In most homes, reinforced concrete cisterns are provided in the basement level of the building where rooftop runoff is collected.

RAINFALL AND CISTERN CAPACITIES

Rainfall in the Virgin Islands (V.I.) varies in time and in space. The average annual rainfall for example, varies from 760 mm on the east end of St.Croix to 1,270 mm on the north-west end of the same island (Torres-Sierra, 1987). Similar variations can be observed on St. Thomas (Torres-Sierra and Dacosta, 1985).

The rainfall amounts in different parts of the two islands are shown in Table 1.

TABLE 1

Average Annual Rainfall (mm)
in Different Regions of St. Thomas
and St. Croix, U.S. Virgin Islands

Island	North-West	Center	East End
St. Thomas	1270	1060	890
St. Croix	1270	1020	760

In the V.I., rain water is collected from hillside catchments as well as from rooftops. Hillside catchments provide relatively large amounts of water, while rooftops provide small amounts for domestic use. All residential buildings in the V.I. are required to provide cistern storage of approximately 400 L per sq. m. of roof area. A uniform standard does not seem appropriate due to the spatial differences in rainfall between different points on the islands. A more rational storage estimate for cisterns should be based on rainfall amounts at any particular location. Since average annual rain fall data are generally available, a simple formula based on this information is proposed below.

In a well-designed rooftop water collection system, a catch efficiency of 80% can be assumed. As the rainwater is being collected, it is also being utilized. Assuming a storage coefficient of 0.7, the design volume of the cistern could be expressed as:

Q = 0.80 x 0.70 x roof area x average annual rainfall, or

$$Q = 0.56 \times A \times P \quad \text{-----------} \quad (1)$$

or

$$Q = K \times A \times P \quad \text{-----------} \quad (2)$$

where

Q = Cistern Capacity (L)

K = 0.56

A = Roof Area (sq. m), and

P = Average annual precipitation (mm)

The storage coefficient depends on a number of factors such as the frequency of precipitation events, rate of withdrawal from the cistern, etc. It could conceivably vary from approximately 0.5 to 0.8 thus resulting in K values of 0.4 (0.8 x 0.5) to 0.64 (0.8 x 0.8).

The generalized equation therefore can be expressed as follows:

$$Q = K \times A \times P \quad \text{-----------} \quad (3)$$

where

Q = Required Cistern Capacity (L)

K = 0.5 (0.4 - 0.6)

A = Roof Area (sq. m)

P = Average annual rainfall (mm)

Table 2 shows the cistern capacities estimated conventionally, and those obtained by the use of the above formula, for selected areas on the two islands.

TABLE 2

Cistern Capacities (L)
on St. Thomas and St. Croix for a
Small Home With Roof Area of 100 sq. m

Formula	North-West	Central	East End
<u>St. Thomas</u>			
Conventional	40,000	40,000	40,000
Proposed	63,500	53,000	44,500
<u>St. Croix</u>			
Conventional	40,000	40,000	40,000
Proposed	63,500	51,000	38,000

Conventional Formula: 400 L / sq. m. of roof area.
Proposed Formula: $Q = K \times A \times P$ $(K = 0.5)$

If the proposed formula were used for designing cistern capacities, a full cistern in the north-west part of the islands can provide 174 L of water per day on average, while on the east end about 122 L would be available per day on St.Thomas, and 104 L per day on St. Croix. It is recognized that the rainfall pattern may be such that in a normal year, the larger cistern would not get filled up; however, there would be enough capacity available to store extra water during wet periods/wet years in order to provide more supplies later during a dry period. The costs of building larger cisterns may be controlled by adopting non-conventional materials as described in the following section.

CISTERN MATERIALS

While reinforced concrete is the most common material for cisterns in the V.I., concrete blocks are also used in some cases. Two other possibilities for cistern materials include fiberglass and ferrocement. Some of the advantages and disadvantages of the three types of cisterns are listed in Table 3.

TABLE 3

Relative Advantages/Disadvantages of Different Kinds of Cisterns

Cistern	Advantages	Disadvantages
Reinforced concrete	Permanent Square/rectangle Large size possible	Expensive Technical expertise needed
Ferrocement	Semi-technical help adequate Low cost	Cylindrical design Semi-permanent
Fiberglass	Low cost Portable Easy to assemble Durable	Cylindrical design Semi-permanent

Although they are not used much in the Virgin Islands, a preliminary cost estimate is made in Table 4 to compare ferrocement and fiberglass with reinforced concrete.

TABLE 4

Relative Costs of Various Cistern Materials

Cistern	Cost ($ / L of storage)
Reinforced concrete	0.20
Ferrocement	0.14
Fiberglass	0.11

It must be recognized that costs vary significantly between different countries, because of differences in material and other costs (Keller, 1982). Reinforced concrete structures are permanent in nature but also the most expensive to build. Ferrocement structures work out to be more expensive in the Virgin Islands than in Asia because of the relatively higher labor costs. Fiberglass tanks can be ordered from the United States, shipped in crates and assembled on site. They are relatively light-weight (portable) and are semi-permanent in nature. Both fiberglass and ferrocement appear to be economically attractive alternatives that need to be explored further in the Virgin Islands.

CISTERN WATER QUALITY

The Water Resources Research Center at the University of the Virgin Islands has been conducting microbiological studies to evaluate the quality of cistern water. Two studies have been completed on cisterns in private homes and those in public housing complexes (Ruskin and Callender, 1988; Ruskin et al, 1989). Currently, a third study is underway to evaluate the water quality of cisterns in hotels and guest houses located on St. Thomas.

In the water quality study of cisterns in private homes conducted during 1986-87, 20 residents volunteered for the project. Bi-weekly water samples were collected and analyses were conducted to determine total coliforms, fecal coliforms, fecal streptococcus, Pseudomonas Aeruginosa, and heterotrophic plate counts. Primary emphasis was on testing for total coliform and Pseudomonas Aeruginosa, an opportunistic pathogen known to cause ear infection, urinary tract infections and diarrhea. Results of this study revealed that out of a total of 271 samples, 197 or 73 percent did not meet the Safe Drinking Water Standard of $\leqslant$ 1 total coliform per 100 mL of water. If only overall averages were considered, not one of the 20 cisterns studied would have met the Safe Drinking Water Standard, and only four of the 20 would have met this standard 50 percent or more of the time. (Ruskin and Callender, 1988). Pseudomonas Aeruginosa was found in 70% of the samples.

The public housing water supply systems, serve 25 or more people and/or have more than 15 service connections, and must comply with the U.S. Safe Drinking Water Act. The water supplied to the residents must contain $\leqslant$ 1 total coliform/100 mL. The public housing study was conducted in 1987-88 on 10 cisterns in 5 public housing complexes, (Ruskin et al, 1989). The results of this study indicated that out of a total of 75 samples, 44% exceeded 1 total coliform per 100 mL and that 52% of the samples contained Pseudomonas Aeruginosa. Although the water quality in public housing cisterns was better than that in private homes, it still fell short of the drinking water standards in many instances. In both the studies, 16% of the samples met the total coliform standard, but still contained Pseudomonas Aeruginosa. The results of both studies are summarized in Table 5.

TABLE 5

Cistern Water Quality in the Virgin Islands

Locations	Total Samples	T.C. > 1	P.A. +ve	P.A. +ve T.C. ≤ 1
Private Homes	271	197 (73%)	191 (70%)	43 (16%)
Public Housing	75	33 (44%)	39 (52%)	12 (16%)
Totals	346	230 (66%)	230 (66%)	55 (16%)

Approximately two-thirds of the water samples did not meet the Safe Drinking Water Standards (T.C. ≤ 1). Some of the major reasons for this are environmental contamination on the rooftops (leaves, dust, animal droppings), lack of cistern maintenance, and inadequate chlorination.

CONCLUSIONS

A cistern capacity of 400 L per sq. m of roof area is required for all dwellings in the Virgin Islands. However, because of spatial variation in rainfall amounts, a new formula is proposed that is simple to use, and may be more appropriate for estimating cistern capacities in different parts of the islands. Larger cisterns can store more water during wetter periods and provide additional water supplies. Alternative cistern materials such as fiberglass and ferrocement are discussed that might reduce capital costs.

Finally, results of the cistern water quality studies conducted during the past two years are discussed. In many cases, the cistern water did not meet the Safe Drinking Water Standards. If the inlets to the cisterns are properly screened, cisterns cleaned periodically (at least once in 5 years), and chlorinated regularly (at least once a month), the water from the cisterns should meet the standards and be safe for drinking.

ACKNOWLEDGEMENT

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INVESTIGATION INTO THE QUALITY OF ROOF-HARVESTED RAINWATER FOR DOMESTIC USE IN DEVELOPING COUNTRIES: A Ph.D Research Study

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ABSTRACT - INTRODUCTION

Features in design, maintenance and operation of roof rainwater harvesting systems which affect the quality of the water obtained have been investigated by a research study of Dundee University in 1982-1985. A complete rainwater harvesting system for domestic water supply was built in the tropical environment of Mauritius incorporating features, excluding water treatment, that would optimise water quality. A programme of water quality monitoring was carried out mainly involving 55 bacteriological samples and 39 chemical samples from the water abstraction point at weekly intervals. The faecal coliform test was negative in 84% of the samples and the mean faecal coliform count was 1.1 per 100 ml. The results of total and faecal coliform examination would be acceptable by WHO Guidelines in 80% of the samples and fully or almost fully acceptable by other guidelines. According to these results, no water treatment is required. Even though pH and conductivity were high initially due to the leaching of cement from tank walls, the aesthetic water qualtiy is also acceptable.

The diversion of the initial flush of rainwater, which is foul, was examined in the laboratory and new foul flush diversion systems were developed at Dundee University.

The most important features optimising water quality are outlined in the main text.

A field survey of roof rainwater catchments and other water supply practices was carried out in the island of Rodrigues, a dependency of Mauritius, as a case study. There, most of the rainwater harvesting systems were found to be inadequately constructed to protect water quality. The problems can primarily be overcome through technical assistance and motivation.

OVERALL WATER QUALITY

The main conclusions of the research study are:

1. From a review of the literature (1), and based on an estimate of standards which can be achieved, guidelines for water quality in roof rainwater harvesting systems have been proposed by the author. They are: a mean of two faecal coliforms per 100 ml.

2. Continuous weekly tests on an idealised rainwater harvesting system which was built by the author in Mauritius (1,2), which incorporated no water treatment, have shown that the faecal coliform test was negative in 84 per cent of the 55 samples, and the mean faecal coliform count was 1.1 per 100ml. The results of total and faecal coliform examination would be unacceptable by WHO Guidelines in 20% of the samples. The supply would be <u>acceptable</u> by the author's and others' guidelines (1).

3. In the same study in Mauritius, aesthetic water quality parameters (pH, conductivity, colour, turbidity, total hardness, chloride, iron and zinc) that were frequently (39 samples) tested, and others (including nitrate) that were occasionally tested, were within WHO Guidelines. The exception was the high pH and conductivity values in the initial stages. Generally the pH decreased with time and was within WHO Gudelines after a year. In the absence of a distribution system, however, the acceptable range can be broader. Moreover, according to the literature (1), high pH values can cause a self-cleaning (bacteriologically) effect in the tank. Conductivity

values decreased dramatically to acceptable levels within two months.

OPTIMISATION OF WATER QUALITY

The author's work has been used to identify the effect of system characteristics on water quality and to improve the original design if necessary, as follows:

1. There is little likelihood that faecal organisms could contaminate an elevated roof surface and gutter and an enclosed diversion and storage system, unless human and warm-blooded animal contamination is deposited by birds on the catchment or inflow system. What could be expected from a rainwater harvesting system is contamination of the catchment surface by bird droppings, lizards and other small animals and also vegetation matter. Comnsequently, features preventing the entry of pollutants into the storage tank are required: foul flush diversion, screening of the inlet pipe, cleaning (of catchment, foul flush diverter, screens), no overhanging trees, smooth catchment surfaces, and especially a covered tank (1, 3, 4, 5).

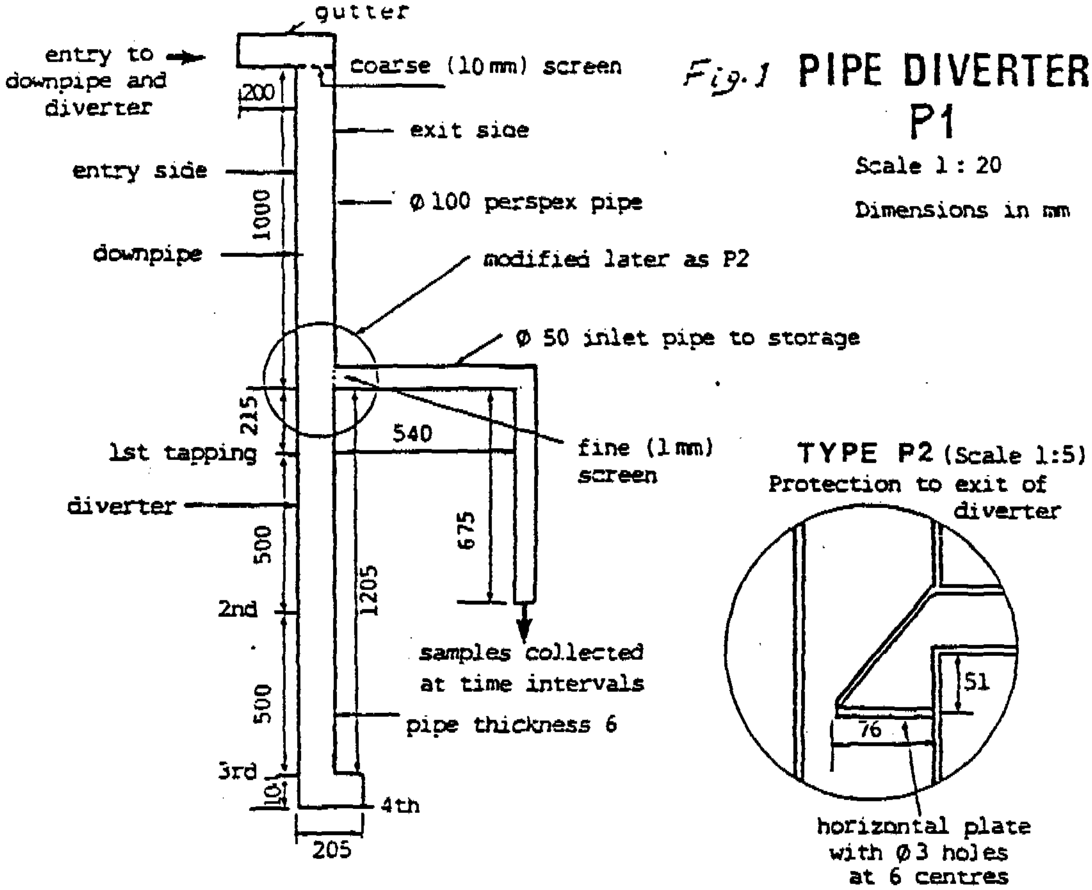
2. Laboratory tests by the author at Dundee University (1, 6, 7) on a variety of proposed foul flush diverters that collect a standard amount of initial rainwater flush, but once are full, act on the overflow principle, have shown that pipe diverter P3 (see Fig. 2) was found to be significantly more efficient than other designs and was installed in the system in Mauritius replacing the original pipe diverter P1 (see Fig. 1).

3. Comparative tests in the field in Mauritius of the quality of water showed that turbidity and zinc levels were higher in the diverter (original one) than in the storage tank and, as expected, the pH and conductivity were lower. Bacteriological sampling showed presence of coliforms at 37 ^{o}C in the improved diverter (P3) in one sample but not in the storage tank. After the incorporation of the improved diverter (which also coincided

Fig. 1 PIPE DIVERTER P1

Scale 1 : 20

Dimensions in mm

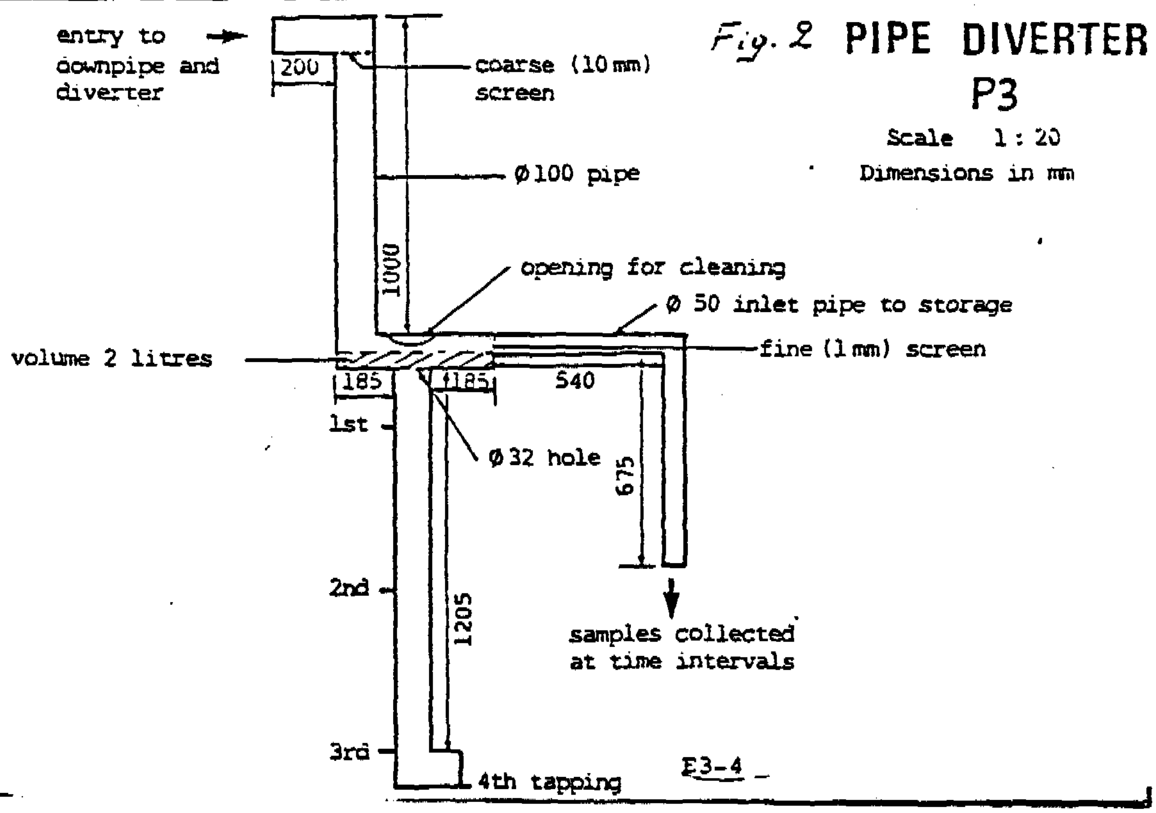


Volume of diverter ≈ 11.3 litres
≈ 11.5 when functioning

Fig. 2 PIPE DIVERTER P3

Scale 1 : 20

Dimensions in mm



with tank washing), 93% of the 15 bacteriological samples were negative for faecal coliforms which were 100% acceptable by the author's guidelines.

4. The provision of adequate screening of the inlet pipe into storage is more important than has hitherto been recognised. Ideas on screening methods were derived from the Rodrigues survey. Laboratory experimentation by the author showed that the screening efficiency of a cloth is satisfactory (1).

5. After each rainfall event, storage, even for a few days, helps improve the bacteriological water quality (1). Long storage is not critical, especially in the rainy season, because of replenishment of water due to abstraction for use, and also because of draining of the tank.

6. Comparative testing of samples from the floor of the exprerimental tank in Mauritius and the outlet of the tank showed higher values from the floor for colour and turbidity (1). Consequently, abstracting water for use at some height above the floor of the tank is required.

7. In the beginning of operation of the system in Mauritius, pH and conductivity values were elevated as the fresh cement applied to the inside wall of the tank dissolved. The most notable decrease was during the months with greater rainfall because rainwater is slightly acidic and each inflow will reduce pH. Draining the tank contributed to the reduction of pH (1).

8. According to the results of the regular bacteriological analysis of the experimental tank in Mauritius (and also considering the drawbacks of water treatment), no water treatment is needed. Moreover, there is no need to treat water to alter the aesthetic parameters.

9. The findings of the survey in the real situation of Rodrigues (1, 8, 9, 10, 11) have shown that most of the rainwater

harvestng systems were found to be inadequately constructed to protect water quality. The reasons for the defects are ignorance, lack of motivation and lack of means. The problems can be overcome through technical assistance. Foul flush diverters and storage covers are the only items that may involve technical and financial constraints if relatively simple solutions are not devised. A manual system could be the answer to foul flush diversion, and jars solve the problem of the storage cover.

RECOMMENDATIONS IN DESIGN, MAINTENANCE AND OPERATION

The most important and simplest features, since there is a limit depending on the resources of communities, are presented in the final list that follows (1).

1. Roofing materials are unsuitable if (a) they are toxic, for example lead, or (b) if their surface is rough and pervious, for example thatch and wood.

2. Painting a catchment surface should be discouraged; if used, then paints should be non-toxic.

3. The catchment should have an even slope, possibly 10%.

4. There should be no overhanging trees adjacent to the catchment.

5. Spraying of chemicals should be discouraged in the area.

6. Gutters of small but uniform slope are required.

7. The screen where the gutter is joined to the downpipe should be a coarse (1 cm size) one. Screening both (a) the end of the downpipe (before discharging into the foul flush diverter) and (b) the entry (which is to be funnel-shaped) to the foul flush diverter with fine (1 mm) meshes and cloth can improve the screening efficiency. Both screens are easily accessible.

8. It is essential that the initial flush, which is foul, of a rainstorm is prevented from entering storage. The author recommends the use of one of the following foul flush diversion methods (1, 6, 7):

(a) a (manual) plug on the downpipe;

(b) a pipe with a floating ball;

(c) pipe P3 of the author's tests;

(d) box B3 of the author's tests (see Fig.3);

or (e) a combination of P3 or pipe with floating ball with a manual diversion valve (1).

9. Storage tanks built above ground are more suitable for optimising water quality.

10. Storage construction materials should be non-corroding, non-contaminating and impermeable.

11. A fully covered and sealed storage tank is absolutely essential. Any manhole should be covered by a tight-fitting well-secured cover.

12. Screening of pipes is essential. There should be fine plastic and hanging screens attached to the inlet and overflow pipes.

13. A storage system should be designed to prevent settled particles from being drawn off in normal use:

(a) the outlet pipe should be positioned at some height, possibly 3 cm, above the tank floor;

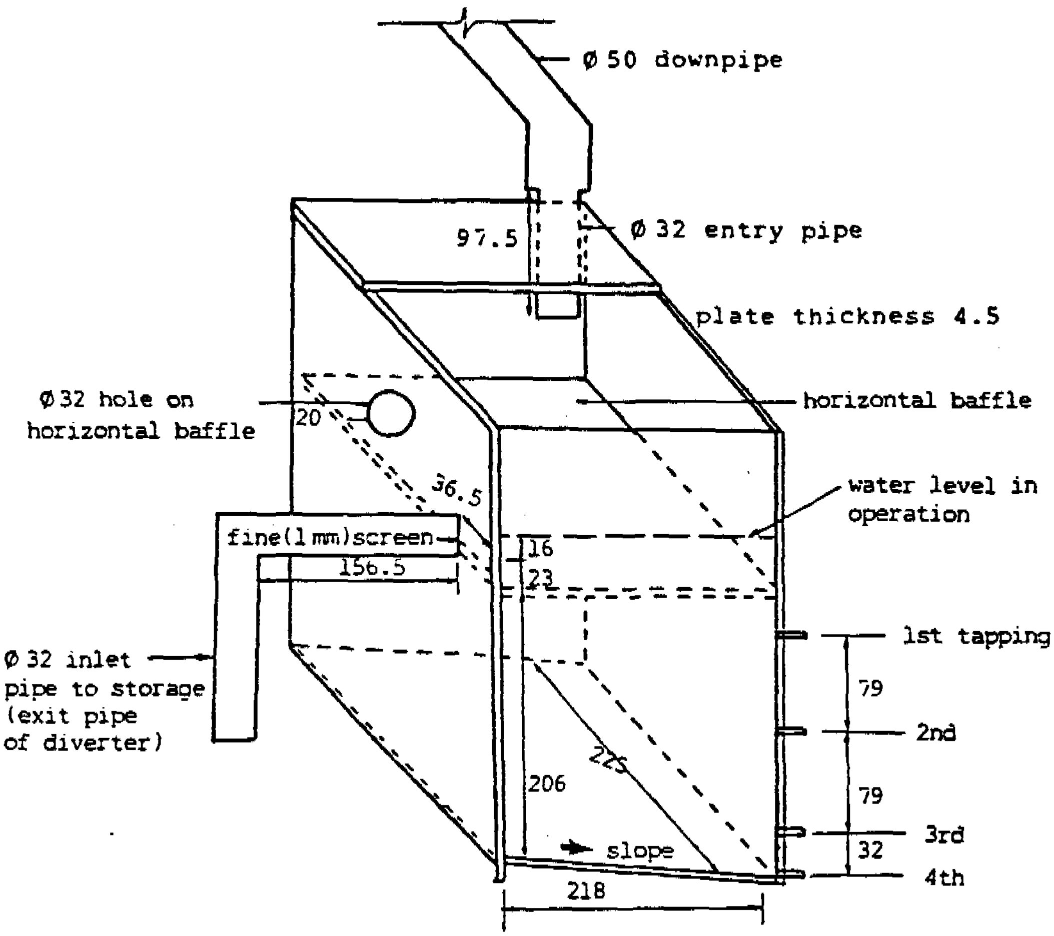
(b) the inlet and outlet pipes should be on opposite sides of the tank;

and (c) the floor of the tank should be slightly sloping upward from the inlet to the outlet side.

14. No connection should be made between tank drain and waste or sewer drains.

Fig.3 BOX-SHAPED DIVERTERS

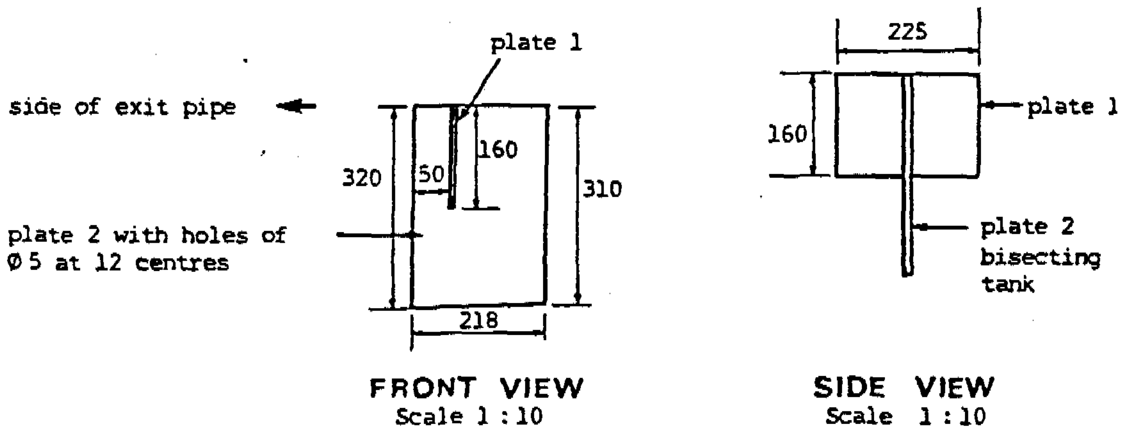
Scale 1 : 5 Dimensions in mm



Type B2 diverter : as shown above

Type B3 diverter : as shown above but with horizontal baffle raised by 21 mm and exit pipe (inlet to storage) by 40 mm

Type B1 diverter : as shown above but with two vertical baffles instead of a horizontal one, as shown below :



E3-8 BAFFLES FOR DIVERTER B1

15. Water from other sources should not be mixed with the harvested supply.

16. Cool storage conditions can be obtained by whitened outside surfaces of the storage tank.

17. Hygienic drainage conditions may be maintained by the provision of: a drainpit or gravel soakway under the outlet tap and the overflow pipe; and a drainage channel under the drain pipe and the waste of the foul flush diversion system.

18. Provisions in design to facilitate maintenance work are: a drain pipe; tank floor sloping toward the drain pipe; access (manhole); and smooth interior surfaces.

19. Regular sanitary inspections and maintenance of the whole system are required. Cleaning of roofs, gutters and screens must be very regular. Foul flush diverters and screens that are accessible, should be cleaned after each rainstorm. The storage tank should be cleaned once a year and more regularly (whenever the water level in the tank is very low).

20. No provision for water treatment should normally be allowed either in design or during operation. Chemical disinfection or boiling of drinking water could be practrised if feasible as a safety precaution after rainfall events (if not always) that follow an extended dry period and/or a period of lack of maintenance of the system.

21. Water may be drawn off the tank for consumption preferably a few days after the last rainfall.

22. A rainwater harvesting system should preferably be operated for the first time in the beginning of the rainy period.

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VIRULENCE CHARACTERISTICS OF BACTERIA ISOLATED FROM CISTERN WATER SYSTEMS IN RURAL NORTHERN KENTUCKY, U.S.A.

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ABSTRACT

In situ membrane filter procedures were used to test the potential virulence activities of bacteria isolated from surface, treated distribution, and cistern water samples. Cistern samples were found to contain higher levels of bacteria expressing hemolytic and/or cytotoxic activities than either the treated water samples or the natural surface water samples. Cistern isolates recovered from a variety of different isolation media exhibited higher levels of cytotoxic isolates than the other two sources. When the levels of multiply virulent bacterial strains were compared, cistern water contained lower levels than surface water and resembled the treated water sources. However, the cistern water contained five times the number of cytotoxic isolates that were found in treated water. Cistern water systems appear to have a decreased level of total bacterial virulence activity when compared to surface water but cistern samples exhibited the highest levels of cytotoxic isolates of all water tested.

INTRODUCTION

The collection and reusage of rainwater is being seriously considered where surface water is either not available, unsuitable, or expensive. Rainfall collected in a well-defined area (called the catchment) can be diverted to a cistern (usually an underground tank) for storage. This type of rainwater storage is the sole source of drinking water (or a feasible alternative) in parts of Australia, Asia, Africa, China, the Pacific Islands, the Caribbean Islands, rural Northern America and many other parts of the world.

The acceptance of cistern water is dependent upon the quality maintained in the system. Very little information is known about the chemical and biological content of cistern water when collected under various conditions and from a variety of catchment areas (Jenkins, 1978, Kincaid, 1979, Ingham, 1982). Because cisterns usually serve only one household (and are often exempt from the mandates of most drinking water legislation) there have been relatively few reports about the microbiological quality of cistern water. Although cistern systems have been reported to be poorly maintained, no epidemiological studies have been documented for users of cistern water. Lye (1987) reported the presence of coliform bacteria in all of the thirty cistern systems he surveyed in the Northern Kentucky region of the United States. Those systems gave high levels of bacteria throughout the cistern distribution network right up to the household tap.

Because of concerns about the health effects associated with the consumption of water containing high levels of heterotrophic bacteria, Lye and Dufour recently developed a rapid screening method for detecting certain bacterial virulence factors. It is now possible to monitor thousands of drinking water bacterial isolates for the expression of single or multiple virulence factors. (Lye and Dufour, submitted for publication, 1989a, 1989b)

This paper reports on the virulence activities expressed in bacteria isolated from cistern systems of the Northern Kentucky region of the United States. Comparisons are made with bacterial isolates from surface water and treated municipal drinking water in the same geographical area.

MATERIAL AND METHODS

Sample collection. Water samples were collected using established methods. (APHA, 1985). All samples were held on ice and processed within three hours of collection. Two municipal chlorinated distribution systems (four sampling points each), four surface water sources and ten cistern systems in the Northern Kentucky region were monitored during May, 1989.

Cistern Water. Tap water samples from cistern systems were taken from outdoor faucets after opening full force for two minutes. Households with point of use water treatment filters were sampled from indoor faucets served by these devices.

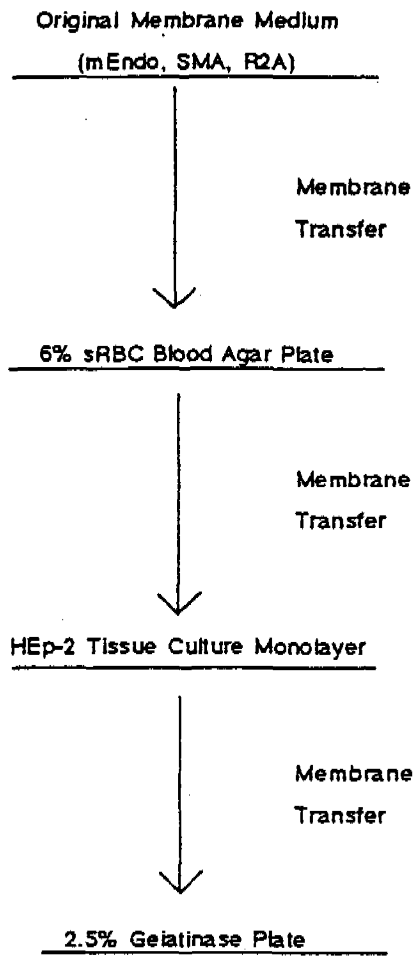
Surface Water. Surface water samples were taken from springs in the rural Northern Kentucky region used as sources of drinking water.

Municipal Water. Treated municipal drinking water samples were collected from distribution systems historically known to contain high bacterial levels when chlorine residuals were low. Treatment of surface water for the systems consisted of flocculation settling, rapid-sand filtration, and post-chlorination with free residual chlorine. All of the distribution samples met current coliform regulations

Microbiological Assays. Water samples were filtered through 0.45 µm membrane filters (HAWG, Milipore Corp., Bedford, Mass.) and placed on appropriate media. Total coliform bacteria were enumerated on m-Endo agar LES. Because cistern and surface water samples contained consistently high levels of bacteria, 10-fold and 100-fold dilutions of samples were required to decrease filter overload for filters grown on nonselective media. Total heterotroph counts were obtained with Standard Methods Agar (SMA) held at 35 degrees C for 48 hours and also with R2A agar held at 25 degrees C for seven days.

Bacterial Virulence Assays. The procedurees used have been described in detail elsewhere. A general procedure for the rapid In situ membrane-transfer procedure for bacterial virulence testing is depicted in Figure One.

Figure 1. In situ Membrane Transfer Procedure for Virulence Testing.



The cytotoxicity assay was performed as briefly described below. Membrane-filters containing bacterial colonies isolated from drinking water were removed from the original growth medium. The underside of each membrane was rinsed and the membrane was then placed upon cell cultures (HEp-2, human larynx epidermoid carcinoma cells). After both short (15 minute) and long (20 hour) exposure periods, the membrane was removed and cytopathic effects were determined.

The hemolysis assay consisted of using Tryptic Soy Agar (TSA) bilayer plates (60 mm) with a three ml upper layer containing 6% sheep erythrocytes. Alpha or Beta hemolysis was reported as positive hemolysis.

Protease production was detected by cleared zones around gelatinase producers grown on R2A medium containing 2.5% gelatin.

RESULTS AND DISCUSSION

Past studies have identified bacteria indigenous to potable water but little is known about their potential pathogenicity. Various investigators have attempted to speciate bacteria isolated from drinking water in order to determine whether opportunistic pathogens are present. A more efficient approach to this problem would be to examine unspeciated isolates for the presence of virulence characteristics using facile, simple techniques.

Bacteria utilize a variety of different pathogenic mechanisms for infecting weakened or compromised individuals. There is no single, reliable in vitro or in vivo virulence assay for determining the potential pathogenicity of opportunistic bacteria. Rapid screening methods for the detection of bacterial virulence factors would greatly increase our understanding of suspected environmental pathogens and also answer many questions about the movements and transfers of potentially harmful genetic materials (both genomic and extrachromosomal) between strains commonly found in the environment. The ability to easily measure cytotoxic activity in heterotrophic bacteria would greatly increase our understanding of the distribution of potential pathogens in the water environment.

Table one shows the percentage of isolates exhibiting virulence factors from each of the different potable water sources surveyed.

Table I. *Percentage of Isolates that Exhibited Virulence Factors from Different Potable Sources.*

TOTAL (%)	# Gelatinase Positive	(%)	#Hemolysis Positive	(%)	#Cytotoxic Positive	(%)
Surface Water						
4884 (100)	3663	(75)	879	(18)	98	(2)
Treated Water						
4738 (100)	459	(10)	2071	(44)	58	(1)
Cistern Water						
1557 (100)	488	(31)	725	(47)	84	(5)

The isolates from cistern water systems expressed the highest percentage of hemolytic and cytotoxic activity. The number of cytotoxic isolates from cistern water was more than twice the number found in surrounding surface water and was five times those found in treated distribution water. Because cistern water samples give consistently high levels of bacteria, the bacterial isolates probably reflect those strains which are capable of growing within the cistern system. Ruskin and Callendar (1988) have reported that water stored in cistern systems does not 'self-purify' like many natural surface waters. They also report that chlorination is effective in controlling bacterial populations for only 3 to 5 days before regrowth occurs.

Table Two looks at the cytotoxic isolates found when different isolation media were used.

Isolation Media.

Isolation Medium	Surface Water Samples Total	Surface Water Samples #Cytotoxic	Treated Distribution Samples Total	Treated Distribution Samples # Cytotoxic	Cistern Samples Total	Cistern Samples #Cytotoxic
mEND	1175	30 (2.6%)	1273	9 (0.7%)	77	18 (23.4%)
SMA	723	5 (0.7%)	1495	34 (2.3%)	364	17 (4.7%)
R2A	1334	5 (0.4%)	1013	2 (0.2%)	582	3 (0.5%)
BAP	900	21 (2.3%)	1839	1 (0.0%)	200	15 (7.5%)
mTEC	343	2 (0.6%)	----	------	----	------
mAH	409	35 (8.6%)	1061	3 (0.3%)	52	14 (26.9%)
TOTALS	4884	98 (2.0%)	6681	49 (0.7%)	1275	67 (5.3%)

mENDO	-	mENDO LES Agar	BAP	-	6% sheep Blood Agar
SMA	-	Standard Methods Agar	mTEC	-	mTEC Agar
R2A	-	R2A Agar	mAH	-	selective medium for *Aeromonas*

Again, cistern water samples exhibited higher rates of cytoxicity as compared to the other water sources.

The opportunistic pathogens commonly implicated in water-associated cases of disease are generally regarded as being of low virulence. The ability to cause infection depends not only upon the expression of bacterial virulence factors but also upon the host state and the type of infection caused. There are no rapid, convenient methods for predicting potential health hazards associated with opportunistic pathogens in drinking water systems. Preliminary studies have shown that the cytotoxic isolates from the cistern water samples are similar to those found in the other water sources but seem to be present at higher levels in the cistern system.

Table Three compares the percentage of isolates grown on Standard Methods Agar from the different water sources which expressed none, one, or two (or more) virulence factors.

Table III. Virulence Characteristics of Isolates Recovered from Standard Methods Agar.

Number of Virulence Characteristics Expressed	Potable Water Source		
	% of Cistern Isolates	% of Treated Water Isolates	% of Surface Water Isolates
None	37	42	15
One only	40	35	27
Two or more	23	23	58

The surface water contained the highest percentage of isolates expressing multiple virulence factors. Cistern water appeared to resemble treated water because it had less multiple virulent isolates than the surface water. However, cistern water does contain higher levels of bacteria capable of cytotoxic activity as shown in the previous tables. These preliminary data suggest that although cistern water has less overall virulence activity than surface water, it does contain bacteria which exhibit cytotoxic activity at higher levels than the other two water sources. Futher study is needed to ascertain if the cistern storage conditions are conducive to the growth of certain bacterial strains beyond those levels found in treated or natural water sources.

The membrane filter transfer method described here has proven to be convenient for preliminary screening of large numbers of individual colonies from a single water sample. The membrane filter procedure not only measures multiple activities related to possible virulence factors but it also quantifies the bacteria expressing each characteristic. The tissue culture cytotoxicity test appears to be a reliable indicator of those bacteria expressing multiple virulence factors such as cytotoxin, protease, and hemolysin activity. Although slow-growing heterotrophs are often present in high numbers in certain areas within all water systems, they appear to lack some of the virulence factors being monitored in this study.

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EVALUATION OF RAINWATER QUALITY: HEAVY METALS AND PATHOGENS

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ABSTRACT

Stored rainwater will be a potentially safe and economic drinking water supply if it is free from any contaminants. This study proposed to determine the bacteriological and chemical quality of stored rainwater. The rainwater samples were collected from collection systems, outdoor and in-house storage containers. Information on sanitary practices which appeared to affect the quality of stored rainwater was also investigated.

The study have shown that all of those sampling points were bacteriologically contaminated. Pathogenic contamination was found in a few samples collected from those sampling points. The pathegens identified were *Salmonella gr. E and gr.C, Aromonas sp.*, and *Vibrio parahaemolyticus*. It was also found that the unhygienic sanitary practices of the villagers were a major factor in bacteriological contamination. The heavy metals analysed in this study were Cd, Cr, Pb, Cu, Fe, Mn, and Zn. Most of the heavy metal concentrations compared favorably with the WHO drinking water standard with two exceptions, Mn and Zn. These two heavy metals are considered to affect the aesthetie quality only, and therefore are not significant to health.

The findings from this study indicate that only health risks evolving from the consumption of stored rainwater would be due to bacteriological contamination rather than from heavy metal contamination.

I. INTRODUCTION

Improvement to the quality of village drinking water supply is part of the government's preventive health strategy. Traditionally, villagers rely on rainwater in rainy season and groundwater in dry season. Rainwater appears to be the most viable option for drinking water when considering the water quality objectives.

Realising the benefits of using stored rainwater,the Thai-Australia Village Water Supply Project in conjunction with the Faculty of Engineering, Khon Kaen University (1984), promoted a national policy to implement a rainwater jar construction program which would provide sufficient rainwater storage to meet the needs of village households. However, even with a sufficient quantity of stored rainwater, the quality remains of questionable benefit to the villagers health condition, as rainwater from roof catchment systems may be subjected to contamination via dirt or decaying debries on the roofs as well as the roofing material itself. The water stored in container may also be contaminated by using unclean storage containers. This study proposes to investigate the quality of rainwater and the health risks associated with its consumption. The specific objectives of this study are:

1) To evaluate the rainwater contamination bacteriologically, in terms of indicator organisms and pathogens, and chemically, in terms of heavy metal concentration.
2) To determine the route of contamination of rainwater by testing samples at various sights along the handling route (from the point of rainwater collection, storage containers to its final consumption).
3) To investigate the villagers' sanitary practices affecting the contamination of rainwater.
4) To develop recommendations for the reduction of contamination in order to improve the quality of rainwater used for consumption.

II. METHODOLOGY

2.1 Sampling Station

Three villages, Ban Kok-Phan Pong, Ban Dang-Noi, and Ban Non-Tun were chosen for this study (Figure 1). Six to seven households in each village were selected as sampling stations.

2.2 Water Sample Collection

Evaluating the route of rainwater contamination in terms of pathogens and heavy metals required that all of the possible sources of contamination from the roof to the storage containers be investigated.

The sampling design is shown in Figures 2 and 3. The sampling points and number of collected samples are summarized in Table 1. There were five types of samples collected. They included:

1) Atmospheric rainwater – An attempt was made to collect atmospheric rainwater to provide a baseline for a rainwater quality comparison. This type of collection required the household owners to participate in the sample collection. Each owner was instructed in how to properly procure the rainwater sample by demonstration by the research team. However, it was found that this method of instruction and collection was not sufficient to insure good quality sample collection and many of the samples were obviously contaminated. It was, therefore, assumed that the quality of atmospheric rainwater does not exceed the standard of drinking water.

2) Roof and gutter – Rainwater samples from galvanized iron roofs with gutter were collected using composite automatic sampler. A composite automatic sampler was specifically designed with the capability of collecting rainwater samples from roof and gutter systems at varied time intervals. The sampler was

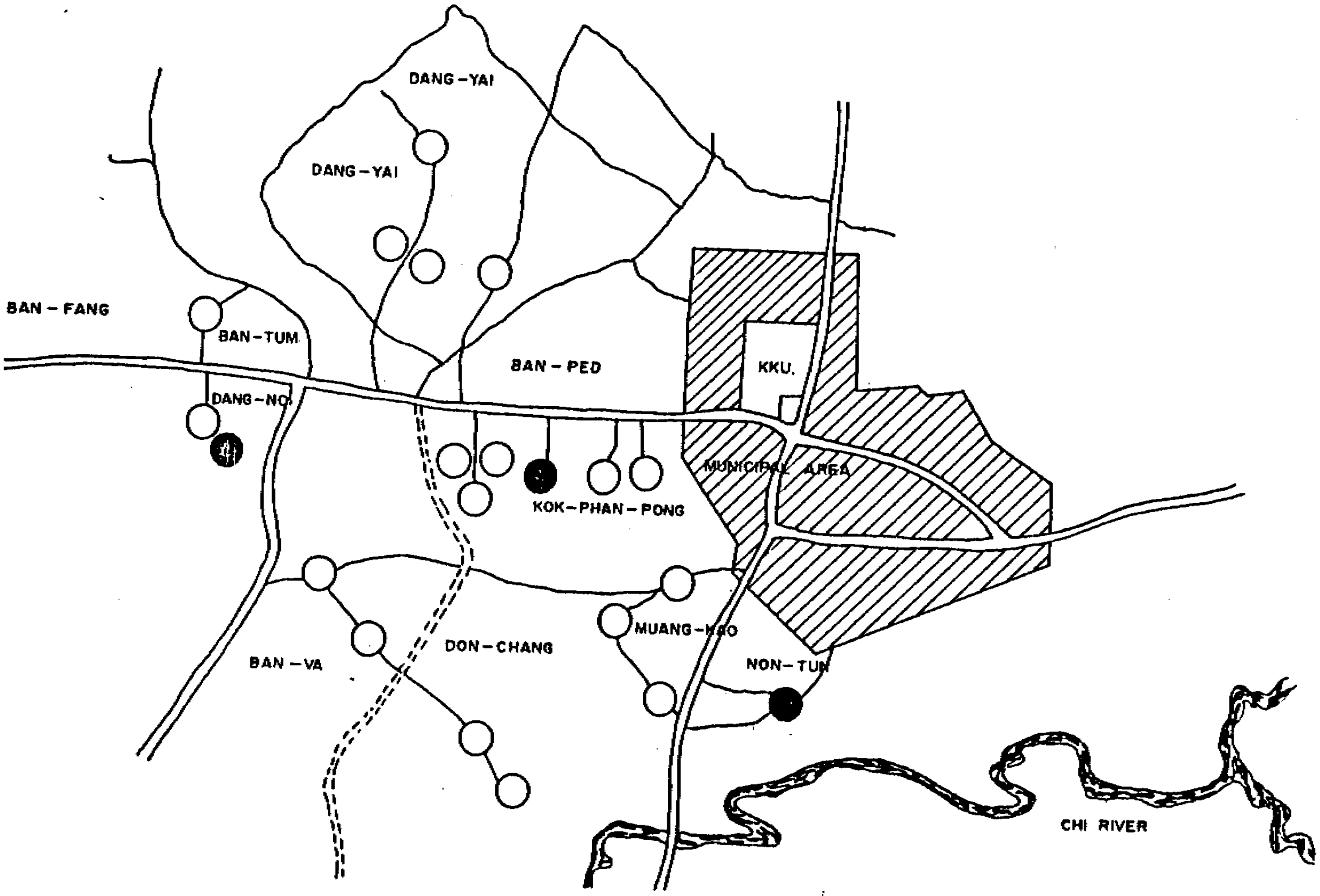

Figure 1. Location of the Villages Selected as Sampling Station.

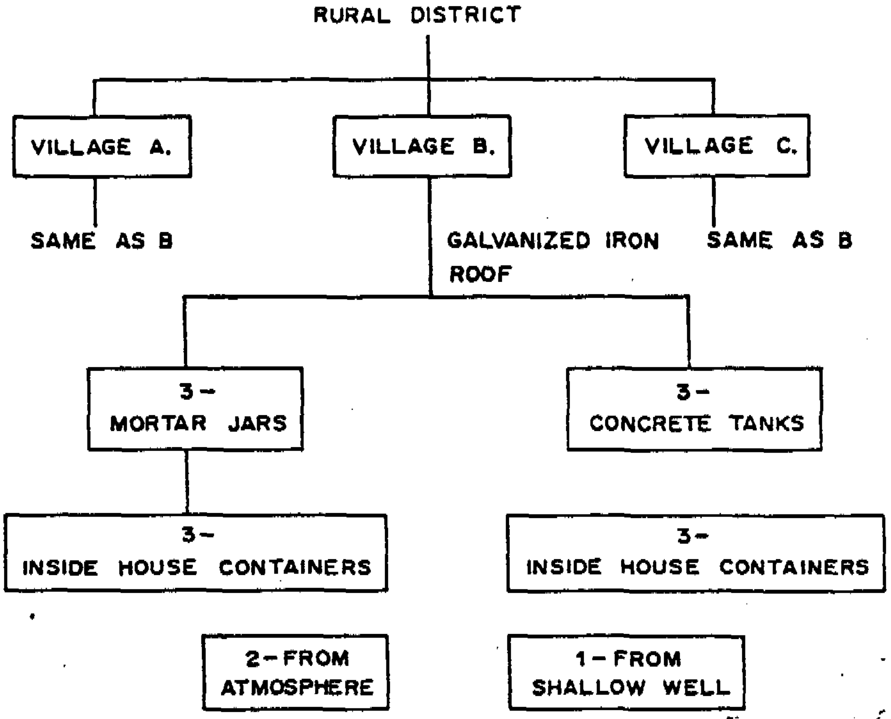

Figure 2. Research Design for Field Water Sample Collection.

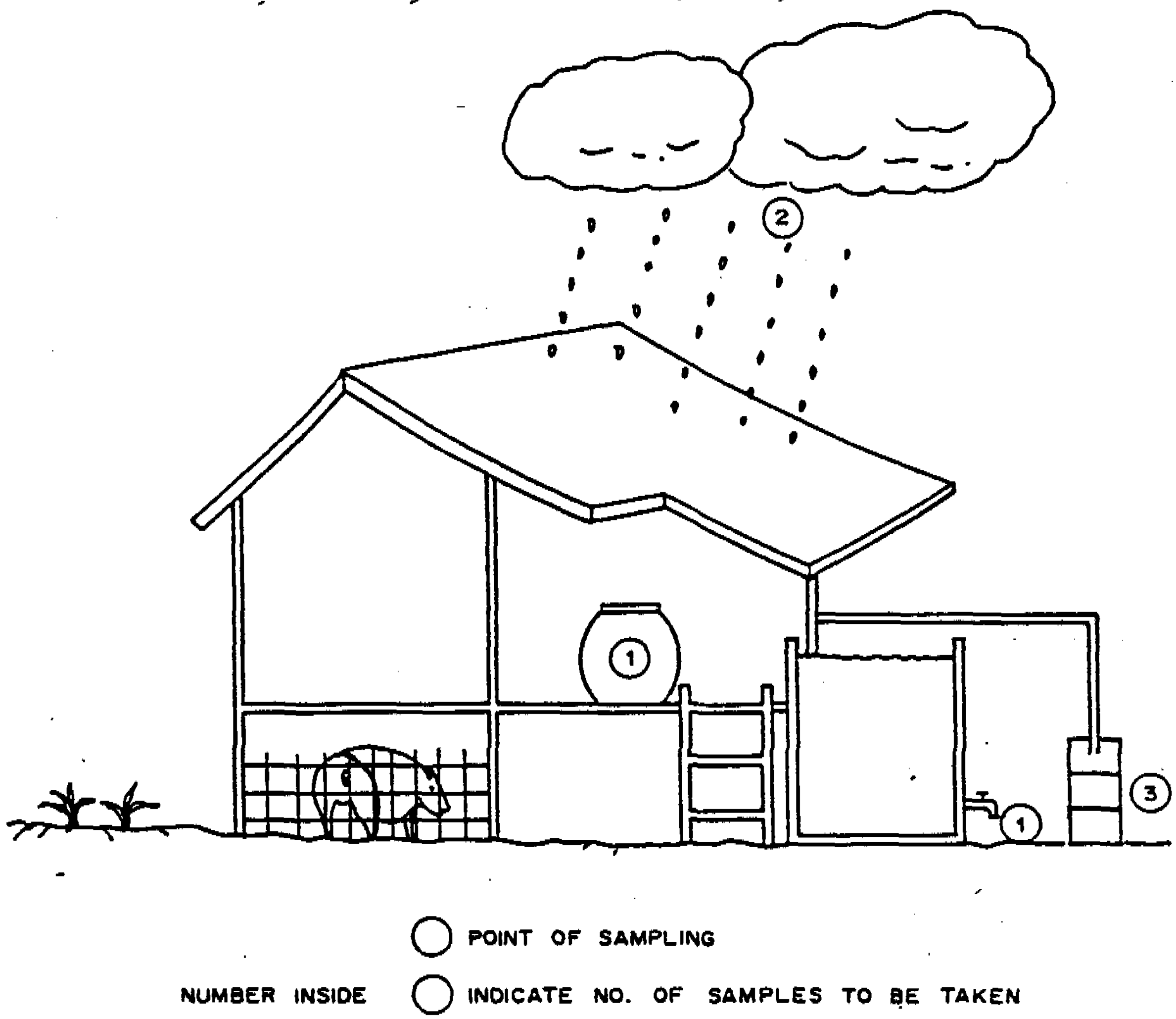

Figure 3. Points of Sample Collection.

Table 1 Sampling points and Number of Samples

Sampling Points	Village 1 Kok-Phan-Pong	Village 2 Dang-Noi	Village 3 Non-Tun
Roof and Gutter*			
-Bottom	7	6	6
-Middle	7	6	6
-Top	7	6	6
Storage Container			
-Tank	3	3	3
-Jar	4	3	3
In-house Container	3	6	1
Shallow Well	1	1	1

* Rainwater samples from roof and gutter were collected in 3-vertical-connected-containers of the automatic sampler. Bottom, middle, and top, represent the position of the 3 containers which collected the first rainfall in the bottom container and the following few minutes of rainfall in the middle and top containers. These are presented in all following tables.

composed of 3 cylindrical containers connected in a vertical series (Figure 4).

The sampler was connected to the bypass of a storage container that so when it rained, water from the roof and gulter were collected at three different time intervals. The first few minutes of rainfall was collected in the bottom container, the middle container collected rainfall after another few minutes has passed, and the top container collected the last time interval.

3) Rainwater storage containers - Rainwater containers are divided into two types, tank and jar. A cement tank (10-12 cubic meters) and a mortar jar (approx. 2 cubic meters) were used in this study. Only two year-old containers were selected. Therefore, the effect of the containers'age on rainwater quality was eliminated.

4) In-house container - To identify a secondary contamination water samples were also taken from in-house containers. Most of the in-house containers are small pots made of clay which are used as drinking water vessels. Water from collection tanks will be transported to these clay pots by carrying vessels. This was considered one of the possible routes of secondary contamination as well as a poor sanitary technique on the part of the home owner.

5) Shallow well water - Samples were also taken from shallow wells, which are sometimes used for drinking water, and analysed for comparison with the quality of rainwater.

2.3 Laboratory Analysis

Two samples were taken from each sampling point. One bottle of about 1000 ml was used for bacteriological analysis. Another bottle of about 500 ml was used for heavy metal analysis.

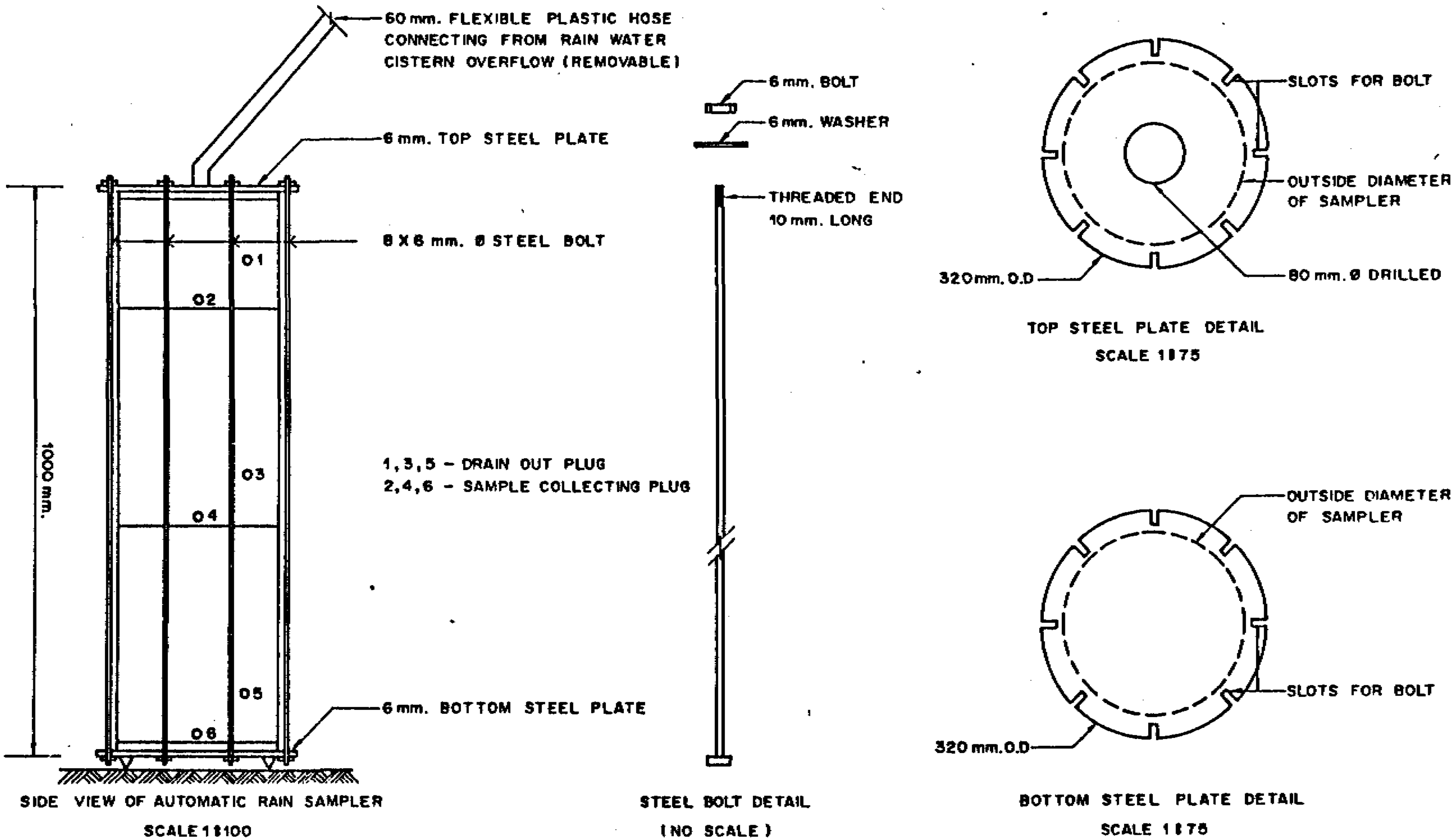

Figure 41 Composite Automatic Roof and Gutter Water Sampler.

The bacteriological analysis included the following indicator organisms and pathogens :

Indicator organisms :	total plate count
	total coliform
	fecal coliform
	Eschericia coli (E.coli)
	fecal streptococci
Pathogens :	*Salmonella*
	Shigella
	Aromonas
	Vibrio

The heavy metal analysis comprised chromium (Cr), cadmium (Cd), lead (Pb), copper (Cu), iron (Fe), manganese (Mn), and Zinc (Zn).

2.4 Sanitary Practices

Rainwater contamination does not only arise during the course of collection (i.e. from the roof and qulter system to the container) but also through poor sanitary practices of the villagers such us water handling and usage, toilet usage, solid waste disposal, house cleaning. Information on samitary practices was obtained by questionnaire, conversation, and visual observation of the researchs assistants who spent one complete week in the selected village.

The information obtained from this survey allowed an assessment of the possible pathways of contamination via rainwater collection systems and/or improper sanitary practices of the villagers.

III. RESULT AND DISCUSSION

3.1 Evaluation of the Bacteriological Quality of Rainwater

Bacteriological quality of rainwater collected from various sampling points were compared to the WHO Standard Drinking Water Quality (1971), which are summarized in Table 2. The standard bacteriological parameters include (a) total bacterial count, not to be higher than 500 cells/ml, (b) MPN of coliform, not to be higher than 2.2 cells/100 ml, and (c) MPN of fecal coliform, not to be present, and (d) *E.coli* , not to be present.

Rainwater samples collected from all of the various sampling points; roof and gutter systems, tank and jar storage centainers, and in-house storage containers failed to meet those standards. The percentage of the various samples in the range of 60-91, 34-78, 43-78, and 10-33 exceeded the standards of total bacterial count, total coliform, fecal coliform, and *E.coli* , respectively.

It was concluded that all sampling points were bacteriologically contaminated. The highest percentage of contamination encountered in samples were from in-house storage containers followed by samples from roof and gutter systems and lastly, tank and jar storage containers.

3.2 The Source of Bacteriological Contamination

The source of bacteriological contamination was evaluated using the ratio of fecal coliform to fecal streptococci (FC:FS). A FC:FS *ratio of greater than* 2-4 *indicates that the contamination was* from human rather than animal origin, while a ratio of less than 1 indicates the contamination was of animal orgin. A ratio of 1-2 indicates that the contamination source originated from either human or animal origin.

Table 2 Analysis of Bacteriological Quality of Rainwater from Various Sampling Points

Sampling Points	Total Number of Samples	Results in % of Total Number of Samples							
		Total Bacterial Count		Total coliform		Fecal coliform		*E.coli*	
		Meet Standard	Doesn't Meet Standard	Meet Standard	Doesn't Meet Standard	Meet Standard	Doesn't Meet Standard	Meet Standard	Doesn't Meet Standard
Roof and Gutter	416	9	91	42	58	42	58	90	10
Tank and Jar Storage Container	189	40	60	66	34	57	43	88	12
In-house Container	100	12	88	22	78	22	78	67	33
Shallow Well	22	13.6	86.4	0.00	100.00	0.00	100.00	68.2	31.8

The FC:FS ratios are summarized in Table 3. About 79% of the samples collected from roof and gutter systems and 84% of the samples collected from rainwater storage tanks and jars had FC:FS ratios of less than 1, indicating that the source of contamination were of animal rather than human origin. Approximately 39% of the samples collected from the in-house storage containers had FC:FS ratios of less than 1 and 47% had FC:FS ratios of greater than 4, indicating that the contamination was from both animal and human origins. It might be concluded that the human contamination occurred due to unhygienic water handling and usage practices.

3.3 Pathogenic Contamination

Table 4 shows the results from the pathogenic isolation of rainwater. The pathogenic contamination was found in samples taken from roof and gutter systems, from storage tanks, and from in-house storage containers. No pathogens were isolated from storage jars. The isolated pathogens from these samples were *salmonella gr E* and *C, Aromonas sp., Vibrio parahaemolyticus*. These pathogens are known to cause diarrheal diseases in humans. However, the pathogens were isolated in only about 0.6% of the sample collected.

3.4 Bacteriological Contamination of Shallow Well Water

The bacteriological quality of shallow well water was also investigated so that the comparison to the quality of rainwater could be drawn. It was found that the bacteriological contamination of shallow well water was higher than that of rainwater in every bacteriological parameter (Table 2).

The FC:FS ratios of shallow well water samples were similar to the results from the in-house storage container samples. Approximately 33% of the shallow well samples had a FC:FS ratio of less than 1 and 43% of the samples had FC:FS ratio of greater than 4,indicating that the source of contamination was of both animal and human origins (Table 3).

Table 3 Ratio of Fecal Coliform to Fecal Streptococci (FC:FS) from Various Sampling Points

Sampling Points	Number of Samples	Results in % of Samples FC:FS			
		>4	>2	1-2	<1
Roof and Gutter	405	8	4	9	79
Storage Container					
Tank	92	8	4	8	80
Jar	95	9	3	4	84
In-house Container	100	47	7	7	39
Shallow Well	21	43	19	5	33

A pathogen was also isolated from the shallow well samples, which was *Aromonas hydrophila* . The pathogenic contamination occurred in approximately 4% of the samples which is a higher rate of occurrence than for any of the rainwater samples (Table 4).

3.5 Heavy Metal Contamination of Rainwater

The heavy metals analysed in this study included Cd, Cr, Pb, Cu, Fe Mn, and Zn. Most of the heavy metal concentrations did not exceed WHO standards for drinking water (1971) with the exception of Mn and Zn (Table 5). However, both Mn and Zn are considered to affect aesthetic quality of water only and are not considered to be significant healthwise.

There was a range of 9 - 20% of the roof and gutter system samples which failed the WHO standards for Mn and 4 - 26% of the samples failed for Zn. Only 2% of the samples taken from the in-house storage containers failed WHO standards for Mn. No samples taken from the storage tanks of jars exceeded the standards in any of the analysed parameters. This indicated that the initial route of contamination originated at the roof and gutter systems and was then recontaminated at the site of the in-house storage container. However, it may be noted that the roof and gutter systems were considered the major source of contamination. It was also found that the first rainfall samples had higher contamination of Mn and Zn than the following rainfall samples, suggesting that Mn and Zn were leached initally from the galvanized iron roofing material and then washed into the storage containers. The lower concentration of heavy metals in the upper layers of stored rainwater could be due to the metals settling to the bottom sediment layers of the storage containers via either adsorption (e.g. Zn) or precipitation (e.g. Mn).

In addition, pH may affect the dissolution of heavy metals. Table 6 shows the pH of the samples collected from the roof and gutter systems ranged from 6.35-7.80, the pH of the storage containers

Table 4 Analysis of Pathogenic Contamination in Water Collected from Various Sampling Points

Sampling Points	Total Number of Samples	Number of Samples Contaminated by Pathogen(s)	% of Pathogenic Contamination	Name of Pathogens
Roof and Gutter	395	1	0.2	*Salmonella group E*
Storage Container				
Tank	89	2	2.2	*Aeromonas sp.,Salmonella group C*
Jar	97	0	0.0	-
In-house Contanier	99	1	1.0	*Vibrio parahaemolyticus*
Shallow well	24	1	4.2	*Aromonas hydrophila*

Table 5 Analytical Results of Heavy Metal Concentrations

Sampling Points	Total Number of Samples	Results in % of Total Number of Samples					
		Cd		Cr		Pb	
		Meet Standard	Doesn't Meet Standard	Meet Standard	Doesn't Meet Standard	Meet Standard	Doesn't Meet Standard
Roof and Gutter							
-Bottom	93	100	0	100	0	100	0
-Middle	125	100	0	100	0	100	0
-Top	100	100	0	100	0	100	0
Storage Container							
-Tank	86	100	0	100	0	100	0
-Jar	96	100	0	100	0	100	0
In-house Container	90	100	0	100	0	100	0

Table 6 pH of Rainwater Collected from Various Sampling Points

Sampling Points	pH
Roof and Gutter	
-Bottom	7.80
-Middle	7.55
-Top	7.65
Storage Container	
-Tank	9.10
-Jar	9.20
In-house Container	8.20

ranged from 9.1-9.2, and the pH of the in-house containers was 8.2. A high pH of stored rainwater may also cause the dissolved form of heavy metals to become insoluble and therefore, deplete the stored rainwater's heavy metal concentration.

3.6 Sanitary Practices

The sanitary practices investigated in this study included: the household structure itself, drinking water sources, characteristics of collection systems, characteristics of storage containers, water handling and usage practices, cleaning practices, excreta disposal facilities, solid waste disposal, and personal hygiene practices.

It was concluded that the sanitary practices played an important role in the bacterial contamination of stored rainwater. Not only did unhygienic practices during collection, storage, and transfer of rainwater affect the bacteriological contamination, but also the unsanitary surroundings of the household itself affected the bacteriological quality of the rainwater.

IV. CONCLUSIONS

The bacteriological contamination of stored rainwater was found. A possible route of contamination was from both unclean collecting systems (roof and gutter) and unclean storage containers (tank and jar). The source of contamination was of animal origin. It is thought that birds may be the main contributing to this source of contamination.

The heavy metal contamination of the stored rainwater was also found, but the concentration of those analysed heavy metals did not exceed the WHO standard drinking water quality (1971). The higher concentration of Mn and Zn were found in the samples collected from roof and gutter systems. These two heavy metals are considered to affect aesthetic quality and are not significant to health effect.

It was concluded that the health risk evolving from consumption of rainwater should be due to bacteriological contamination rather than heavy metal contamination.

The bacteriological contamination was also caused by poor sanitary practices of the villagers in rainwater collection, handling and usage, toilet practices, solid waste disposal, and unsanitary conditions of the household.

Rainwater is potentially the safest and the most economical source of drinking water with the improvement of hygienic collection procedure, storage, and sanitary practices.

ACKNOWLEDGEMENTS

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HYDROLOGICAL DATA

AND

ANALYSIS

TWO RECENT METHODS FOR COMPUTING AVERAGE PRECIPITATION

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ABSTRACT

Three techniques, a traditional approach (isohyetal map) and two recent developments, (a distance weighted method and a finite element approach) have been used to estimate the average area precipitation on several different catchments. Since it is generally recognised that the isohyetal map technique produces the most accurate results of the traditional methods, these have been used as a basis for comparison with the values obtained from the two new techniques. Each method has its advantages and disadvantages, but the results indicate that in terms of accuracy there is little difference between the techniques.

INTRODUCTION

In nearly all hydrological studies it is necessary to estimate the average depth of precipitation over the catchment under consideration. Precipitation measurements are made at specific points from a network of rain gauges distributed over the area of interest, and the mean areal depth of precipitation is calculated by one of several methods. The current techniques available include three established methods.

(1) arithmetic mean,

(2) Thiessen polygon,

(3) isohyetal map

and two more recent developments

(4) a distance-weighted method; and

(5) a finite element approach.

Arithmetic Mean

This is the mean of all gauge readings within the catchment with equal weight given to each gauge irrespective of its location. It is the simplest and quickest technique which yields good results if the topography is relatively flat, a large number of gauges are fairly evenly distributed over the area and individual gauge measurements do not vary widely from the mean, Linsley et al (1975). The approach neglects any influences of gauges outside the catchment boundary and may produce poor estimates if any of the above conditions are not satisfied.

Thiessen Polygon

If the areal distribution of gauges on the catchment is uneven, the Thiessen or isohyetal graphical methods attempt to allow for this non-uniformity by the use of weighting factors. The Thiessen approach divides the catchment into a series of polygons surrounding each gauge such that all points within each polygon are closer to their respective gauges than to any other measuring station. The area relating to every gauge then becomes its weighting and may be re-used for different precipitation data. The method, which assumes a linear variation of precipitation between gauges, usually gives more accurate results than those obtained by the simple arithmetic average. However, no consideration is given to any localised orographical features. Advantages of the technique are that the total area in the calculations is exactly equal to that of the catchment and the influence of gauges located outside the catchment boundary are taken into consideration.

During the past few years attention has focussed on the computer evaluation of the weighting factors, Diskin (1969 and 1972) and Shih et al (1975). However recent work by Ramaseshan and Anant (1977) concludes that the Thiessen weights can be considered a satisfactory optimum solution, but that their dependence upon hydrometeorological and pysiographic effects requires further study.

Isohyetal Map

This method is considered to be the most accurate for averaging the precipitation over a catchment as the analyst can take into account orographic features and storm characteristics when constructing the isohyets. Areas between the isohyetal lines then become the weighting. The method is highly dependent on the skill of the analyst and if linear interpolation between the gauges is resorted to, the results will be essentially the same as those obtained with the Thiessen polygon method, Shih et al (1975). If nonlinear interpolation is assumed a contour plotting program may be used to produced the isohyetal map, but it cannot make use of any natural effects.

Isohyetal plotting is subjective with its accuracy dependent on the skill and knowledge of the analyst. Like the Thiessen method it involves a graphical construction, which must be drawn for every storm, and measurements of area. Hence both techniques may prove to be very laborious and time consuming.

Distance-Weighted Method

To overcome some of the disadvantages of the above graphical approaches two new techniques have been proposed; one of the most recent developments being the distance-weighted method, Goel and Aldabagh (1979). This approach assumes that all factors affecting the precipitation distribution are proportional to the distance between the gauges. Goel and Aldabagh (1979) suggest that the shortest distances between the gauges are joined to form a triangular mesh. Average precipitation is then calculated by multiplying the length of each line by the arithmetic mean of the precipitation of the gauge measurements at each end, summing the products for the whole mesh and dividing by the total length of all lines. It is recommended that only those lines which lie 50 per cent or more within the catchment should be included in the calculations.

The advantages of the technique are its speed and simplicity (measurements of area are avoided), and it may be readily programmed for large networks. Weighting is determined from the number of lines radiating from a particular gauge.

Finite Element Approach

This method, which was introduced by Akin (1971) and extended to include altitude corrections by Hutchinson and Walley (1972), is analogous to some elementary concepts used in finite element techniques. The gauge points in the area of interest are used to form an arbitrary triangular or quadrilateral mesh, approximately as closely as possible to the shape of the catchment. It is assumed that the precipitation varies linearly over each triangular area or element, whilst the quadrilateral mesh uses the bilinear approximation to represent the precipitation surface over each element. The average depth over the network is then calculated by summing the volumes of precipitation and dividing by the total area. The idealisation is similar to that of a Thiessen polygon, except that each prism is now either triangular or quadrilateral in plan with the horizontal upper face having the mean value of its nodes, Chidley et al (1972). Weighting is dependent on the number of elements connected to a particular node.

The advantages of this approach are its simplicity and the fact that the procedure is easily automated; network modifications such as gauge removal require only minor input data changes. However, there are several limitations with this technique. The mesh only approximates the catchment area, accuracy is directly dependent on the assumed rainfall distribution over an element and topographical features are not considered. A further criticism by Edwards (1972) is the freedom of choice of the network, although presented as an advantage by Akin (1971), leads inevitably to ambiguity if a fully automated program is contemplated. Edwards suggests that an objective choice of triangular mesh can be arrived at by first constructing Thiessen polygons and then joining the gauge points between which the polygon sides are perpendicular bisectors. This leads to a single triangular mesh, since the Thiessen network is unique if correctly drawn.

EXAMPLES

To compare the results from the various methods of analysis, six catchments have been selected (References numbers 1,13,14,9,10,2) which vary in size, shape, topography, gauge distribution and density, so the merits of each method can be fully examined. Since the isohyetal method has long been recognised as the most accurate, only the results obtained from this traditional approach have been used as a basis for comparison with the results from the two recent techniques. Further investigations in the construction of the networks have been considered for the recently developed procedures. Outlines of the various catchments together with the available data indicated on them are shown in Figs. 1-6.

DISCUSSION

Table 1 shows the results obtained for the average precipitation of each of the six catchments. Also shown, in parenthesis, are the percentage variation in these estimates from those of the isohyetal method.

The distance-weighted method was simple and efficient, requiring little skill in the network construction. Minor alterations to the mesh, which violated the rules suggested by Goel and Aldabagh (1979), appeared to have little effect on the values.

The results obtained from the finite element approaches, using the Edwards (1972) criteria for choice of network, are comparable with the results from the other techniques. In general the linear triangular mesh and bilinear quadrilateral mesh produced similar values with good estimates from the catchments shown in Figs. 1 and 4. Both these areas however were relatively flat with a fairly uniform distribution of gauges, and a reasonable approximation was achieved in modelling the shape of the catchment. This later point seems to be a major drawback in the finite element approach as it is not always possible to adequately model the true area. This was evident with the catchments C, E and F in Figs. 3,5 and 6 respectively. As with the distance-weighted method minor changes to the various networks appeared to have little effect on the results.

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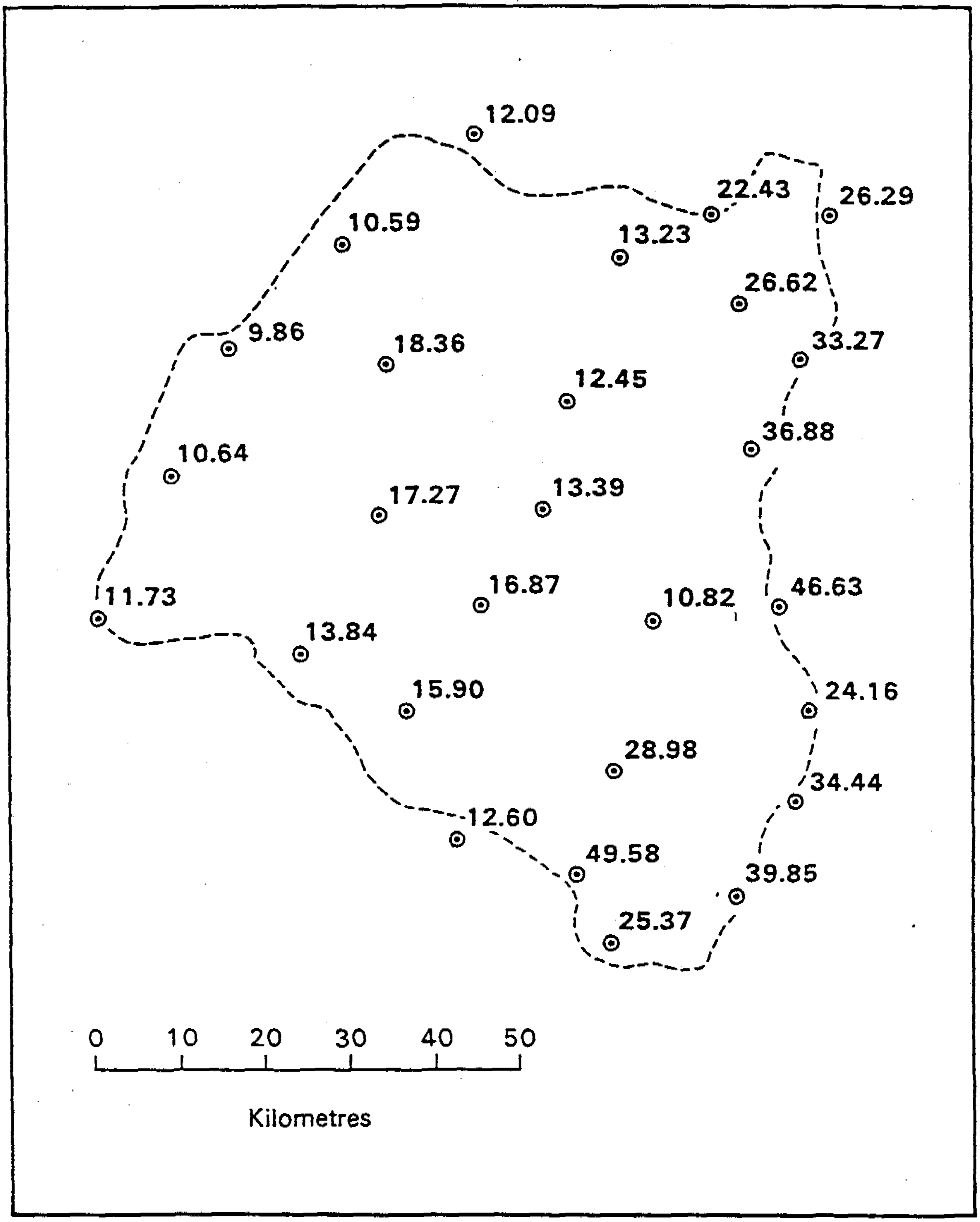
TABLE 1 Comparison of results from various methods

METHOD	AVERAGE PRECIPITATION (cms)					
	Catchment A (Fig.1)	Catchment B (Fig.2)	Catchment C (Fig.3)	Catchment D (Fig.4)	Catchment E (Fig.5)	Catchment F (Fig.6)
ISOHYETAL MAP	19.71	6.35	7.82	12.27	6.63	79.25
DISTANCE-WEIGHTED	19.53 (-0.9)	6.83 (+7.56)	7.24 (-7.4)	12.7 (+3.39)	6.22 (-6.18)	75.82 (-4.33)
FINITE ELEMENT (TRIANGULAR MESH)	19.58 (-0.66)	6.91 (+8.82)	7.47 (-4.48)	12.24 (-0.25)	6.32 (-4.68)	75.77 (-4.39)
FINITE ELEMENT (QUADRILATERAL MESH)	19.79 (+0.4)	6.81 (+7.24)	6.96 (-11.0)	12.19 (-0.66)	6.50 (-1.96)	To few gauges

Note:- Figures in parenthesis are the percentage variation in results of various methods from those of the isohyetal method.



12.09
10.59
22.43
26.29
13.23
26.62
9.86
18.36
33.27
12.45
36.88
10.64
17.27
13.39
16.87
10.82
46.63
11.73
13.84
15.90
24.16
28.98
34.44
12.60
49.58
39.85
25.37
0
10
20
30
40
50
Kilometres

FIG.1

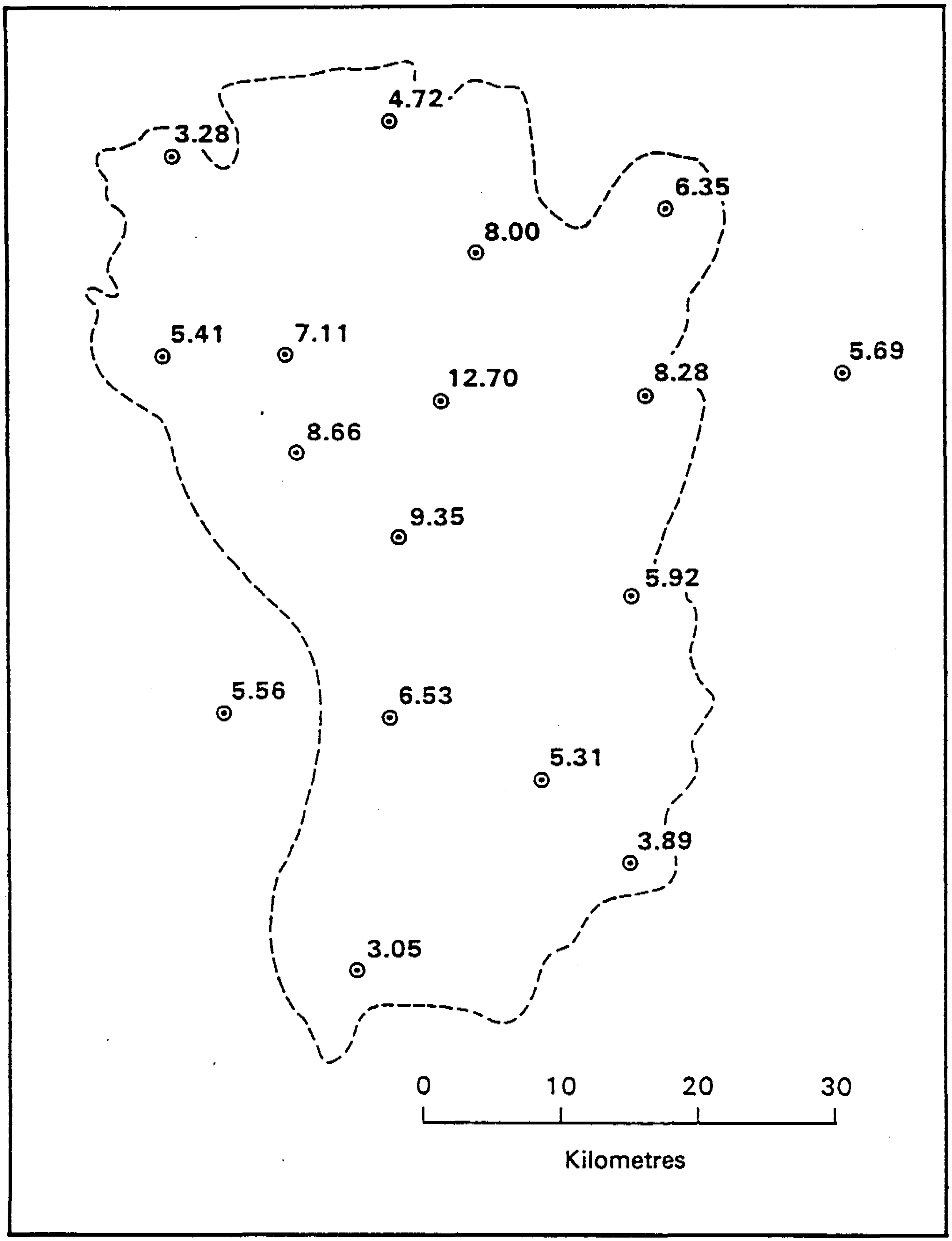
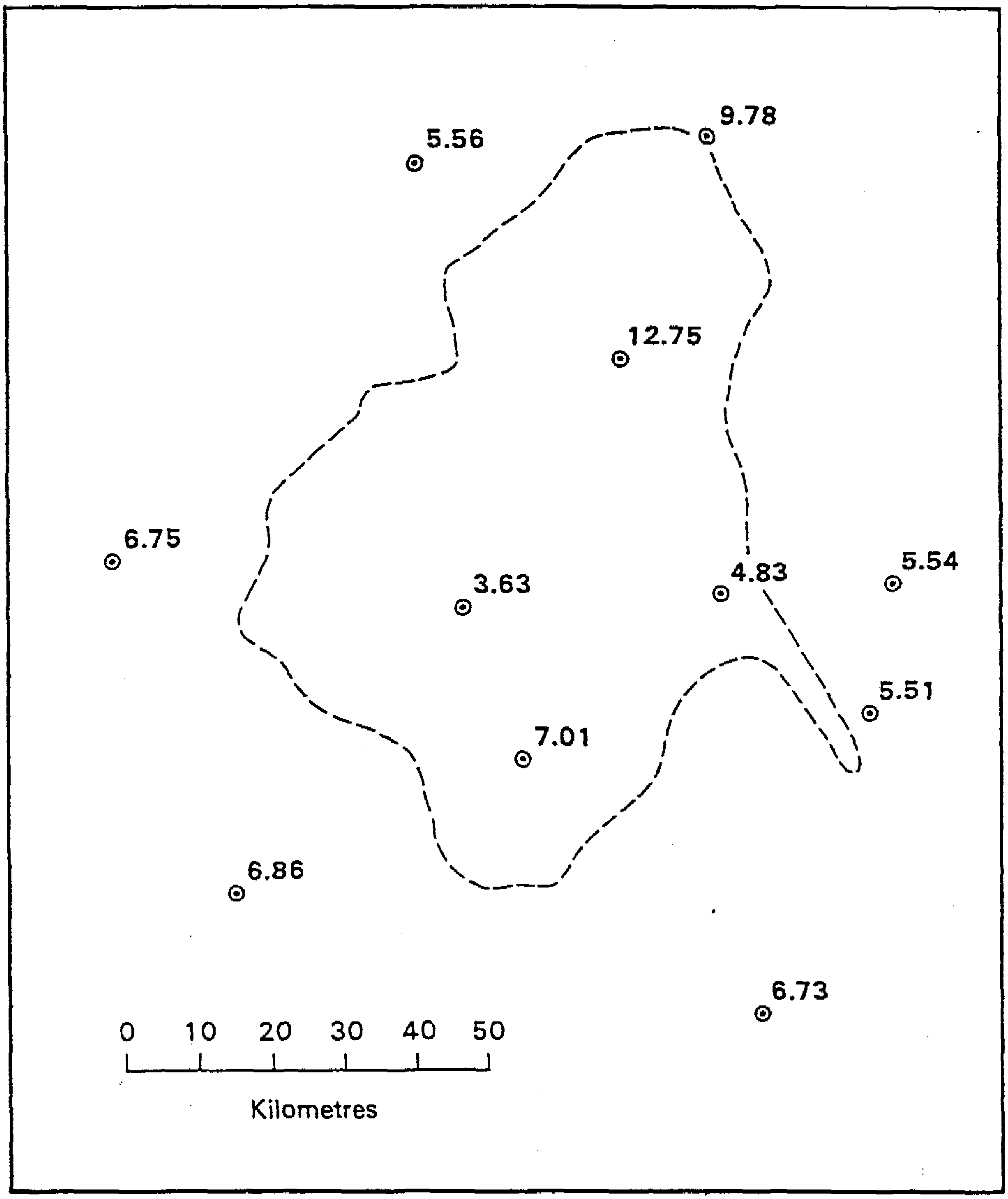

4.72
3.28
6.35
8.00
5.41
7.11
5.69
12.70
8.28
8.66
9.35
5.92
5.56
6.53
5.31
3.89
3.05
0
10
20
30
Kilometres

FIG. 2



9.78
5.56
12.75
6.75
3.63
4.83
5.54
5.51
7.01
6.86
6.73
0
10
20
30
40
50
Kilometres

FIG. 3

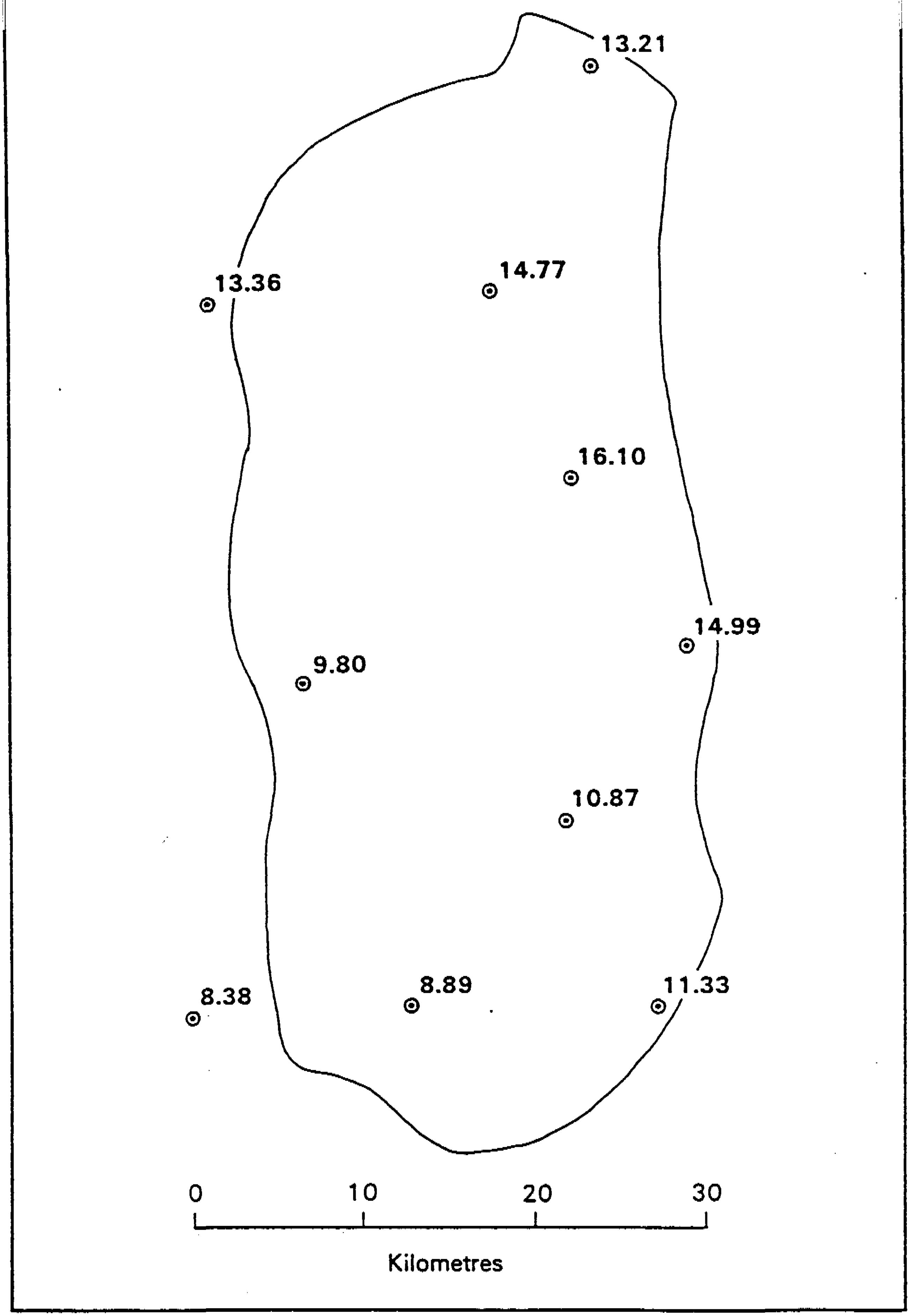

13.21
13.36
14.77
16.10
14.99
9.80
10.87
8.38
8.89
11.33
0
10
20
30
Kilometres

FIG. 4

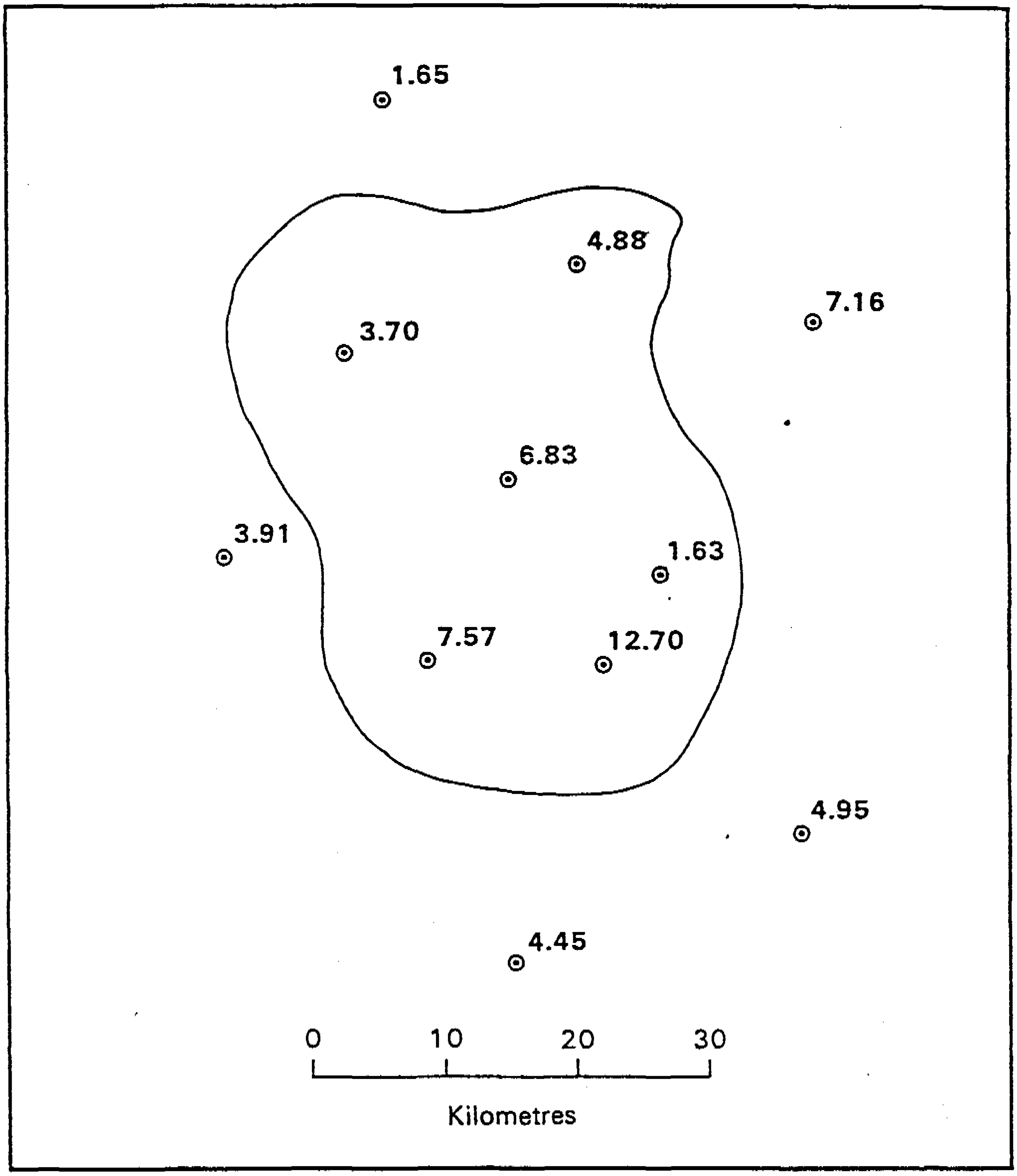

1.65
4.88
7.16
3.70
6.83
3.91
1.63
7.57
12.70
4.95
4.45
0
10
20
30
Kilometres

FIG. 5

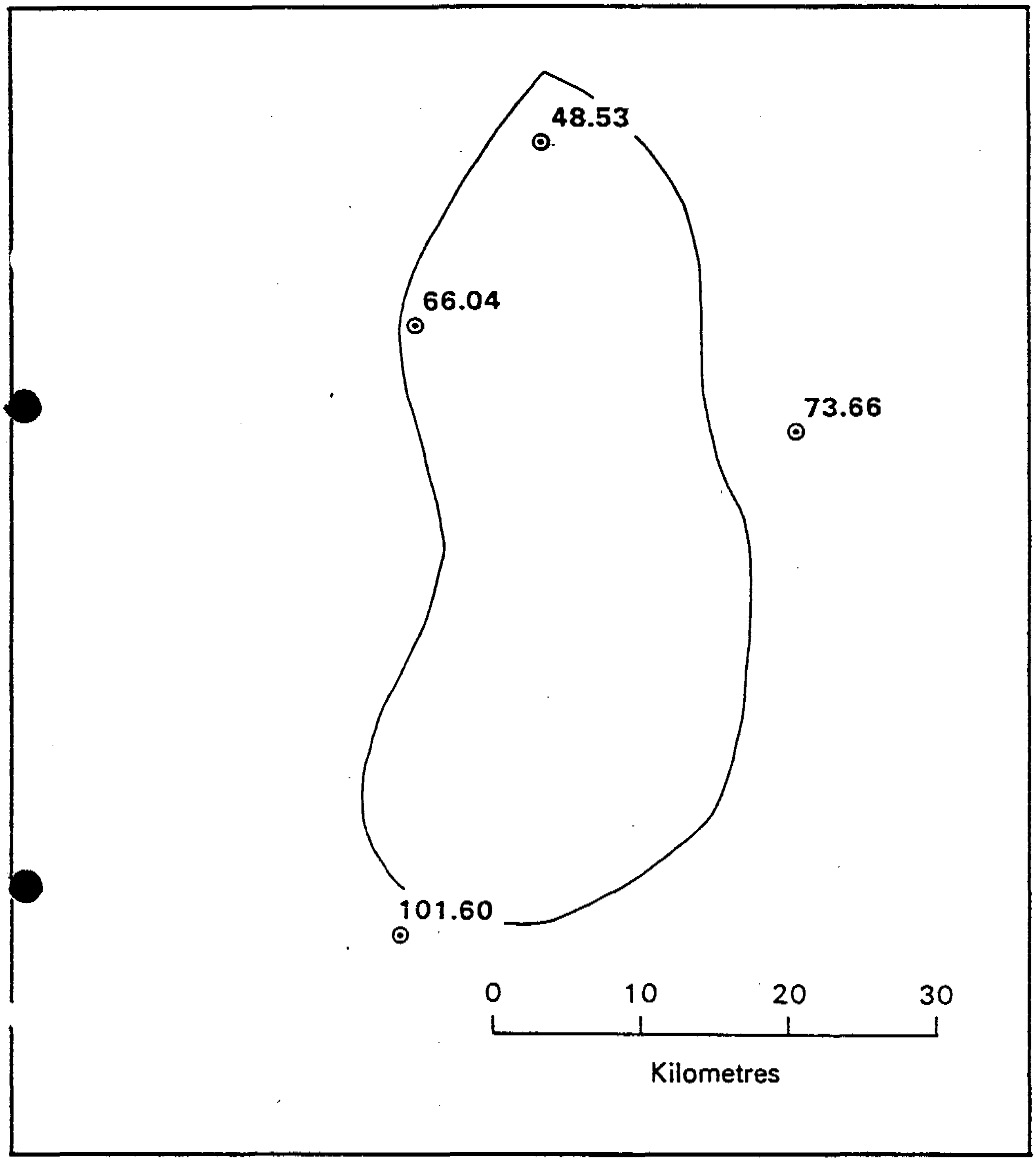


FIG. 6

ESTABLISHING NORMAL MONTHLY RAINFALL FOR RAIN WATER CISTERN SYSTEM DESIGN

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ABSTRACT

To properly design and operate a rain water cistern system, it is necessary to understand the dynamic and stochastic nature of rainfall processes. These processes are greatly influenced by random variations as well as cyclical effects. However, there is no general theory available which establishes the length of record required to provide a representative normal period of rainfall. The purpose of this study attempts to establish such a value.

To investigate the variability of monthly rainfall over a long period of time, an island station on the Pacific (Western Samoa) was selected for a number of statistical tests. The length of records required was first computed by the stability of mean approach. The number of years necessary to reach different stability levels were established for each month of the year. For locations lacking long-term rainfall records, a relationship between the years of average and the tolerance limit at different confidence levels was developed using the classical statistical approach. A rough estimate of the required length of the most important input variable (rainfall) would aid in the design and operation of a rain water cistern system.

INTRODUCTION

The four major design factors for rain catchment cistern systems are rainfall, catchment area, storage capacity and water demand. Of these, only rainfall is uncontrollable by the system designer. Thus, the initial basic decision for the cistern owner is to determine the minimum length of rainfall record which can provide necessary rain water cistern system design information. However, there is no general theory available which establishes the length of rainfall record required to establish a "normal" period of rainfall. The purpose of this study was to attempt to establish such a value.

To many scientists, a normal period should not be shorter than 35 years. Conventionally, the arithmetic mean calculated from such a period is called normal. In England, 35 years was chosen as normal of the metorological elements. Landsberg (1951) basing his study of rainfall data at one single station, concluded that the median is more adequate than the mean to define the rainfall "normal", through comparison of the length of record with the convergence of the two statistics to a respective stable value. He also stated that, "For most of the months 45 years of records would be needed to define satisfactory 'normals' for comparative studies of rainfall."

STABILITY OF MEANS

In order to understand the variability of monthly rainfall over a long period of time, one station located in Western Samoa was selected for a number of statistical tests. The reason for choosing this station is primarily that it has relatively long, concurrent, uninterrupted records of precipitation during the period from 1890 to the present. It is located in Apia, the capital of Western Samoa, with an average annual rainfall of 2,870 mm. Mean monthly rainfall distribution of this station is shown in Fig. 1. The graph shows significantly more rainfall in summer months (December to March) than in winter months (June to September). Since this station is not near the equator (about 14°S), it shows a single maximum during or just after the high sun period (Atkinson, 1971).

For this station, the mean was established for the first ten years (1890-99) of the records and then successive values of this statistic was calculated by including more data, one year at a time. Thus, a series of values for the mean for successive periods 1890-99, 1890-1900, ..., 1890-1971 was obtained and plotted in Fig. 2 for the wettest month of January and the driest month of July.

Criteria for the stability of the mean can be set either by the absolute change of the monthly rainfall between consecutive years or by the percent of variation of that value from the mean value. In Landsberg's work, the criterion for the stability is that the absolute change of rainfall would vary within 5 mm. Since the rainfall distributions usually display extremely large variations from season to season, both the more realistic criterion (percentage of variation) and the arbitrary criterion (absolute change) were included in deciding the required length of rainfall records.

The number of years required to reach different stability levels are summarized in Table 1. A longer (8 to 9 years) duration of rainfall records was required to reach the most "relaxed" stability level (10% tolerance) for the drier months (June to September). However, a remarkable improvement in stability (5% tolerance) is achieved with an addition of a relatively short (less than 10 years) length of rainfall records for the months of February, June, October and December. The wetter months (December to February) achieved lower stability earlier but required a slightly longer period to achieve the "stringent" stability level. In general, less than 10 years of rainfall records are needed for the mean values to reach a 10 percent level of stability; about 20 to 25 years to reach a 5 percent; and at least 70 years to reach a 1 percent stability level.

Based on the absolute change criterion, the mean monthly rainfall for the drier months would not experience more than 5 mm change if more than 35 years of continuous rainfall records were used to establish the mean. However, more than 50 years of records would be necessary to constitute a normal for the wetter months.

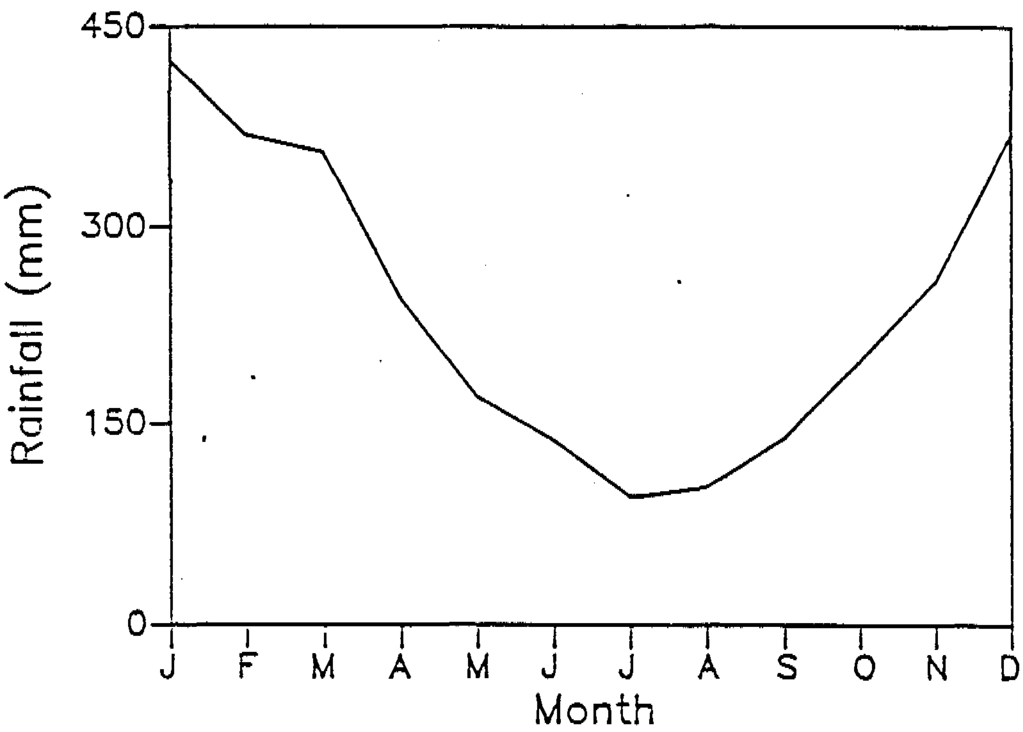

FIG. 1. Mean Monthly Rainfall in Apia, Western Samoa.

TABLE 1. Period of Record, in Years, Required for Mean Monthly Rainfall Values to Reach Stability at Specified Tolerance Levels.

Month	Absolute change of 5 mm	Percent of the mean		
		1	5	10
1	52	55	20	4
2	47	47	15	6
3	66	73	35	8
4	41	79	19	9
5	37	68	37	6
6	28	78	15	9
7	13	78	36	8
8	32	80	31	8
9	21	82	20	8
10	32	80	15	7
11	50	77	19	8
12	82	82	14	5

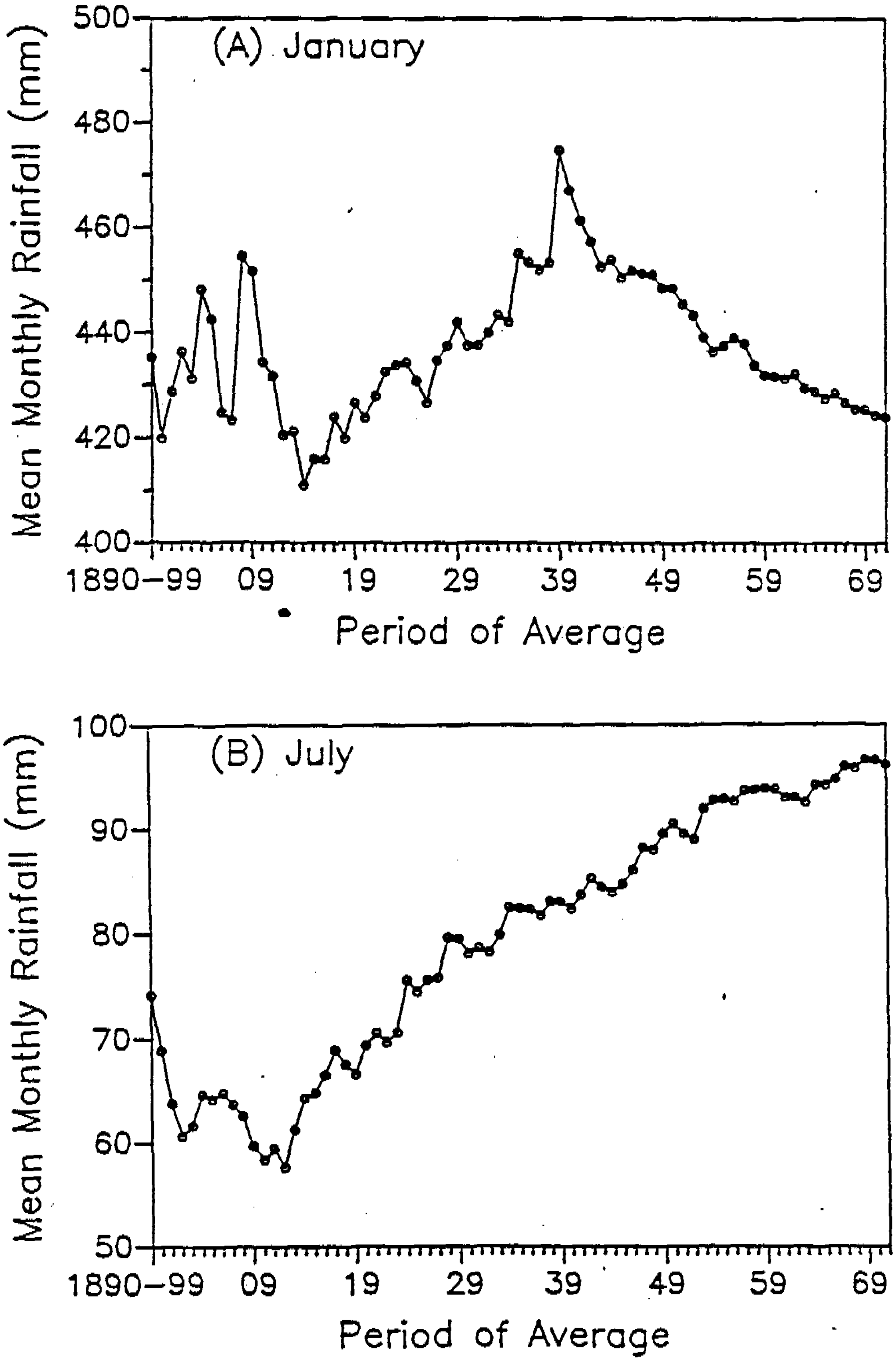

FIG. 2. Stability of Mean Monthly Rainfall in:
(A) January, and (B) July, 1890-1971.

CLASSICAL STATISTICAL APPROACH

For other locations, the same process would have to be repeated, which is not always possible due to data unavailability. Such tests would likely show a different number of years required for stability at different locations. A classical statistical method was tested to simplify the choosing an optimum sample size. The first step in this analysis is to decide how large an error we can tolerate in the estimate. The next step is to express the allowable error in terms of confidence limits. If L is the allowable error in the sample mean, and we wish to take a maximum 5% chance that the error will exceed L (95% confidence), the required sample size is given as (Snedecor and Cochran, 1967):

$$N = (1.96\,\sigma/L)^2 \qquad [1]$$

In this study, N would stand for the number of years of rainfall records used in computing the mean value and σ would have the same meaning as the standard deviation of monthly rainfall. The constant 1.96 corresponds to the value of normal deviate, Z, with 95% confidence probability. The use of normal distribution is based on the "Central Limit Theorem" (Mood and Graybill, 1963), which stated that even when the original population is not normal, the sample means obtained from the original population tend to become normally distributed as the sampling size increases.

Eq. [1] requires a knowledge of σ. Often a good estimate of σ can be made from results of previous samplings of this population or other similar populations. However, if this estimate was being used in some later year, the variance might change from year to year. In lieu of this estimate, Deming (1960) has pointed out that σ can be estimated from a knowledge of the highest and lowest values in the population and a rough idea of the shape of the population distribution curve. Defining H as the "range" of a population, which is simply the difference between the highest and the lowest value, then,

$\sigma = 0.29$ H for a uniform distribution;

$\sigma = 0.24$ H for a symmetrical distribution;

and $\sigma = 0.21$ H for a skew distribution.

Mink (1960) computed frequency distributions of monthly rainfall values from 10 rainfall stations in the State of Hawaii. None of those locations showed a significant difference from the log-normal distribution as determined by the chi-square test. To test if the same distribution prevails for rainfall in Apia, monthly rainfall obtained were subjected to the classical frequency analysis. As a first presentation of the total data picture, frequency histograms were constructed by grouping the monthly rainfall data into 10 classes. Fig. 3 display frequency distributions for the months of January and July. It is noted that the number of occurrences of monthly values smaller than the median is greater than monthly values higher than the median, suggesting possible skewed probability distributions for both months. To select a distribution model that best fits the actual values, common models such as normal, log-normal, or gamma families were tested.

The first major model is based on the normal distribution function, which is used extensively in statistical applications. This distribution function can be described by two parameters, the mean μ , and the standard deviation, σ, and can be represented by the following probability function (Haan, 1977):

$$f(x) = \frac{1}{\sigma(2\pi)^{1/2}} \exp\left[-(x-\mu)^2/2\sigma^2\right] \qquad [2]$$

One helpful tool for direct testing of normality is normal arithmetic probability paper. With such paper, values of a variable are plotted against the percentage of sample values that are greater than (or less than) that value and then fits a curve to the points. For a normally distributed random variable, the fitted curve is expected to be a straight line. Fig. 4 shows such plots for the months of January and July. The solid straight lines in the diagram are theoretically derived normal distribution curves using the computed mean and standard deviation from each month (Table 2) and substituted back to eq. [2]. Small deviation between the theoretical line and the computed data points for the month of July suggests that the monthly rainfall values are normally distributed. However, this is not true for the month of January.

The sample skewness coefficients is another aid in testing

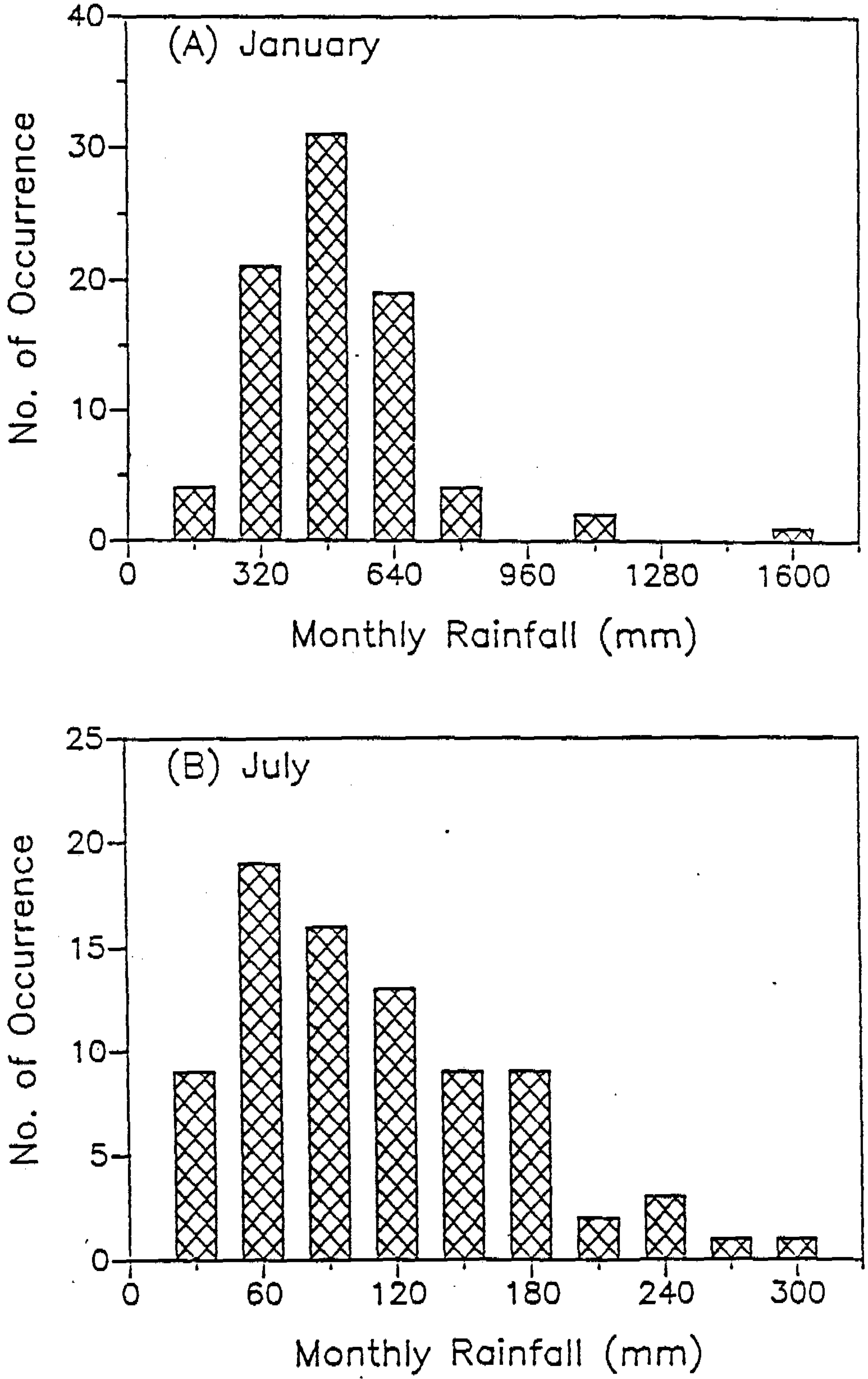

FIG. 3. Frequency Distribution of Monthly Rainfall in: (A) January, and (B) July.

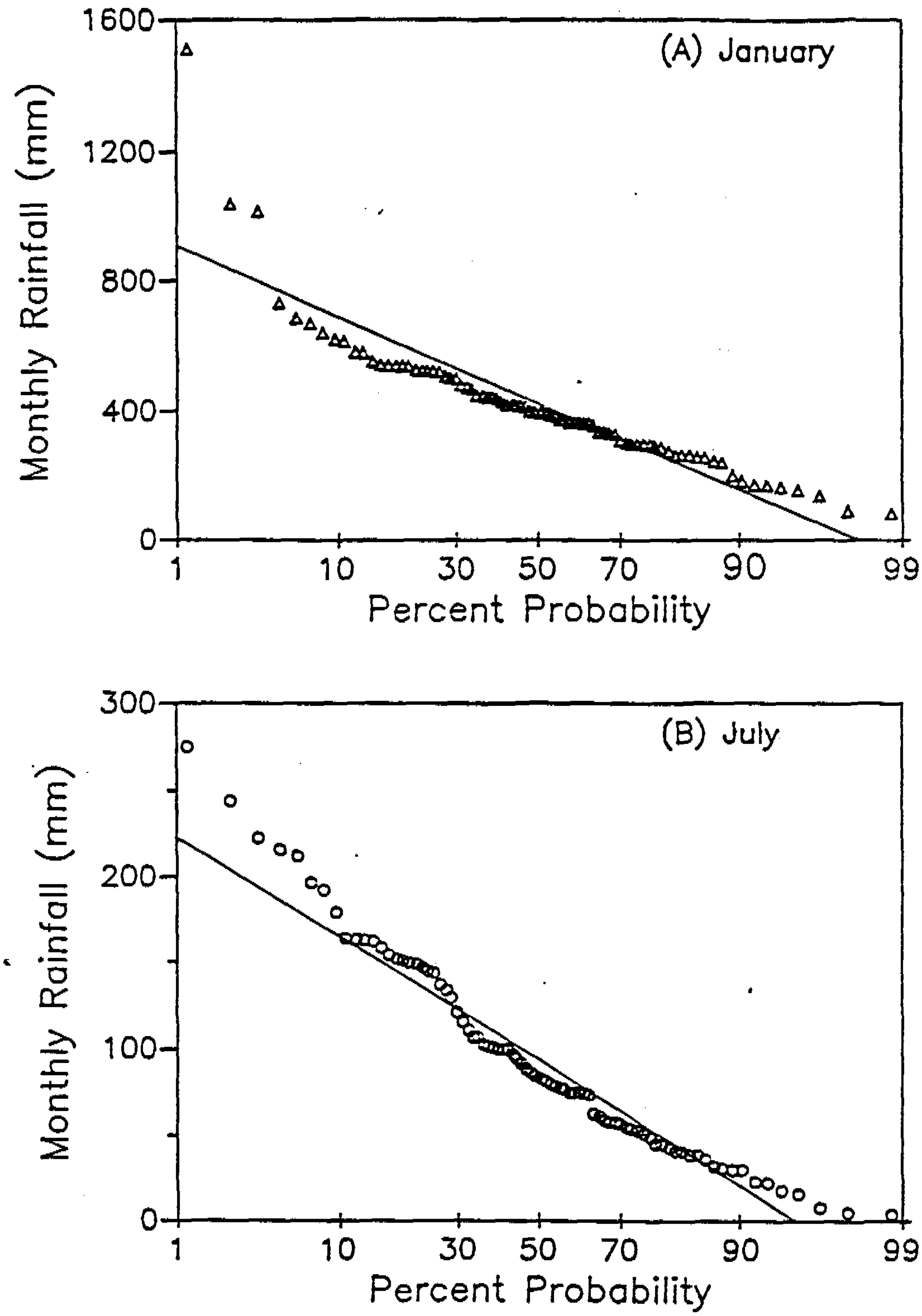

FIG. 4. Normal Probability Plot of Monthly Rainfall in: (A) January, and (B) July.

normality. Since the skewness coefficient of the normal distribution is zero, the sample skewness coefficient from a normal distribution should be close to zero. The calculated skewness coefficients for each month are also listed in Table 2. Coefficient values for the months of January, March, May, August, November and December far above zero indicate possible skewed distributions. For the other months, the coefficient values are very close to zero.

A second major distribution model widely used in frequency analysis is the log-normal distribution. This distribution function differs slightly from the normal distribution. Instead of the actual values, their logarithms follow a normal distribution and the probability function can be written as (Haan, 1977):

$$f(y) = \frac{1}{\sigma_y (2\pi)^{1/2}} \exp\left[-(y-\mu_y)^2/2\sigma_y^2\right] \qquad [3]$$

where, $y = \log x$.

To test whether a sample belongs to a population with a log-normal distribution, the logarithms of the sample values are first taken and the same normality tests described above are then applied to the logarithms. Alternatively, log-probability plots on especially designed paper can be used to save computation time. The log-normal probability plot for the month of January (Fig. 5) showed a definite improvement over the normal probability plot (Fig. 4). Most of the data points lie along the theoretical log-normal distribution straight lines, obtained by substituting values of mean and standard deviation (Table 3) into eq. [3].

The computed skewness coefficients for each month after the logarithmic transformation are shown in Table 3. Compared with the coefficient values obtained in Table 2, it is safe to conclude that monthly rainfall values in Apia follow the skewed probability distribution for six months of the year (January, March, May, August, November and December) and the normal distribution for the other six months of the year (February, April, June, July, September and October).

Once its distribution has been determined, the population standard deviation of the monthly rainfall can be estimated from its range (H) by the relation $\sigma = 0.24H$ (for normally distributed

TABLE 2. Statistical Parameters Computed from the Monthly Rainfall Values

Month	Minimum (mm)	Maximum (mm)	Range (mm)	Mean (mm)	Standard deviation (mm)	Coefficient of skewness
1	84.2	1513.1	1428.9	424.16	209.76	2.19
2	90.0	765.0	675.0	369.32	155.93	0.37
3	36.1	1297.4	1261.3	356.44	180.78	2.02
4	45.0	528.3	483.3	246.28	111.26	0.45
5	10.0	599.2	589.2	170.62	107.51	1.27
6	16.5	341.6	325.1	137.57	83.56	0.58
7	4.0	275.0	271.0	96.06	59.31	0.75
8	2.0	392.0	390.0	103.38	80.56	1.24
9	7.0	402.6	395.6	139.94	82.90	0.96
10	31.0	434.8	403.8	197.31	95.35	0.47
11	25.0	847.0	822.0	259.15	130.07	1.23
12	77.0	933.0	856.0	369.45	177.84	0.83

TABLE 3. Statistical Parameters Computed from the Logarithm of the Monthly Rainfall Values

Month	Minimum (mm)	Maximum (mm)	Range (mm)	Mean (mm)	Standard deviation (mm)	Coefficient of skewness
1	1.93	3.18	1.25	2.58	0.21	-0.52
2	1.95	2.88	0.93	2.52	0.21	-0.67
3	1.56	3.11	1.55	2.50	0.22	-0.81
4	1.65	2.72	1.07	2.34	0.22	-0.76
5	1.00	2.78	1.78	2.14	0.32	-0.95
6	1.22	2.53	1.31	2.04	0.31	-0.57
7	0.60	2.44	1.84	1.88	0.35	-1.30
8	0.30	2.59	2.29	1.85	0.45	-1.05
9	0.85	2.60	1.75	2.06	0.31	-1.15
10	1.49	2.64	1.15	2.24	0.24	-0.65
11	1.40	2.93	1.53	2.35	0.25	-1.18
12	1.89	2.97	1.08	2.51	0.23	-0.50

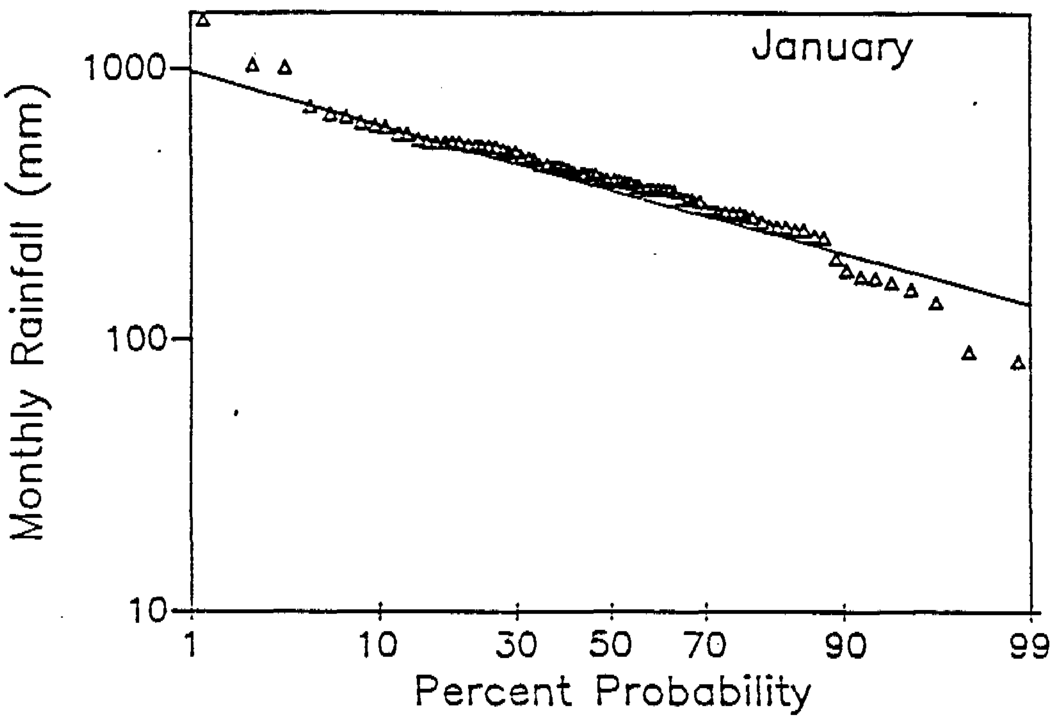

FIG. 5. Log-normal Probability Plot of Monthly Rainfall in Juanary.

TABLE 4. Comparison of the Computed and Estimated Standard Deviation.

Month	Computed (mm)	Estimated (mm)	Month	Computed (mm)	Estimated (mm)
1	209.8	300.1	7	59.3	65.0
2	155.9	162.0	8	80.6	81.9
3	180.8	264.9	9	82.9	94.9
4	111.3	116.0	10	95.4	96.9
5	107.5	123.7	11	130.1	172.6
6	83.6	78.0	12	177.8	179.8

rainfall) or $\sigma = 0.21H$ (for skew distributed rainfall). Table 4 shows a good comparison between the computed and estimated standard deviation except for the months of January and March. Substituting these relationship back to eq. [1], we find that:

$$N = (0.47H/L)^2 \quad \text{for normal distributions} \quad [4]$$

$$N = (0.41H/L)^2 \quad \text{for skew distributions} \quad [5]$$

For other confidence probability levels, the value of normal deviate, Z, changes as well as the constant in the above equations. The term (H/L) can be defined as the tolerance limit which is simply the ratio of the range of the monthly rainfall values to the tolerable error. Relationships between N and H/L at different confidence levels are plotted in Fig. 6 for the symmetrical and skew distributions. These figures should be applicable for any locations.

To make use of these diagrams, one needs to set a certain tolerance limit. If it is decided that only 10% of the range is tolerable or H/L is equal to 10, Fig. 6A shows it will require 7, 11, 20, and 38 years of normally distributed rainfall records in order to achieve 80, 90, 95, and 99 percent confidence levels, respectively.

CONCLUSIONS

The temporal variability of monthly rainfall in Apia, Western Samoa was investigated based on eighty two years of uninterrupted rainfall records. The length of records required to achieve different stability levels, set by the percentage of variation about the mean value and the absolute change between consecutive years were determined. It generally takes more than 10 years of rainfall records for the mean monthly rainfall values to reach a 10-percent level of stability; more that 20 years to reach a 5-percent; and at least 70 years to reach a 1-percent stability level.

For locations lacking long-term rainfall records, a relationship between the years of average and the tolerance limit at different confidence levels was developed. A rough estimate of the required length of rainfall records to provide a representative unbiased mean monthly rainfall value can be obtained at a given

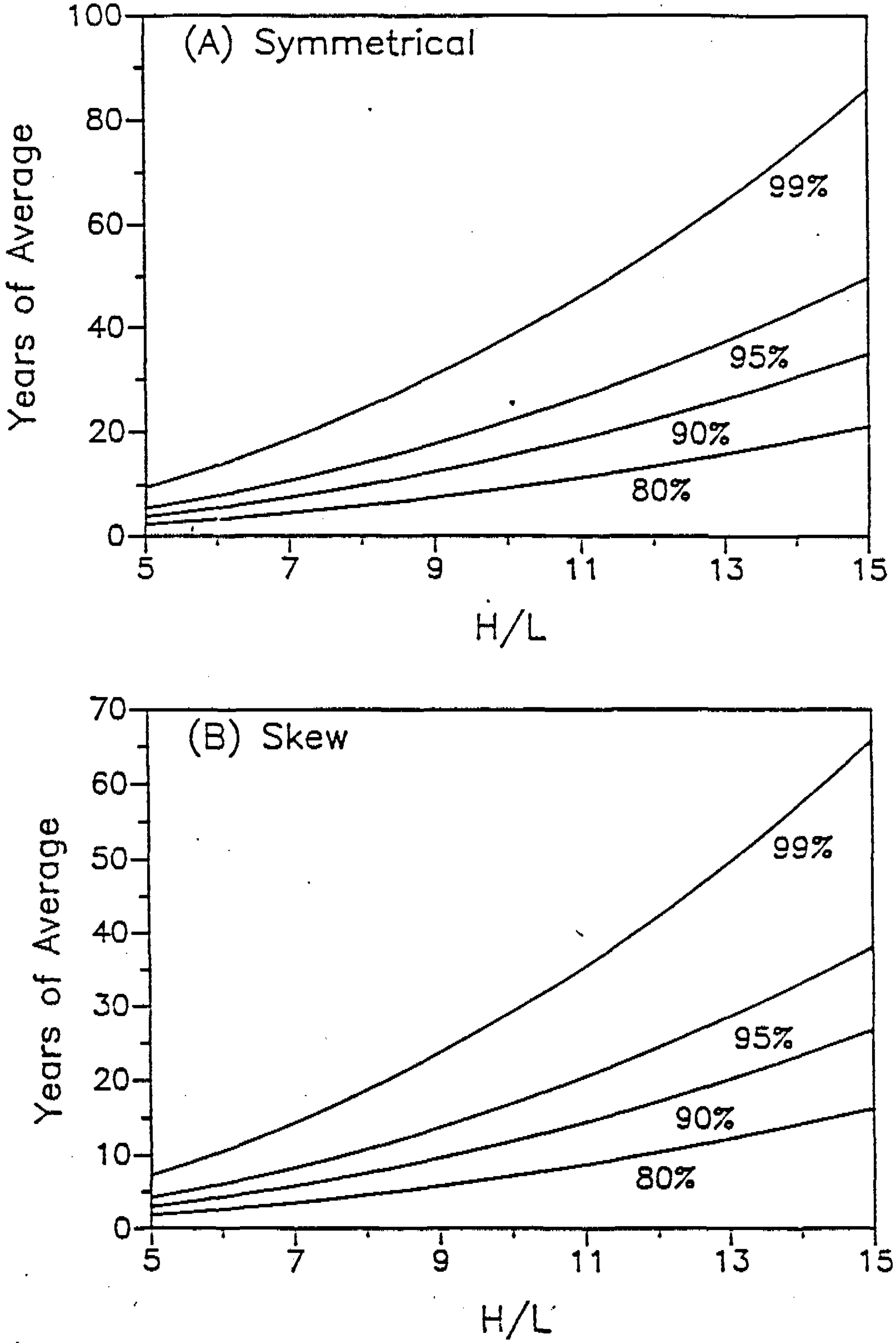

FIG. 6. Relationship of Years of Average and Tolerance Limit (H/L) at 80, 90, 95, and 99 Percent Confidence Levels for:
(A) Symmetrical Distributions,
(B) Skew Distributions.

tolerance limit. This would aid in the design and operation of a rain water cistern system.

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CATCHMENT

AND

STORAGE SYSTEMS

DIRECT DEVELOPMENT OF RAIN WATER RESOURCES BY TAMEIKES(FARMERS GROUP POND)

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ABSTRACT

The rural region where no irrigation facilities were constructed in several handred years.had many tameikes (farmers group pond) in the Setouchi of Japan.
These tameikes are special facility of water resources for farmers who were suffering from serious drought ,and this is a convenient structure reflecting their special social situation, then I would like to use the word "tameike" as a technical term.Tameike could be constructed and operated by farmers group.and they has exclusive water right of tameike. The tameike is key facility of paddy rice production and of social activity of farmers ,and these farmers are active menber for economic activity of agricultural corporation. We have transfered the tameike from Setouchi region to Northeast Thailand through cooperation study between Kyoto University and Chulalongkorn University, as the key facility of integrated small-scale rural development among rainfed paddy rice field on flat land of Notheast Thailand .Though there was strong salinity in ground of Northeast Thailand ,the rainfall collected in tameike could dilute the salinity to the level of irrigable water.It was very successful facility. We are going to show our experiences and theoretical evaluation for tameike of the region not only fresh ground water area but also salt ground water area in Northeast Thailand.

SYMBOLS

Ab=bottom area of tameike.Ain=inner slope area.Ag=area of ground surface level,Ao=area of crest.Arp=area of rainfed paddy rice field.Az =area of water surface :

Bb=width of bottom of tameike. Bg = width at the level of ground surface, Bz = width of water surface:

C=salinity of tameike,Co=initial salinity of C,Cp=salinity of rainfed paddy rice field,Cpr=coefficient of run-off from rainfed paddy rice field.Cr=salinity of rain.Cg=salinity of soil water,Cgf=salinity of fresh water stored under slopes:

D=salt supplied in tameike, dt = time integration ;

E=evaporation from water surface ,Et = water consumption:

F=discharge released; G=gravity accerelation:

Hb=depth of bottom under ground surface, Hg = depth of original ground water from bottom,

I=integer of days ;

k=permeability coefficient of ground m/s;

L=thickness of frsh water stored under slope,Lo=initial value of L,Lv=vertical thickness of fresh water stored under bottom, Lvo = initial value of Lv:

P=run off coefficient from crest of embankment:

q=seepage from slope(unit width).Qa=rainfall on tameike, Q4 = seepage from four slopes, Qb=flow to tameike from rainfed paddy rice field,Qi=release for irrigation,Qe=evaporation from tameike;

R=rainfall per day ,Re = effective rainfall;

Sa=salt due to rain , Sb = salt due to return flow, Sc = salt due to seepage through slopes, Sd = salt go out due to. seepage, Se = salt released from tameike;

t=time , T= seconds per day;

v=velocity of seepage, vv= vertical seepage velocity, V = total volume of water, Vp = volume in tameike , Vg = fresh water stored under slopes ,Vgo = initial value of Vg, Vgv = fresh water volume stored under bottom, Vgvo = initial value of Vgv, Vpo=initial value of Vp:

Xg=effective hydraulic radius ,Xo = middle point of slope:

Z=depth of water from bottom of tameike,

1. INTRODUCTION

So far ,though the big irrigation project were adopted for water resources development by many countries, but there has remained many isolated places with no water in the humid Asia.Nevertheless ,there are plenty of rainfall,for example 800-1500 mm per year in Southeast Asia.

The development of water resources on these isolated areas should be done by the new idea.I would like to present the direct development of rain water resources by means of Tameike(farmers group pond).

2. PRESENT SITUATION of WATER RESOUCES DEVELOPMENT

The water use development by big project are already tried by government agency for several decades. These are large- and medium-scale irrigation projects.The principle of project selection was the best b-c ratio in economics. The construcion flow of big irrigation preject is presented in Fig.1.

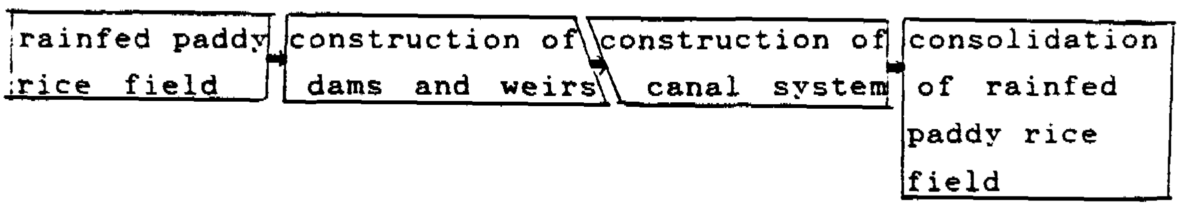

Fig.1 construction flow of big irrigation project

This irrigation project needs very big construction cost, long construction period and high level technology. Then all irrigation projects become very expensive now. The rural area of no water resources has been isolately remained under low economic activity. We should develop the new method of direct development of rain water resources at rural region.Now,I would like to present the construction flow of new water resouces development by means of tameike in Fig.2.

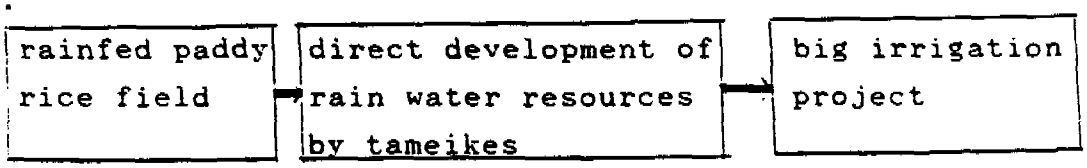

Fig.2 construction flow of rain water recouces development

We would like to recommend the development flow of Fig.2, namely the development from small-scale development by means of tameike to larger scale project with canals,weirs and dams in Southeast Asia because there are much rainfall every year.

3. PRESENT SITUATION of RAINFED PADDY RICE FIELD

The rainfed paddy rice field has spread on almost of the flat land in Southeast Asia.When the rainy season start, farmers would plant seed of rice, and rice plant grows in accordance with the increase of rainfall.When the rice plant has matured ,rainy season would over.Farmers can enjoy the harvest .If there are reasonable distribution of rainfall, such agriculture of rainfed is actually reasonable method. But unfortunately, there occurs big variation of rain and they had been continuously suffered serious drought disaster due to the lost of buffer action by deforestation.

4 TAMEIKES of SETOUCHI REGION in JAPAN

The Setouchi region in Japan island had flat plateau and annual rainfall 1300 mm/year,comparing 1800 mm/year that is mean value of Japan Island.All areas are used for rice production .The farmers had constructed many tameikes(farmers group pond) handred years ago by farmers themselves with several families. The tameike could collect direct rain from their own paddy rice field.The typical features of tameike are as follows.

a.The tameikes were constructed on flat land,no mountains and no rivers.

b.There are intensive agriculture by tameike.

c.The farmers group was organized by several families who have blood relation.

d.The farmers who had constructed tameikes had the water use right exclusively.

e.Tameike is not only the facility of direct rain collection but also the reliable social structure.

f.Tameike is a key facility of small-scale integrated rural development.

g.The density of tameike distribution has reached 20-30 percents of flat land.

h.Total rain on the paddy rice field near the tameike could be collected and stored.

i. Farmers group had duty to control, operate and maintain tameikes without any help from government.

j. Land for tameike construction would be donated by farmers.

The typical model of tameike can be shown in Fig.3.

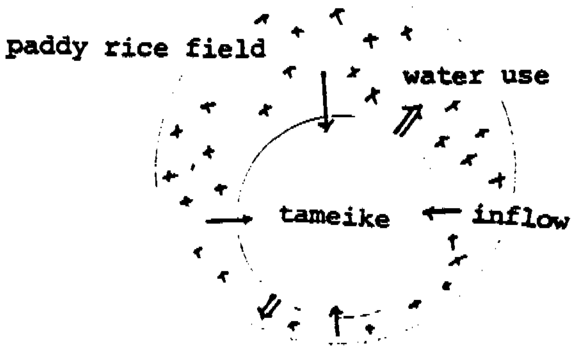

Fig .3 standard tameike model

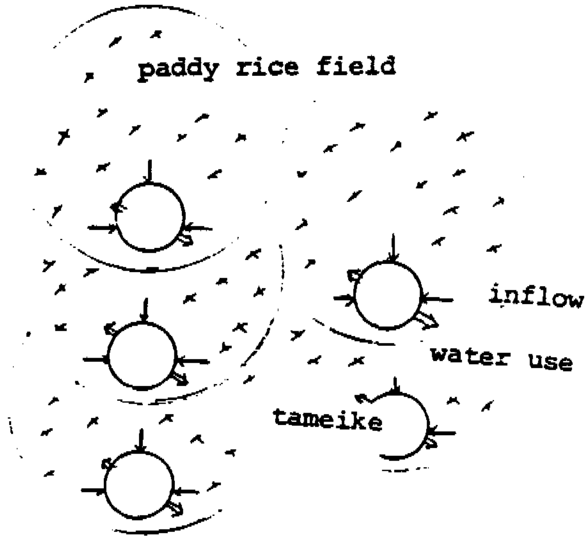

Fig.4 tameike group model

(1) Development of Tameike

Due to the increase of population at the area ,tameike had expanded to the tameike system. Fig.4 shows the distribution of tameike group,and Fig.5 shows the connection canal between river and tameike .Tameike groups were again connected with long canals to the big parent reservoir to set up parent-children tameike system as shown in Fig. 6 .

(2) Differnces between Tameike and Reservoir

The reservoir has following characteristics different from tameike.

a. Reservoir has big watershed in upstream only,but tameike has flat paddy rice field as watershed.

b. Reservoir has been constructed by dam crossing valley,but tameikes has been constructed on flat and.

c. Water of reservoir can be used by only down stream paddy rice area.

d. Reservoir can be constructed and operated only by govenment,but tameike is constructed,operated and maintained by farmers group.

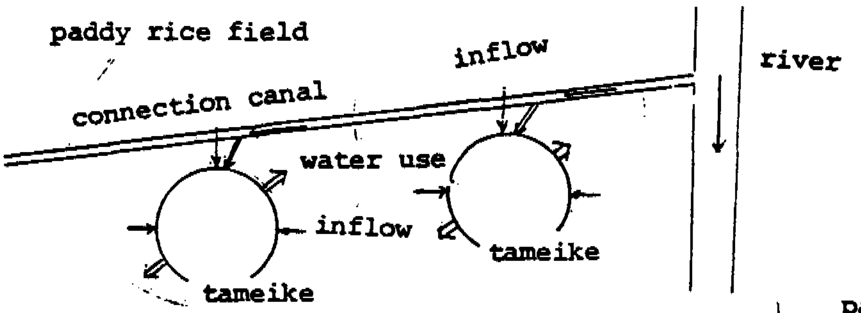

Fig.5 tameikes connected
with river

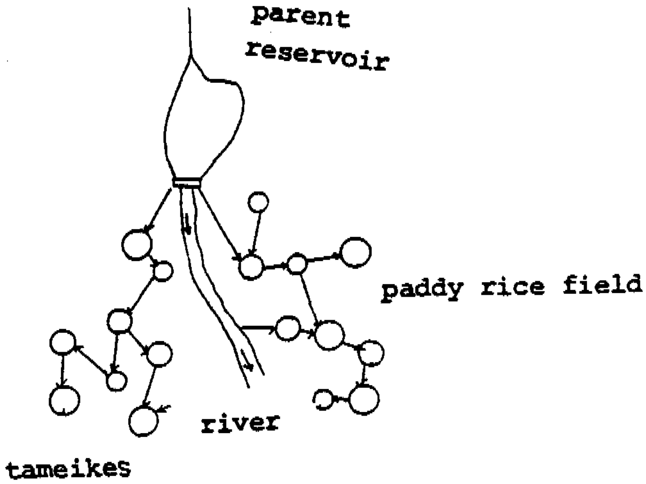

Fig.6 children-tameikes
connected with parent
reservoir

5.INTRODUCTION of TAMEIKE to NORTHEAST THAILAND

The Northeast Thailand has similar water situation with Setouchi region in Japan in Summer as follows.

a.Farmers are going to raise paddy rice in rainy season.
b.Annual rainfall is from 1,000 to 1,300 mm/year in both regions.
c.The need of water resources development becomes very high.
d.Farmers would prefer the development of water resources which produces benefit in one year after construction.
e.There are no mountain and no big river near the rainfed paddy rice field .
f.Small-scale integrated rural development would be welcomed.

There are some special problems in Northeast Thailand different from Setouchi as follows.

a.There are not only fresh water but also salt water in underground of Northeast Thiland.
b.Though tameike construction of Setouchi region were performed in very old time by means of man power,but now we have big construction machines and big government.Then the

where Vp=water volume in tameike,Vg=fresh water volume stored under tameike, V = total storage of tameike , Aout = outside slope area of embankment, Ao=crest area, Ab=area at bottom of tameike ,Ag=area at the ground surface level,Ain = inside slope area, Hb=depth of bottom from ground surface,Hg = depth of original ground water from botttom , Z=depth of tameike water from bottom,Bb = width at bottom of tameike , Bg=width at the level of ground surface ,@=angle of slope,Bz=width at water surface, Az= area at water surface;

$$Bz = (Bg - Bb)*Z/Hb + Bb \qquad (2)$$

$$Az = Bz*Bz \qquad (3)$$

$$Vp = 1/6 *Az*Bz - 1/6 *Ab*Bb \qquad (4)$$

When the water elevation of tameike is higher than ground water elevation in Fig.9-1,the fresh water of tameike can go into the ground by seepage, and can push original salt water outside, then the fressh water mass can be stored under tameike. This feature can be expected in rainy season. Otherwise,when the water elevation of tameike is lower than ground water elevation as shown in Fig.9-2, the fresh water stored under tameike flows back into tameike.When the lower surface hold long days , the dense salt water of original ground would seep into tameike .

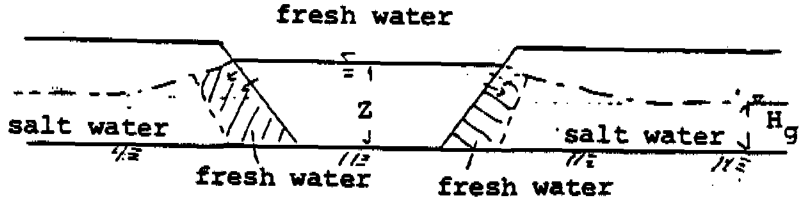

Fig.9-1 Cross section (H_g < Z)

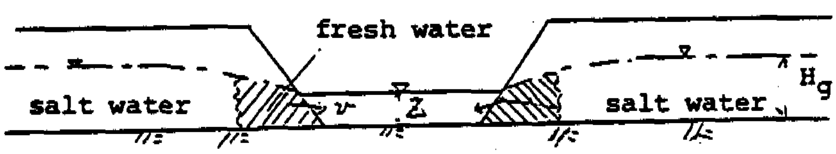

Fig.9-2 Cross section (H_g > Z)

Fig.9 various status of ground water depth

The fresh water stored under the slope is given by Eq.(12) as shown in Figs.9-1and 9-2. The seepage in unit width of slope is calculated by Eq.(5).

$$q = k/2 *(Hg*Hg - Z*Z)*1/(Xg-X_0) \quad (5)$$

where X_0=(origin of distance on inner slope),Xg= effective hydraulic radius , L = thickness of fresh water under the slope of tameike in Fig.9-1,L_0=initial value of L,v=horizontal seepage velicity through slope,k=permeability coefficient(m/s) of ground.The thickness of fresh water stored is given by Eqs.(6) and (8), when the water elevation of tȧmeike is higher than ground water surface.

$$L = L_0 + v* dt \quad (6)$$

$$v = q/(Z*cosec(@)) \quad (7)$$

$$L = L_0 + (k/2 *(Hg*Hg - Z*Z)* sin(@)/(Xg*Z))* dt \quad (8)$$

Ha<Hb; (-) (8)'

$$As = (Bb + Bz)/2 *Z *1/sin(@). \quad (9)$$

$$Q4 = 4*As*v \quad (10)$$

Hz<Hb;Q4 =-4*As*v (11)

If there are hard rock under the tameike,so we can neglect the fresh water stored under bottom.Then the fresh water stored under slopes is given by Eq.(12).

$$Vg = Vgo -2*k*(Bb+Bz)*(Hg*Hg-Z*Z)/Xg *dt \quad (12)$$

When the depth of bottom rock is deep enough,we can calculate the fresh water volume stored under the bottom by Eq.(15).

$$vv=k*(Z -Hg)/Lv \quad (13)$$

$$Lv = Lvo + vv* dt$$

$$= Lvo + (Z-Hg)/(Lv) *dt \quad (14)$$

$$Vgv = Vgvo +Ab*k*(Z -Hg)/(Lv) *dt \quad (15)$$

where vv=vertical seepage velocity,Lv = vertical thickness of fresh water under bottom,Lvo=initial value of Lv, Vgv=fresh water volume stored under bottom,Vgvo=initial value of Vgv.

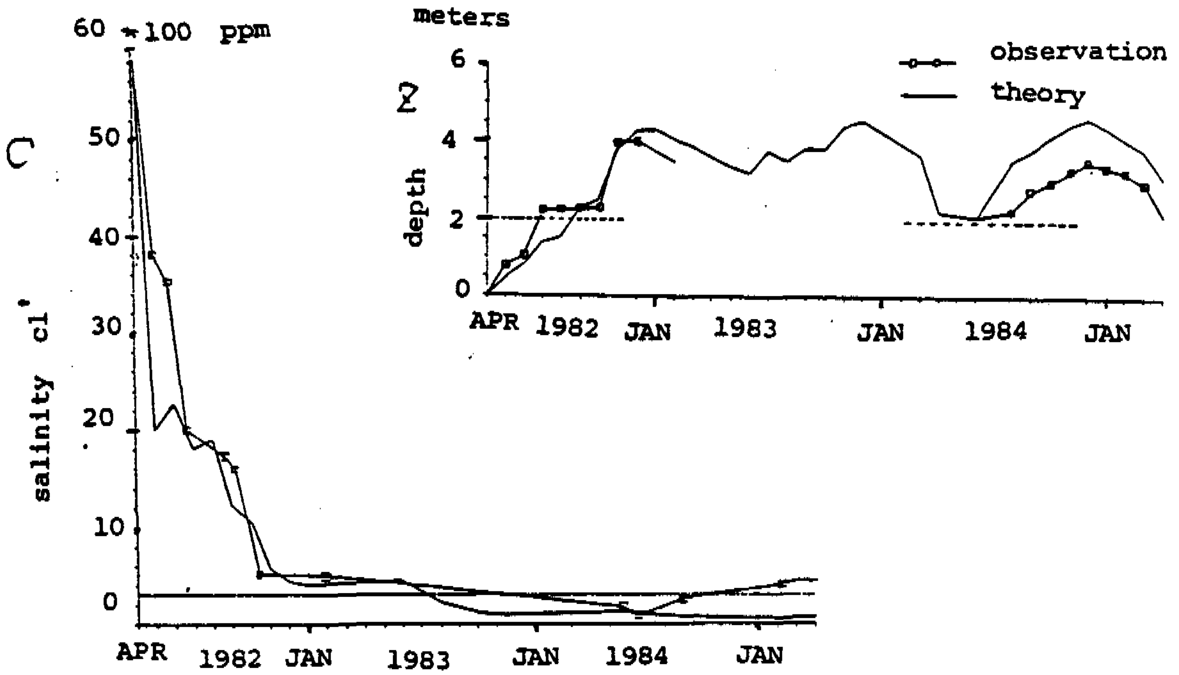

Fig.10 comparison between simulation and observation for experiment tameike

The water volume of tameike can be calculated through the time integration of the difference between inflow and outflow discharges at tameike.

(1) Inflow to tameike

Inflow into tameike can be given by Qa,Qb and Q4 as follows.

$$Qa = (Ag+Ain+Ao*P)*R/T \quad (16)$$

$$Qb = Cpr*Arp*Re/T \quad (17)$$

$$Re = R - Et \quad (18)$$

where Qa = water from rainfall, R = rainfall mm/day , P= coefficient of run-off,Qb = return flow from rainfed paddy rice field into tameike, Cpr = coefficient of run-off from rainfed paddy rice field(=0.3), Arp = area of rainfed paddy rice field,Et=water consumption mm/day ,Re=effective rainfall mm/day.

when Hg> Z

$$Q4 = 2*(Bb + Bz)*k*(Hg*Hg - Z*Z)/(Xg) \quad (19)$$

(2) Water go out from tameike

Go out discharge can be given by Qe,Q4 and Qi.

$$Qe = Az * E \tag{20}$$

where E=evaporation from water surface of tameike mm/day, Qe=discharge due to evaporation, Qi = intake for irrigation from tameike;

when Z > Hg

$$-Q4=2*(Bb+Bz)*k*(Z*Z-Hg*Hg)/(Xg) \tag{21}$$

(3)Water balance of tameike

when Hg > Z

$$Vp = Vp_0 + ((Qa' - Qb + Q4 - Qe))* dt \tag{22}$$

when Hg < Z

$$Vp = Vp_0 + ((Qa + Qb) - (Qe + Q4))* dt \tag{23}$$

When there are fresh ground water ,the storage simulation can be done by Eqs.(22) and (23) only.

6.3 Salinity Model for Tameike

As there are great area of rainfed paddy rice field where salt ground water lies in underground ,the following salt anal should be performed.

(1) Salt flow into tameike

Salt flow into tameike can be given by Sa,Sb and Sc.

$$Sa = Cr *(Ain + Ag + Ao *P)*R/T \tag{24}$$

$$Sb = Cp *Arp *Cpr*Re/T \tag{25}$$

when Z < Hg and Vg > 0

$$Sc = 2*Cgf*k*(Bb+Bz)*(Hg*Hg-Z*Z)/(Xg) \tag{26}$$

when Z < Hg and Vg = 0

$$Sc = -2*Cg*K*(Bb+Bz)*(Hg*Hg-Z*Z)/(Xg) \tag{27}$$

where Sa=salt due to rain, Cr = salinity in rain,Sb=salt due to return flow from rainfed paddy rice field,Cp = salinity of the water of rainfed paddy rice field,Sc=salt seepage through inner slope of tameike,Cgf=salinity of fresh water stored under tameike,Cg=salinity of soil water in underground.

(2) Salt flow out from tameike

Salt flow out from tameile can be given by Sd and Se.

when Z > Hg

Sd =2*C*K*(Bb+Bz)*(Z*Z-Hg*Hg)/(Xg) (28)

Se = C*Qi (29)

There is uniform sality distribution in experiment tameikes.
where Sd = salt flow out due to seepage,C = salinity of water in tameike,Se = salt released by irrigation from tameike.

(3) Salt balance of tameike

Salt balance of tameike can be given by Eq.(30).

C*Vp' = Co*Vpo + (D-C*F)*dt (30)

when Z < Hg and Vg > 0

D = (Cr*(Ain+Ag+Ao)*R +2*Cp*Arp*Re+Cgf*k*(Hg*Hg-Z*Z)*(Bb+Bz))/(Xg) (31)

F =Qi (32)

when Z < Hg and Vg = 0

D = (Cr*(Ain+Ag+Ao)*R+Cp*Arp*Cpr*Re+2*Cg*k*(Hg*Hg-Z*Z)*(Bb+Bz)/(Xg) (33)

F = Qi (34)

when Z > Hg

D =Cr*(Ain+A+Ao)*R +Cp*Arp*Cpr*Re (35)

F = Qi-2*k*(Hg*Hg -Z*Z)*(Bb+Bz)/(Xg) (36)

where C_o = initial value of C ,D = salt supplied, F = discharge taken out;

The salinity Cgf of fresh water stored under tameike would be given through the result of leching test of the sandy soil at the Iran by Eq.(37).

Cgf = 0.2*Cg (37)

Also the salinity in fresh water stored under tameike is approximately uniform in all directions.

(4) Simulation Model for Salinity

The simulation for water volume and salinity of tameike can be simultaneously done through the Eqs.(38) and (39).

$$dVp/dt = Qi - F \quad (38)$$

$$dC/dt = (D - Co*F)/Vp \quad (39)$$

If we use the integer I for days ,volume in tameike Vp(I), fresh water Vg(I) under tameike and salinity C(I) in tameike can be calculated through three Eqs.(40),(41)and (42).

$$Vp(I) = Vp(I-1) + (Cpr*Apr*Re + (Ag+Ain+Ao*P)*R(I) + 2*k+(Bb+Bz(I-1))*(Hg*Hg-Z(I-1)*Z(I-1))*dt/(Xg) - Az(I)*E(I)-Qi(I)) \quad (40)$$

$$Vg(I) = Vg(I-1)-2*k*(Bb+Bz(I-1))*(Hg*Hg-Z(I-1)*Z(I-1))*dt/(Xg) \quad (41)$$

$$C(I) = C(I-1)+ (D(I)-C(I)*F(I))/(Vp(I)) \quad (42)$$

We could get the solution for Vp, Vg and C as shown in Figs. 10 , 11 and 12 by the simulation with one day step.

7 CHECK of THEORY by EXPERIMENT TAMEIKE

The Eqs.(40),(41) and (42) were checked through simulations by the observed data of experiment tameike. Fig.10 shows the storage variation by the depth through years,and the comparison of salinity between simulation and observed data for the experiment tameike are shown in Fig.10.These results show good applicability of the simulation method for tameike evaluation.

8 SENSIBILITY TEST

As we got good simulation model through comparison between mathematical simulation and observed data of experiment tameike ,we could perform following sensibility tests. Fig.11-1 shows the depths of water in tameike under the ground water depths 3.5,3.0,2.5 and 2.0 meters respectively. Fig.11-2 shows the fresh water Vg stored under the tameike for the same arrangment of ground water depth.Fig.11-3 shows the salinity of tameike water under the same ground water depths for 1982,1983 and 1984.
Fig.12-1 shows depths of tameike under three permeability coefficients k=0.000001,0.00001,and 0.0001 m/s respectively.

Fig.12-2 shows fresh water Vg stored under tameike for the same permeability coefficients. Fig.12-3 shows the salinity of water in tameike for three permeability coefficients.

a. sandy soil(k=0.0001 m/s)is no good for water storage characteristics when ground water level is comparatively low , but good for ground water utilization when there is no salinity and high ground water elevation.

b. Fine sand (k = 0.00001 m/s) is good for water storage due to small seepage,and good for salinity control by good dilution effect through good water operations.

c. The soils(k<(0.00001-0.000001)m/s) can be utilized for direct development of rain water resources by means of tameike.

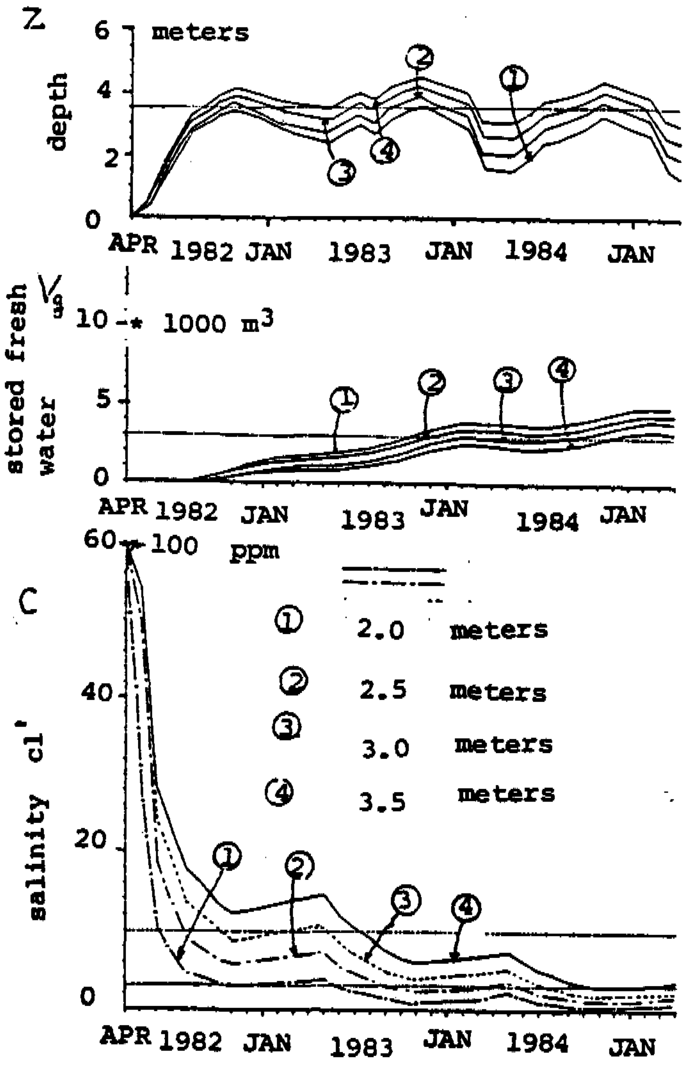

Fig.11 simulation on various ground water depths

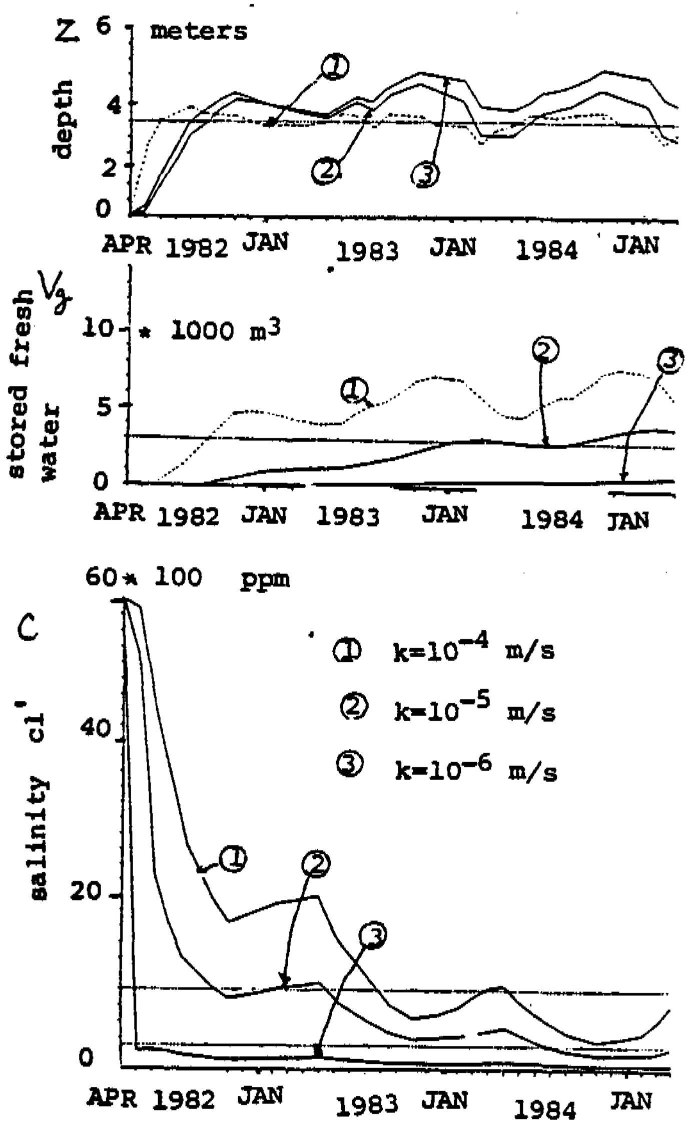

Fig.12 simulation on various permeabilty coefficients

9. CONCLUSION

Water resources develepment by big irrigation project is going to difficult due to the lack of good places from the stand point of construction cost.The direct development of rain water resources become very important and resonable for the small-scale development of rural area . The studies on the design and planning for the direct development of rain water resources by means of tameike is very meaningfull reseaech problem not only for construction cost but also for social property in rural area. If the systematical comparison of the experiences between big irrigation project and tameike group development,in all humid region of the world,are integratedly performed we are very plesased.

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THE USE OF RAINWATER AS THE SOLE SOURCE OF SUPPLY IN AQUACULTURE

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ABSTRACT

A novel water conservation methodology in Singapore is presented where both surface runoff and rainwater gathered from the roofs of structures are exclusively used in an aquaculture farm. In this farm which has a catchment area of 25 hectares, not less than 4% of the land area is covered by corrugated zinc roof. The annual rainfall of about 2200 mm is collected from both the roof and the remaining land area and stored in four large ponds. Water is continuously pumped to the fishtanks and aquatic plant tanks to top up the losses in the system. The wastewaters from the fishtanks are directed to facultative lagoons from which the effluent overflows into the water and algal ponds. The nutrient-loaded water at lower levels of the facultative lagoons are directed to the aquatic plants or algal ponds which reduce the nutrient contents and then overflow back to the facultative lagoons. This system does not need a supplementary source other than rainwater to make up the losses and could be a forerunner for such schemes in other developing countries.

INTRODUCTION

The Republic of Singapore lies 1^{o} 9' north of the equator and has a land area of 620 square kilometres. Limited land area in a rapidly industrialising country has led to competing demands for its use. There is an annual rainfall of about 2400 mm and almost 70% of the land area is being used as water catchment. There is also an escalating water demand (Appan 1987) and, hence, there is an understandable reluctance to encourage water-intensive industries, especially when they also tend to use large tracts of land. However, in the north-eastern part of the island where the land is not so attractive for other industrial activities, it was ascertained that the rainwater abstractable in a 25 hectare land area would be more than sufficient for use in an aquaculture farm. The main objective of this paper is to describe the existing system of utilisation and recycling of the harnessed rainwater with special emphasis on the method of collection and the potential volumes that are extractable.

THE USE OF RAIN/ROOF WATER AS A SOLE SOURCE OF SUPPLY

In recent times, most of the larger Rain Water Cistern Systems (RWCS) involve the collection, storage and use of roofwater for mainly potable uses. This approach is exemplified in developing countries like Thailand (Hayssen 1986, Wironajagud and Chindaprasirt 1987), Indonesia (Aristanti 1986) and The Philippines (Appan et al 1989) where the quantities abstracted meet the essential drinking water requirements.

Roofwater ,in a number of instances, has been recommended for use in non-potable areas. It has been suggested to be used for flushing of toilets by integration of RWCS with existing supply systems (Ikebuchi and Furukawa 1982, Appan et al 1986). A study was also conducted in the United Kingdom on the reuse of rain and wastewater for water closet flushing (Fewkes and Ferris 1982). It was also proposed that in the Kennedy Space Center in Florida, stormwater collected from rooftops and parking lots could be used in conjunction with wastewater effluent to satisfy 100% of the cooling water requirements (Dwornick et al, 1984). A further use of rainwater collected from a bus-depot in conjunction with an existing recycling system was shown to be feasible and economically viable (Appan 1988). Most of the above systems involve the use of rainwater in combination with other existing supply sources.

The sole dependence on rainwater for non-potable uses is reported in one of the smaller scale rainwater collection systems involving an annual water yield of 1673 m^3. This scheme was shown to be economically viable for aquaculture and hydrophonics and was designed in the Virgin Islands (Rakocy et al 1984).

On the whole, the exclusive use of rainwater for intensive, large-scale aquaculture appears to be a relatively new area of application. In such a system, water is continually being recycled with the losses being replenished only by the stored rain/roof waters.

THE AQUACULTURE FARM IN PUNGGOL, SINGAPORE

The farm is located in the north-eastern part of Singapore and is well set out in a 25 hectares of land. The farm was established in February 1986 and has been operational from December 1987. Shown in Figure 1 are the various units and the flowpaths in the two major land areas involving the culture of ornamental fish and foodfish . Details of these two areas are as follows:

a. Ornamental Fish Area

This area occupies about 64% of the total land area and involves most of the unit operations in the system. The four main ponds in this area are:

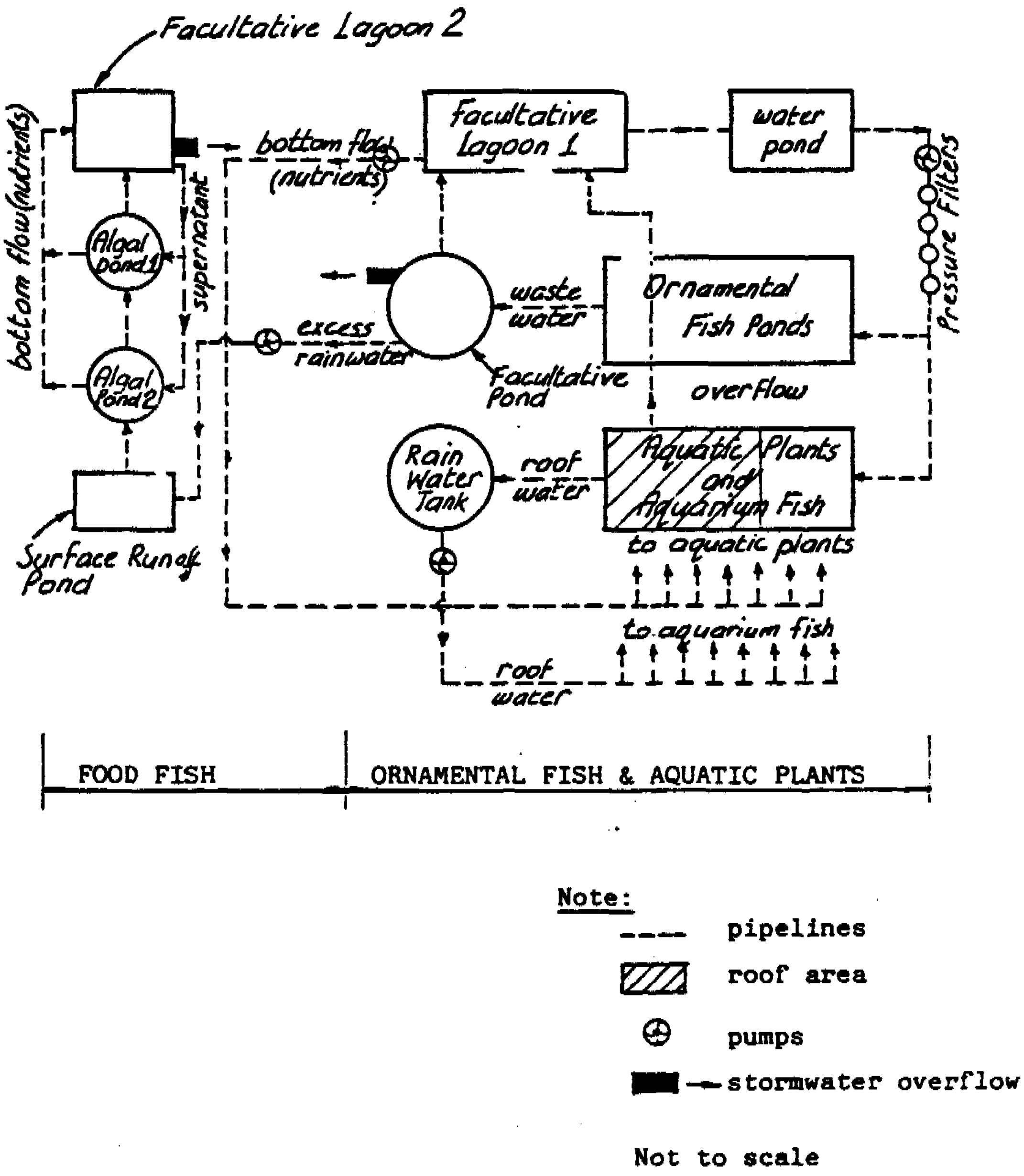

Figure 1

SCHEMATIC DIAGRAM OF AQUACUTURE FARM SHOWING PONDS, LAGOONS & PIPE NETWORK

The Water Pond	(101,000 m^3)
The Facultative Lagoon 1	(15,000 m^3)
The Facultative Pond	(12,000 m^3)
Roof Water Pond	(10,000 m^3)

Rainwater from the roof is collected both in the Roof Water Pond . During heavy downpours, the excess surface runoff is discharged through a stormwater overflow arrangement in the Facultative Pond 1.

The wastewater carrying the faecal discharges of the fish is transferred from the two groups of Ornamental Fish tanks to the Facultative Lagoon 1. The supernatant from this tank overflows to the Water Pond from which the water is pumped through 4 high-rate sand gravel pressure filters. This filtered water is pumped at a rate of 400 m^3/hour for a period of 6 to 12 hours to the two groups of ornamental fish tanks. The nutrient-rich water in the lower levels of the Facultative Pond 1 is withdrawn and pumped to the Aquatic Plant tanks that are located between the Aquarium Fish tanks. The nutrient-rich water on passing through the aquatic plants will be rid of most of the high nutrient loads and overflows back to the Facultative Lagoon 1.

b. Food Fish Area

Food Fish Area: The area occupied is about 36% of the total area and has the following units:

Algal Ponds (2 groups)	(53,500 m^3)
Facultative Lagoon 2	(10,000 m^3)
Surface Runoff Tank	(10,000 m^3)

The Algal Ponds 1 and 2 house the foodfish. The faecal wastes of the fish are discharged from the bottom of these ponds to the Facultative Lagoon 2 from which the supernatant is pumped back to the Algal Ponds. There is also an overflow facility in the Facultative Lagoon 2 for discharging excess rainwater. Suitable aerators are provided in the Algal Ponds to make adjustments for the diurnal variation in the dissolved oxygen levels.

Surface runoff in the area is collected in the Surface Runoff Tank and water is topped up in both the Algal Ponds using this stored rainwater. There is also provision to receive additional rainwater overflows from the Facultative Pond.

SYSTEM PARAMETERS

The choice of a suitable model depicting the input/output relationship in such systems is of paramount importance for analysis. In this system, the rainfall is the only input. The losses are the evaporation from the large water surface areas, the absorption in the Zinc roof, seepage through the sides and bottom of the tanks and the backwash wastewater from the pressure filters.

Choice of RWCS Model

The simplest model for determining the reliable yield was based on the concept of computation of the daily status of a known storage volume for a specific draft (Appan 1982). The computer program used (Appan et al 1986) was modified slightly to take into consideration the dual sources of supply from the stored surface runoff and roofwater.

Rainfall

There is an extensive network of about 63 rainfall stations in Singapore. However, the nearest rainfall station to the Aquaculture Farm is at Paya Lebar that is hardly 6 km away and is deemed to be the most representative. Rainfall figures in Paya Lebar for the last 5 years indicated an annual average of 2200 mm. In this case study, daily rainfall records were used for the computations.

Losses in the System

The major output in this closed system is the evaporation losses. The values used (Pang and Quah 1987) were based on average monthly Evaporation Pan values (see Table 1).

TABLE 1

Evaporation Pan Values (mm)

Jan	Feb	March	April	May	June	July	August	Sept	Nov	Dec
124	126	138	128	113	118	115	120	107	102	97

The second source of losses was due to the continual operation of filtering the water that was flowing through the system. This was computed on the basis that the filter backwash losses did not exceed 2.5% of the throughput.

From the field observations and the geology of the area, it was deemed that the seepage losses should be in the region of 5 to 10% of the total storage volume.

The net demand in the system was thus the sum of the evaporation losses, the loss due to filter backwash wastewater and the seepage losses. In the case of the roofwater collection system, the roof absorption losses were also included.

RELIABLE YIELD

There are two separate systems viz., the Roofwater Collection System that directly supplies to the Rain Water Tank and Surface Runoff Collection System that accounts for all the water that falls on the water surface area and the 5% exposed land area. These two systems are interconnected.

The Roofwater Collection System

The roofwater is collected from the Zinc roof that covers part of the structure housing Aquatic Plants and Aquarium fish (See Fig 1). This area amounts to 10,000 m^2. The demand has been worked out to be 31 to 37 m^3/day and takes into consideration an absorption loss of 0.25 mm (Appan 1982) and the evaporation pattern as shown in Table 1.

In Fig 2a is shown the relationship between the daily demand and the % of rainwater that meets this requirement and the spillage volume. Upto a demand of 60 m^3/day, rainwater can independently meet the requirements though the spilled rainwater for the current demand varies from 110% to 83% of the water demand. In Fig 2b is shown the relationship of the spillage volumes with respect to the Storage Volumes. For zero-spillage, the corresponding Storage Volumes will be as shown in Table 2.

TABLE 2

Zero-Spillage in Rainwater Collection System

Daily Demand in m^3/d	31	34	37
Storage Volume in m^3	14,750	13,725	12,675

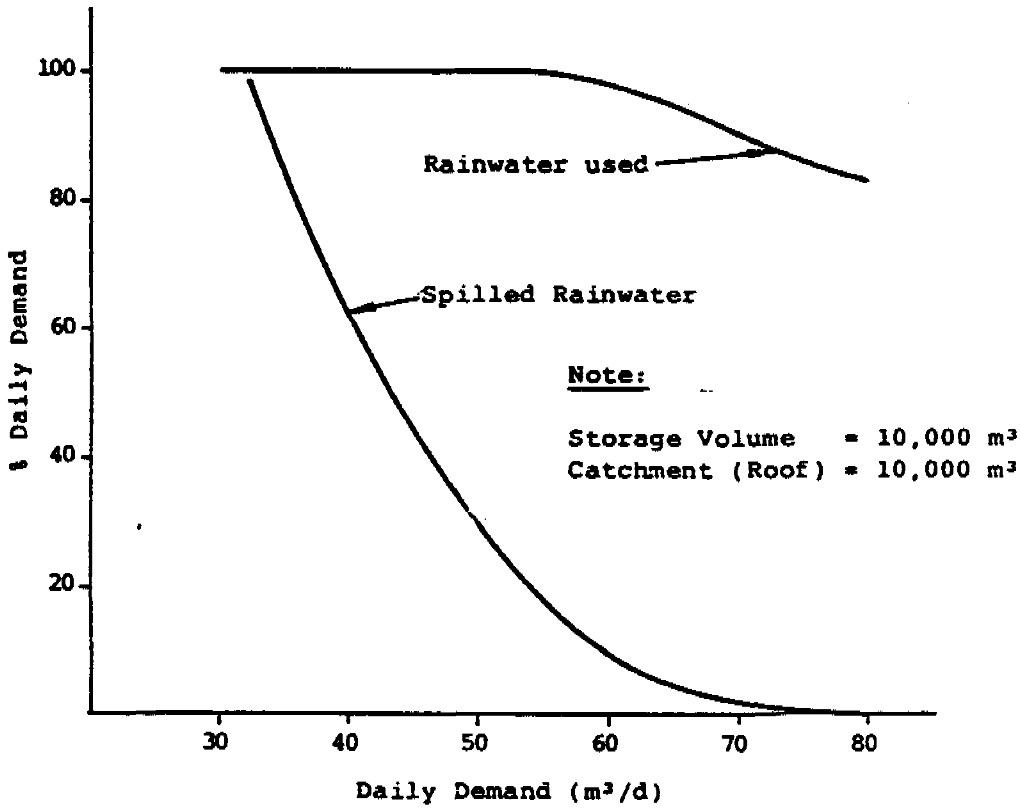

Fig. 2(a): Daily Demand vs Rainwater Used/Spilled

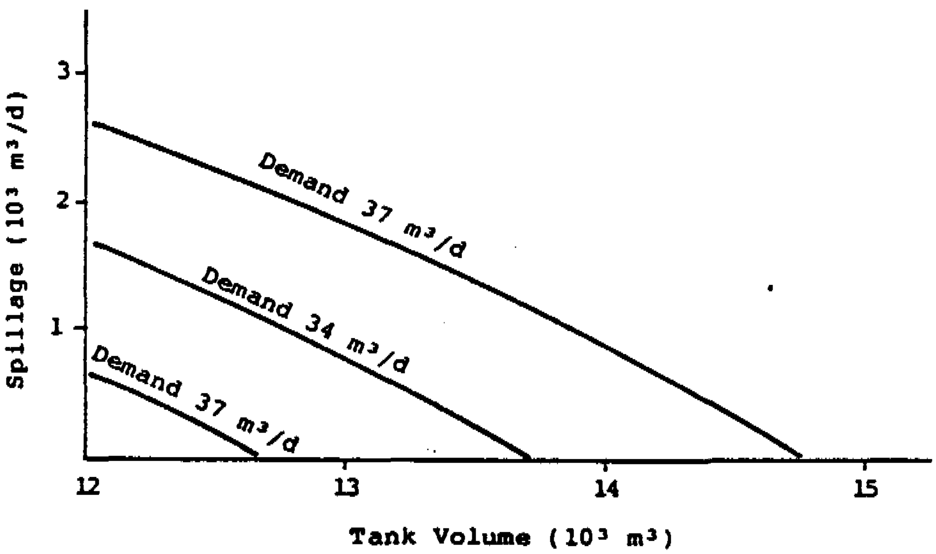

Fig. 2(b): Spillage vs Tank Volumes

FIGURE 2 : ROOFWATER COLLECTION

The demand was calculated to be 800 to 950 m^3/day. The net surface area is 240,000 m^2 and a storage volume of 256,500 m^3 was used for the computer runs. From Fig 3a it can be seen that for the existing storage and volume criteria, the rainwater meets the current demand range and can do so till the demand reaches 1400 m^3/day. However, there is bound to be overflows for existing conditions. Using the current storage volumes, all the collected surface water can be used only if a demand of 1800 m^3/day is maintained. In this case, the stored rainwater will only be able to account for 80% of this demand and the remaining 20% should be met by other sources.

To determine the tank sizes in relation to the spill volumes, another set of runs were done and the results shown in Fig 3b. Based on these figures, the volumes for zero-spillage conditions are as shown in Table 3.

TABLE 3

Zero-Spillage in Surface Runoff Collection System

Daily Demand in m^3/d	800	850	900	950
Storage Volume in m^3	350,000	332,000	314,000	296,000

DISCUSSION & CONCLUSIONS

1. In a country having abundant rainfall but where water has to be used sparingly, the system of aquaculture developed using stored rainwater exclusively is proving to be a working proposition that is economically viable.

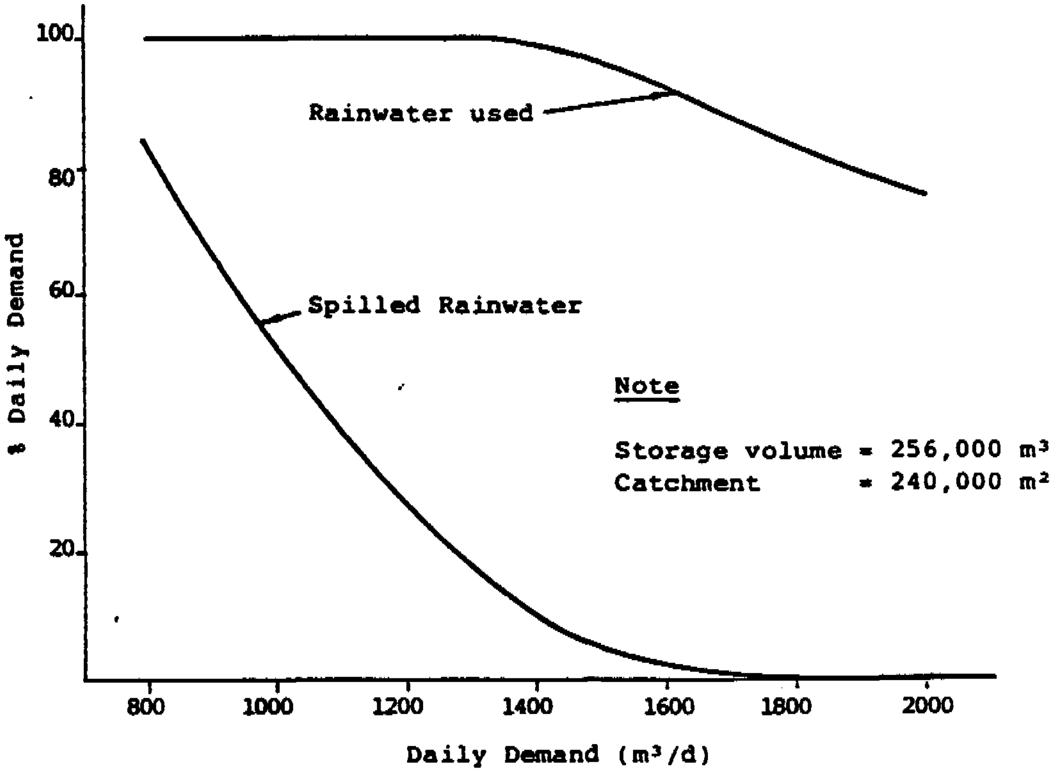

Fig. 3(a) : Daily Demand vs % Rainwater Used/Spilled

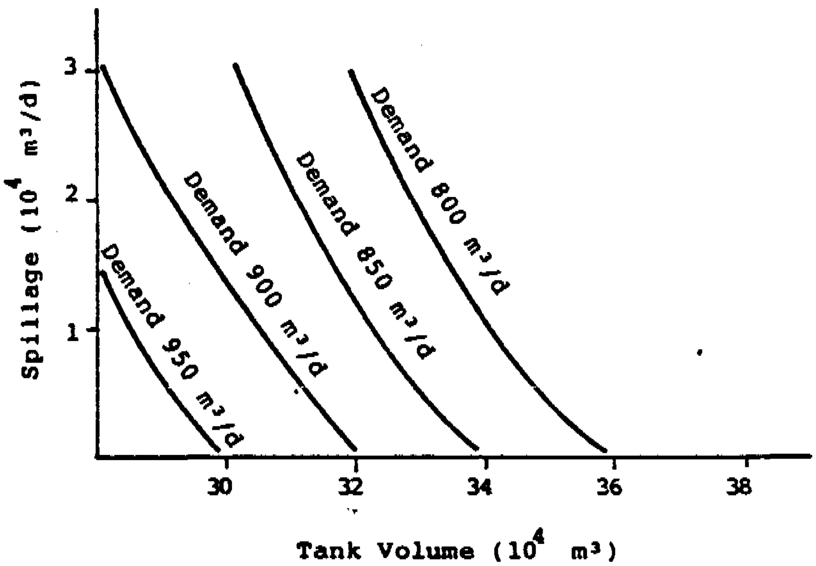

Fig. 3(b): Spillage vs Tank Volumes

FIGURE 3 : SURFACE RUNOFF COLLECTION

2. In the case of roofwater storage, the current demand is adequately met by the supply with a fair amount of spillage. At present, the stored rainwater is being used in the culture of aquarium fish and the excess roofwater is indirectly fed to the rest of the system. If the full potential of the abstractable roofwater (which is of a much higher quality) is to be utilised, then the storage volume has to be increased from the present 10,000 m3 to 14,750 m^3.

3. The surface storage system also has overflows which are being discharged though, at present, all the water requirements are met with by the collected rainwater. The spillage volume can be eliminated provided the storage volumes are increased from 256,500 m3 to 350,000 m^3.

4. On the whole, though there is a fair amount of spillage at present, this volume helps immensely in dilution of the waste products and could be instrumental for the lack of build-up of nutrients and organic loads. Before embarking on a programme to fully utilise all the collectible rainwater (zero overflows), this aspect of the role played by the spillage volumes should be thoroughly studied and analysed.

5. The intermittent discharge of nutrients and organic loads could be quite crucial especially if such a build-up can cause operational problems. Relief of pollutional load can be achieved by scouring the beds of the Facultative Pond 2 and the Facultative Lagoon. This operation can be carried out when stormwater is tending to overflow. However, the quality of such waste discharges should lie within the standards set out in local legislation (The Trade Effluent Regulations 1976).

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DELIVERY

AND

DIVERSION SYSTEMS

STUDY OF DIVERSION AND DELIVERY IN RAIN WATER CISTERNS IN INDIA

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ABSTRACT

In some hilly areas in North-East India, seasonal rainfall, being only source of drinking water, is collected in Household Jars and Cisterns of Brick, Masonry and Corrugated Tin. Presently Concrete and Ferro-cement Cisterns are also built for adaquate storage to meet family needs throughout the year. Rain water collected in Metal or Tile Roofs is conveyed through Gutter and Downpipe directly to the Cistern below. But nowadays, because of increased road traffic, there is much settlement of dust on the roofs in dry months. Roof Wash Filter and Diversion for Foul Flush is introduced. Flexible pipes or Flap Valve and inverted 'Y' Pipe arrangements are used. System, however, is not very effective as people neglect to manually change position after rains. The objective of this paper is to offer a simple but Automatic Diversion System using a leaking Bucket and Counterweight principle. Water delivery from Cisterns above ground is by gravity flow. Hand pumps are used for cisterns below ground, for which a more effective foot pedal pump is being tried out. For larger applications for community use, a simple, low cost single mast windmill, held in position by guy ropes, has been developed using components such as Bicycle and Hand Pump parts which are all easily available in the local market. Specifications, technical details and photographs presented. The paper also reccomends suitable measures for promoting rainwater harvesting techniques in drought prone areas in India and other developping countries.

INTRODUCTION

Rain water Harvesting systems have been in use in different parts of India since ancient times. In the early Buddist era, Monks living a Monastic life in mountain caves, had labouriously hewn intricate series of gutters and water cisterns on the adjoining rock face to provide for their domestic water supply throughout the year. We see evidence of their amazing skill and enterprise in the Elephanta Caves near Bombay and in the Udayagiri and Kandagiri caves in Orissa.

Down South, Chola and Pandya kings in the 7th and 8th century A.D. had constructed rain water catchment tanks and reservoirs at the foot of many hills and hillocks. Temples like the famous Meenakashi Temple in Madurai have a big water tank in the middle, where the rain water run off from the massive Gopurams (Towers) are collected. Communities living around, had depended on such temple ponds for their domestic water needs.

But in recent times, with the advent of piped water supply in many towns and villages, the importance of maintaining rain water harvesting systems, even as an augmented source of supply has sadly diminished, resulting in their neglect and consequent deterioration. Many rain water tanks and ponds have silted and become unservisable.

Only in the North Eastern parts of India, particularly in Nagaland and Mizoram, rain water harvesting techniques are still widely used. Here, seasonal rainfall, available for about 6 months of the year, is the only source of water supply. But the people manage very well by storing rain water for use throughout the year. Even a Big 200 Bed Hospital community in Durtlang meets all the needs from roof catchment and storage in a huge underground reservoir. Nowhere else, except here, house hold cisterns with roof catchments, provide domestic water for a large segment of the population. In Aizawl, by the side of every house, one can see, rain water cisterns of various sizes, made of tin, concrete or Masonry, for storing the rainfall run off from roofs of corrugaged iron or tile.

Taking note of the successful utilization of rain water harvesting in the NorthEast, for providing adaquate domestic water supply to individual households, on a year round basis, Planners are now veering round to the idea of adopting these techniques in other drought

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prone areas in the rest of the country. Thatch and Asbestos roofs are not quite suitable. But for other roofs, it is quite practical.

DIVERSION SYSTEMS

But the people, in general, have a reluctance to use roof catchments and domestic rain water cisterns as they are under the impression that rain water, thus collected, will not be potable, in view of the high settlement of dust, and dry leaves etc on the roofs in the dry months. Areas with high road traffic are always dusty. There is also the danger of contamination from droppings from scavenger crows and other birds and redends like rats and mice.

It is therefore necessary to show the people that the purity of rain water can be maintained quite easily, with a few safeguards. Normally, at the start of the rainly season, all the accumulated dirt and other pollutants, will be washed off in the first new rains, leaving the roof, quite clean from which, reasonably pure rain water can be collected and stored.

Hence, what is needed, is some provision in the system, by which, the first water from each shower containing dirt called the foul flush gets diverted from the water cistern and allowed to run to waste. Only after all the dirt is washed off, the rain water is let into the container through a roof wash filter. This can be effected by providing some arrangement in the down pipe connecting the roof gutters with the water cistern. This is called a diversion system.

To further safeguard the quality of water, the roof gutters should slope evenly towards the down pipe and not allowed to sag, so as to prevent open pools of water forming there, which are sure to become breeding places for mosquitoes. To prevent vermin like rats, mice and lizards and also insects like cockroaches etc taking shelter in the pipes, it is necessary to cover all exposed pipe ends by a close mesh screen which must be cleaned periodically, so that it is not clogged by dry leaves and dust particles.

Types of Diversion Systems

The following three types are, some of the diversion systems in use in different parts of the world.

A diversion arrangement, in its simplest form, is just a flexible pipe connected at the discharge end of the down pipe. At the start of the rain, the flexible pipe is placed in the drain so that the foul flush is washed off. After some time when the water looks clean, the pipe end is shifted to the storage water container. A typical arrangement, popular in Thailand is shown in Fig.1

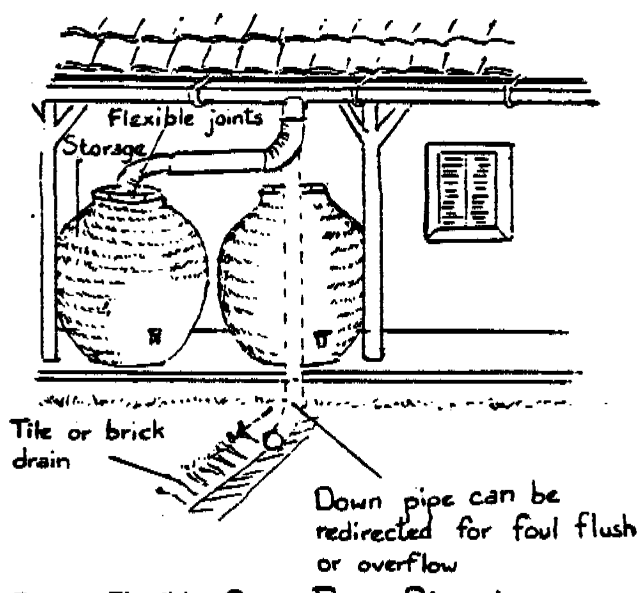

Fig.1 Flexible Down Pipe - Diversion

Another arrangement for diverting the foul flush is, by means of a roof washer through which the rain water is passed before it is let into the water cistern. Such an arrangement is shown in Fig.2.

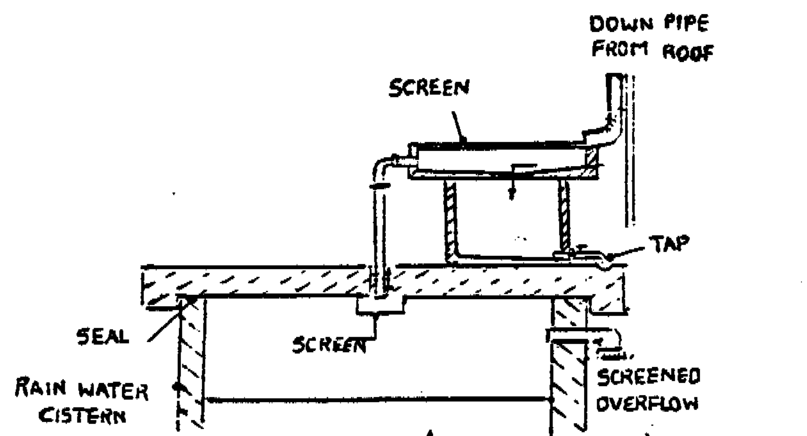

Fig.2. Arrangement for diverting "first foul flush"

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Yet another arrangement is an underground storage tank receiving rain water that overflows from a vessal placed above the ground. In the surface vessal, there is a tap provided at the bottom for foul flush during the first rains, and later on, when the water is clean, the clear water in both the containers are used for domestic needs.

The above three arrangements have been tried out in India. But they have not proved very successful because of following disadvantages.

Whichever, the diversion system used, the people have to come out, in the heavy down pour to activate it, which they often neglect to do. So much so, they end up either with very dirty water in the cistern or they would be wasting precious drinking water, which they can otherwise use for their domestic needs. This is the crux of the problem which the designers have to solve.

Automatic Foul Flush Diversion System

Hence a diversion system, which is simple, and economical but which is effective and which can function satisfactorily, without much attention is called for. The objective of this paper is to present such a diversion system, which is automatic and needs very little attention. The proposed arrangement is shown in Fig.3.

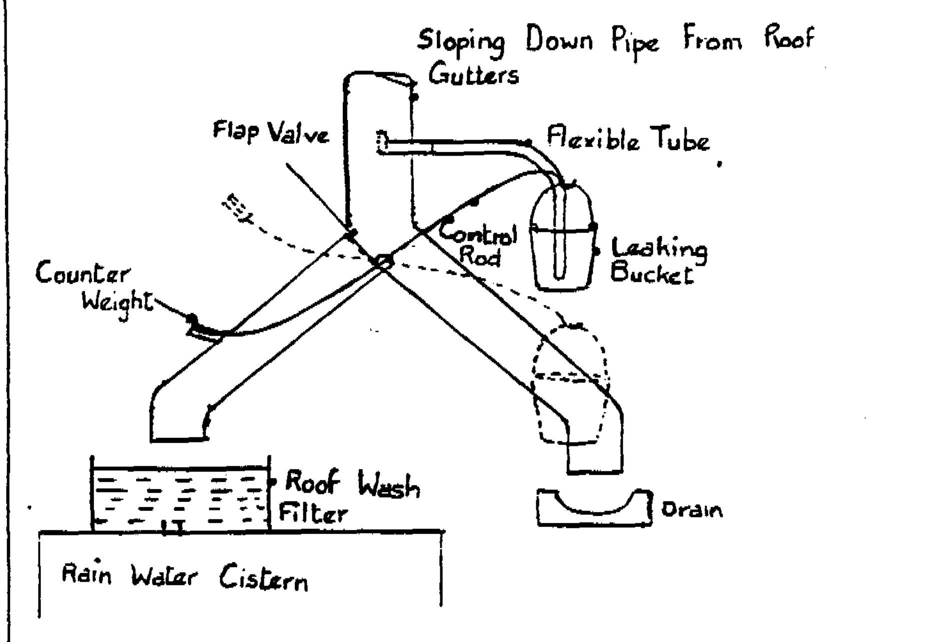

Fig. 3. Automatic Foul Flush Diversion System

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In this arrangement, the sloping down pipe is terminated in an inverted Y section, onearm of which is connected to the water cistern through a roof wash filter and the other arm to drainage, and a flap valve inside the junction point, is actuated by a 'S' Type Control Rod outside, so as to close or open either of the two arms. The change of position of the flap valve for closing one arm or the other is effected by a small angular rotation of the flap valve shaft by means of the control rod, so as to direct the water flow either to the drainage side or to the water cistern. At one end of the control rod is hung a water bucket with a few pin size holes in the bottom, and at the other end, a counter weight, so balanced that the control rod remains tilted down at the counter weight side at normal times. In this position, the flap valve is open to the drain side and closed to the water cistern. In the back side of the sloping down pipe, a little above the junction point, is a small pipe nipple to which, is connected a flexible pipe of size about ½", the other end of which, is inserted in the water bucket.

The working principle of the automatic diversion system is as follows- At the start of the rainfall, as the flap valve is open to the drain side, the first shower with the accumulated dirt on the roof catchment is flushed into drain. The water coming down the main pipe will also flow through the small size flexible pipe which slowly fills the bucket. The size of the bucket and the flexible pipe are so determined that it should take about 5 minutes to fill the bucket. It is a reasonable assumption that in about that time, all the accumulated dirt on the roof catchment would have been washed off.

When the water bucket gets filled, due to the additional weight of water in the bucket, the control rod at the bucket end tilts down, resulting in the shift of the flap valve to the other position and the rain water, now flows into the water cistern, instead of the drain.

After the rain ceases, the water in the bucket slowly leaks through the pin holes in the bottom and the bucket becomes empty, and the control rod again tilts down at the counter wight side shifting the flap valve to its normal position i.e. allowing water flow to the drain side. At every rainfall, this cycle is repeated.

This automatic diversion system should prove useful in places with intermittant rain fall and in areas with high dust settlement on the roofs.

DELIVERY SYSTEMS

A good rainwater harvesting system should also have a proper means of delivering the water to the users. The construction, operation and maintenance of the water delivery and distribution system must be simple, and easy while at the same time, economical.

In North East India, most of the earlier systems have an above ground cistern from whcih the water is delivered through a tap fitted in a convenient side. In such a system, one must ensure that the tap does not leak. But unfortunately taps do leak, resulting in wastage of precious drinking water.

Now, more and more household rain water cisterns are built underground, as such storage offers several advantages like saving of space above ground and that of easy construction in view of the good structural support offered by the ground. More over the water remains cool through out the year and there is no loss of water through evaporation.

But a major disadvantage of an underground storage is extraction of water. Unlike the above ground storage systems where a simple tap arrangement will do, in a below ground system, a good hand pump is needed to remove the water.

Households with underground cisterns normally use a 2½" or 3" cylinder sizecast iron Hand pump. In such pumps, the break down rate is quite high, as the leather bucket cups in the piston gets worn out and needs frequently replacement.

Now attempts are being made to find cheaper but definetely, better alternatives. A Hand pump, where the cylinder is made of plastic (P.V.C.), serves much better. An experimental pump made of plastic converted for easy pedal operation is under trial in a few places. One such pump is shown in Fig.4.

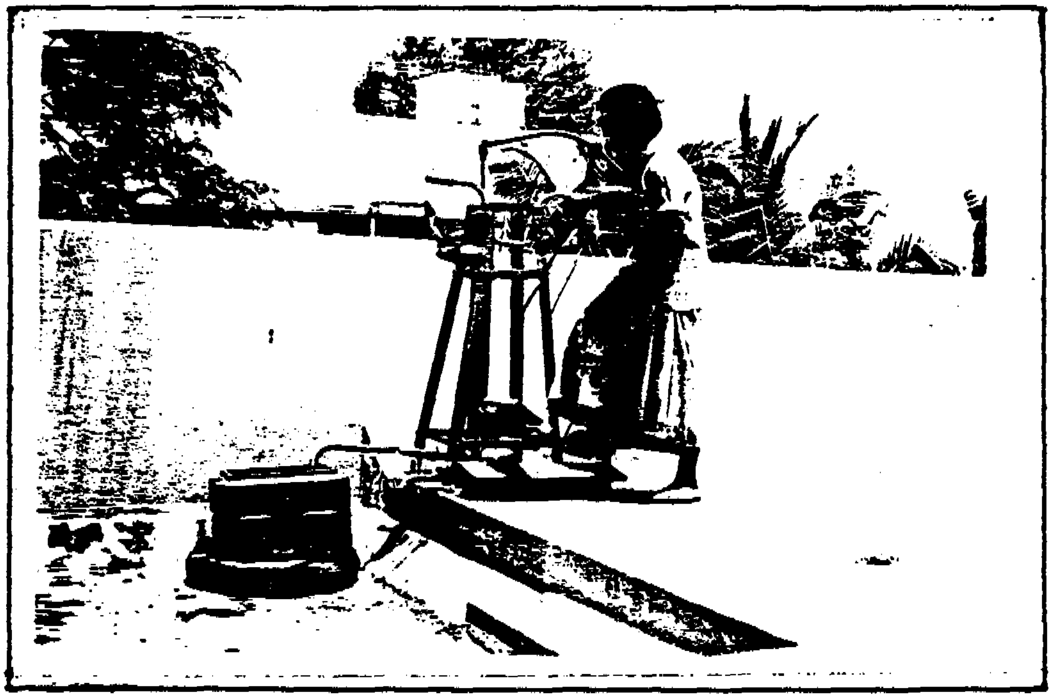

Fig.4 PEDAL TYPE WATER PUMP

For larger community storage and distribution, in a few places, where the wind regime is quite high, they use wind mills.

In fact, in most places in the North Eastern States of India, wind speeds exceed 8 kilometers/hr for a major part of the year, the introduction of wind mill water pumping systems is a possibility.

Unfortunately windmills have not become very popular because of the high installation cost and their poor record in dependability.

Analysing the hardware cost structure of windmills, it is found that the total cost of the windmill is taken up by the following components.

1. Structural parts.
2. Transmission system including gear reducer
3. WindWheel
4. Water Pump
5. Pipes and Pipe specials.

It is possible to economise on all the above 5 component parts of the system and still have a dependable unit. For community level, rain water cisterns and for similar applications. One such windmill which has been developped recently is shown in Fig.5.

Wind Mill Drive Mechanism shown separately in Fig.5a

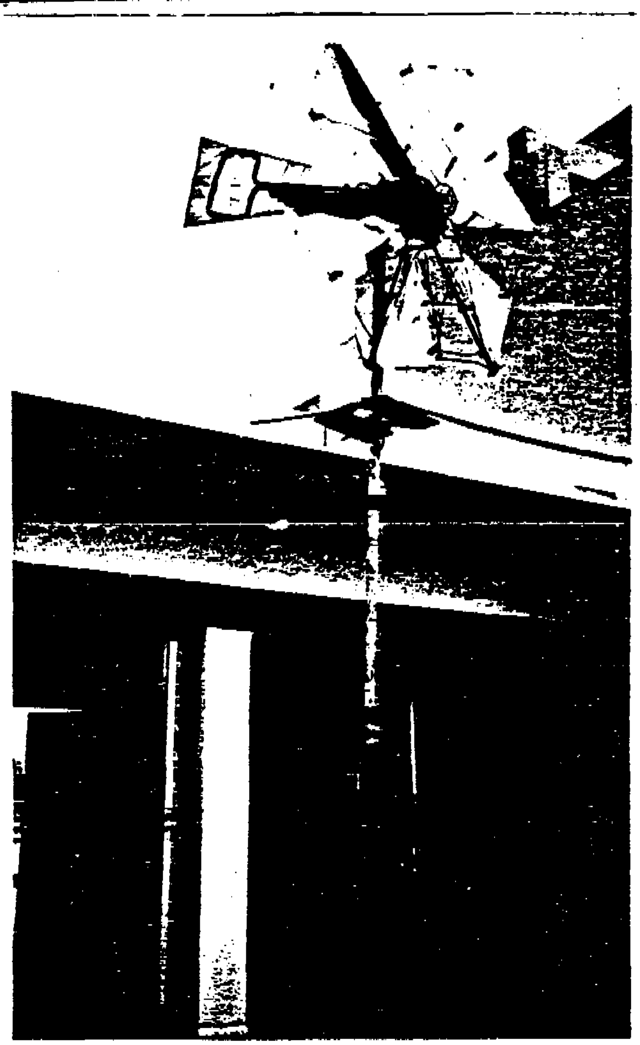
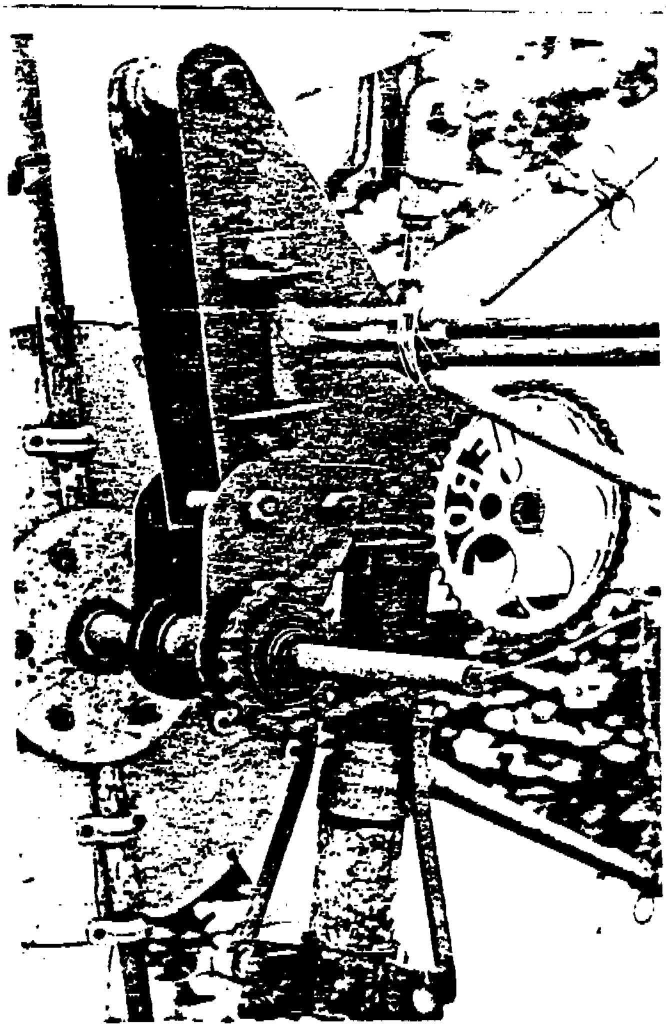

Fig 5. SINGLE MAST LOW COST WIND MILL. Fig 5a. WIND MILL DRIVE MECHANISM

This is a low cost wind mill water pumping system capable of operating in wind speeds as low as 8 km per hour, with an output of about 2000 litres per hour at 15 km winds.

In this windmill there is no structural tower. The delivery pipe, itself, is the main mast, held in position by 3 guy ropes. On top of . is the wind wheel and transmission gear box in a revolving frame with a tailvane which automatically keeps the wind wheel facing the wind in the right direction.

The 6 ft diameter wind wheel and other components like the gear reducer and other parts have been made of aluminium sheets and light weight steel plate fabrications and readily available Bicycle parts.

The windmill powers the 2½" reciprocating type water pump through the crank, chain and sprocket arrangements (Reduction 2:1) so as to keep the piston travel within permissible limits of 150 strokes per minute.

The water pump used is either the commonly available India Mark II Hand Pump, cylinder and Piston arrangement or a pump made of plastic (P.V.C.) developed locally.

Because easily available parts have been used in these windmills, they can be installed and maintained by local village artisans. This low cost, high utility windmills is undergoing trial in a few places and their results are quite promising.

CONCLUSIONS AND RECCOMENDATIONS

Household cisterns are an important means of storing rainwater for family use. In places where rain water is the primary source of drinking water, adequate storage for community use is also necessary to ensure that people have access to a sufficient quantity of good quality water, year round. It is a strange phenomenon that in the developing world, floods and drought are yearly occurance, and yet the people would not adopt simple rain water harvesting techniques.

It must. however be admitted that, even though the cost of constructing below ground ferrocement cisterns turns out to be much cheaper than other formsof construction, the system, as a whole, i.e. the roof gutters, down pipe, with the diversion system for foul flush, the roof wash filter with the water cistern and the water pump and pipes in the delivery system, all costs considerable sums of money. Otentimes, the cost is beyond the means of ordinary people.

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Yet the Benefits of adopting appropriate rain water harvesting techniques in drought prone areas are immense, far out weighing other considerations. Hence, it is, of utmost importance to educate and convince people of their practical utility.

First of all, town and village planners should adopt these techniques in their own buildings, which are under the direct control of the Government. Public buildings like town halls, markets, schools, hospitals and banks etc should have rain water systems in good working condition, serving the community. These will act as demonstration units to the people. Civic authorities should also encourage individual house holders to construct rainwater harvesting systems in their houses for their own domestic use by offering suitable incentives like tax benefits and easy loans at low interest for such constructions.

Secondly Engineering Research Institutions, in close co-operation with the building industry, must come forward to actively participate in the development process of evolving rainwater techniques suitable to a particular region, taking into consideration, not only the rainfall pattern in the area but also the socio economic condition of the common people, who should be the main beneficiaries. The development work should not be confined just the design of a water cistern alone but should make a detailed study of the system as a whole and offer practical solutions.

Design and construction specifications and drawings should be easily available to the people. Fabricated items like gutters, down pipes, diversion flap valves, roof wash filters as well as suitable pumps, etc. should also be available off the shelf. All items must be of good workmanship without costing too much money. Successful implementation of rainwater techniques will depend a great deal on how well the people are conditioned to receive these new ideas. Conducting regular training programmes for the common people in a particular area will greatly benefit them. In this area, voluntary agencies engaged in social services and in development works can help a great deal.

The Development work done at the Rural Technology Development Center of the Christian Industrial Training Association, Madras had given us experience in the design, fabrication and field testing of a variety of water extraction devises suitable for house hold as well as community level rain water harvesting systems.

EDWARD PAMANA[illegible]

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HYDRAULICS OF RAINWATER CATCHMENT GUTTERS

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ABSTRACT

In the author's observation, a frequent weak link in rainwater cistern system performance is the catchment gutter. Collected rainwater is spilled before reaching the cistern. In some instances, gutter maintenance is neglected. In some instances, gutter construction is faulty. In some instances, gutter design is fundamentally inadequate. This paper addresses design issues, the relation of precipitation intensity and roof area to gutter cross-sectional shape, size, slope and length. A spatially varied hydraulic profile solution is reduced to a general statistical rule for design. Consideration is given to aspects of gutter technology in developing regions.

SYMBOLS

A_g = Cross-sectional area of gutter (cm^2)
A_l = Cross-sectional area of leader (cm^2)
A_r = Roof area, horizontally projected (m^2)
C = A constant related to gutter shape
D = Hydraulic depth (m)
g = Gravitational constant (m/s^2)
i = Rainfall intensity (cm/hr)
($i A_r$) = Total gutter loading ($m^2/hr * 10^2$)
($i L_r$) = Unit gutter loading ($m^2/hr/m * 10^2$)
L_g = Gutter length (m)
L_r = Roof length, crown to eve, horizontally projected (m)
n = Manning roughness
Q = Gutter discharge (m^2/s)
q = Roof discharge per unit width ($m^2/s/m$)
S_f = Friction slope
S_o = Gutter slope
w = Nominal dimension: radius or base width (cm)
x = Distance (m)
y = Depth (m)

INTRODUCTION

"Very little concern has been shown for gutters. Their purchase and installation are usually not part of the project and they are usually left to the owner to supply and install. The result is that gutters are poor, leaking or inadequate and valuable water is wasted. In low rainfall areas, collecting all the rain available is crucial to delivering all the benefits of the system. In high intensity rainfall areas, considerable attention should be put on ensuring that the gutters are large enough to handle intense showers." (Lathem and Gould,1986)

The gutter frequently inhibits the performance of a rainwater catchment system. Rainfall intercepted by the roof is lost in transmission to the cistern. If the gutter is blocked by debris, the problem is one of maintenance. If the gutter is improperly installed, the problem is one of construction. If the gutter is fundamentally undersized, too flat, or too long, the problem is one of design.

This paper addresses the hydraulic design issue, the relation of precipitation intensity and catchment area to gutter shape, size, slope, and length. The basis of design is that of spatially-varied open channel flow, a topic concise in theory while complex in computation. Through statistical simplification, a basic design relationship is derived.

LITERATURE REVIEW

According to Pacey and Cullis (1986), "Guttering seems to be a difficulty for many householders, yet it is rarely mentioned in reports from technical assistance programs." A brief review of technical reports substantiates this observation; guttering is totally ignored in roughly three-fourths of rainwater catchment reports. The remaining quarter, however, do provide some documentation on current practices. The following literature review is divided into two sections, the first dealing with the technology of gutter construction, the second dealing with sizing.

Technology

Fabricated gutters

Fabricated metal or plastic gutters come in standard dimensions. Graf (1985) describes ten commercial gutter cross-sections ranging in width from 9 to 20 cm, and four conventional leaders (downpipes) ranging in cross-section from 25 to 150 cm^2. Hanger and strap installation is specified. Graf suggests that the gutters be without slope for aesthetic reasons. For a developed region, Graf provides a reasonable basis for building code. For a developing region, even where fabricated gutters are available, Graf's conservative standards may be unrealistic.

Sheet metal gutter use in developing regions is discussed by Edwards, Keller and Yohalem (1984), verbatim from Keller (1982). They conclude that cost (U.S. $5 per meter) and commercial unavailability preclude its common use. Pacey and Cullis (1986) suggest $12 per Zimbabwean house ($6 for materials, $6 for repairs) for metal guttering, 16 percent of cistern costs. Malik (1986) computes a fabricated household gutter in Malaysia to be $80, 60 percent of cistern costs.

Stone glides and wooden troughs

Pacey and Cullis (1986) describe a Bermudan practice of placing triangular stone ridges ("glides") diagonally on smooth roofs, diverting the water before it reaches the eves. They also note a Ghanean use of low wooden troughs below the eves, a technology compatible with thatch roofing.

Bamboo

Bamboo is distributed throughout tropical, subtropical and mild climates at elevations to 4000 m. A number of species have diameters in the range of 15 cm. McClure (1953) provides a comprehensive technical summary of bamboo construction in general.

Bamboo is widely used for catchment guttering. Edwards, Keller and Yohalem (1984) provide details of guttering configuration and construction. There appears to be no appropriate published data regarding costs, an understandable void if bamboo is truly a free good. If, on the other hand, bamboo has associated costs (an obvious one being that of time for installation), the costs should not be ignored in project planning.

Sizing

Gutter

Gutter design ranges from the overly-simplified to the computationally-impractical. At the overly-simplified end is Pacey and Cullis' (1986) criteria for rainwater catchment in tropical areas: gutter gross-sectional area A_g should be 200 cm^2. For a semicircular section, the diameter would be 23 cm, a size achieved only by the largest bamboo species.

Edwards, Keller and Yohalem (1984) suggest A_g be 70-80 cm^2, the minimum width for square and semicircular gutters be 8 cm, the minimum width for a triangular gutter, 10 cm, and the minimum depth for all shapes, 7 cm.

Benji (1934) determines for a semicircular gutter,

$$A_g = 0.383\ (i\ A_r)^{0.8} \tag{1}$$

where A_g is in cm^2, i is rainfall intensity in cm/hr and A_r is roof area in meters. The $(i\ A_r)$ term can be called "total gutter loading" with units of volume per time. For a roof with a roof length L_r, crown to eve, horizontally projected, of 5 m and a gutter length L_g of 20 m, roof area A_r is 100 m^2. For a rainfall intensity i of 20 cm/hr, $(i\ A_r)$ is 20*100 and A_g is 167 cm^2. Benji also evaluates a rectangular gutter; the result, involving the gutter's three dimensions, is computationally impractical for general design.

Leader

In simple rainwater catchment systems, a cistern located at the end of the roof is fed directly from the gutter's end. Dropping flow through a leader leaves less head for elevated storage. In some systems, the cistern may be situated at a midpoint along the roof, drawing water, directly or by leader, from both sides. In more complex cases, leaders from gutters on both slopes of a roof transmit water to a removed cistern. For small systems, leader area A_l may be of less concern than A_g. For large systems, leader sizing becomes more important.

Pacey and Cullis (1986) suggest that the leader area A_l be at least 78 cm^2. Graf (1985) specifies that A_l be,

$$A_l = 0.02\ (i\ A_r) \tag{2}$$

where A_l is in cm^2. For the above example, 40 cm^2 of leader is needed. It should be noted that Graf assumes multiple leaders to waste runoff; all the flow is not dropped to a single location for storage.

McCuen (1989) indicates that A_l should be,

$$A_l = 0.173\ (i\ A_r)^{0.75} \tag{3}$$

For the example, A_l is 52 cm^2.

Fundamental basis

None of the above references takes into consideration the fact that the flow profile in the gutter is spatially varied, i.e. discharge increases with downstream position. Rajapakse (1986) notes that this should be done and provides the necessary differential equation,

$$\frac{dy}{dx} = \frac{S_0 - S_f - 2Qq/gA_g^2}{1 - Q^2/g/A_g^2D} \tag{4}$$

where y is depth, x is distance, S_0 is gutter slope, S_f is friction slope, Q is total gutter discharge (i A_r), q is discharge per unit of roof width (i L_r), g is the gravitational constant, and D is the hydraulic depth. Rajapakse concludes,

> "This is a very tedious equation to solve, which has to be done by trial and error. Tables giving the gutter size for given roof area and rainfall intensity could be developed using the above formula for use by practising engineers. In the development of such tables, consideration should be given to the common practice of the country with regard to gutter materials and shapes, the available range of roof areas and the range of rainfall intensities experienced."

Rajapakse suggests that gutters be designed for the one-year storm for a 5 minute time of concentration. No more than 5 percent of rainfall should be lost in a wet year.

Of significance in Eq. (4) is the inclusion of slope terms and the unit width discharge term. Gutter performance does depend upon gutter slope and friction slope (a function of gutter roughness). Flow depth in a 2 m gutter draining a 5 m (crown to eve) roof is different than the depth in a 5 m gutter draining a 2 m roof, although in both cases the gutter drains 10 m^2. Whereas Eqs. (1) - (3) reflect experience with standard gutter technologies, Eq. (4) allows evaluation of alternative designs.

ANALYSIS

Three cross-sections, as shown in Fig. 1, were selected for analysis: the semicircle, the trapezoid with 1:2 sideslopes and depth equalling width, and the square. The semicircle is assumed to be bamboo, Manning roughness n of 0.025. The trapezoid and the square are assumed to be sheet metal, field-fabricated, n of 0.015. Size is characterized by a nominal dimension, radius or base width, w. All cross-sections are presumed to flow full.

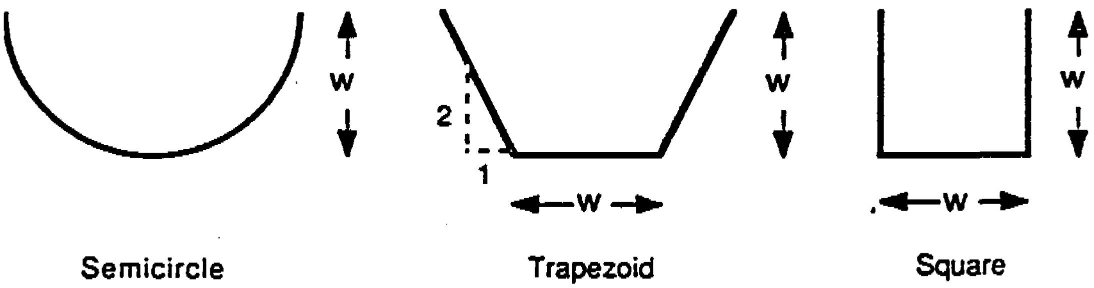

Figure 1. Gutter Cross-sections

Solution of Eq. (4) rests upon identification of the initial boundary condition. As discussed by Chow (1959), control is established by critical conditions which may be at the overfall, or may be upstream where discharge passes from subcritical to supercritical. Chow provides a lengthy case-study graphical solution relating to the spillway at Hoover Dam.

Eq. (4) and the boundary condition were solved numerically by computer for each cross-section for four roof lengths, four nominal gutter dimensions, and three

...opes. The results are in terms of ($i\ L_r$), the product of rainfall intensity and roof length. Units can be expressed as the rate of roof runoff per unit roof width. The term ($i\ L_r$) can be denoted "unit gutter loading". Unit gutter loadings are given in Table 1.

Table 1. Unit Gutter Loadings [i (cm/hr) • L_r (m)]

		Circular n = 0.025			Trapezoid n = 0.015			Square n = 0.015		
		S_o			S_o			S_o		
L_g (m)	w (cm)	0.01	0.02	0.03	0.01	0.02	0.03	0.01	0.02	0.03
5	5	99	132	170	106	146	181	68	86	107
	10	576	689	825	578	713	849	392	464	530
	15	1535	1817	2042	1536	1823	2017	1077	1258	1387
	20	3064	3569	3969	3046	3505	3875	2140	2409	2688
10	5	49	75	90	57	82	104	33	47	63
	10	297	398	489	316	437	510	207	258	324
	15	824	1032	1269	839	1077	1260	577	681	821
	20	1704	2066	2423	1703	2058	2430	1161	1355	1581
15	5	33	55	63	41	59	75	22	33	41
	10	207	295	355	222	310	388	140	186	236
	15	577	763	912	594	840	968	394	490	623
	20	1193	1496	1884	1176	1549	1817	813	988	1180
20	5	25	42	49	29	46	58	16	26	32
	10	157	239	276	178	254	312	103	149	175
	15	433	623	736	467	640	799	294	392	498
	20	887	1226	1446	941	1321	1527	609	775	980

In the earlier example ($i\ L_r$) is 20*5 and L_g is 20. If S_o is 0.01, a 10 cm radius semicircular section will transmit the runoff (100 < 157). A 5 cm section will not transmit the flow at an S_o of 0.01 (100 > 25) or at an S_o of 0.03 (100 > 49). A 5 cm section might be used at an S_o of 0.02 if four evenly-spaced leaders were employed, reducing L_g to 5 m (100 < 132).

The design-specific data in Table 1 can be statistical simplified,

$$(i\ L_r) = C\,\frac{w^{2.206}\,S_o^{0.44}}{L_g^{0.835}} \qquad (5)$$

where C is a constant, 97.55 for semicircles, 101.80 for trapezoids and 64.70 for squares. Eq. (5) comes within 10 percent of the tabled unit gutter capacities in 60 percent of the cases. The error is less than 20 percent in 88 percent of the cases.

The constant C, a function of the roughness and the cross-sectional shape, is best determined experimentally for a particular gutter technology. If that is not possible, the three given values provide a basis for estimation.

Eq. (5) can be reformulated,

$$w = C \frac{(i\ A_r)^{0.453}}{L_g^{0.0747}\ S_o^{0.199}} \tag{6}$$

where the C's are now 0.125, 0.123 and 0.151 for the three respective shapes. In the example, w (the radius for a semicircle) is 7.8 cm, giving an A_g of 97 cm^2. Were the roof rotated such that L_r were 20 m and L_g were 5 m, A_g would become 120 cm^2. The higher unit gutter loading would require a larger gutter.

Table 2 summarizes the gutter and leader areas for the example.

Table 2. Example Gutter and Leader Areas (cm^2)

Reference	A_g	A_l
Pacey and Cullis (1986)	200	78
Edwards, Keller and Yohalem (1984)	70 - 80	
Benji (1934)	167	
McCuen (1989)		52
Graf (1985)		40
Eq. 6	97	

Table 2 illustrates a wide range of sizings. The first two references are general, taking no account of rainfall intensity, roof area or particular gutter technology. The next three consider intensity and roof area. Eq. 6 also employs gutter shape, size, slope and length. It is not known what margin of error or freeboard, if any, is included in any of the first four references. The last two include no allowance for excess flow; upsizing is left to the designer.

Eqs. (5) and (6) can be employed to assess alternative designs. To correct a gutter that spills half its total loading, Eq. (6) calls for an increase in nominal dimension by a factor of 1.37, an increase in length by a factor of 66.7, or an increase in slope by a factor of 4.8. The length option calls for making the roof 66.7 times as long and 1/66.7 times as wide, not a solution. The size and slope alternatives might be plausible. From Eq. (5) it can be shown that the flow would be transmitted without spill if the leader spacing were 0.44 times as great, another option.

CONCLUSIONS

Gutter have received relatively little consideration in rainwater catchment literature. That which has been printed tends to reflect conventional practice, not a basis for improvement. In that gutters are frequently a weak link in the catchment system, more technical consideration is in order. The analysis above illustrates the sensitivity of gutter capacity to dimension, slope and length. A statistical summary of numerical results indicates the relative degrees which changes in each of these variables might improve gutter performance.

Two final notes are in order, one directed upward in the development process, the other directed downward:

1) Neither the builder nor the consumer will be able to employ the computations discussed in this paper. If gutter design is to be improved, technical impetus must come from a higher level. Regional development or sanitary authorities must take initiative in determining and publicizing appropriate standards in understandable form. This paper provides those authorities with some engineering basis for their decision.

2) Design is but one portion of the engineering problem. Yohalem (1984) and Edwards, Keller and Yohalem (1984) provide illustrative detail on the socio-engineering of gutter systems. Gutter technology must be appropriate to those who employ rainwater catchment. Neither Eqs. (1) - (6) nor any other computation can yield a proper design if that design cannot be constructed and maintained. Proper design must combine sound hydraulic theory with achievable implementation.

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INTEGRATION WITH OTHER WATER SUPPLY SYSTEMS

HIGH WATER BILLS: CAN RAIN WATER SUPPLEMENT PART OR WHOLE OF IT?

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Abstract

Water resources in many developing countries around the world have been stretched to its limits within the available financial resources. This paper looks at the problem in SRI LANKA as a model for other countries in providing Rain Water as a direct source of water supply in many Urban and rural areas.

Further more, the paper spells out some design criteria for the effective sizing of rain water catchment systems in places where ever this system could be incoporated to reduce cost to consumers and pressure on supplyers.

List of Symbols and Units

A	- Catchment Area	-	m^2
C	- Daily consumption per person	-	liters
f	- Catchment Run-off coefficient		
N	- Number of people		
Q	- Quantity of water required	-	m^3
R	- Rainfall	-	mm
T	- Drought period	-	months
V	- Volume required	-	m^3
Y	- Yield	-	m^3
lpcd	- liters per capia per day		
NWS&DB	- National Water Supply and Drainage Board		

INTRODUCTION

Water, water everywhere, but why are the Water Bills so high! This is the common talk of the day when the Water Bill is opened by the house wife, the shop owner, hotel manager, school principal or for that matter any one in any part of the island where the billing is under operation.

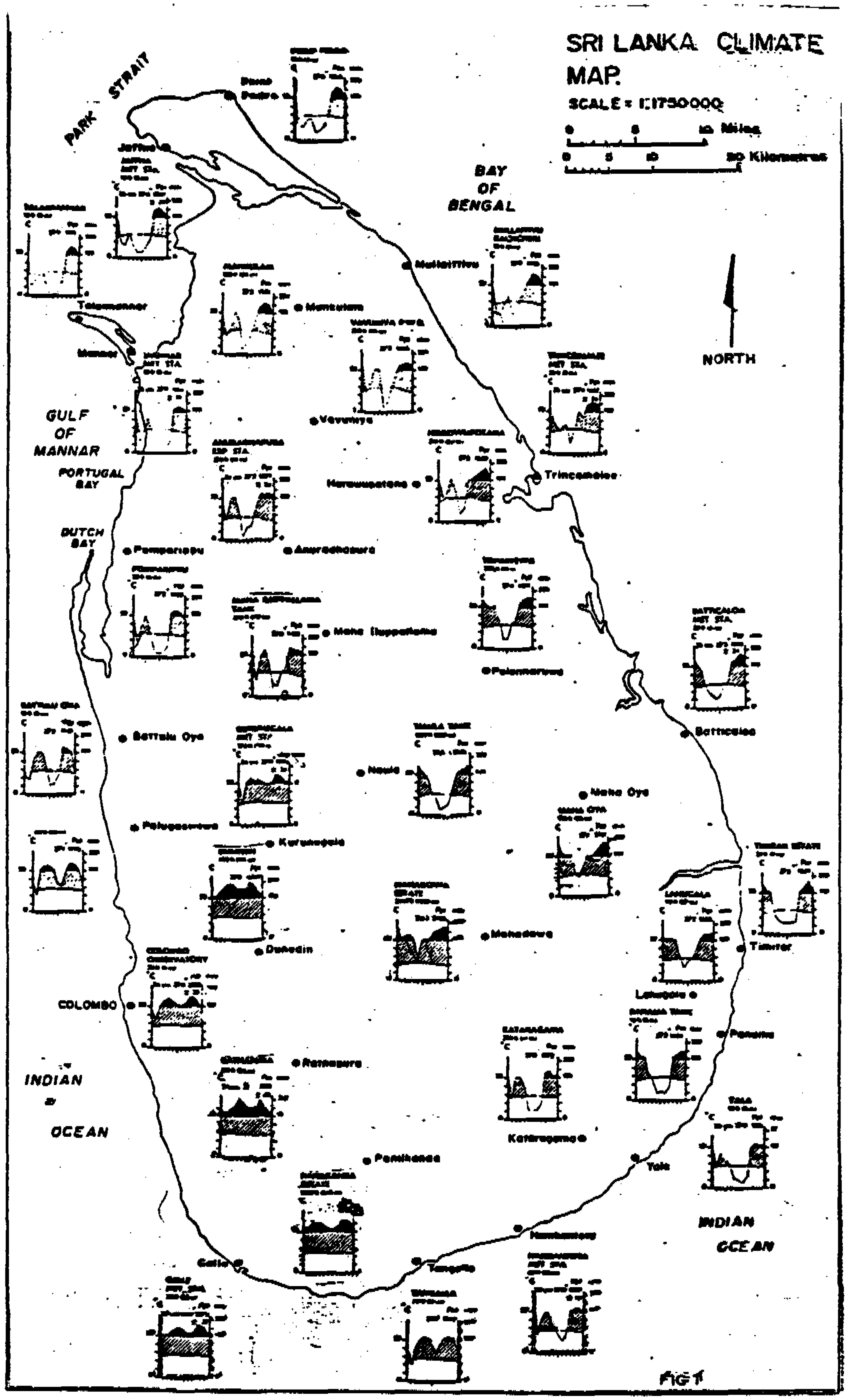
To assess the severity of this problem let us first have a look at the water supply situation in the country.

The 1981 population census found a total population of 14.85 million of which 21.5% (3.2 million) lived in Urban areas and 78.5% (11.65 million) in rural areas. The average growth rate was estimated to be 1.7% per annum with the Urban areas growing slightly less than rural areas.

Water - the life sustaining substance has to be managed efficiently if one wishes to overcome the odds that has been already experienced by the other developing countries around us. Inorder to achieve good results one has to think many alternatives and advice the population to take measures in the correct direction to achieve higher standard at reduced costs. With the ever increasing cost of living, a small saving in one sector could be used to enhance the other important sectors of human life.

PRESENT LEVEL OF WATER SERVICE

Piped water supplies in the country range from a few systems with 24 - hour service and adequate quality to that of a large number of systems with intermittent service and unacceptable quality. According to data collected in 1982 over 65 urban water supply systems served about 25% (0.8 million) of the urban population through house connections and another 22% (0.7 million) through stand posts.



SRI LANKA CLIMATE MAP.
SCALE = 1:1750000
Miles
Kilometres
PARK STRAIT
BAY OF BENGAL
NORTH
GULF OF MANNAR
PORTUGAL BAY
DUTCH BAY
COLOMBO
INDIAN OCEAN
INDIAN OCEAN
Trincomalee
Batticaloa

FIG 1

The remaining 53% (1.7 million) used private community wells (49%) and rivers (1.1%) or other sources. In the rural areas, there are over 500 piped water supply schemes servicing a total of 5.1% (0.6 million) of the rural population through a mix of house connections (1.8%) and stand posts (3.3%). Over 80% (9.5 million) of the present rural population draw their water supplies from protected and unprotected wells with the reminder using tanks, streams and irrigation channels.

Due to the increase in population and increasing demand for water (quality and quantity) in urban and rural areas of the Island the Water Supply and Drainage Board, an autonomous organization under the Ministry of Local Government, housing and construction was compelled to manage their systems effectively. Thus there is no alternative but to request the users to pay for the water that they consume. This action will enable the user to continue to have water at a price.

Without questioning the rate structure (claimed to be the lowest in the world!) and the efficiency in the operation and maintenance and the cost involved in running these water supply systems, the consumer is compelled to look at alternative ways to supplement his water needs. One such way is harnessing the Gift of God "The Rain". After working in the Water Board for nearly 10 years, I have not come across anyone engaging in utilizing this natural resource directly anywhere in the Island, as a possible alternative to the domestic and public water demand.

BACKGROUND DEVELOPMENT

SRI LANKA is well located on the globe with a history standing behind it for its agricultural success. The agricultural development in the country was strongly influenced by rainfall. (see fig. 1) However this resource is not considered by the authorities in any small way as a source of drinking water population. Sri Lanka is influenced by the two Monsoons which dominate weather patterns in the Bay of Bengal and the Indian Ocean.

The South-West Monsoon affects the island most strongly from May to September and the north-east Monsoon from December to February.

The south-west of SRI LANKA and most of the central hill mass which receive considerable amounts of rainfall during both monsoons are said to comprise the "wet zone" of the island. The flatter lands in the north and east where rainfall is concentrated in the north-east monsoon comprise the "dry-zone".

Even in the dry zone Agriculture predominates having irrigated paddy rice, chillies, onions etc. using water stored in ancient tanks which were built between the 3rd and 12th centuries AD.

In the northern dry zone most of the annual rainfall occurs during the north-east monsoon. Tank storage is used to supplement this rainfall and to recharge the aquifers.

Evidence shows how the primitive man was able to exist amids all the difficulties for existence. In fact I have seen and helped my Grandma to errect three sticks (for equilibrium) and to tie up an old cotton saree together with a paper weight at the centre, to form a cone shape to collect rain water by keeping a bucket underneath. This system provided the household with sufficient clean drinking water during rainy days, as during the olden days it was correctly felt that the usual unprotected water wells are polluted due to flooding with surface waters.

However with the development of new technology man has forgotten the past and day by day looking for more sophistication. Now a stage has been reached in most of the developing countries, that due to increased in cost of everything, one has to look at some cheap safe reliable alternatives on anything. One

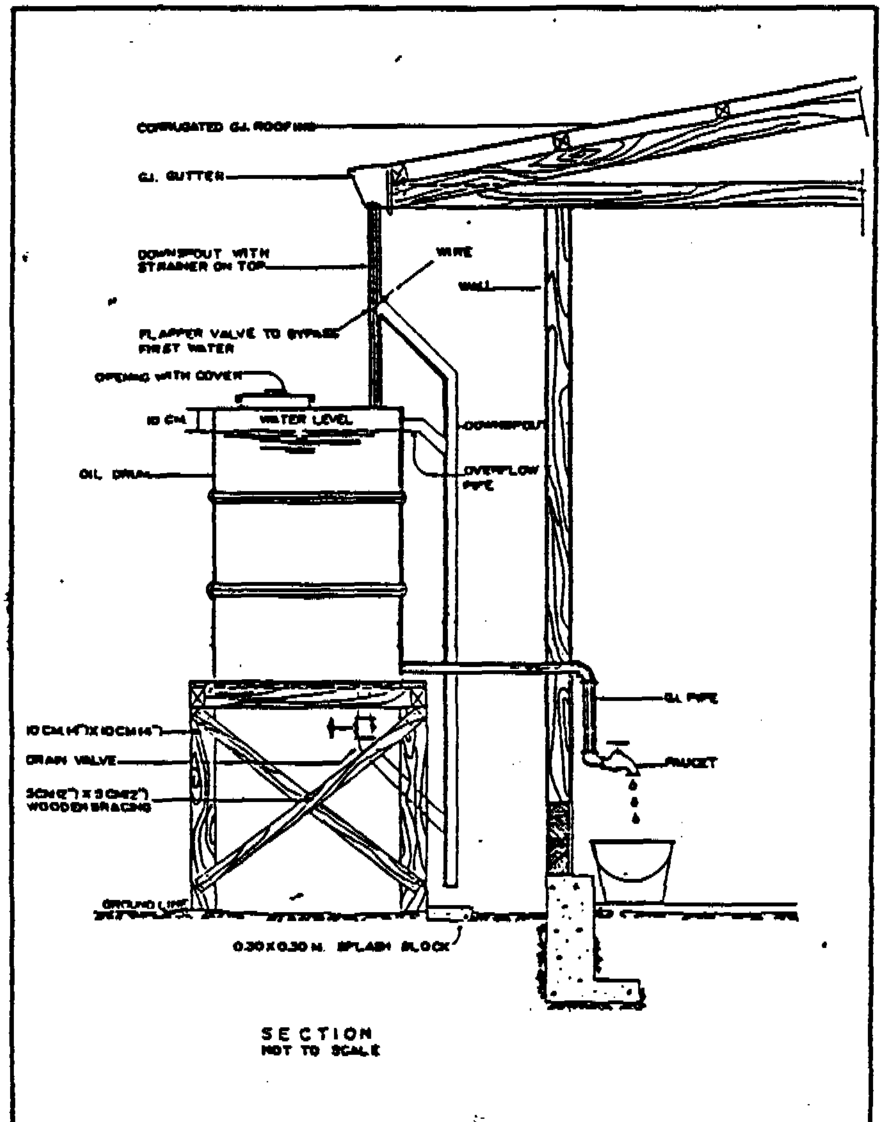


FIGURE
2

RAIN WATER STORAGE

such thought is the use of rain water catchment system designs to supplement the needs, where ever appropriate.

DESIGN CONCEPTS

The most natural Gift of God is rain. In places where rain is uniformly distributed throughout the year rain water may be used as a source of water supply. See fig. 1 for rainfall distribution over the island. These are 1972 figures obtained by the Ceylon Meteorology Department. (use as a guideline value)

A rain water collection system has three essential components. (see fig. 2)

(1) An impervisous roof to collect rainfall

(2) Gutters and down pipes to convey water to a storage tank.

(3) A tank for the storage of collected rainfall.

The tank is the most expensive item in the whole system. Rainfall records representative of the catchment are essential for the design of a system. The yield could be calculated using

$$Y = \frac{f * A * R}{1000} \; m^3/\text{month} \quad \text{............Eq. (1)}$$

when y - yield m^3/month
A - catchment Area m^2
R - rainfall in mm
f - catchment Run-off coefficient

Table (i) below shows the different catchment run-off coefficients for different type of roofs.

TABLE (i)

Type of catchment	f
covered catchment (roof) tiles	0.8 - 0.9
corrugated sheets	0.7 - 0.9
plastic sheets	0.7 - 0.8
thatched roof (coconut leaves or paddy leaves)	0.5 - 0.6

The quantity of water required per month can be obtained using

$$Q = \frac{N * 30 * C}{1000} \quad (m^3/\text{month}) \qquad \text{.................................... Eq. (2)}$$

When N - number of people to be supplied with drinking water from the rain water system.

C - daily consumption per person (liters per capita day)

To give you an example, let us consider a family of 6 people in a rural village in Kurunegala where the annual rainfall is 1500 mm wishes to have a water supply system built. If the daily water consumption is 15 lcpd and the roof material is corrugated iron, let us find the minimum roof area required to satisfy their needs.

Also if the drought period is 3 months, over the hydrological year, find the storage volume required to take the family through this critical period.

Number of people N = 6

Annual rainfall = 1500 mm

Per capita consumption = 15 lpcd

Roof material corrugated iron (use f = 0.7)

now

$$\frac{N * 30 * C * 12}{1000} = \frac{f * Amin * (R_1 + R_2 + R_3 \ ...R_{12})}{1000} \qquad \text{............... Eq. (3)}$$

where $(R_1, R_2, R_3 \ ... R_{12})$ = monthly rainfalls during year of minimum recorded rainfall.

$$\text{therefore } Amin = \frac{N * 30 * C * 12}{f * (R_1 + R_2 + R_3 \ ... R_{12})}$$

$$= \frac{6 * 30 * 15 * 12}{0.7 * 1500}$$

$$= 30.85 \text{ say } 31 \ m^2$$

Hence, a corrugated iron roof plan of 4 m * 8 m is sufficient to provide 15 lcpd of water for each family of 6 if the annual rainfall is 1500 mm.

Note:- If there is a large variation in the rainfall distribution, the most critical parameter is the minimum storage volume required.

$$V_{min} = \frac{N * 30 * C * T}{1000} \ m^3 \qquad \text{.......................... Eq. (4)}$$

Vmin = minimum storage volume

T (month) = drought period in months

$$V_{min} = \frac{6 * 30 * 15 * 3}{1000} = 8.1 \ m^3$$

Hence a family of 6 require a storage volume of 8.1 m^3 to span a three month drought.

Again, let us consider another situation where you are living in a dry rural area in SRI LANKA where monthly recorded rainfall during the year of minimum recorded rainfall figures are.

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
0.0mm	30mm	55mm	112mm	60mm	28mm	22.5mm	0.0mm	0.0mm	0.0mm	0.0mm	0.0mm

Rain starts in February each year. The family consists of 6 people and the roof of the house is corrugated sheet of section 10 m * 10 m and water consumption is around an average of 10 lpcd.

Calculate required storage capacity to survive the whole year. Also due to the arrival of a baby, the water consumption increased to 12 lpcd. Calculate the number of months the family will be without a water supply?

A self explanatory graphical solution is given below. see fig (3)

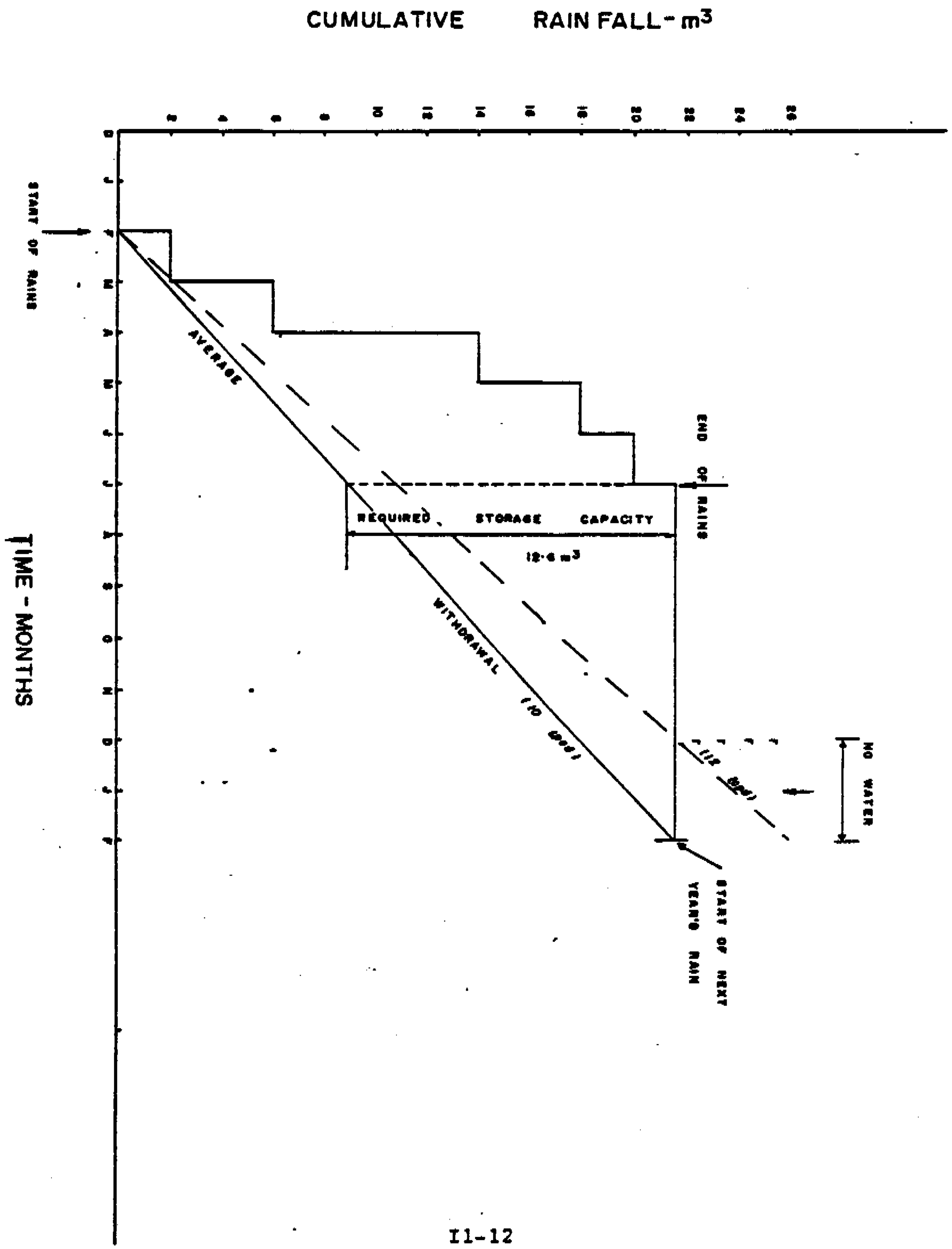


FIG 3

SUGGESTIONS FOR IMPROVEMENTS

If the roof is directly connected to the storage tank, all the dust, leaves, roof dirts, birds dropping etc. will be carried into the tank with first rain after a prolong drought period.

Little modification such as shown below will enhance the quality of outlet water very much.

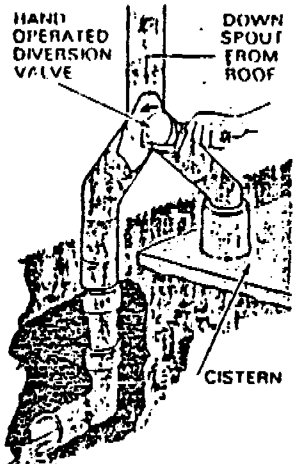


FIG 4

Fig. (4) shows the hand operated diversion valve which can be turned to the outlet direction during the first rainfall to allow sediments etc. to go waste.

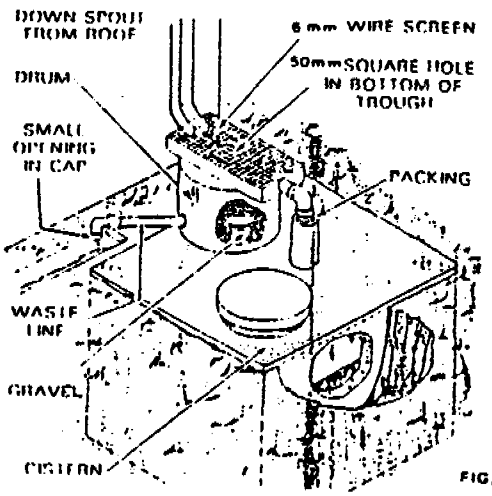


FIG5

Fig. (5) shows the arrangement of automatic roof wash. The first rainfall flows into the drum. After the drum is filled the remaining water flows into the storage tank. During the period without rainfall, water dripping from the opening in the waste line empties the drum and keeps it ready for the second rain.

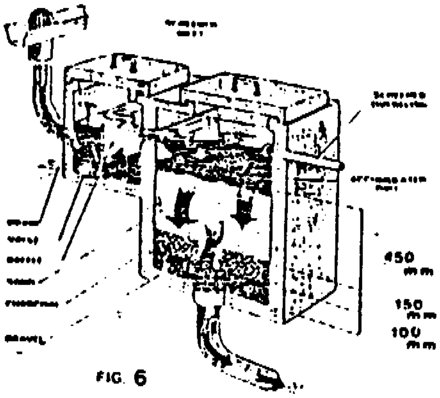


FIG. 6

Fig. (6) shows a very effective means of improving the quality of water. A small scale sand filter arrangement is incoperated to the system which removes most of the pollutants. This arrangement works very well provided, it is cleaned regularly. Rainwater can be collected from roof of building's, houses etc. and connected to a cistern or storage tank.

CONCLUSION

Even though rainwater catchment systems could be considered as a hundred percent drinking water supply source in many rural and urban areas of SRI LANKA, the focus of this paper, however is on a dual system for houses, hospitals, hotels, schools, religious places, public buildings etc. to reduce the high water bills.

The concept of using multiple water systems and matching the high and low quality water supplies to appropriate uses has to be introduced for the coexistance of Water Board (producer) and the general public (consumers) without complaining about each others performance.

The dual water system could provide sufficient water for outdoor uses such as gardening, car washing and general washing. Also this supply could be used indoors for toilet flushing and general cleaning.

It is however not my objective here to investigate the economic aspects of the dual system concept, and it is up to the user to carry out investigations on his own system conditions before embarking upon this type of systems. The objective of this paper is to spell out and examine some concepts in the design of rain water catchment systems to supplement your public water supply system.

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PROPOSAL FOR A DUAL-MODE RAIN WATER CISTERN SYSTEM IN INDUSTRIAL AREAS OF TWO HECTARE LOTS

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ABSTRACT

In 1968, the Jurong Town Corporation was established with a view to develop a predominantly industrial zone in the south-western part of Singapore. Land-lots of various sizes were allocated to industries according to their needs and, to date, only potable water is being supplied to most of the industries. The quantity of water used in each of these industries is as varied as the quality required for different purposes. It is approximated that that the average land area occupied by the larger industries is about two hectares. In this study, the potential volume of water that can be tapped independently from such small areas is studied taking into consideration the stochastic pattern of rainfall, the varying demand and quality of the rainwater. Also a simple dual-mode system that is economically viable is proposed wherein the perennial supply of water is guaranteed whether or not stored rainwater is available.

INTRODUCTION

The attraction to use rainwater for industrial purposes is understandable as the quality is of a high order but the reliability of supply questionable. Particularly in some the industries, where the supplied water has to be further treated to attain specified quality levels, the high-quality roofwater should be preferred as it will have to undergo minimal treatment. Such roofwaters, if available in sufficient quantities to meet the demand, should therefore be economically more viable. The Jurong area that lies in the south-western corner of Singapore, is a predominantly industrial zone. Here, land-lots of specific area are allocated to cater for a variety of industrial activities. Not less than 10% of the industries are involved in activities related to the electronic industry where part of the water is subjected to reverse osmosis or ion-exchange processes before it can be utilised. In this paper, the main objectives are to study the possibility of tapping the water from such 2 hectare land-lots, and to determine an optimal-cost RWCS in terms of tank size and reliable yield, with or without supplementary supply of potable water.

DUAL-MODE SYSTEMS UTILISING RWCS

The limiting case in the matter of using roofwater occurs when all the requirements can be met with by this source. Since there are the usual constraints like limited roof area, excessive demands, limited storage volume etc., the use of roofwater has been studied in conjunction with the existing potable water supply sources. Such dual-modes of supply have been pursued in relation to the use of roofwater for toilet flushing as an independent system (Ikebuchi and Furukawa 1982) and as a combined system (Appan et 1987). RWCS have also been used successfully for laboratory purposes (Sivanappan 1982) and the use of rainwater in combination with wastewater has been studied for toilet flushing in the United Kingdom (Fewkes and Ferris 1982). Stormwater in combination with wastewater has also been suggested for use as a cooling water source (Dwornik et al 1984) and the use of roofwater and surface runoff in aquaculture is being practised in Singapore (Appan and Tay 1989). All these systems use rainwater as a supplementary source and have separate or combined systems which ensure that drinking water is a separate entity.

RAINFALL IN THE JURONG AREA

Quantity

Rainfall is the major input for most hydrological systems but it can be considered to be the most unpredictable variable. To represent the Jurong area, six years of rainfall data (1980 to 1985) from four of the most representative rainfall stations were selected. The polygon area-weighted mean rainfall was taken for all analysis. Some assumptions made regarding the rainfall data are:

(a) The data is valid for for a one day discrete time interval.

(b) Rainfall falls vertically over the entire catchment area.

(c) Effects due to droplet size, variation in wind velocity and barometric pressure at site are ignored.

(d) The rain intensity is assumed to be uniform through out the day.

The average annual rainfall in this area was found to be about 2100 mm.

Quality

The quality of rainfall in the Jurong area has exhibited relatively low solid contents over the specified period of time. A comparison is made in Table 2 with the existing potable water that is being supplied to the Jurong area (Wong 1986).

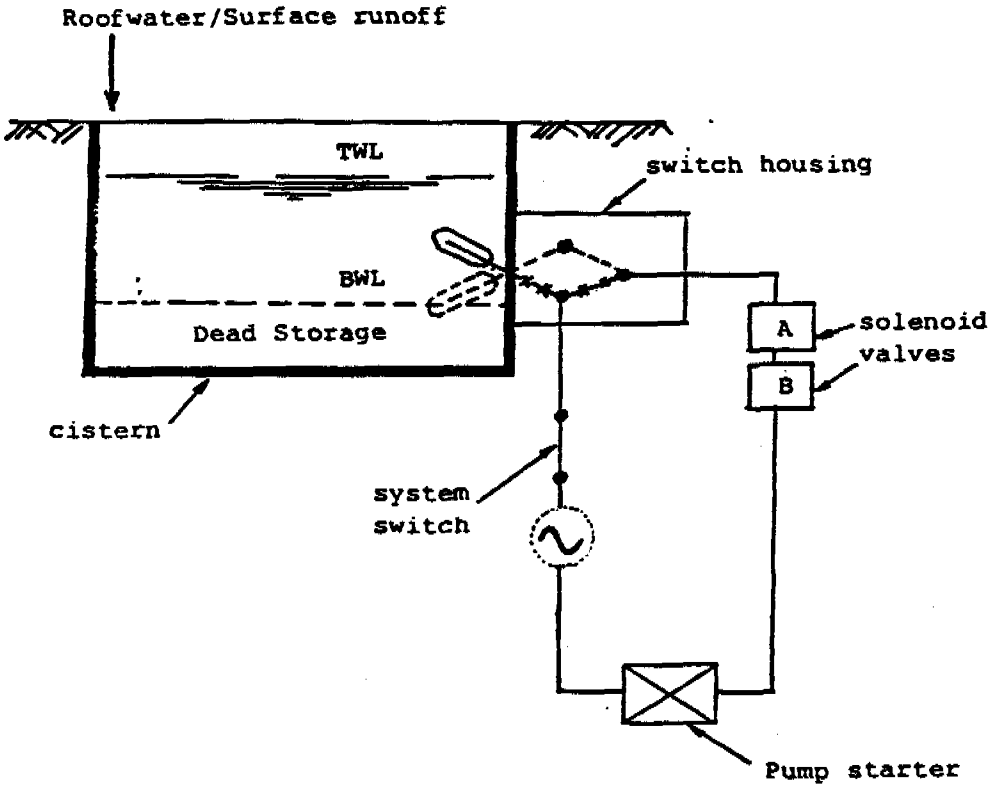
Table 2
Solids Contents in Water

Parameter	Rainwater	Potable Water
Suspended Solids	2 - 35 mg/l	1 - 3 mg/l
Total Solids	4 - 48 mg/l	240 -400 mg/l

From the limited data available in Singapore from roofs of high-rise buildings it would appear that in terms of solids contents the average value is in the region of 50 mg/l (Appan 1982).

PROPOSED DUAL-MODE SYSTEM

In terms of industrial usage, since the demand for water has to be met with, whether or not stored rainwater is available, a dual-mode of supply has been proposed. In such a system, the existing potable water supply is used as a supplement when the rainwater tank is almost empty. Then an automatic valve will immediately switch on the supply of potable water. This will ensure that there will be a continuous supply of water for the needs of industry. A simple system incorporating a float switch near the bottom of the cistern is shown in Figure 1. When the water level



Note:

---x---x---	Circuit closed, pumping commences Valve B opens - RWCS activated.
-----------	Circuit broken, pumping ceases Valve B closes-potable supply activated

FIGURE 1

DUAL-MODE OF SUPPLY

falls to the dead storage level, the circuit is broken, the RWCS valve closes and the potable water supply valve opens. Thus a perennial supply of water is ensured.

COMPUTER SIMULATION OF RWCS

The basic concept involves the quantity of rain that falls on a catchment area (roof or land) and then enters a storage tank (of known volume) during a specific period of time (one day in this instance). If the storage volume is exceeded, water overflows and is wasted. Water is extracted (demand) from the tank at the end of the day and any water left over will be carried over to the next day. This simple concept (Appan 1982) was used to develop a simulation program (Appan et al 1988). In this program, there is provision for rainfall to be used as the sole input and, in instances where the demand cannot be met by this primary input, the supplementary source (existing potable water supply) can be utilised. The major system parameters are the rainfall, storage volume, catchment area and demand.

TANK SIZE ANALYSIS

The catchment area used was 2 hectares and runs were made for demands of 50 to 100 m^3/day varying the tank size from 100 to 1,600 cubic metres. It was assumed in this program that the cistern is initially empty and that if the water in the tank is insufficient for the day's demand, the potable water supply will be supplied directly to the industrial user.

Based on the computer runs, Figure 2 has been plotted. It can be seen that as the tank size gets to be bigger, more rain water can be stored as a result of which less potable supply will be needed to supplement the demand. But, as the rate of increase of rain water decreases with tank size, it would appear that the RWCS could be less attractive after an optimum tank size is exceeded.

COST OPTIMISATION OF RWCS

To appraise whether or not the proposed tank sizes are economically viable, a cost analysis was done using present worth analysis for interest rates of 8% and 12%. It was assumed that the useful life of the underground concrete tank is 60 years and that of the mechanical and electrical works (excluding the piping) is 15 years. The power and water costs were based on current prices. Provision was also made for geotechnical investigations. Structural dimensions of the tank were fixed based on a depth of 5 metres, a wall thickness of 25 cm and a square base.

A simple program was developed for this purpose which displayed the Present Worth values for individual tank sizes. To display the results for various tank sizes, macro-programming was resorted to

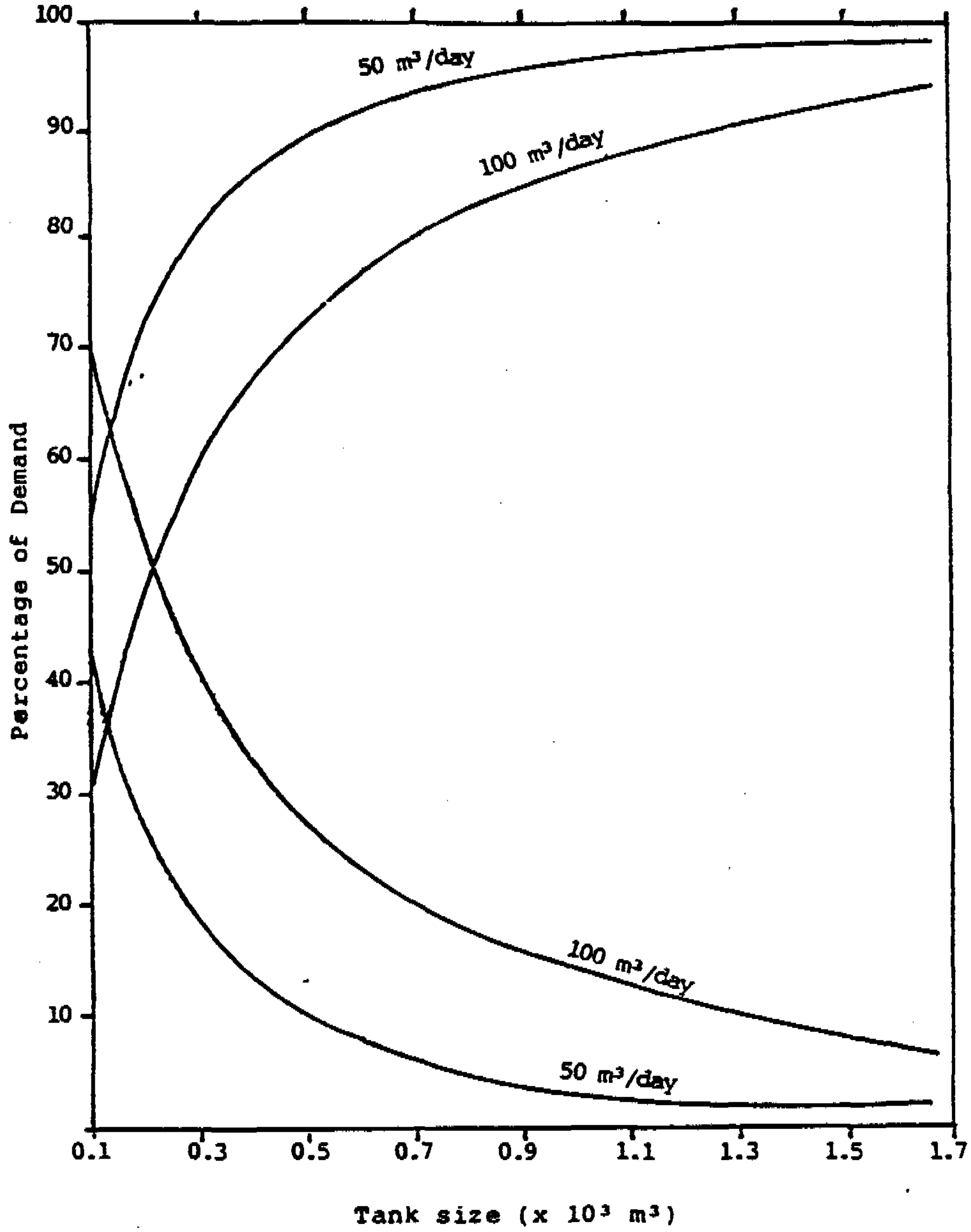


FIGURE 2

TANK SIZE ANALYSIS

thus obtaining a set of values of tank sizes versus Present Worth Savings (see Figures 3).

Initially the graphs show increased savings for larger tank sizes and tend to increase at a decreasing rate for any fixed demand. After a certain point, the tank becomes relatively big and the savings will then tend to decrease due to the relatively larger capital expenditure.

An optimum tank size can therefor be selected for the maximum savings. This can be represented for the 8% interest rates as shown in Table 2.

Table 2
Optimum Present Worth Savings

Demand	50m^3/day	75m^3/day	100m^3/day
Tank Size	400 m^3	550 m^3	750 m^3
Annual Savings	S$10,500	S$44,000	S$84,500
Potable Water	13%	20%	25%

It can be seen that for 8% interest payments, as the tank size and demand keep increasing, the % of potable water used and the annual savings also tend to increase.

DISCUSSION AND CONCLUSIONS

1. The success of a dual-mode system largely depends on the reliability and economics of the system. As the automatic system of controls plays an all-important role in maintaining continuous supply, the valves incorporated should be highly efficient and ,practically, no restriction should be imposed on the continuous supply of water to the industry.

2. From the exercise carried out it can be concluded that for an industry having a roof area of 2 hectares, by designing an economically viable RWCS, the relationship between optimal size of tanks, reliable yield and Present Worth Savings can be established (see Table 3). However, the choice of appropriate sizes in a real-life situation will be dictated by the site configuration and, very often, the unrestricted availability of water for industrial uses.

3. Note should be made that the analysis of tank sizes in relation to the apportionment of quantities from the potable and roofwater sources is a vital component of the cost-optimisation model.

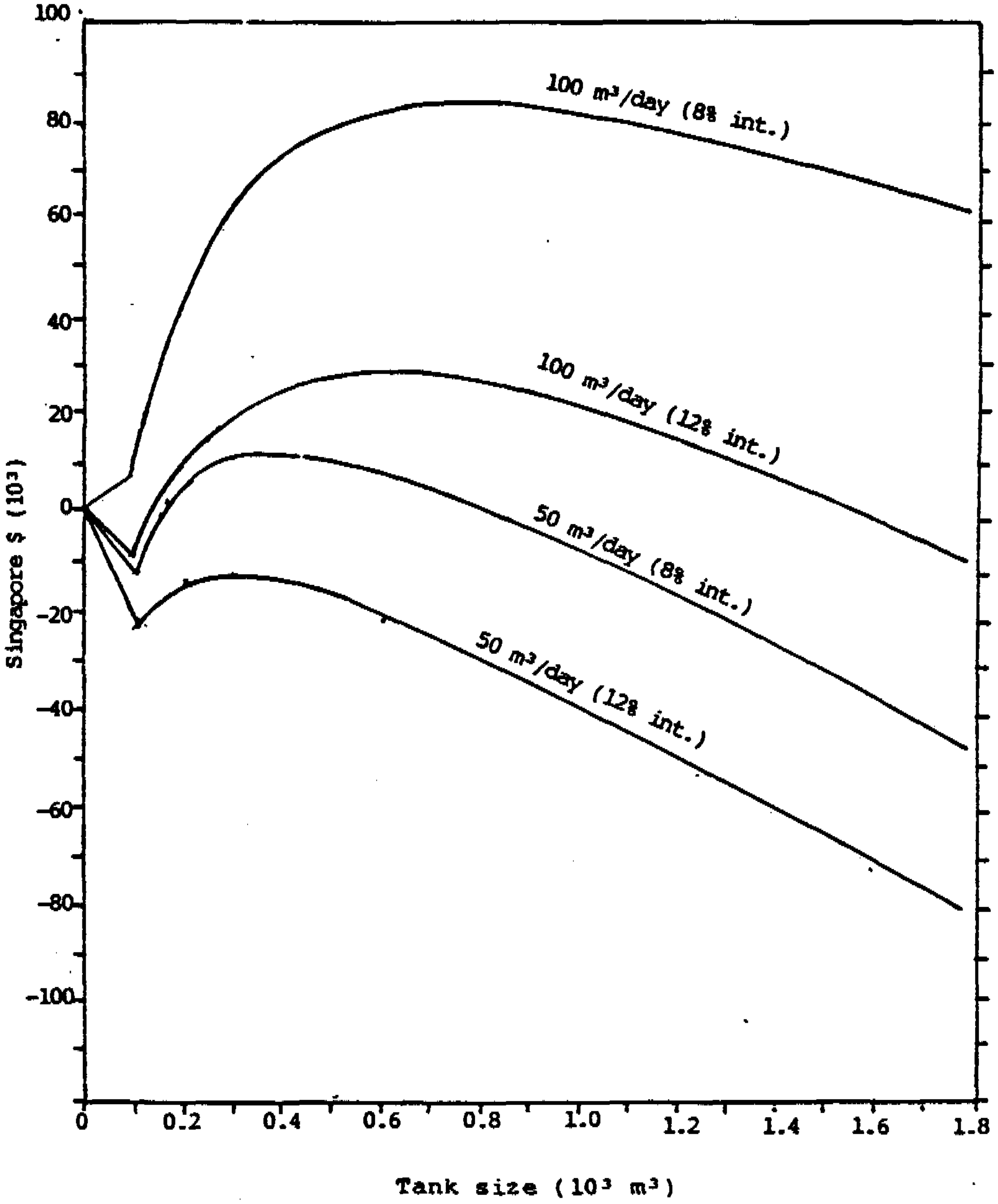


FIGURE 3

PRESENT WORTH SAVINGS VS TANK SIZES

4. From the cost-optimisation exercise carried out, it would appear that there will always be some Present Worth Savings. This need not necessarily be true as the returns are sensitive to the interest rates. For example, when the interest rate is 12%, for a demand of 50 m^3/day and tank size of 300 cubic metres, an annual payment to the extent of S$ 12,000 will have to made. Generally, as interest rates increase, the rate of increase of Present Worth Savings will decrease.

5. The quality of rainfall can be a telling factor in adopting RWCS for industrial uses especially when the water being supplied at present has to be treated further. Most of the electronic industries need water that has very minimal or no solids and hence they have to install reverse osmosis or ion-exchange plants. These treatment systems are capital-intensive and involve high maintenance costs. The use of rainwater as the sole source, or in combination with potable water supply, should reduce the treatment costs considerably due to the low range of both total and suspended solids contents in rainwater. This economic factor has not been considered in computing the Present Worth Savings in this model.

6. The RWCS can be designed as a single-mode system when there is a larger catchment and when the water demand of the specific industry is low. It will then be possible to determine the optimum storage when the relevant rainfall figures are available.

7. In the storage model, the catchment area does not cater for the possibility of part of the area contributing roofwater and the rest of the area having surface runoff. The model should preferably make provision for this condition. If the surface runoff quality is not of a high order, the installation of subsoil drains may be considered. In such a system, the time lag due to longer concentration times should, probably, make the storage volumes more effective.

8. The proposed system is an economically viable method of encouraging industries to conserve water by using the roofwater within their premises that is otherwise going to waste. In Singapore, where conservation is a way of life, there are tax incentives being provided for conservation systems involving capital expenditure (Straits Times 1983). Such incentives could also be introduced in other developing countries which thrive on industrial development and are beginning to worry about their escalating water demands.

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RAIN WATER CISTERN SYSTEM - A NEW APPROACH TO WATER SUPPLY IMPROVEMENTS IN NEPALESE HILLS

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ABSTRACT

Nepal is a land locked country with 83% of its area occupied by mountains. More than 50% of the country's population live in the hills, majority of which still have to be provided with safe drinking water. Broken topography and settlement pattern in the hills have resulted in hundreds of water schemes serving limited house-holds. This has caused difficulties in implementation, operation, and maintenance of water supply systems.

Deforestation and landslides are gradually depleting suitable water sources in the hills. Landslides have also damaged existing water systems. Use of Rain Water Cistern System (RWCS) can improve water supply situation in the hills. Analysis of rainfall, house-hold status, and storage method show that the system can be developed as primary water supply system in acute water shortage areas, or as a supplementary system during dry periods.

The crucial question in the use of Rain Water Cistern System is, will it be socially acceptable ? People in the hills use running water and not still water for drinking and cooking. Rain Water Cistern System is a new concept and is not in use. Greater efforts are needed on the part of implementing agencies to ensure its wider use in Nepal.

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Nepal is south of the Himalayas, which separates it from its northern neighbour, the Peoples Republic of China. The country is bounded on east, west and south by India. Roughly rectangular in shape, the country has an area of 141,181 square kilometers and extends east west for 885 kilometers. The country lies across one of the highest relief features on earth, with a highly broken topography. Almost 83% of the country is occupied by mountains with 17% constituting the plains in the south. The altitude varies from more than 8000m above mean sea level in the north to less than 300m in the south. Geographically, the country can be divided into three zones that run roughly parallel along the east west. These are (a) High Himalayas, (b) Mountains, and (c) Terai Region.

Nepal's weather condition varies from region to region. The northern snow covered mountains are cold where temperature falls below freezing point. In the Valley and Mountains, the summer is warm while winter is cold and chilly. Summer and late springs temperature range from more than 40 c in Terai to about 28 c in mid section of the country. In winter, minimum temperature in Terai range from mild 23 c to a brisk 7 c while central valley experiences 12 c maximum and temperature below freezing point.

Nepal is under the influence of Indian sub-continental rainfall pattern, which has two rainfall seasons. These are the summer and winter monsoon seasons. The summer season, which lasts from June to October, brings about 80% of the annual rainfall which is estimated to be 1500mm. 20% of the rainfall occurs during the winter monsoon. Mean annual rainfall in stations selected from different regions in the country is shown in Table 1.

Rainfall is however, non uniform and variations exist within different geographical regions. While southern slopes of the himalayas receive greater rainfall, the northern part on the rain shadow receive very little. More than 3500mm rainfall occurs in Pokhara while Jomsom, which lies on the other side of Himalayan range, north of Pokhara receives only 250mm rainfall in a year.

Nepal is richly endowed with huge water resources. Annual run off from the country comes to an order of 200 billion cu.m. This water is drained out of the country by more 6000 large and small rivers. Availability of this vast water amount however, does not show the disparity that exists in supplying drinking water to majority of the population.

The government's Sixth Five year Plan (1980-85) coincided with the first five years of the IDWSSD and raised the number of people having access to drinking water facilities from about 10% of the total population in 1980 to almost quarter of the population in five years. While many water supply systems built in the country have brought benefits, problems have arisen with their uninterrupted functioning. In the hills, gravity flow system have faced difficulties in their implementations, and later on with operation and maintenance. Growing population, and detriorating

TABLE 1

Mean Monthly Rainfall in mmat Selected Stations (1961-1980)

Region	Station	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Total	% of Total	
															Wet	Dry
Mid West	Surkhet	242	424	380	170	56	4	16	24	32	38	20	62	1468	87	13
West	Syangja	599	756	658	430	165	18	11	23	44	42	163	344	3153	83	17
Central	Kathmandu	272	371	297	163	69	5	8	15	18	34	50	97	1399	85	15
East	Dhankuta	199	256	131	105	75	11	10	14	13	20	66	114	1014	77	23
Far West	Dipayal	168	372	279	46	8	3	27	14	33	109	44	107	1240	74	26
North	Jomsom	26	43	38	32	31	16	3	7	9	20	15	8	248	75	25
Season of Rain		Wet Season						Dry Season								

Source: CBS, Statistical Pocket Book, The Central Bureau of Statistics, 1984.

environmental situations in the country have further exacerbated the problems of drinking water supply improvement programmes. Rain Water Cistern System (RWCS) in this context can be an effective form of water supply system. This paper highlights problems of existing water supply systems in the hills. Use of Rain Water Cistern System (RWCS), in meeting water supply needs in pockets with critical water supply problems, is proposed.

POPULATION

Nepal's demographic scenario is perilous. The country has a population of 16 million whose annual growth rate in the past decade has been 2.5%, and is expected to reach about 24 million by the year 2000 A.D. (CBS 1988). In addition to the human population the country also has to support 14 million browsing animals (Joshi 1982).

Population growth, technological interventions, and transportation development resulted in major shift in population redistribution over the past few decades from the hills to the terai. The terai, which was infested with malaria was opened as a new frontier for occupation, once malaria was eradicated. Migration from the hills and other areas caused population concentration in the terai with far reaching consequences in its redistribution and landuse changes (New Era, 1981). The share of terai's population increased from 37.6% of the total population in 1971 to 43.6% in 1981 (CBS 1988).

Similar shift in population have occured in lower mountain valleys and river terraces also. A recent study showed that population in a town at the bank of Marsyangdi river in Central Nepal, along the Kathmandu-Pokhara highway increased by 50% in a ten year period from 1971 to 1981 (New Era, 1989). This change in population shift and a trend towards urban growth is of recent origin and is evident only since 1970s (Mathe, 1987). By 1981, almost 6.3% of the country's population was found residing in 23 urban designated centres and altogether about 18% of the population was living in settlements of over 5000 population (Mathe, 1987). In spite of this urban growth and population concentrations in cities, hill population has continued to grow, though its share has decreased from 62.4% in 1971 to 56.4% in 1981 (CBS, 1988).

ECONOMY AND ENVIRONMENTAL PROBLEMS

Nepal is predominantly an agricultural country with 62% share of agriculture in GDP. Agriculture accounts for 75% total export and absorbs 90% of the labour force (CBS, 1988) This dependence on agriculture and high population growth rate have resulted in one of the highest population density per arable land which stands at 600 persons/sq.km (HMG/DE 1979). With a per capita income of $ 160.00, Nepal occupies its place among the least developed nations in the world.

Past six planned development programmes, that started in 1956/57 have emphasised on creating social and economic infrastructures. But very limited successes have been achieved in increasing national income, and in solving problems of poverty. The country's economic problems also inmate from its location and topography. Basic transport facilities do not exist to channalise benefits of modern development in the predominantly mountainous environment. As such lack of growth in secondary and tertiary economic activities has forced people to adopt more extensive methods of cultivation and grazing (Gurung, 1982).

The pressure of population has resulted in severe degradation of the mountain environment. Trees are being cut to create land for growing food (Bajracharya, 1983) and to meet domestic energy need which accounts for 87% of the country's energy requirements (Joshi, 1982). As a result forest was depleted at a such fast rate that more than half of the forest in 1963 was lost by 1981. The combined effects of marginal cultivation, deforestation and over grazing have thus created serious problems of soil erosion and landslides (Dixit and Shanker, 1985). This in turn has affected hill economy, and damaged development projects like irrigation, hydropower and water supply. Population, growth in hills, and environmental deterioration hence demand greater efforts to tackle the endemic economic problems by input of external resources.

WATER SUPPLY SCENARIO

Water supply systems are needed to provide clean water to the people at convenient places, so that it can be used for beneficial purposes. Till four decades ago, only a small fraction of Nepal's population had access to piped water supply. Drinking water facilities existed only for priviledged elites in the capital and elsewhere. By the end of 1985, however, 23% of the coutry's population had access to piped water supply systems. This accounted for 84% of the urban and 19% of the rural population (NPC, 1985).

In hills, settlement/villages are dispersed and exist on ridge tops and hill sides rather than on more accessible river terraces, valleys and along streams. This practice has been followed to allow maximum use of valleys for food production and to avoid malaria (New Era, 1979). Majority of villages are far from dependable water source, and people especially women, have to walk few hours to fetch water to meet their house-hold needs. Communities are cutoff from mainstream development which has hampered the efforts of providing basic water supply facilities. Although, areas with population concentrations have emerged, after eradication of malaria and transportation development, significant delays have occured in providing even such areas with water supply facilities.

The government of Nepal has accorded a highest priority to provide water to the population as a basic need and as a primary input to improve health. The government plans to supply piped drinking water to 50% of the population in the hills and mountains by 1990 (NPC, 1986).

WATER SUPPLY SYSTEM IN HILLS

Hill water supply system in Nepal mostly use gravity flow technology. This entails utilizing source at higher elevation to supply water to the users. Numerous centralised systems of varying sizes catering to the needs of limited house-hold, which are scattered all over the landscape, have been built. The physical setting of water supply system in hills can be broadly catagorised into two types as (a) Population Concentration Settlement (b) Dispersed Settlement.

Population Concentration Settlement

These settlements on valleys and river terraces, generally have clustered pattern. Higher water sources are available which permit their use by gravity. The regions connected to road head are more accessible. Water supply improvement programmes in these settlements are relatively straight forward and easy, though problems do exist.

Dispersed Settlements

Water supply to dispersed settlements is more difficult and considerably stretches available resources. The characteristics of the settlements are:

- Difficult terrain
- Transportation difficulties
- Large distribution network
- Unsuitable water source
- Poor education level and manpower shortages

Transportation is the biggest problem faced by these communities. Many villages can be reached only after 2 to 3 days walk from road head. This greatly increases the burden and cost of material transportation. Difficult terrain renders handling of materials during construction very difficult, while higher level differences result in more system components/structural elements. And since, settlements are dispersed, large distribution network is needed. In many cases, water sources around the villages are not suitable and sources at greater distances have to be utilized. All these factors result in higher project cost. Many hilly regions have inherent skilled manpower limitations and shortage of personnel to supervise construction of projects. This is one of the reasons why many projects have sub-standard quality.

A water supply system in the hill consists of following components:

<u>Spring Source</u>

Mountains and hills are abundant with spring sources which are free from surface contamination. Springs are regarded by people as synonymous with pure, sweet and tasty drinking water (Campbell, 1973). Spring source, is preferred because it eliminates the need for treatment. But, this is always not possible and other surface water sources also have to be used.

HDP Pipes

High density polythene pipe is used, because metal pipes pose transportation and handling difficulties. The pipes come in coils, have lesser weight, and can be carried on human backs. However, greater caution in design, construction and maintenance is needed because of its vulnerability against higher pressure and vandalism.

Public Tap Stand

Recommended quantity of water is supplied via public tap stand allowing a flow of 0.225 l/s to cater the need of about 200 people. Taps are located such that collecting distance does not exceed 150m.

Local Materials

Emphasis is laid on use of local materials for construction. This eliminates use of external materials that require expensive transportation arrangements.

User's Involvement

Water supply improvement programmes in Nepal emphasise on involving community in all stages of project cycle such as project identification, planning, construction and maintenance. Some portion of the cost is also borne by the users in the form of voluntary labour in portering and during construction. This is expected to induce a sense of belonging, and contribute towards better operation and maintenance of scheme, which is handed over to the community once the construction is completed.

Water supply systems thus built have ameliorated water borne diseases and have brought benefits. However, many of these systems are not functioning as intended. Studies show that between 50 to 70% of the schemes constructed in certain region were not functioning or had major flaws (Schramm and Gurung, 1981), (Ommen, 1982). Problem has arisen with operation and maintenance of completed water systems.

PROBLEM OF HILL WATER SYSTEM

Many water supply systems have flaws and are non-functional because construction quality has been compromised due to some of the constraints as mentioned earlier. Centralised water systems, built at community level, need management skill to ensure uninterrupted water supply. But, the approach of system maintenance involving users has failed to make a head way in many places, because the locals who have been assigned with this duty do not have the skill. Also in many cases, villagers do not regard the system as theirs and regard maintenance as the responsibilities of agencies who construct the project.

Deforestation and continuing environmental degradation are also showing their impact on water supply systems in the hills. Deforestation of watersheds leads to increased runoff, decline in infiltration and drying up of springs (Eckholm, 1976), (Reiger, 1976). Consistent drying up of springs in mountains have reduced water sources to a mere trickle (Mosquera, 1986) and experience of difficulties in supplying water to communities have been noted (Dixit and Shanker, 1985). In many cases, dry weather flow have become so meagre that whole villages are seasonally abandoned (New Era, 1979). Destruction of sources, intakes, and supply lines by landslides have rendered many water projects non-functional. While this has been the case with existing systems, many settlements on hill tops and ridges do not have good spring water sources around because the upper catchment is totally devoid of trees and vegetation. Settlements such as these have serious water supply problems.

Source conflict both among users and between water uses (irrigation vs. water supply) is another reason why many water systems have remained non-operational. Continued encroachment of higher slopes for agricultural purposes can lead to contamination of water sources as the probabilities of men and livestock tampering with water sources become high.

Water supply improvement programmes in hills are influenced by project location, population, its distribution and shifting pattern. The degrading environmental condition in the hill also has its share of influence. These and other shortcomings need careful consideration in all future programs. Much greater efforts should be made to address the identified shortcomings so that all water supply systems become functional on a long term basis. At the same time, newer techniques of providing water, which would be less affected by prevailing problems should be explored.

Rain water storage during wet season and to be used in dry periods is an attractive alternative to drinking water problems.

RAIN WATER CISTERN SYSTEM IN NEPAL

Rain water cistern is not common water supply system in Nepal. It is a new concept though isolated examples of stored rain water uses are found. In ancient time, stone water spouts with a perfected system of filtration, and drainage arrangements, that used water stored in ponds, were built. Such taps still exists in different parts of Kathmandu. Many of these taps could not use river water (Tiwari, 1986) and as such could have stored rain water in ponds. Rain water tank was built in leprosy hospital at Pokhara some twenty years ago and the system is still operational. Most recently, Rain Water Cistern Systems (RWCS) were built at Pokhara and Narayanghat in Central Nepal by American Peace Corp, Nepal. Rain water is also stored in petroleum drums to be used for purposes other than drinking in some areas. Rain water storage had been considered as an option of supplying water to a mountain town, Deilekh, in Western Nepal. The scheme however, was not selected because the cost of creating impervious area was too high (HMG/DWSS, 1975).

Rain Water Cistern System (RWCS), to serve water needs of individual house-hold, can function as primary water supply system in areas where sources are not available, inadequate, contaminated or when gravity flow system become prohibitive from both cost and maintenance considerations. It can also serve as supplementary water system during dry seasons. Rain water cistern is a decentralised system and can be appropriate in the dispersed hilly settlement. Compared to centralised water system, it will have lesser chances of breakdowns , and fewer maintenance needs. The system will be cost effective and allow water users/beneficiaries to take more initiative in solving their drinking water problem. In the following sections preliminary analysis is done to evaluate the use of this system to meet drinking and cooking need of an average Nepali house-hold in the hill.

The main requirements for development of rain water system are:

(a) Adequate good quality rainfall
(b) Suitable catchment, and
(c) Water chanelling and storage method.

In order to evaluate adequacy of rainfall, water demand for the twin purpose needs to be fixed. How much water an average house-hold in Nepal use for its drinking and cooking needs? A typical Nepali family with 10 members uses 18-20 pathi2/ of water in a day (Campbell, 1973). This gives per capita demand of little less than 10 litres. Water consumption per capita as low as 10-15 litres in a day has also been proposed (HMG/DWSS, 1975). Water demand however, depends on a number of factors like social expectation, water source location, climate, and can vary from one place to another. A per capita demand of 10 litres in a day has been taken as the water demand of a typical house-hold, which on average has 6 family members (CBS, 1988). The daily water demand for different demand period are summarised in Table 2.

TABLE 2

Water Demand

Population	Per Capita Demand	Water Demand for			
		One Day	One Month	One Year	Dry Season as per Table 1
No.	Lpcd	cu.m	cu.m	cu.m	cu.m
6	10	0.060	1.8	21.6	10.80

2/ 1 pathi is equivalent to 4.5 litres.

The problem now is to evaluate if this demand can be met by prevailing rainfall, and if a suitable catchment surface is available. Hundred percent rainfall can not be used, as account has to be made for variation, evaporation, cleaning needs of catchment and gutters, and catchment absorption. The proposal for water storage system at Dailekh used 50% as usuable rainfall (HMG/DWSS, 1975) and may be adopted for all regions represented by rainfall stations in Table 1.

The extent and type of catchment area affects the volume and quality of water that can be collected. Metal sheet roof make most efficient water collectors while slate and tile roofs can also be used, but with less priority as chances of contamination is higher. Thatched roof apart from absorbing rain, contaminates it and is not recommended to be used as collector without upgrading (Programme Guide, 1982).

The roof area to be used as catchment surface can be acertained by evaluating housing situation in Nepal. It is reported that 93.6% of house-hold live in their own dwelling (NPC, 1987) which are of three catagories: Permanent3/, Semi-Permanent4/, and Temporary5/. Of these three, the second and third type combined, account for about 80% of the dwelling (NPC, 1987). It is also reported that more than 83.4% of house-hold, falling in second and third catagory, have floor area of 37 sq.m (NPC, 1987). A house in the hill usually has rectangular shape and inclined roof which projects little (about 2 feet) beyond the walls. A minimum roof area of 40 sq.m can be thus considered for majority of the house-hold. The twin needs of drinking and cooking of an average house-hold in a hill can be easily met by collecting even half of the annual rainfall in the roof. However, more surface area will be needed for region where rainfall is scanty. The comparison is shown in Table 3.

The method of chanelling water from catchment, its storage and catchment improvement are details which can be decided when the system is to be built. Half cut high density polythene pipe, and bamboo can be used as chanelling medium. Fabricated metal sheet can also be used, which can be assembled locally in most areas by local blacksmith with little guidance. Water storage tanks, especially using ferro-cement technology are widely used and acceptable water storage methods in gravity flow water systems. It is therefore, feasible to use Rain Water Cistern System (RWCS) in Nepal. But the prevailing social factors and acceptability far more outweigh the available technological options in using this system.

3/ Use lime, brick powder, cement joint, baked brick stone, wood for walls with slates, tile or corrugated sheet roofing.

4/ Use unbaked bricks, wood in walls, but has thatched roof.

5/ Use bamboo and other temporary type construction material and roof made of thatch.

TABLE 3

Water Demand, Usuable Rainfall and Roof Area

Mean Rainfall mm	Usuable Rainfall mm	Demand cu.m		Area sq.m	Volume Available cu.m
		Annual	Dry Season		
1468	734	21.6	10.8	40	29.20
3153	1576.5	"	"	"	62.80
1399	699.5	"	"	"	27.98
1014	507	"	"	"	20.28
1240	620	"	"	"	24.08
248*	124	"	"	124*	21.60

* The rainfall is scanty hence more area is needed for same volume.

SOCIAL ACCEPTIBILITY

The main issue in the use of RWCS in Nepal is not the technical part of its development. The crucial question is, will people accept and use the water thus collected and stored? People in Nepal normally use water from following sources for domestic uses. These are Pond (Pokhari), Open Well (Inar), Puddle Water (Kuwa), Spring (Mul), River (Nadi) and Canal (Kulo). Within these catagories for water sources, the broadest classification of water from its acceptability for human use is still and running water (Campbell, 1973). The second type of water source is considered more acceptable, because of its ritual significance arising out of the concerns with purity and pollution. Running water is considered to wash away all sins. Mostly river, spring, canal or water that is replenished naturally (Open Well) are used for domestic purposes. Still water (Pond), on the other hand, is used for buffalow wallow, irrigation and in some cases washing clothes. Only in rare cases, still water from pond is used for drinking. It is probably out of this concern for running water that villagers in hills have continued to walk hundreds of feet, climbed slopes morning and evening, every day to fetch water from a running source.

This is probably one of the reasons why Rain Water Cistern System has not found acceptance and use in Nepal. Since, water in the system is stored for a long time, people may have reservations in its use for domestic purpose as this water will be still, old and stale. This is the biggest challange facing the use of RWCS in Nepal. The advantages of drinking uncontaminated water in place of polluted source uses, however, should be a motivating factor for ensuring its acceptability. But, people have to be convinced that stored water is drinkable.

CONCLUSIONS

This paper has attempted to present situations of existing water supply systems in Nepal to build up a case for Rain Water Cistern Systems (RWCS).The problems of water supply improvement need closure scrutiny, and revised approaches to make future programmes more effective. Due cognizance should be taken of the need for proper operation and maintenance of existing and new schemes to maximise benefits. Rain Water Cistern System can supplement water needs of people and help improve water supply programmes in Nepal. The system will be suitable for the dispersed settlements in the hills, where centralised gravity water supply scheme have met with difficulties. The rainfall pattern, housing, and storage technology in hills permit the use of this system. The main question is whether water thus stored will be acceptable to the people, who have been using running water and not still water for drinking and cooking.

Agencies involved in water supply improvement programmes in Nepal should explore ways of using this system. This calls for formulations of methodologies at policy level to introduce the system in a much wider scale. Action studies, where such systems have been built, should be carried out to select suitable technology of Rain Water Cistern System development, while focussing on its social implications. Only by understanding the issues, can correct strategies be worked out. The process should be started by developing Rain Water Cistern System in areas having acute water problems. The effectiveness of the programme will be enhanced, if people themselves take initiative in opting for the system.

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Rainwater Harvesting for Potable Water in The Eastern Llanos of Venezuela

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ABSTRACT

Rainwater collection and storage represent a superior alternative to tank truck delivery for supplying the potable water needs of rural schools and health clinics in the Eastern Llanos of Venezuela. The lack of adequate storage facilities and handling methods has limited the use of rainwater in the past. With filtration, a covered tank, a solar-powered submersible pump and simple treatment methods, water quality can be guaranteed even after prolonged storage. The system is highly reliable and requires very little maintenance which is extremely important in the rural setting.

Potable water can be saved by substituting VIP latrines for flush toilets which typically consume around 50% of the available supply and do not stand up well under hard usage. This type of latrine virtually eliminates the problems of flies and odors.

INTRODUCTION

In much of the sparsely populated, Eastern Llanos of Venezuela ground water is difficult to find and well yields are low. Surface water is abundant in a few places, especially toward the south, near the Orinoco river.

The typical village of more than 1000 inhabitants is located near a small stream which provides the municipal water supply. Service is only sporadic as the system is usually poorly-maintained; water quality and quantity are chronic problems. Population on the fringes of the towns and the dispersed rural population rely on tank trucks for water delivery. The water usually receives no treatment. Furthermore, the service is unreliable. For example, trucks frequently break down, roads become impassable in the rainy season, or drivers do not make regular deliveries. Since there is little supervision and consumers lack effective channels to voice complaints,poor service is simply accepted as one more of the numerous disadvantages of rural life.

Contamination from inadequate storage facilities and careless handling are also problems. The most common household tank is an old oil drum, perhaps painted with concrete slurry to reduce rust, and covered with a makeshift, ill-fitting top. Water is usually dipped out.

The lack of a safe and reliable supply of potable water adversely affects the quality of rural life in many ways. To cite one example, teachers and health workers refuse to reside in the zone preferring to commute long distances from larger towns. Absenteeism is accordingly high.

One of the more promising solutions to this problem, rainwater collection and storage, has been largely overlooked. Rainfall in this area is abundant during 6 months of the year. During the rainy season many households collect small amounts of rainwater to supplement other supplies, but there is no effort to store water for the subsequent 6 months of drought.

The basic problem is to devise an economical means of storage which will minimize losses due to evaporation and guarantee water quality. Dams and reservoirs can be ruled out in most cases because there are few suitable sites, the soil tends to be extremely permeable and annual evaporation is in excess of annual rainfall.

GENERAL DESCRIPTION

As part of a pilot project sponsored by the Maraven Oil Company(*) to improve rural education and health care, more than 25 schools and health clinics have been equipped with roof collection and storage systems. The installations, which also provide water to an adjacent residence for the teacher or nurse, are designed to provide an initial flush which channels the first rains to a separate collection tube and drain. The tanks are covered and sealed and rain water from the roof first passes through a coarse filter. Water is pumped to the tap or to an overhead tank by a small, electric pump which is activated by a doorbell-type button. Energy is provided by a solar panel.

Prototype for Rural Schools, "Escuela El Manguito"

Basic system components consist of 1) a 20,000 Lt., galvanized metal tank with a concrete bottom and clean out drain, covered with a conical, metal roof, 2) an elevated plastic tank (optional), 3) a 12 VDC,

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(*) Maraven is one of the three operating affiliates of the national holding company, Petróleos de Venezuela. It is engaged in exploring and evaluating a large area of the Orinoco Heavy Oil Belt, located in the Eastern Llanos.

submersible, bilge pump and 4) one or more photovoltaic panels with associated peripheral equipment and storage battery (see Figure 1).

Potential Supply

The catchment area is defined by the size of the roof. The typical, two-room, rural school has a roof area of about 90 m^2. The potential annual catchment volume is on the order of 80 m^3.

Demand

Around 50% of the water normally consumed by a typical household can be saved by substituting VIP latrines for flush toilets. Another 20% can be saved by eliminating the shower, except in the case where there is an adjacent teacher's residence.

Since, the remainder is used only for drinking, hand and dishwashing, and general clean-up, 4 liters per person per day should suffice. Combining the estimates of monthly catchment and monthly consumption for an average school population of 30, the estimated average monthly volume of water available is listed in Table 1.

Table 1: Predicted End-of-Month Volume, Rainwater Tank "El Manguito"

	(1) mm	(2) Lt.	(3) Lt.	(4) Lt.
August	146	6570	0	6570
September	141	6327	0	12897
October	112	5018	2400	15515
November	48	2160	2400	15275
December	24	1089	1200	15164
January	14	621	2400	13385
February	4	185	2400	11170
March	12	522	2400	9292
April	35	1584	2400	8476
May	84	3784	2400	9860
June	117	5270	2400	12730
July	170	7637	1200	19167

Tank emptied and cleaned during school vacations in August.

(1) Average monthly precipitation.
(2) Roof catchment, 45 m^2, one half of the existing roof.
(3) Average monthly consumption. 30 students, 4 lt/day, during 20 teaching days per month, except holidays.
(4) Balance in the tank, a part of which supplies an adjacent clinic.

The need to also supply water to a nearby health clinic, some 50 meters distant, required the addition of a 500 Lt. overhead tank to which water first was pumped from the main tank and then distributed by gravity flow. The small sump pump filled the overhead tank in

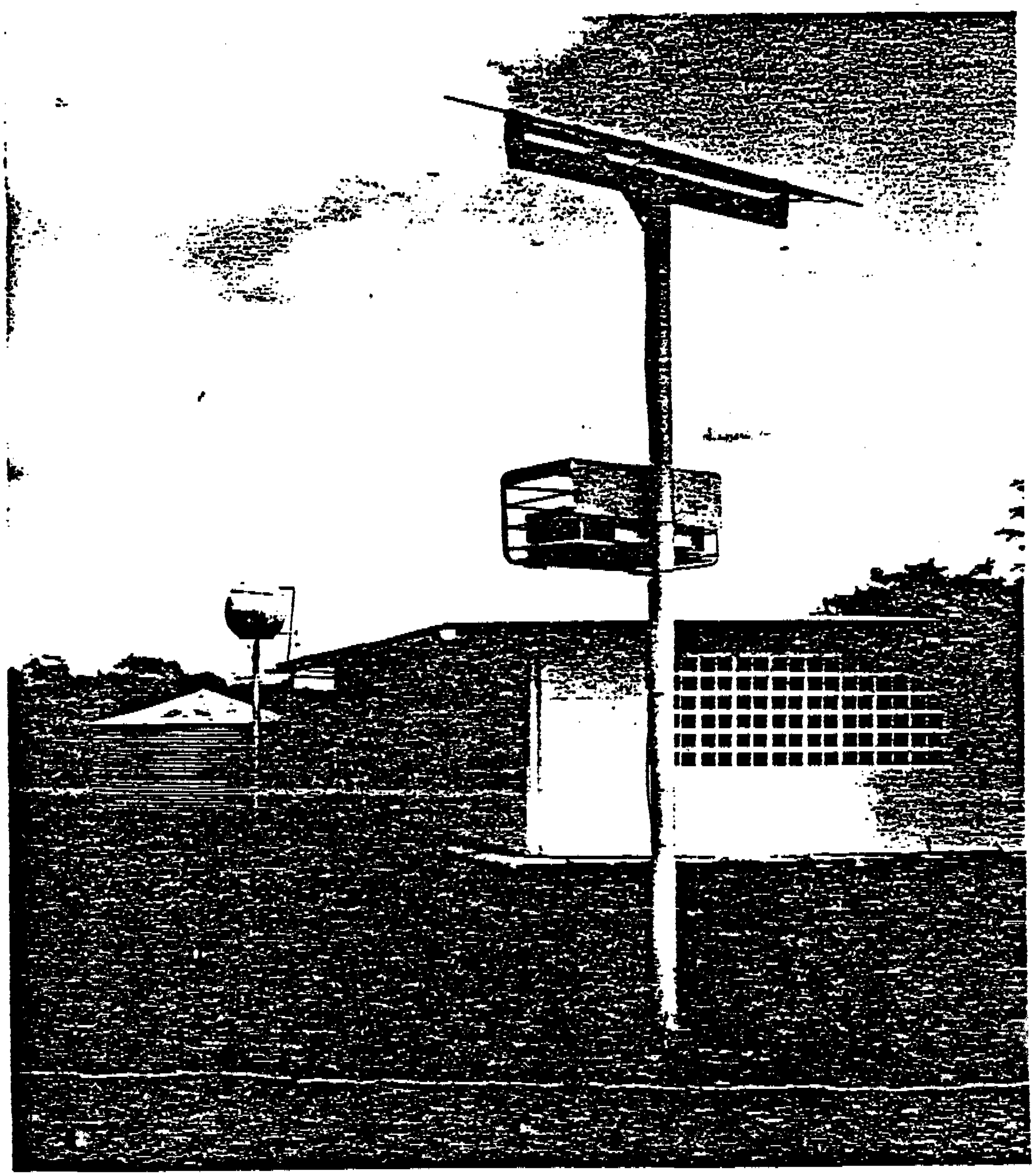


Figure 1. "Escuela El Manguito"

about 10 mins, consuming 2 amphere hours of 12 volt DC current, or 24 watt hours. Since the tank needed to be filled only slightly more often than once per week, the required energy could be easily supplied by one, small, solar panel. The solar plant for the prototype system was designed to have a generating capacity of 800 watts per day, in order to supply energy for lighting, ventilating fans and audio-visual equipment, so the additional energy consumed by the pump was insignificant.

Costs

Ignoring the cost of the solar plant, the installed cost of the tank, with its accessories, in prices updated to January 1988, was around Bs. 45000 or US $ 1500. Assuming a useful life of 25 years and a total production of 1000 m^3 of water, the average cost per Lt. is Bs. 0.045. This is currently less than the subsidized cost of tank truck delivery which runs between Bs. 0.05 and Bs. 0.06 and is expected to rise rapidly in response to general inflation and as budgetary pressures continue to force cut backs in government subsidies.

Health clinic prototype

The system devised for health clinics is basically a scaled-down version of the school prototype designed to supply less water at a reduced cost. A 3000 Lt. plastic tank replaces the 20000 Lt. galvanized tank, and the overhead tank is eliminated permitting the use of a smaller pump (0.05 lps). Water is pumped directly to the tap when the user depresses a button conveniently located beside the wash stand (see Figure 2).

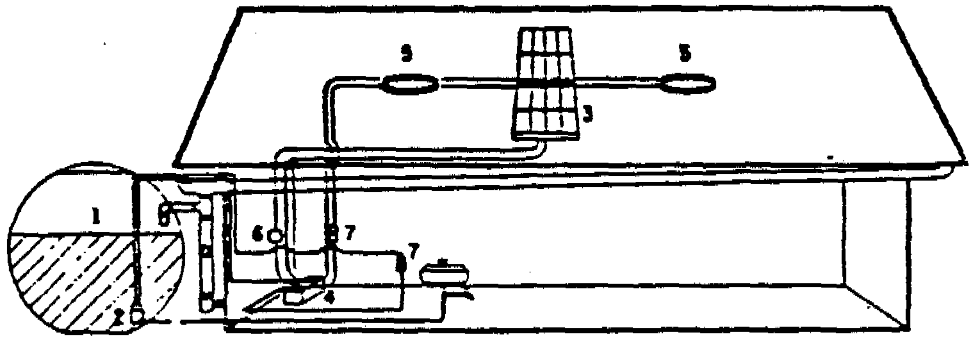
The installed cost of this system, less the electrical plant which is primarily used for lighting, is around Bs. 12000 or US $ 400.

Water quality

From the outset, one of the principal concerns was the possible deterioration in water quality during long periods of storage. Although the rainwater itself was pure, some contaminants could always be washed off the roof. Therefore, the first task was to minimize this potential source of contamination.

This objective was aided by the intense insolation in the area. The temperature of an unshaded, metal roof typically rises to as high as 120 °F during the heat of the day which is sufficient to kill most airborne pathogens (Feachem, 1983).

The second prototype also provides a flush for the roof by channeling the first rainfall to a closed downspout (Figure 3) which can be opened and cleaned out after each rain. A plastic mesh filter was initially placed over the inlet to the tank. This filter is now being replaced by a coarse gravel filter after the unfortunate experience of having thirsty rats tear a hole in the mesh and fall into the tank.



1 PLASTIC TANK
2 SUMP PUMP
3 SOLAR PANEL
4 BATTERY
5 FLUORESCENT LAMPS
6 VOLTAGE REGULATOR
7 CONTROL SWITCHES
8 RUBBER GASKET
9 FLOAT (OPTIONAL)
10 CLEAN OUT VALVE
11 DEPOSIT FOR SEDIMENT

DETAILS OF FIRST FLUSH SYSTEM

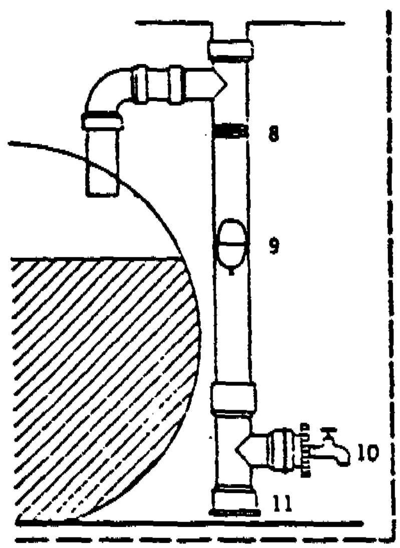


Figure 2 Prototype For Health Clinics

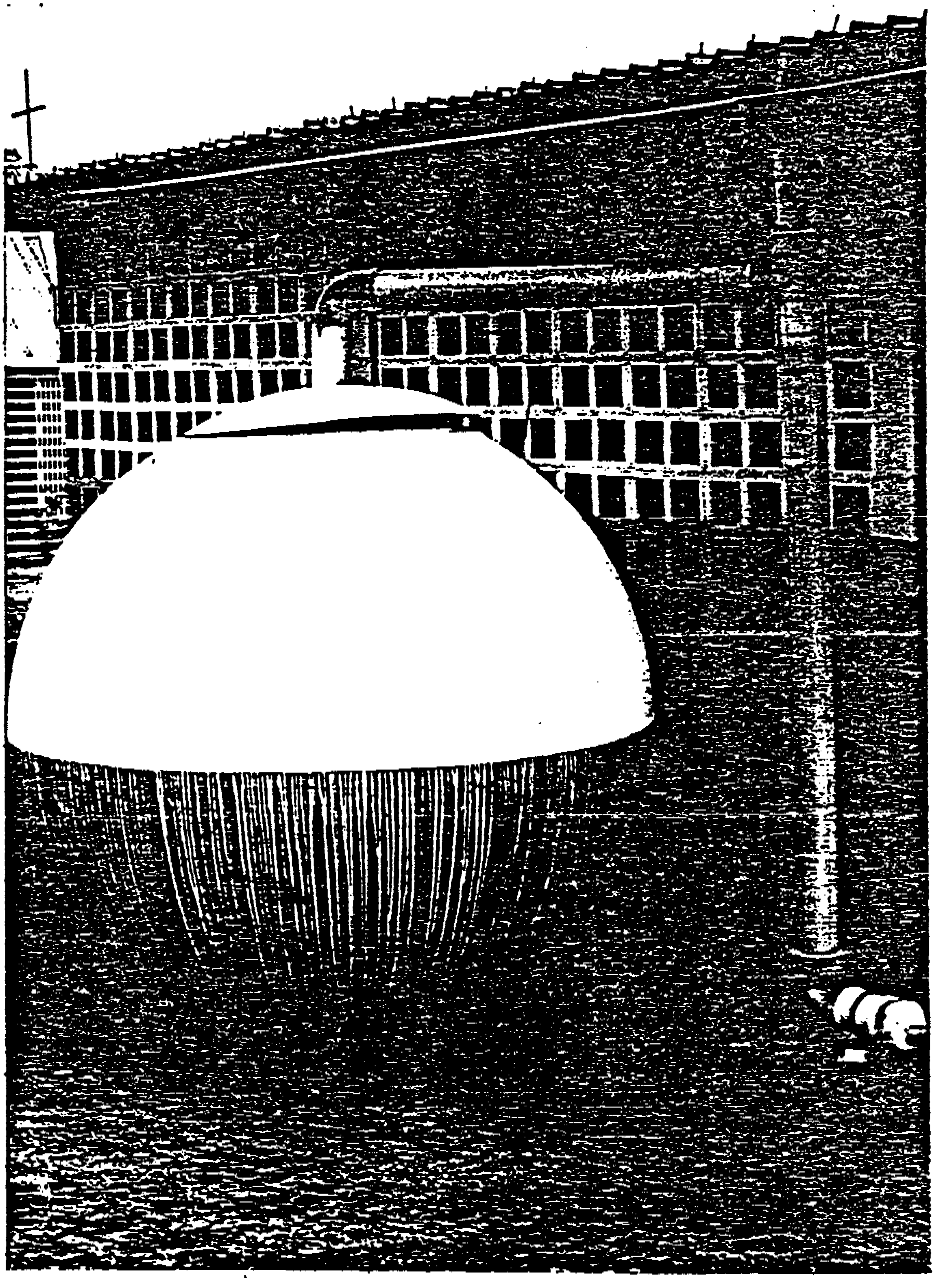


Figure 3. Health Clinic Type Showing "First Flush" System

The principal continuing problem comes from bird droppings on the roof which, from time to time, introduced coliform bacteria into the tanks. Nevertheless, the problem has not been serious and, after an initial chlorination,coupled with an annual clean out, the tanks have remained virtually free of contamination (see Table 2). Probably the few pathogenic organisms which do enter the tank die fairly rapidly in the absence of light and suspended organic material (Pace, 1986).

Table 2: Bacteriological Analysis, Water Tank, Escuela "El Manguito"

Date	Fecal Coliforms Colonies/100 ml	Total Coliforms Colonies/100 ml
October 1984	0	48
November 1984	0	0
February 1985	0	150
November 1985	0	0
January 1986	0	0
March 1986	0	0
June 1986	0	0

As a final precaution, teachers and nurses have been provided with a supply of hypochlorite and a 20 Lt. plastic jug, along with instructions on how to chlorinate. They treat a quantity of water sufficient for the estimated daily consumption and monitor results with a small, residual chlorine tester, of the type commonly available in swimming pool supply houses.

The physico-chemical properties of the rainwater comply with maximum standards set for drinking water in Venezuela (see Table 3). As can be seen, the water is extremely pure with a very low level of dissolved mineral salts, perhaps lower than would be regarded as healthful under ideal conditions. Nevertheless, this low salt content is typical of the rivers of the zone from which virtually all drinking water has been drawn in the past and there is no evidence that this has caused any unusual health problems.

Table 3: Physico-Chemical Analysis

	MAX. LIMIT	RAINWATER EL MANGUITO (MG/LT.)	RIO TERECAY*
HARDNESS	300	3.0	2.0
ALCALINITY	400	13.1	9.0
IRON (Fe^{+++})	0.3	0.0	0.7
CALCIUM (Ca^{++})	.75	0.8	0.4
MAGNESIUM (M_g^{++})	30	0.2	0.2
CHLORIDE	250	7.1	6.4
BICARBONATE (HCO_3)	100	16.0	11.0
SULFATE (SO_4)	250	1.1	3.0
SILICA (SiO_2)	50	0.0	6.0
TURBIDITY	15 units	1.9	
pH		6.5 - 8.5	6.75

* A typical small river in the zone which supplies drinking water to the District Capital.

EXPERIMENTAL SYSTEMS

It is theoretically possible to reduce the cost of storage tanks by 30% to 40% using polyethylene bags. However, such tanks are highly vulnerable to puncturing and sun damage and therefore require special care and handling.

A prototype tank with a storage capacity of 7000 Lt. was installed in a shallow trench adjacent to a house near "El Manguito" school. The tank was left uncovered for demonstration purposes and within the first 3 months it developed a series of small leaks, probably caused by animals and children. The material, with a thickness of 400 microns, appeared tough and resistent, but in practice it did not stand up well under field conditions. Furthermore, polyethylene has the characteristic of being almost totally inert which is desirable for water storage, but it is extremely difficult to repair under field conditions, there being no known adhesive.

Otherwise, the system performed well and was quite economical. If the problems of protection and repair can be solved the system appears promising for large-scale distribution to rural households.

Another alternative, small catchment basins with 500 m^3 to 1000 m^3 capacity, lined with plastic, and covered with a floating plastic membrane to reduce evaporation, is currently being evaluated. A 700 m^3 prototype has been installed with a hand pump and peripheral fence, to serve a small community (Mata Palo), consisting of around 20 houses. Filling of the storage pond will begin with the onset of the next rainy season in May, 1988.

CONCLUSIONS AND RECOMMENDATIONS

The rapid urbanization and modernization of Venezuela during the last two decades has left pockets of rural poverty, including much of the Eastern Llanos where vital public services such as education, health care and the supply of drinking water have been allowed to deterioriate adding to the already strong pressures to migrate to overcrowded cities. Modern technology has displaced traditional solutions to basic problems creating a dependance on external agencies over which the local inhabitants exercise little control.

For rural schools and health clinics, collection and storage of rainwater under hygienic conditions is technologically feasible, economically competitive and has the added advantage of restoring a measure of local control over the supply of this essential resource. Therefore, these systems should figure prominantly in present governmental plans to revitalize rural areas.

ACKNOWLEDGEMENTS

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SYSTEMS DESIGNS

OF

RAIN WATER

THE CITY OF RAIN:
The architecture of rainwater collection in Singapore

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ABSTRACT

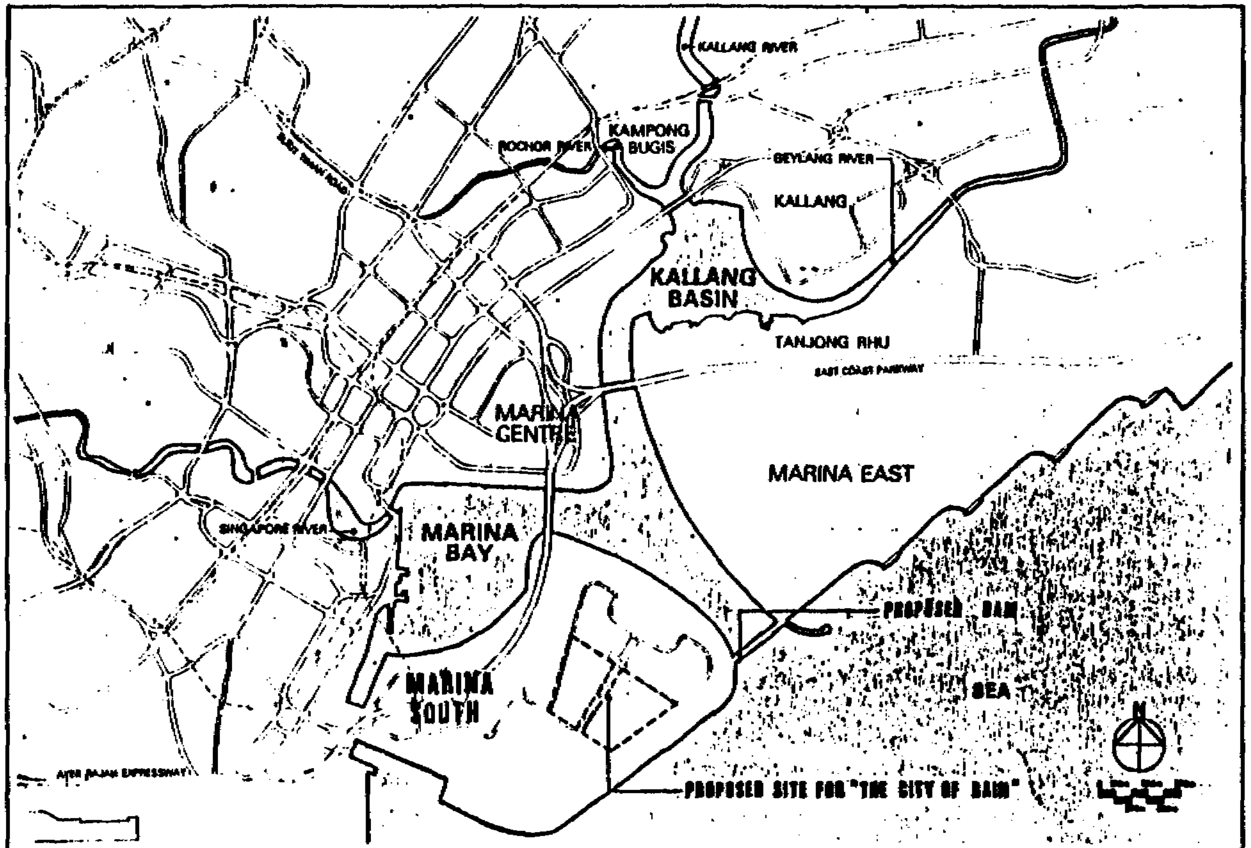
In Singapore where land area is limited, there is a need for more effective water conservation techniques and unconventional approaches to rainwater harvesting. This paper outlines the potential of rainwater collection in built-up areas through architectural design; involving a rethinking of conventional practises in site planning, building forms and building details. The instrument for these explorations was a proposed "City of Rain", conceived in June 1988, sited at Marina South. In this city, collected rainwater became an alternative water supply which was proposed to be used to supplement the utilitarian needs of the city and in the creation of new amenities for the community. The aesthetic effects evolved from rainwater collection, the new amenities and other possibilities could foster a unique urban character in Singapore.

INTRODUCTION

The island-nation of Singapore, located 1 19 N of the equator in a humid tropical zone, has utilized half of its land area for water catchment and has developed practically all its major surface water sources. However, to meet the water demands of a population of 2.6 million confined to an area of 570.4 square kilometres, additional water supplies have to be purchased from the neighbouring Malaysian state of Johore. With the dual concerns of the projected supply capacity being exceeded before the year 2000 and the increasing cost of water production (PETIR, 1987), there would be a need for more effective water conservation techniques and unconventional approaches to water collection and storage. In Singapore rain falls every month of the year; modified by marine and monsoonal influences, and with an average annual rainfall of 2367mm a potential area for more effective measures would be built-up areas which took up the other half or 53% of land area. Although some have been sited within the water catchment; built-up areas in Singapore, but for a few buildings, had been and remained dormant towards rainwater harvesting. The architectural design potential for more effective rainwater collection and storage involving a rethinking of conventional practises in site planning, building forms and building details were therefore explored in the proposed "City of Rain".

PROPOSED SITE FOR THE "CITY OF RAIN"

The proposed "City of Rain" was illustrated through an architectural project on a 23 hectares site at Marina South, Singapore. The land in Marina South, reserved for a city of the future, was reclaimed from the sea at the confluence of 4 rivers and a proposal had been made to dam the river basin and turn it into a fresh water lake (fig. 1). This proposal is testimony to the vital importance of water to this nation. Surrounded by this lake and the sea the setting would be ideal for the "City of Rain". This city was proposed to house mainly a residential population mixed with some commercial outlets and offices.



MARINA BAY AND KALLANG BASIN
LOCATION PLAN

fig. 1

The study of artefacts for rainwater collection revealed 3 primary models. They were the "FUNNEL", the "HAT" and the "DISH". These models dictated the pattern for rainwater collection at the centre, the periphery and the surface respectively. Synthesized and abstracted in architectonic terms as defined by Suzuki and Maeda (1981) for spatial images of water, the "FUNNEL" corresponded to spatial unity, the "HAT" to spatial limitation and the "DISH" to spatial direction. In other words the element of water would constitute the "heart of a composition", a " frame for a composition" and "a spine" respectively (Campbell, 1978). These were expressed diagrammatically as shown in figure 2. These images thus formed the conceptual design models for the "City of Rain" through which an underlying order was given for the articulation of the land and buildings in order to harvest the rain more effectively (fig. 3).

THE PLAN FOR THE "CITY OF RAIN"

The plan for the "City of Rain" was proposed to be composed of two "HATS" divided by an axis created between two monuments. Two long "DISHES" housing social, educational, recreational and commercial retail activities on opposite sides along the axis formed the market place gallery. The market place was proposed to be covered to serve as a sheltered public town square. Beyond the "DISHES" were the "FUNNELS" and they formed the residential neighbourhoods (fig. 4 & 5).

The plan essentially divided the city into sectors for localized rainwater collection and storage. It was proposed that each sector would have its own storage cistern located within its distinctively shaped court and that the focal point of each court would be a water landscape feature (fig. 6). Storage cisterns were proposed to be fed with rainwater collected from the roofs of buildings and paved surfaces within each sector. It was also proposed that the entire city be seated on a concrete plateau

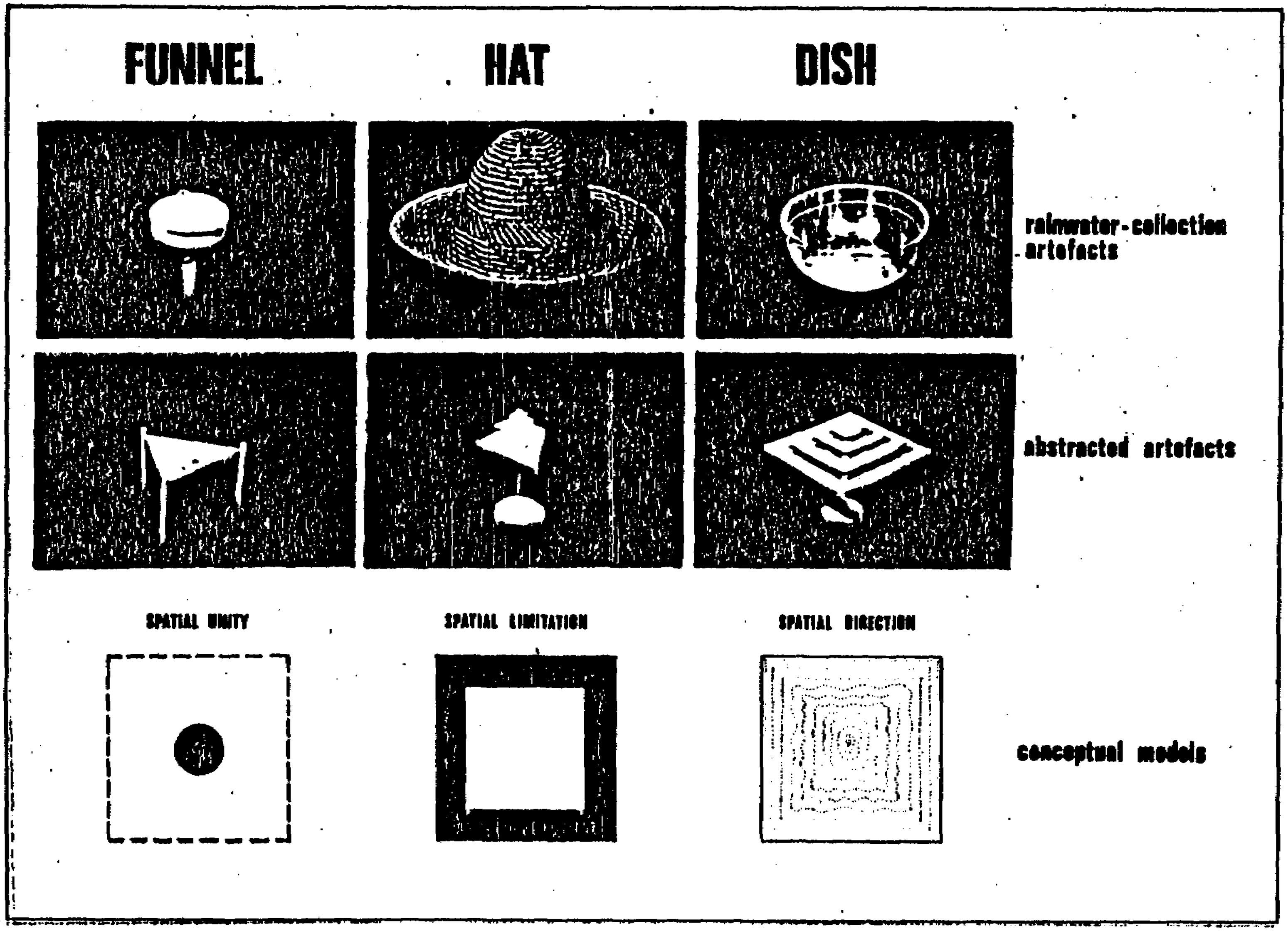
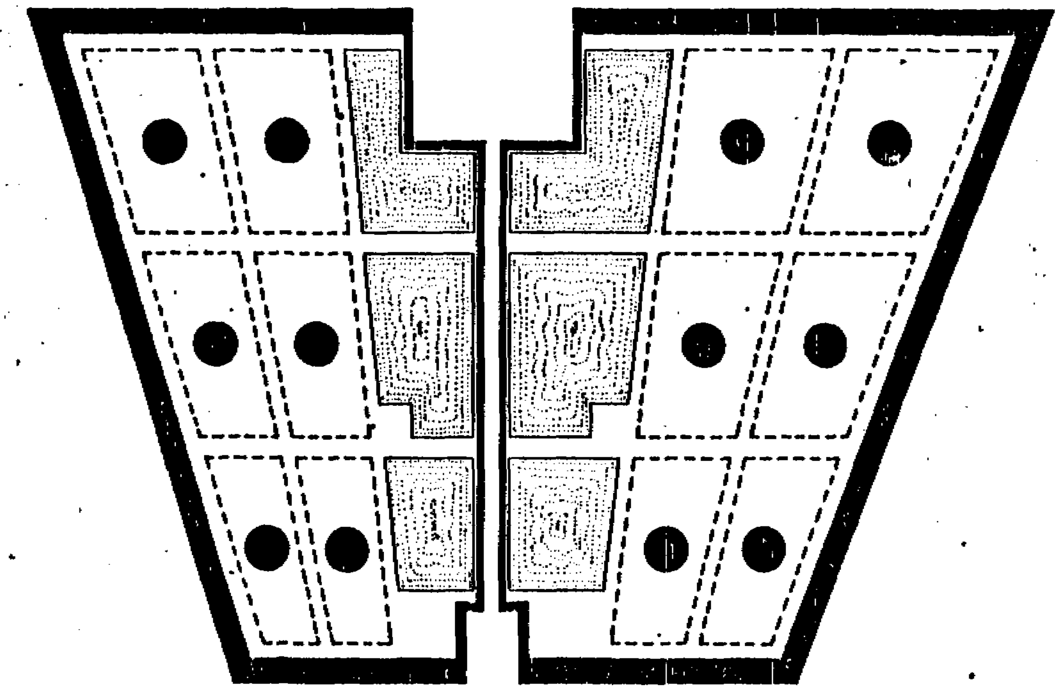

FUNNEL
HAT
DISH
rainwater-collection artefacts
abstracted artefacts
SPATIAL UNITY
SPATIAL LIMITATION
SPATIAL DIRECTION
conceptual models

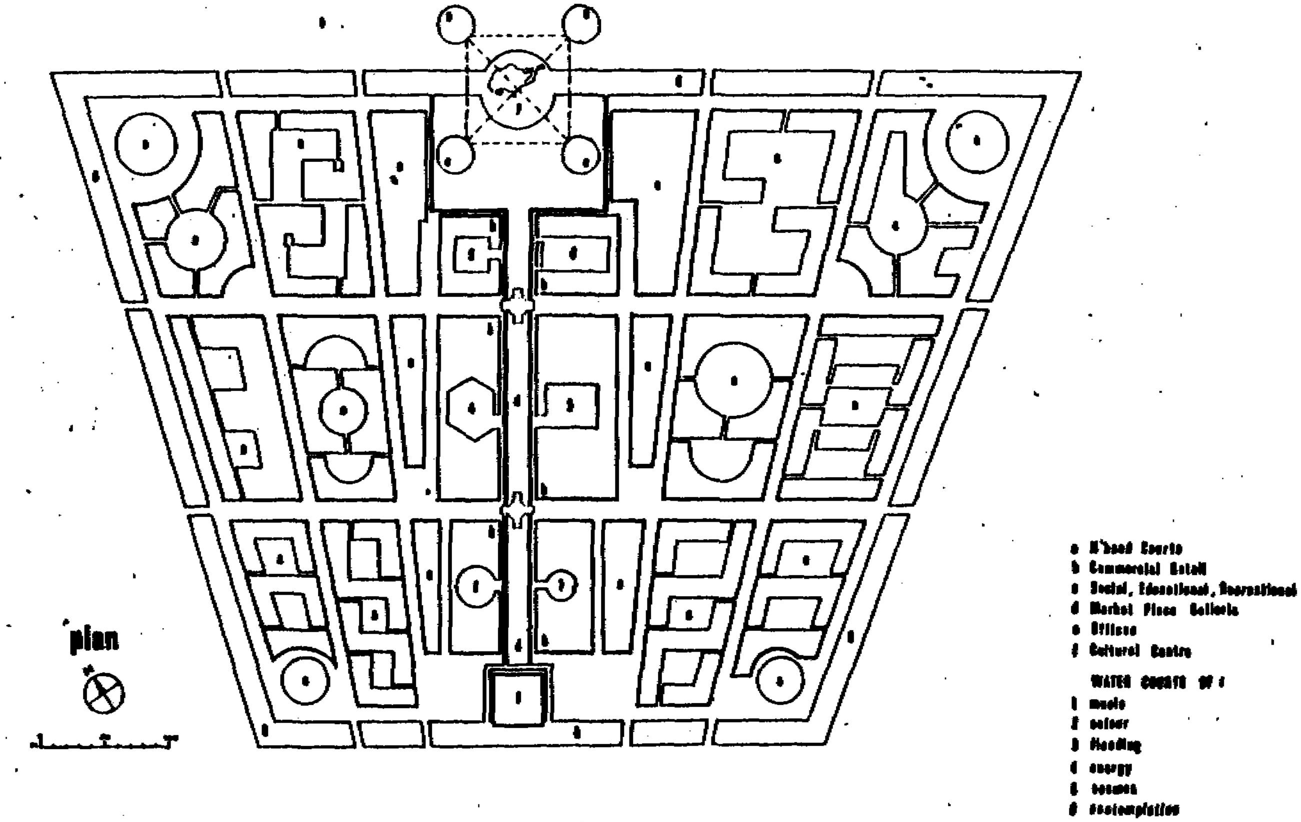
fig. 2

RAINWATER COLLECTION AS DESIGN GENERATOR

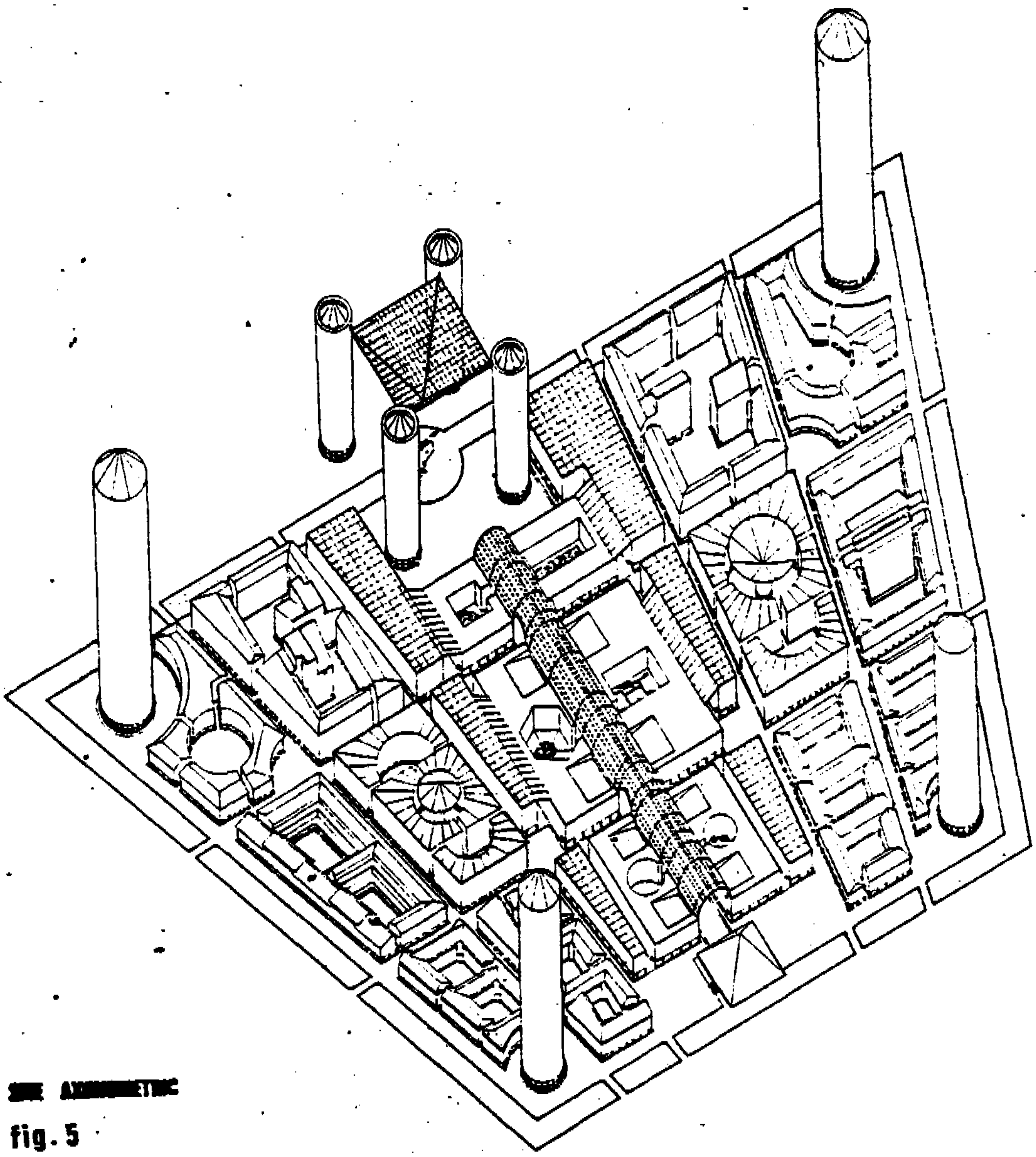


City of RAIN
conceptual model

fig. 3

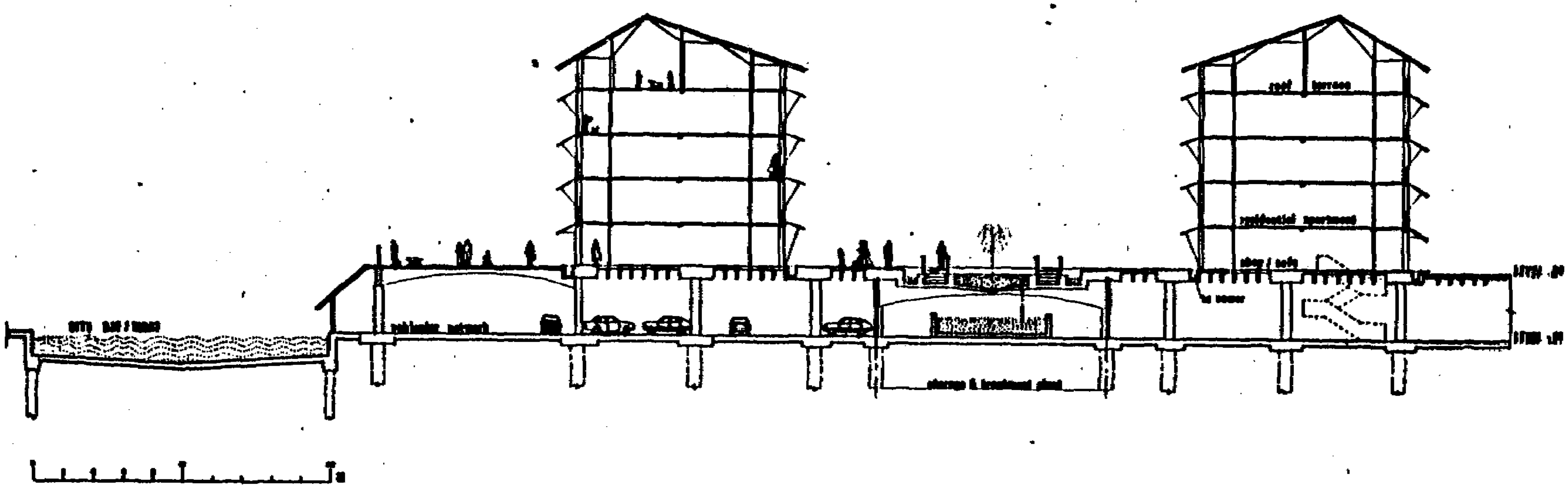


urban facility layout
fig. 4



SITE AXONOMETRIC

fig. 5



Typical Neighbourhood Section

fig. 6

raised above the ground so that vehicular traffic and car-parking within this city were confined beneath the plateau. This liberated more area for buildings and pedestrians and enabled an attempt at reducing vehicular pollution over the city in an effort to collect rainwater of a higher quality. Storm runoff from the pedestrianised streets and areas outside the sector catchments were then reclaimed by a moat which defined the outer edges of the city.

PROPOSED USES OF RAINWATER

It was proposed that collected rainwater would not only go to serve the non-potable needs of the city, such as toilet flushing, but also to facilitate the creation of new amenities for the community such as water landscape features. Although such features had its origins in drier lands (Campbell, 1978) they could give aesthetic character and ambience to the urban spaces in the "City of Rain". Fountains and decorative pools could provide the visual, aural and tactile pleasures of water as exemplified in the fountains of Villa d'Este at Tivoli, and like the Dharas (public baths) of Nepal they could also become the attraction and focus for social interaction and communal living. Fountains using harnessed rainwater in the "City of Rain" were proposed to be activated only in the event of rainfall to dramatize and heighten the experiential phenomena of tropical rain. Collected rainwater was further proposed as a source of water supply for air-conditioning cooling towers as well as a cooling agent to the external surfaces of buildings with the intent of modifying their internal environment. These aspects of rainwater usage will be discussed in the following section.

THE "RAIN MONUMENT"

The building design aspects of increasing roof catchment area and the uses of rainwater were explored in the proposed "Rain Monument". The monument comprised four high-rise office buildings supporting an inverted pyramidal parasol (fig. 7). It was proposed that the four towers were bridged across diagonally by viewing galleries above which overlooked the suspended "funnel". The "funnel" was intended not only to collect rainwater and provide shade for the plaza below but also to create an aesthetic effect of a waterfall of monumental proportions. The climax of this waterfall display at the plaza would see a spray of water over a scaled model of the City within a catchment reservoir. The evolution of the design of the "Rain Monument" was a deliberate attempt to evolve a symbol for the city: one that would connote and forward the spirit of an Architecture that attempts to exhibit and celebrate a sense of the place of Climate, in this case Rain.

Water that flowed through the "funnel" was contributed by rain as well as hot water discharged from the air-conditioning systems of the four office towers. It was proposed that the "funnel" would become the central cooling tower for the four air-conditioning systems and displace the installation of separated conventional cooling towers. It was conjectured that the cooling tower would operate in similar principle to that of the hyperbolic-paraboloid cooling towers of nuclear reactors. Water collected at the reservoir would then be recycled to cool the chillers of each air-conditioning system within the four towers before returning to the "funnel". It was proposed as a self-contained, perhaps self-sufficient, system which collected rainwater to replenish itself. Perhaps through the use of sensors inside and outside the building, the entire cooling system could be regulated by 'intelligent' automated systems to maintain its efficiency. Could the fabric of the "funnel" not also embody solar energy collection devices or serve as a satellite communication dish? Could the "Rain Monument" then also be an archetype for a highly technological-intelligent tropical building? Perhaps cooling towers may neither be part of 'hidden mechanics' nor displayed merely as 'functioning organs' but instead take the stage of 'art' in the formal composition of a building's design as illustrated in the "Rain Monument". To further exploit the rainwater harvesting potential of the "Rain Monument" it was assumed that the facades of the towers could also contribute towards rainwater collection by virtue of their greater surface area compared to that of the

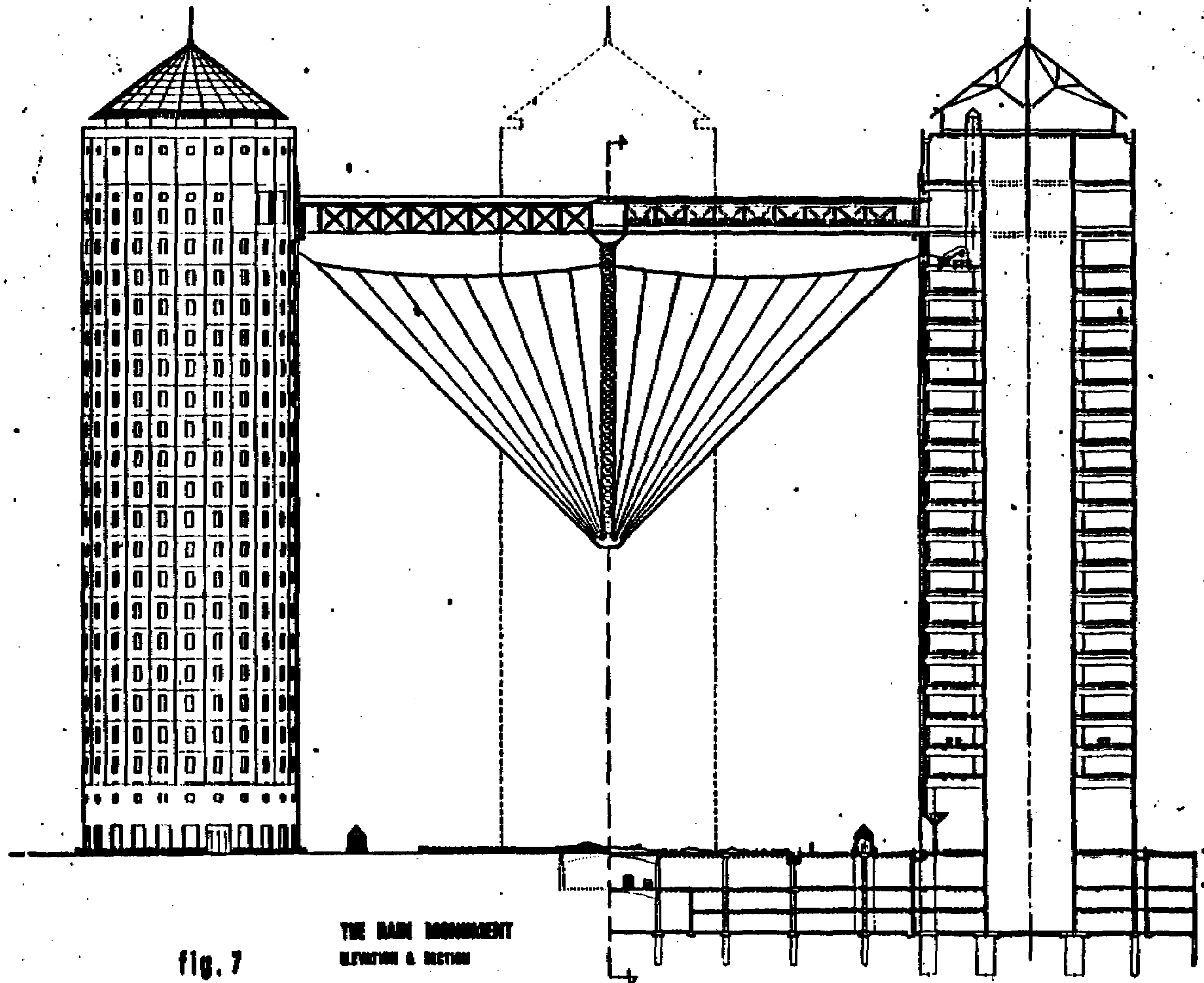


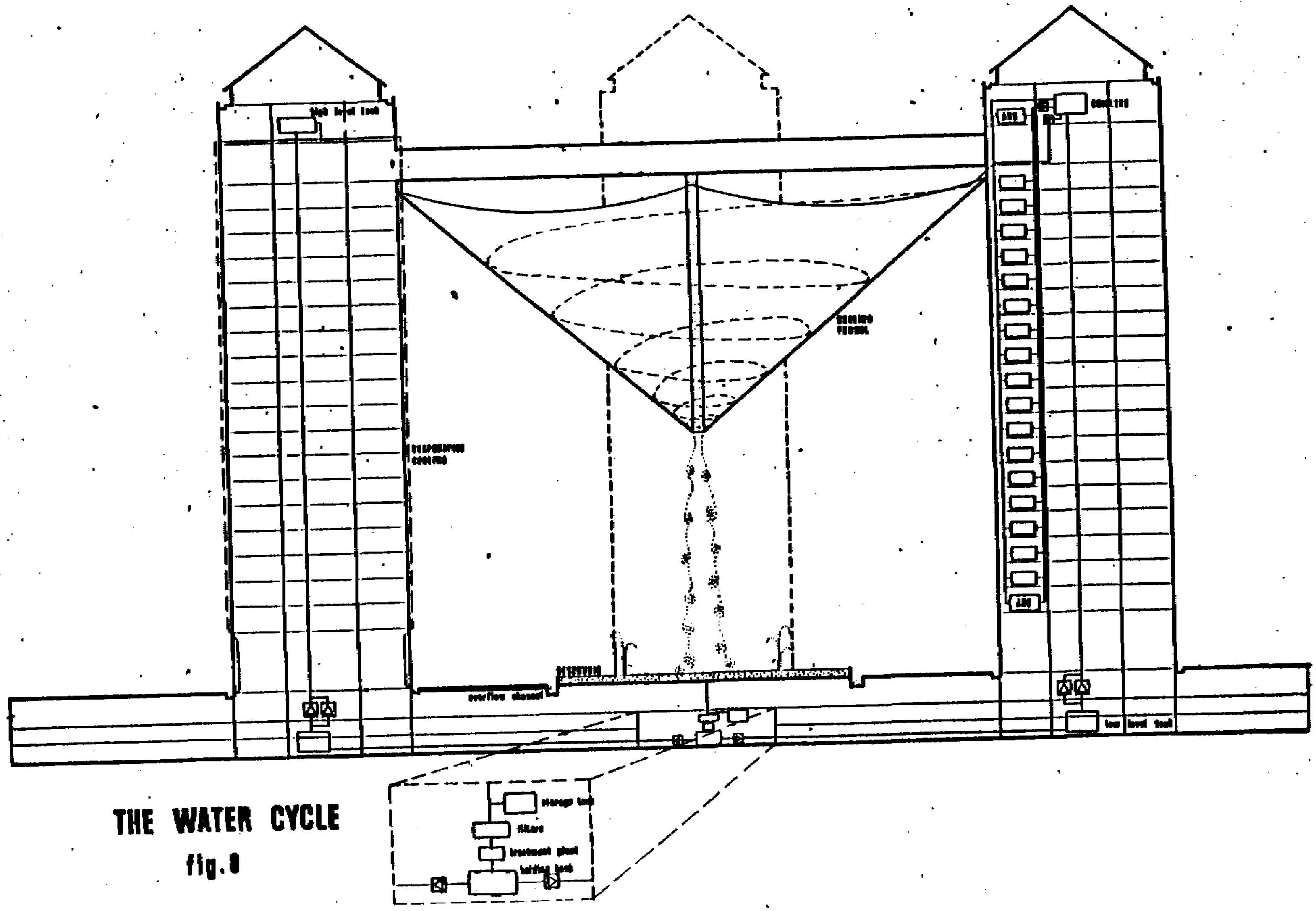
fig. 7

THE RAIN MONUMENT
ELEVATION & SECTION

roofs. The proposed external finishes to the facades of the four towers in the "Rain Monument" therefore attempted to simulate the 'sponge' enabling them to absorb and collect rainwater. It was also proposed that in the event of a hot day heat sensors would trigger off a release of collected rainwater into the 'sponges' with the intent of stabilizing their surface temperatures through evaporative cooling. This use of rainwater as a cooling agent for the buildings to 'perspire' was to avert the building up of surface temperatures which would either impose a greater cooling load on the buildings' air-conditioning systems or require heat insulators to be incorporated into the design of the walls. Laboratory tests have indicated a decrease of 25-30% in air-conditioning power consumption for opaque exposed walls that had received a continuous sprinkling of water over its surfaces (Rao, 1989). To achieve the desired performance of a 'sponge' for the external finishes, a loosely mixed composite consisting of cement mortar and exfoliated vermiculite granules was proposed. This finishing material was proposed to be applied with water-proof adhesives over precasted concrete wall panels. These panels were detailed at their horizontal joints to incorporate a duct for collecting water running over and through its surfaces, and a water sprinkler pipe. These devices were continued with water downpipes and sprinkler feed pipes respectively at alternate vertical joints of the panels. Rainwater collected on the roofs and through the vertical surfaces of the four towers including the excess water used for evaporative cooling were proposed then to be channeled into the reservoir at the plaza and recirculated as a cooling agent (fig. 8).

CONCLUSION

The proposed "City of Rain" served to demonstrate the objective of exploiting architectural design to explore the possibility of harvesting the abundant rainfall more effectively for built-up areas in Singapore. The rainwater harvesting potential of built-up areas could be enhanced with increased roof and surface catchment areas combined with localized storage systems. In the process of the exploration the project also searched for potential uses of collected rainwater not only to supple-



THE WATER CYCLE

fig.8

K LIM CHIOW TECK

ment the utilitarian needs of th[illegible] to create a unique aesthetic dimension [illegible] the proposed "City of Rain" was evolved on undeveloped land, its ideas could be adopted into existing built-up areas through the process of urban renewal. Thus with the incorporation of a supplementary source of water supply to complement the existing municipal supply, Singapore could perhaps defer the development of new sources of water and also reduce her dependency on imported water.

As design tools for the project the "Dish", the "Hat" and the "Funnel" had generated ideas for site planning, building forms and details. Although these models suggested the functional role of the design concepts underlying the "City of Rain", they could in the process establish a formal aesthetic statement for its architecture as exemplified in the design of the residential neighbourhood courts and in particular the "Rain Monument". As the symbol for the "City of Rain", the "Rain Monument" is an architectural statement towards the making of an Architecture that Singapore could call her own. It's concept could be incorporated into her buildings independent and beyond whatever stylistic inclinations in architecture that may prevail. It could however also provide an alternative to an architecture devoid of local expression whose roots and principles are alien to our context, and perhaps instill an architectural identity and character that could be unique and indicative of Singapore. This project therefore hopes to touch upon the possibility of an evolution of architectural principles, through the technology of rainwater collection systems, that may be better suited to Singapore. What further implications the ideas proposed in this project would have on the potential uses of rainwater, architectural design, policies and others are currently being researched.

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RAIN WATER CISTERN SYSTEMS IN NORTHEAST BRAZIL AND NORTH YEMEN

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ABSTRACT

This paper deals with the situation and comparison of the tropical rain water cistern systems in Northeast Brazil and North Yemen (Yemen Arab Republic), both of which are located in the tropical arid or semi-arid regions.

Northeast Brazil (NORDESTE) consists of 8 states of Bahia, Sergipe, Alagoas, Pernambuco, Paraiba, Rio Grande do Norte, Ceará and Piauí. The writer surveys on natural environments of all states of NORDESTE and Santana do Ipanema located 170 km. to the west of Maseio, the capital of state of Alagoas. Rain water cistern in Santana do Ipanema in NORDESTE have three types in a village shown in Figs. 3, 4 and 5. All these cisterns have roofs and water is in a better sanitary condition for human health, because it does not contain polluted water contaminated by human and domestic animal, but the water causes fragile teeth.

On the contrary, all the rain water cistern located in the vicinity of San'a, the capital of North Yemen, are located in the lower part of the villages and constructed by digging ground surfaces and some are in underground area only. They are all without roofs and take in water polluted by people and domestic animals. Consequently, foreigners visiting there cannot drink cistern water.

There are many types in tropical rain water cisterns in the world. We need to compare and examine these types and to select the best cistern type from the viewpoint of sanitation.

I. INTRODUCTION

It is one of the most urgent problems to make certain the water resources for drinking water for the people of tropical dry lands. Therefore, they have fried to do the best to obtain the water resources since old ages.

To get drinking water,the following methods have been used since old ages:1) drinking water residential areas and their surroundings has been obtained by means of digging wells and building dams across rivers, and 2)drinking water has been trnsported by conduits.

Whether drinking water in obtained effectively and cheeply in the residential areas and their surroundings or not is one of the greatest problems in the areas of difficulties to get drinking water by geomorphological and hydrogeological conditions.

There are many different types of rain water cisterns in the world. Isolated islands in southern Japan such as Nii-Jima and Miyake-Jima of Izu Islands also have rain water cisterns.

In this paper, the writer would like to consider the tropical cistern systems in Northeast Brazil and North Yemen (Yemen Arab Republic).

II. RAIN WATER CISTERN TYPES IN NORTHEAST BRAZIL

1. General Tendencies of Water Resources in Northeast Brazil

Tere are vast semi-arid region located to the inland of the Brazilian Northeast (Nordeste). The region called sertão is subject to frequent drought with various cycles of years. As a result, Sertanejos (inhabitants in the Sertão)have frequently suffered from the great famines and a large number of inhabitants have flowed out every lean year from Nordeste to the great urban areas such as Recife, Salvador, Rio de Janeiro and São Paulo. This calamity area is called poligono das secas (drought poligon) and is under jurusdiction of SUDENE (Superintendency for the Developent of Notheast)(Fig.1).The great Northeastern Region-under jurisdiction of SUDENE- comprises 1,600,000km², a fifth of area of Brazil. A large semi-arid region - called the Sertão for the most part-within Nordeste comprises 940,000 km².

Rainfall amount is less than 1,000 mm annualy in the semi-arid region and the area with annual rainfall of less than 650 mm. are distributed in the northan of the state of Rio Grande do Norte, larger part of the state of Paraiba and western part of the state of Pernambuco. The area of less 500 mm. annual rainfall are distributed in the western part of Borborema Highland and the middle lower part of the Rio Sanfrancisco. The small area of less than 400 mm. are scattered here and there. All of these areas are the typical semi-arid regions. Santana do Ipanema of the state of Alagoas located in Sertão and is very near to the middle lower part of the Rio Sanfrancisco.

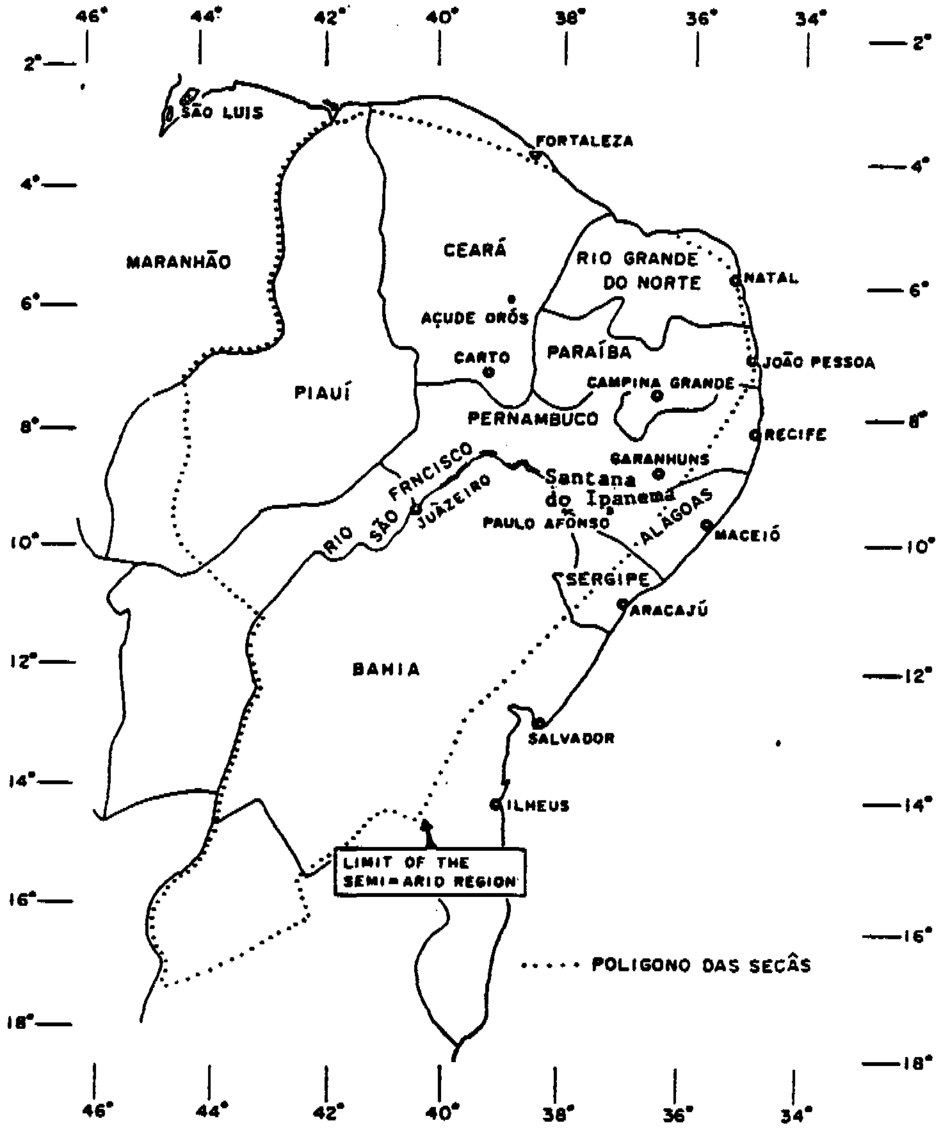


Fig.1. Area of the Brazilian Northeast (NORDESTE).

The Sertão receives a small amout of rainfall which is not dependable because of its irregularity. Dry season is from July to December usually, and August and September are the most dry months. Rainfall variability is very high in the Sertão, for example, some years have no rain and occasionally rain does not fall continouslly throughout 2 or 3 years. These years extremely droughty, so that the people in the Sertão have to look for water by means of digging dry river floors and many people flow out from the Sertão to urban areas to get food and habitat. Many of these migrated people have formed slums (favelas in Portuguese) in these urban areas.

Water is the most importnt and critical resource for Sertanejos living in the semi-arid region in Nordeste. Food production also restricted frequently by the occurreces of warter. The writer carried out a field research on the semi-arid region of Nordeste during the period of 2 months from December of 1966 to January of 1967, and particularly he tried to carify the occurrence of water including use of rain water cisterns(M. Ichikawa and Sh, Yamamoto, 1972).

2.Aspect of Groudwater and Its Use

The larger part of Nordeste consists of Pre-Cambrian crystalline rocks such as granites, mica-schists, migmatites and pegmatites. Sedimentary rocks composed of Cretaceous sandstones and shales are distributed in the southern part of the state of Ceará,northan part of state of Rio Grade do Norte, a part of the state of Pernambuco and eastern part of state of Bahia (Fig. 2).

There are no aquifers in the crystalline rocks,then the occurrence of groundwater seems to be very limited from the viewpoint of hydrogeology. Groundwater occurring in the crystalline rocks is fissure water only.

Because of high mineral contents, groundwater in Nordeste is not suitable for persons and domestic animals to drink and for crops to irrigate. Although chemical qualities of groundwater vary with the types of rock in which it occurs, particulary the fissure water in the crystalline rocks is highly mineralized. Therefore, we could not drink natural groundwater even in the magnificent hotels in Brazil. However, potableness range of Sertanejos is much larger than any other places in the world (W.D.Cost, 1965).

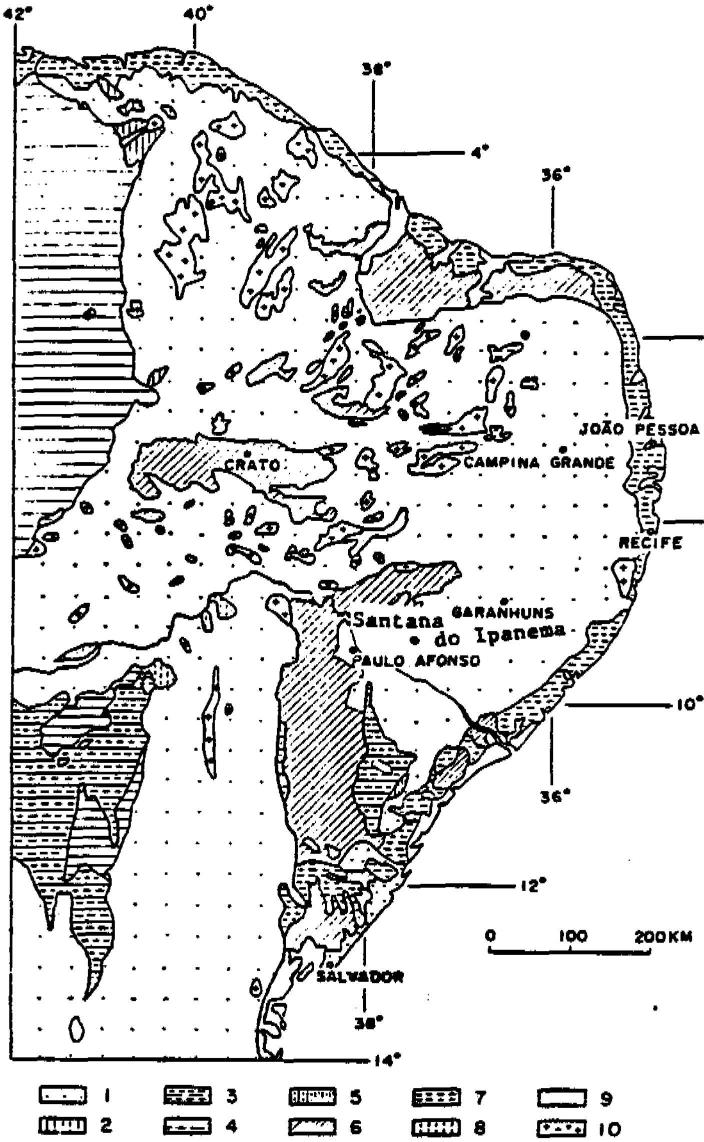


Fig. 2. Geological map of the Brazilian Northeast.

1: Pre-Cambrian crystalline rocks. 2: Cambrian rocks. 3: Silurian formation. 4: Devonian formation. 5: Permian formation. 6: Cretaceous formation. 7: Tertiary formation. 8: Diluvium. 9: Alluvium. 10: Granite.

CONESP (Companhia Nodestina de Sondagens e Perfurações) has made efforts to develop groundwater by drilling into the crystalline rocks. Nevertheless it seems quite pessimistic for the people there to get enough fresh water because of high salinity and small quantities of groundwater yield. We cannot rely on the wells drilled in the crystalline rocks of this area for any purpose but for domestic and, some cases, grazing needs. However, the potableness range is much larger here than in any other places in the world, then inhabitants in the

Sertão must take highly mineralized water daily (E.W.Duarte,1965).

Standards of water qualities for drinking for Sertanejos in the crystalline rock areas are shown in table 1 (W.D.Cost, 1965). This table shows the water containing CL of 0-177 ppm is good and of 355-720 ppm is medium for drinking in the Sertão. It is surprising to see that Sertanejos can drink highly saline water.

Table i. Standard of drinking water for Sertanejos in Noedeste.

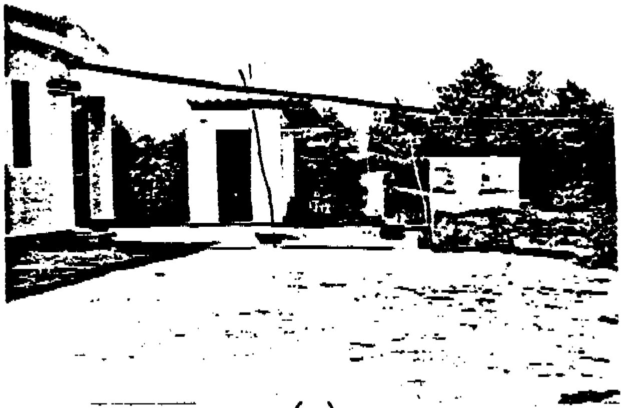
Name of reserv.	State	Hard-ness	Cl (ppm)	HCO_3 (ppm)	SO_4 (ppm)	Ca (ppm)	Mg (ppm)	Na (ppm)
Soledade	Paraiba	320	435	130	15			
São Gonçalo	"	?	370	256	4	119	80	98
Mâe	"	?	400	390	102	254	77	152
Pesqucira	Pernambuco	275	620	220	?			
Bezerro*	Pernambuco	68	38	30	0			

* Good for driking it through a filter. (After COST,W.D.,1965)

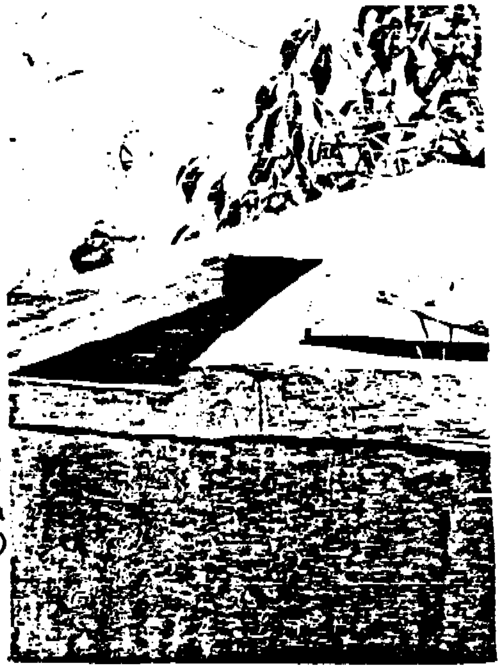
3. Use of Rain Water

The surface water and groundwater in the Sertão are not available for potableness on account of quantitative and qualitative restriction, therefore with the assistance of water cisterns in many places, the water has been used for drinking. Photo. 1 shows the conditions of rain water use by a farmer at Santana do Ipanema mentioned above. Rain water falling on roofs of main house and corn storage is collected into the cistern which is made of concrete and is covered by roofs. There are three types of water cistern shown in Fig.3,4 and 5 (for Fig.4 and 5 is after by D.D. Cederstrom and J.C. Assad, 1964 and Fig. 3 is drawn by the author).In case of Fig.3, its area is 40 m^2 and a water depth is 3 meters, the capacity of water storage being 200 m^3. This volume may be enough for the domestic use of water in the farmer during the period of dry season. This cistern constructed by digging the ground surface to a depth of 2 meters, not reaching to the groundwater table.

For Fig. 4, the rain water falling on the roofs is collected into the cistern constructed in the ground, whose bottom is connected with a boring well by means of a pumping tube with strainers and then both grounwater and rain water are pumped up from the cistern. For Fig.5, rain water collected into the well whose bottom reaches to the



(a)



(b)

Photo. 1. A type of rain water cistern (type I) in Nordeste (a & b)

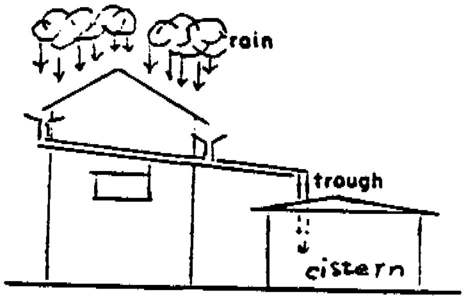


Fig. 3. A type of cistern (type I) in Nordeste.

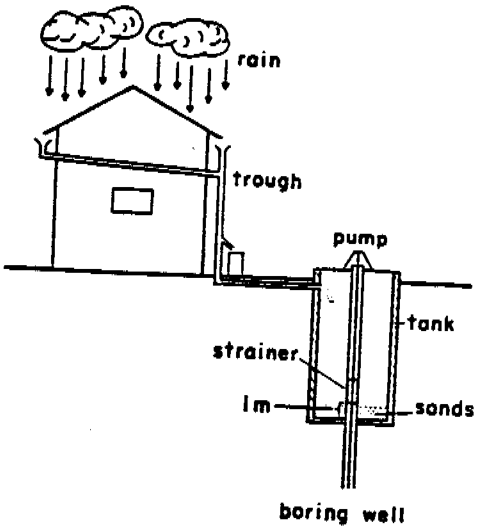


Fig. 4. A type of cistern (type II) in Nordeste.

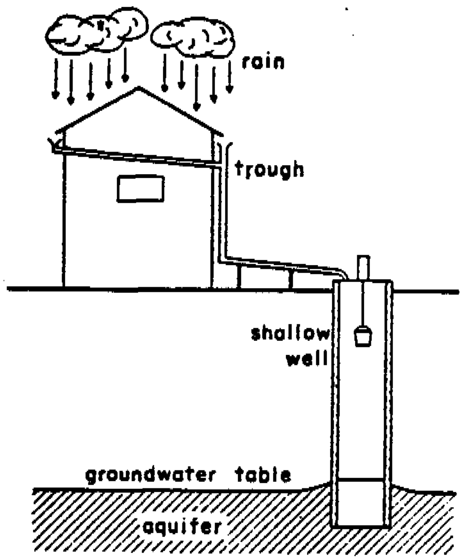


Fig 5. A type of cistern (type III) in Nordeste.

shallow aquifers, is drawn up with a bucket.

Water in the cistern explained in Photo. 1 is rainwater and similar to pure water which has no minerals. Causes for the bad teeth of many Sertanejos are uncertain yet, but the fact that Sertanejos drink rain water daily may be at least one of the major causes for their having bad teeth. In the cistern having such structures as shown in Fig 4 and 5, the salinity of groundwater is diluted by rain water. Consequently, the water in these types of cistern is relatively avilable for potable and domestic uses.

III.Rain Water Cistern Sytems in North Yemen

North Yemen is located in the southwestern part of Arabian Peninsula, and the study area includes the capital San'a, which is located from 15° to 15°30'N., and from 43°30' E., as shown in Fig.6.Population in this area was 671,800 and the number of total rain water cisterns was 653 (Y. Tagutchi, 1989).

1. Location and Altitude Distribution of Rain Water Cisterns

Mountainous villages of North Yemen located in the highest site was overviewed. There, rain water cisterns are located in the lower part of villages.These rain water cisterns were constructed by digging 2-5 m. from the surface of ground and also some were constructed in shalow underground. They have no roofs and have great a problem from the sanitary point of view, because they can take in all polluted waters (Fig.7 and Photo. 2).

Distribution of rain water cisterns in North Yemen almost coincides with altitudes of ground surfaces, because they were constructed on the ground surfaces or the shallow underground. Distribution of the cisterns is plotted every 15' longitude between 15°-15°30' N (Fig. 8-(a)). The solid line in Fig.8-(a) shows highest frequency and this is almost coincided with the mean altitude above sea level of cisterns. Number of rain water cisterns every relative height of 100m. in the study area is shown in Fig.8-(b)), and it shows that the highest frequency of the altitude distribution of rain water cisterns is 2,600 m. or 2,700 m. except the maximum frequency of altitude of San'a loca-

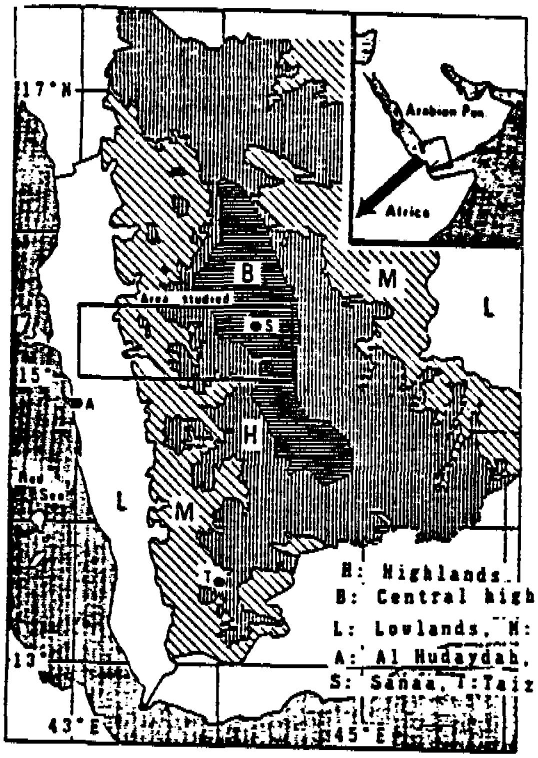


Fig. 6. General map and study in North Yemen.

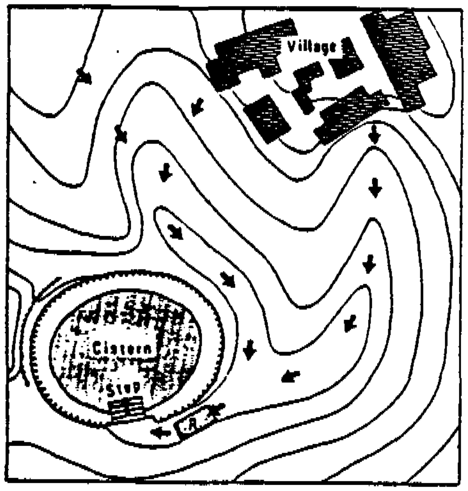


Fig. 7. Typical rain water cistern near San'a of capital of North Yemen.

R: A settling pond, ⟶ :Directions of surface flow.

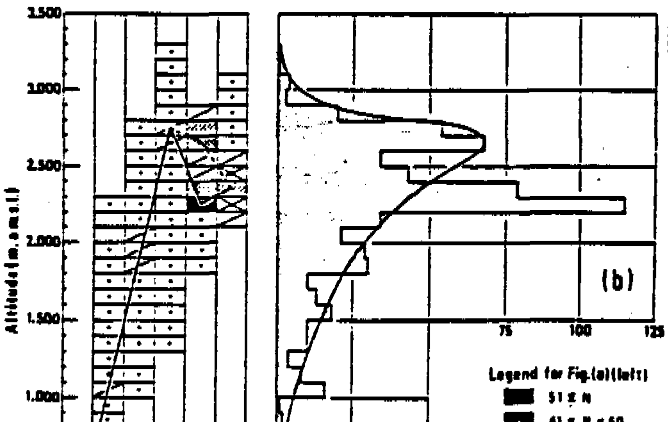


Fig. 8. Distribution of cisterns every 15'E. and frequency distribution of relative height 100 m. of cistern in North Yemen.

Photo 2. A rain watern cistern in North Yemen

ted in 2,200-2,400 m.above sea level (solid line in Fig. 8-(b)).

2. Use of Rain Water in North Yemen

Rate of use of cistern water is less than 10 per cent of the

On the contrary, in the case of North Yemen, all water cisterns located in the lower part of villages and are constructed by digging the surface of ground and some of them are constructed in the underground in a shallow depth.

The cisterns there suffer from people and domestic animals severely. Therefore, the cistern water does not suit potableness for people and domestic animals. These facts have proved to identify that almost of all foreiners visiting ther must buy mineral water.

ACKNOWLEDGEMENTS

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THE DESIGN AND EVALUATION OF A RAIN WATER CISTERN SYSTEM FOR W.C. FLUSHING

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ABSTRACT

The general problem concerns the use of rainwater for w.c. flushing. In the United Kingdom 30% of the potable water supplied to the domestic sector is used for the transportation of foul waste. This paper describes a method of obtaining the optimum storage capacity for which both the input and output are stochastic processes; that is, two unrelated time series. Two w.c. supply systems are evaluated using a numerical simulation model. The findings indicate that the storage volumes of earlier designs were considerably over estimated; moreover additional storage is of no use unless the catchment area is also increased.

INTRODUCTION

Inhabitants of the arid areas of the world are only too aware of the need to conserve water; consequently their water often has repeated usage and is finally used for land irrigation. In developed countries such as the U.K., one flush of the w.c. typically uses 9 litres of purified water: the result is that 30% of this expensive potable water supplied to the domestic sector goes down the foul sewer. As water charges increase coupled with difficulties of maintaining adequate water quality standards (Howarth, 1981), the efficient utilization of our existing water resources will become apparent. The use of rainwater for w.c. flushing is a simple and practical method of reducing the demand on both the public water supplies and waste treatment facilities.

The economics of a rainwater cistern is related to its storage capacity because this is the one parameter controlled by the builder; the roof area is determined by other considerations and the rainfall is an uncontrollable natural resource. This paper shows that the stored volume of rainwater needed for toilet flushing can now be reduced by a factor of 10 compared to previous estimates for the U.K.; that is we are concerned with storing 1 tonne of water instead of 10 tonnes.

The relationships between catchment area, tank size and daily rainfall levels are investigated; for a specified demand there is an absolute minimum roof area required, irrespective of the storage used. A numerical model is developed which determines the optimal combination of roof area and reservoir capacity needed to meet the w.c. demand. The paper concludes with descriptions of several configurations of storage tank layouts and arrangements.

THE COLLECTION OF RAINWATER AND THE INFLUENCE OF METEOROLOGICAL AND PHYSICAL FACTORS

The roof of a house provides an ideal catchment area for collecting rainwater provided it is made of a suitable material such as slate or tiles (lead and asbestos are unsuitable). Ground catchments provide an alternative to roofs, their effectiveness is dependant on their slope and impermeability to water, although they are unlikely to be practical in urban areas.

The annual level of rainfall depends on geographic location; the average in the east and south east of England is 500-600 mm while in the north and west is approximately 1525 mm. The average for England is 840 mm and for the whole of the British Isles 1205 mm. The frequency distribution of rainfall also varies from area to area; heavy falls (25 mm or more) occur more often in the summer season in south-eastern, north-eastern and eastern England while in North Scotland such rains occur most frequently in Autumn (Bilham, 1932). Because the level and frequency of rainfall varies throughout the country, there is expected to be a corresponding variation in optimal tank sizes and method of construction.

The roof area available for collecting rainwater is related to the size and type of dwelling. The average roof area of a house in the UK is 50 m^2 (Vale 1976); a bungalow has a greater collection potential than a comparable house.

STORAGE CISTERN DESIGN

Design Problem

The determination of the smallest tank volume which will satisfy the toilet flushing demand for a particular catchment area is the design problem: the derivation of rainwater supply patterns is thus essential. These supply patterns are non-deterministic and follow a time dependent, non-stationary stochastic process. A collection of sampled values made sequentially in time from such a process is known as a time series, which may be continuous or discrete.

Two methods of obtaining the time series which describe adequately the randomness of rainfall were considered: either the collection of actual flow patterns or their simulation using a numerical technique. The first method was rejected because the manipulation of, say, three or four years daily rainfall patterns into a form suitable to model the storage system is both inefficient and time consuming.

The rainwater time series are used as the input to the simulation model of the storage system. For each roof area the model evaluates the volume of rain collected and used each year expressed as a percentage of the total flushing demand. Several assumptions have been made:

(i) the rainfall is vertical and over the entire roof area
(ii) evaporation losses are negligible
(iii) any effects due to droplet size and variations in wind and pressure around the roof are ignored

These aspects may be included in the model as they become pertinent to a particular design.

Storage Volume and Geographical Location

The performance of a rainwater flushing cistern is evaluated with tanks ranging from 100 to 1200 litres capacity; the evaluation is repeated for the same five towns. The average annual rainfall levels range from 600 mm for Nottingham to 2350 mm for Treherbert. The mean volume of rainwater collected per annum expressed as a percentage of the total flushing demand is determined for each storage vessel using fifty years of simulated data; the accuracy of the results is within the range $\pm$ 1%. The results relate to a family of six people; a lower level of occupancy results in an increase in system efficiency because of the lower demand for flushing water.

A house in Nottingham with a catchment of 25 m^2 can supply only 30% of the w.c. flushing water with a storage capacity of 900 litres; a similar dwelling in Treherbert with the same cistern and roof area conserves at least 80% of the potable water supplied to the toilet (Fig 1). The performance curves for Bath and Inverness are close together because their annual rainfall levels are similar, 812 mm and 750 mm respectively. The poor performance of the systems is Sussex, Bath Inverness and Nottingham is due to insufficient roof area; that is, for a specific demand there is an absolute minimum roof area required, irrespective of the storage used. An increase in storage capacity in excess of 800 litres results in only a negligible improvement in system efficiency (Fig 1). Whereas previously large storage volumes have been proposed for the U.K. without consideration to the catchment area (Rump, 1978).

An increase in roof area to 50 m^2 results in a corresponding improvement in system efficiency. In Nottingham a 1000 litre tank provides 55% of the w.c. flushing water, the figures for Inverness, Bath, Sussex and Treherbert are 64%, 67 %, 73% and 96% respectively (Fig 2). With a catchment of 75 m^2 the performance of each system is further increased (Fig 3). However, between tank capacities of 100 to 800 litres the efficiency of the Inverness system is marginally better than Bath's. This effect is pronounced with a roof area of 100 m^2 (Fig 4); the performance of the Scottish system is superior than that of both Sussex and Bath. This indicates how the frequency distribution of rainfall can affect the performance of a system; Inverness has a lower annual rainfall than both Bath and Sussex but is more efficient with a roof area of 100 m^2.

Generally an increase in tank capacity results in a rapid rate of growth in system efficiency. However, a point is reached on each set of curves where increases in storage capacity result in only a marginal improvement in performance. That is, the maximum efficiency of a rainwater flushing cistern is related to roof area and the demand within the household.

STORAGE CISTERN CONSTRUCTION AND OPERATION

A rainwater cistern of 10,000 litres is recommended by Rump (1978) to provide a third of a U.K. households requirements, while Vale (1976) suggested a quarter of the annual yield required needs to be stored. Consequently storage tank designs often suggested are expensive, normally constructed from reinforced concrete and unattractive in a developed country such as the U.K. with an established water supply system.

The storage requirements estimated in this study are less than previous proposals and range from 400 litres to 1500 litres depending on geographic location and roof area; cheaper methods of construction can therefore be used and a greater flexibility in tank location achieved. Tanks located below ground level keep the water cool and inhibit bacterial growths; alternatively a vessel positioned at the first or ground flow obviates excavation work and alterations to the below ground drainage system. Collection vessels cannot be located in the roof space because the inlet would be above or at the same level as the gutter.

Irrespective of location, all tanks must be fitted with lids to reduce evaporation and discourage algal growths. The bases should slope slightly up at the outlet to allow settling particles to accumulate at the opposite end. The larger tanks can be fabricated from G.R.P. or a series of smaller polypropylene vessel connected together to provide an equivalent capacity, both of these materials are light, durable and economical.

A single tank system (Fig 5) positioned at or below ground level collects the rainwater by gravity feed and is then pumped at a minimum flow rate of 7 lit/min (B.S. 6700, 1987) to the flushing cistern; a cartridge filter removes suspended solids. An overflow is fitted to the storage vessel and the pump controlled by a float switch in the flushing cistern. When the level of rainwater falls below a critical value make-up water is supplied via a delayed action ball-valve, this prevents system failure (Fig 5). The system simulation model is based on this simple rainwater flushing cistern.

A dual tank arrangement (Fig 6) with an extra tank in the roof enables the w.c. to be gravity fed at the necessary flow rate B.S. 6700, 1984) and the pumping between storage tanks to be less than 7 lit/min. Because the total storage is shared between two vessels, both excavation and possible alterations to the drainage at ground level can be reduced.

Excess rainwater overflows from the ground store to the household drain via an overflow. A float switch, which de-activates the pump at a pre-defined level, prevents wastage of filtered water from the roof store. A float switch also prevents the collection vessel emptying completely. Mains water is supplied via a ball valve to the roof store to prevent system failure.

Both the single and dual tank systems are fitted with a simple device which diverts the initial flow from the roof, this will be contaminated with particulate matter which has collected on the catchment area during the dry-period. At the beginning of a rainfall, the inlet to the storage tank will not be flowing full and the contaminated water will flow into the 'vee' section pipe (Fig 5 and 6) which diverts the water into the drain. However, as the flow increases it's trajectory will by-pass the 'vee' section and flow directly into the storage vessel.

CONCLUSIONS

A w.c. supply system has been designed and evaluated using a simulation model. Time series based on a minimum interval of a day are generated using the Monte Carlo technique; these series provide input to the model of a single tank unit to obtain the optimum storage capacities for different catchment areas.

To provide 85% of flushing water with a single tank rainwater cistern, a Nottingham household requires a minimum catchment of 100 m^2 and a 1500 litre tank which will weigh 1.5 tonnes when full. Houses in Inverness, Bath and Sussex with a 100 m^2 roof area require storage capacities between 750 to 850 litres to satisfy 85% of the w.c. flushing demand. However, due to the higher level of rainfall in Treherbert, a combination of 50 m^2 roof area and tank capacity of 600 litres is capable of providing 85% of the flushing requirement; the storage volume is reduced to 400 litres with a 100 m^2 catchment.

The results indicate that tank capacities suggested by Rump and Vale are considerable over-estimates, moreover the additional storage is not needed unless the catchment area is increased to collect more rainwater.

A dual tank system is shown to have a more flexible design and a more efficient pump duty. However, the flow rates between the tanks and the combinations of different storage capacities must be carefully selected to optimize system efficiency.

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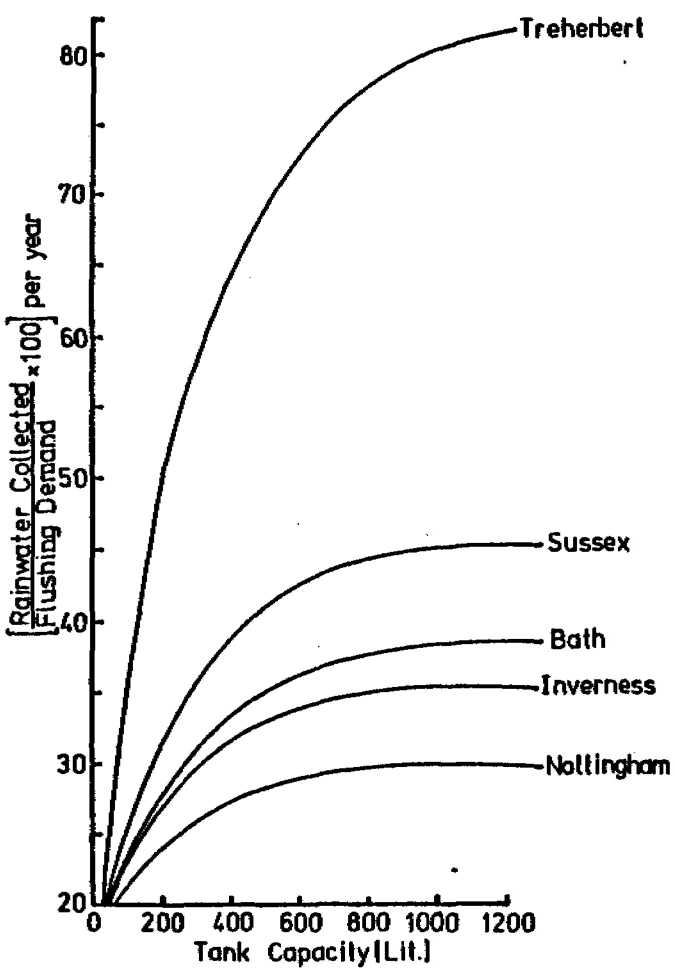

Figure 1. The effect of geographic location on the capacity and efficiency of the rainwater store - Roof Area 25m^2

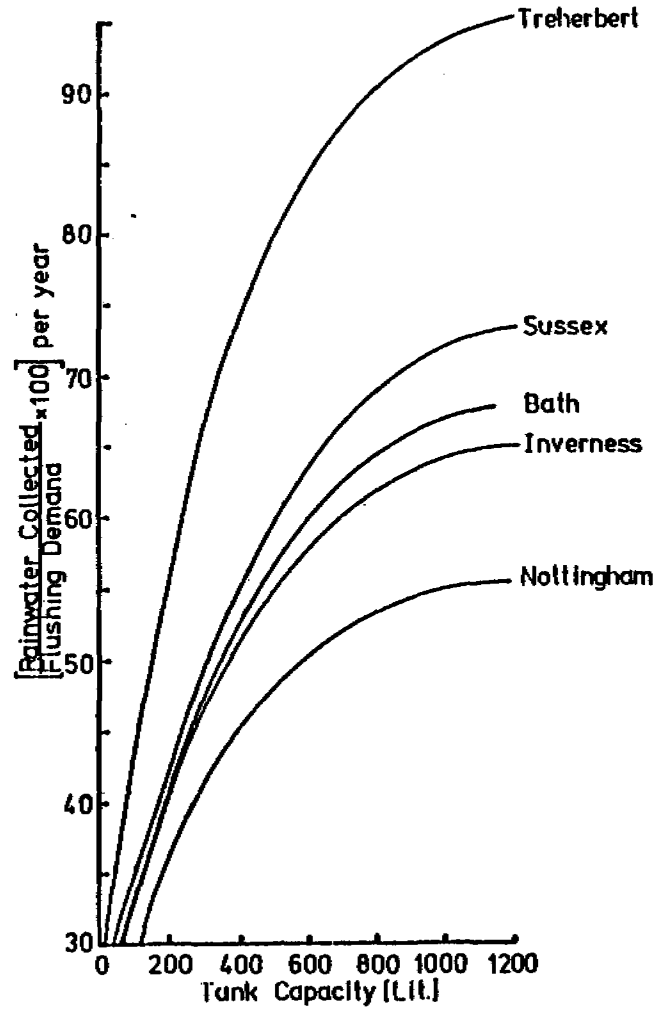

Figure 2. The effect of geographic location on the capacity and efficiency of the rainwater store - Roof Area 50m^2

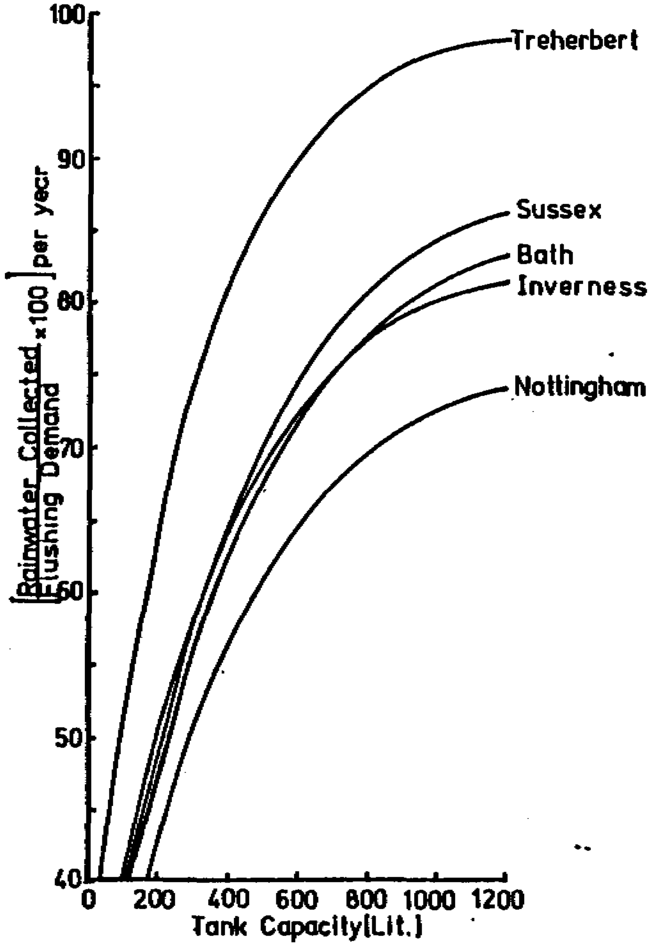

Figure 3. The effect of geographic location on the capacity and efficiency of the rainwater store - Roof Area 75m^2

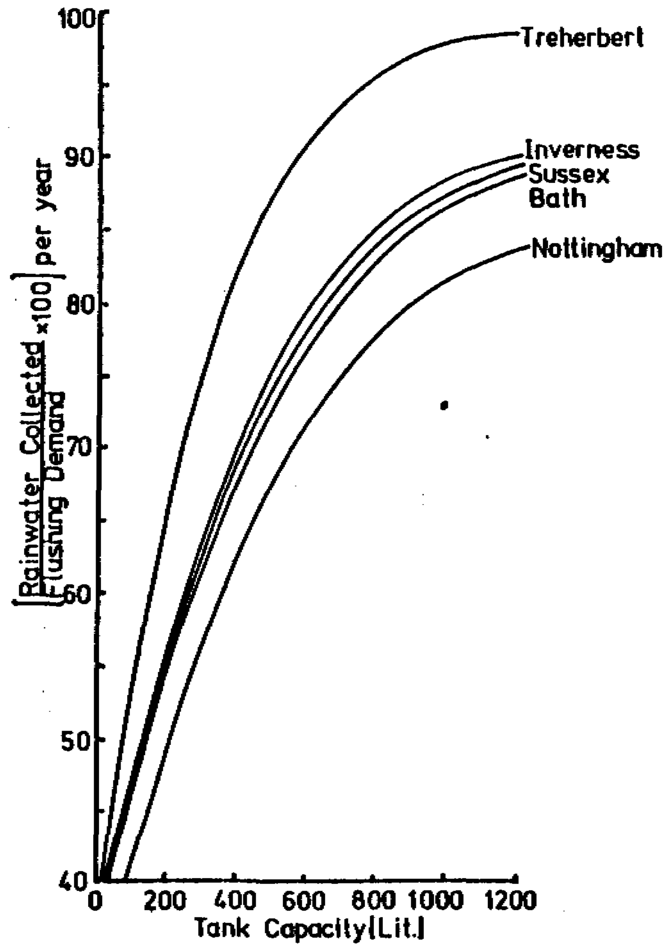

Figure 4. The effect of geographic location on the capacity and efficiency of the rainwater store - Roof Area 100m^2

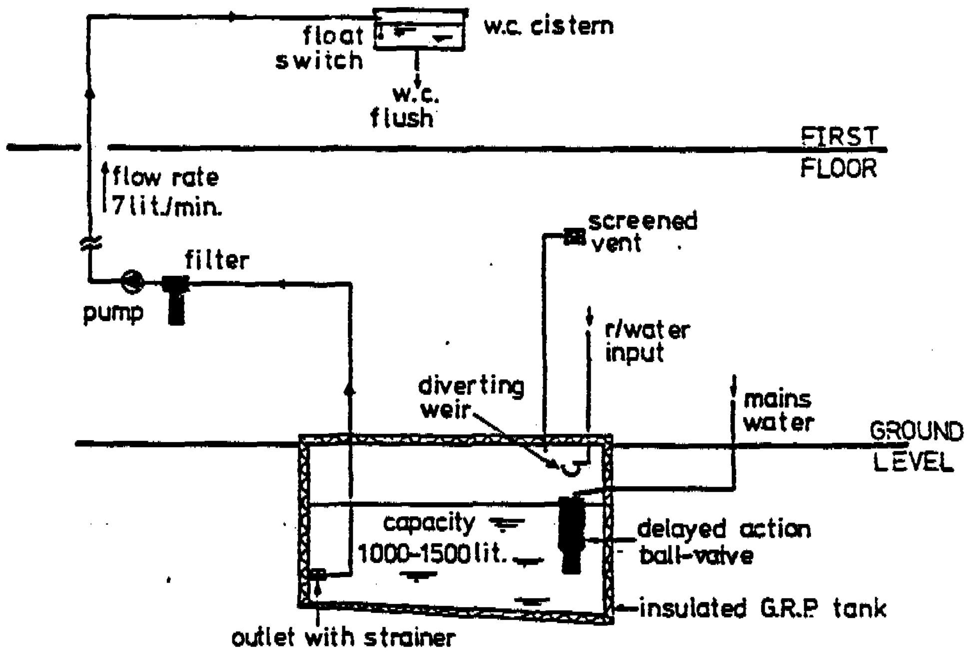

Figure 5. Underground single tank G.R.P. rainwater cistern

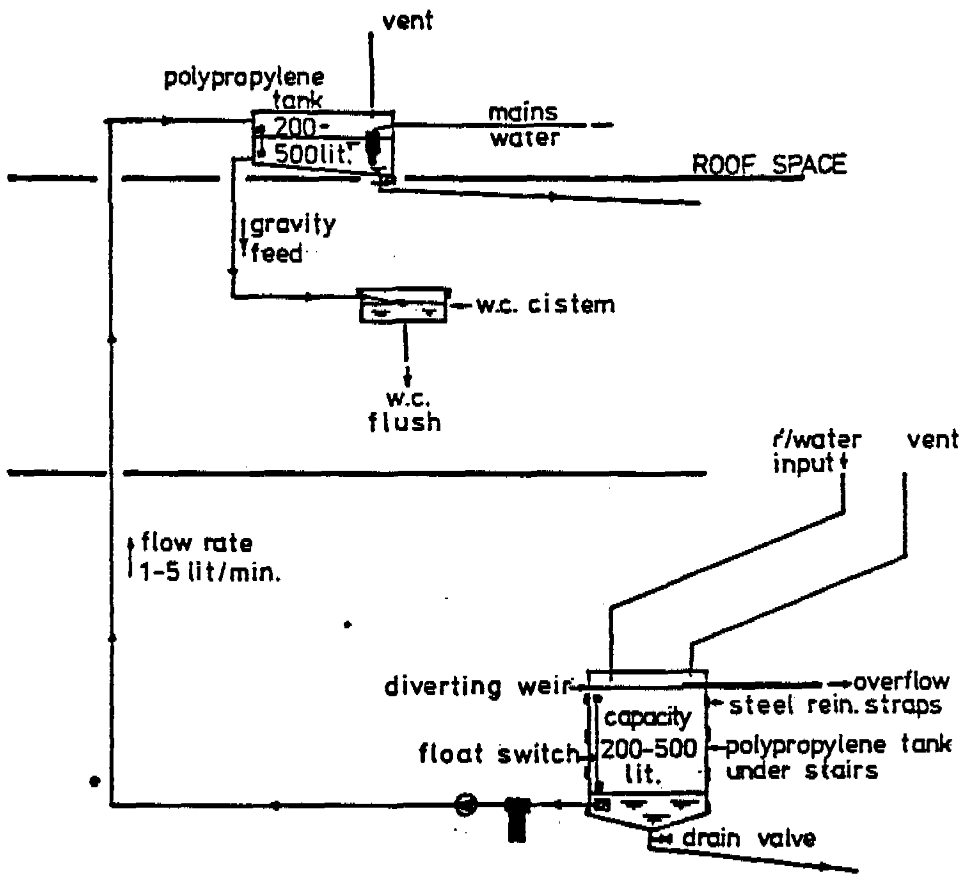

Figure 6. Dual tank rainwater cistern

APPLICATIONS

AND

COST ANALYSES