DESIGN PARAMETERS FOR RURAL WATER SUPPLIES IN BANGLADESH

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A Thesis

by

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ABSTRACT

This study investigates the pattern of rural water use, the factors affecting rural water consumption and appraises the need for improvement in the present rural water supply system in Bangladesh and the impact of such improvement on rural water use for the social and economic well-being of the rural community.

This study attempts to establish some design criteria like appropriate location of tubewell site, type of pump, platform dimensions, allowable chemical contents in tubewell water, and the maximum distance of a tubewell from each household for the future water supply construction programme in rural Bangladesh.

An attempt is also made to determine the optimum number of users per handpump tubewell considering various physical, social and economical factors, so that the optimum number of tubewells for an area can be estimated from the population figures for that area.

Simple descriptive statistics were used to analyse the data and to present the pattern of water consumption and the effects of various factors on water collection from tubewells. The variables which were found to be significantly associated with per capita rural water consumption from rural tubewells were distance to the source, number of people of the area under its command, average household size, location of the source, platform dimensions, quality of water, presence of other sources, and socio-economic status of the users.

Water collection from tubewells before and after some improvement to the source were compared. An increased water collection was observed after some improvement and modification in platform dimensions, arrangement of privacy of the source and improvement of water quality. It was also observed that the volume of water collected from tubewells varies inversely with distance of the household from the tubewell. The presence of other convenient unprotected sources of apparently acceptable quality reduce the use of tubewell water significantly where the tubewell water supply is associated with various problems. In the absence of other nearby sources people will usually collect tubewell water not only for drinking, but for other domestic purposes as well.

CHAPTER I

INTRODUCTION

1.1 Statement of the Problem

Safe, adequate and accessible supplies of water together with sanitation are recognized as basic health needs and essentital components of primary health care. Many of the diseases affecting underserved population especially the rural poor, could be greatly reduced by meeting these basic health needs[1]. Furthermore water is an essential element for other areas of development. It is universally accepted that an adequate supply of water for drinking, personal hygiene and other domestic purposes and an adequate means of waste disposal are essential to public health and well-being. Unfortunately, a great number of people living in rural areas do not have access to a safe and convenient source of water[2]. In 1970 the World Health Organization surveyed 91 developing countries and found that only 14 percent of their rural population has a reasonable access to drinking water[3]. Reasonable access to water in a rural area, as defined by the World Health Organization, simply means that the housewife or members of a household do not have to spend a disproportionate part of the day in fetching the family's water needs.

Saunders and Warford[2] have estimated that in 1970, only 29 percent of the population of 91 countries surveyed, were with safe and accessible water against an investment of U.S. $ 1000 million. The United Nations for its Second Development Decade (1971-80) has set its goal to supply safe water for about 200 million persons. It is estimated that "even if the United Nations development goals were achieved, there still would be more rural inhabitants without proper water supply in 1980"[2]. According to the World Health Organization it was estimated that 13,000 babies die each day as a result of the use of polluted water[4]. This reflects the magnitude of the problem on a global scale and connotes the need for massive resource allocations required to ameliorate it.

Asia has the largest rural population in the world and the majority of people without safe water supply also live in the developing countries of Asia. The World Health Organization's estimate of rural population of developing countries in South East Asia with adequate water in 1970 was only 5 percent[5].

The rhythm of water supply in rural Bangladesh oscillates between the two extremes of abundance in the rainy season and scarcity in the dry season. With the highest density of rural population in the world, the country thus faces an acute problem not only in terms of sufficient water supplies, but also in terms of water quality and diseases related to sanitation[6].

Since 1972, with UNICEF's assistance, Bangladesh has been engaged in a massive action program to provide potable water to the 93 percent of its population residing in the rural areas, but she is still far behind the objective of providing potable water to the whole rural population. The situation in Bangladesh is not as acute as in other developing countries of Asia, but from the statistical records of Bangladesh, it is found that 40 percent of children, before reaching the age of ten are partially disabled either mentally or physically due to attacks of various water borne diseases and consequent malnutrition. It is also estimated that more than 50 percent of cases of mortality among infants in Bangladesh are due to diarrhoeal diseases[7]. A recent survey[8] indicates that 21 percent of rural people use unsafe surface water sources for all domestic purposes, even when there are approximately 0.44 million public hand pump tubewells existing the country now[9].

1.2 Rationale of the Study

During the four months of the rainy season, water is in abundance; but for three months of the year, there is a scarcity. Settlement patterns have dictated through the centuries traditional water use habits. Ponds, rivers, ditches, canals and dug wells are all sources of water for domestic use. The absence of sanitary excreta-disposal and unhygienic practices renders many of these sources dangerously contaminated. In the past, 93 percent of the population which lives in rural areas depends primarily on natural sources of water. To stop Cholera epidemics in rural Bengal, together with other antiepidemic measures, the possibility of supplying pure drinking water by means of some ring wells and hand pump tubewells was first considered in the mid-twenties and some tubewells were sunk in 1928. In 1935 the District Board took the responsibility of sinking tubewells. The first real target was set at 1 tubewell for 400 people in 1948[10]. The standard of one tubewell for every 400 people had been raised to one tubewell for every 200 people in the year 1963 for the expected design population of 1970. Today after several years of sinking and resinking of tubewells, there is one working tubewell for approximately 260 people. But still there are many localities with no tubewells. Three independent surveys carried out between September 1975 and December 1976, indicated that only 52 percent of the rural people use tubewell water at least for drinking and 21 percent of the people use surface water sources for all domestic purposes including drinking, although 70-80 percent of the rural households were within 700 feet of a hand pump tubewell[8]. BIDS conducted a separate survey on domestic water use in four different areas of the country and observed that a subtantial quantity of water is used from surface sources for domestic purposes, which is not desirable. The reasons for this under utilization of the present capacity are not clearly known.

It has been observed that the greater the use of tubewell water for all domestic purposes the less is the incidence of diarrhoeal attack[36]. To encourage people to use more tubewell water, one needs to determine the effect and magnitude of various economic, social and cultural factors on tubewell water use quantitatively in order to plan and design an effective rural water supply system for the future.

Presently two main distribution criteria are followed, namely (i) to provide one tubewell for 150 people; and (ii) to install one tubewell within 250 yards of every household in areas where there is sufficient population to justify a public well[11]. Recently it has been suggested to provide one tubewell for every 75 people by 1985[12]. These targets are based on little scientific study. There are about 68,000 small and big villages throughout the country; settlement patterns are not the same in all these places, and conditions vary from place to place. As such, population may not be the only basis of distribution of tubewells.

Information is required on whether small and less costly tubewells will be sufficient when few people use one tubewell.

During the United Nations Water Conference in 1977 in Argentina, it has been decided to provide every one with safe drinking water and sanitation by the year 1990[13]. In order to reach this goal, it is essential to make a critical analysis of the condition and problems of present water supply systems. It is necessary to determine the reasons for non-usage of tubewell water for domestic purposes and what improvements are needed; and further, how feasible they are for the development of some applicable general basic design criteria for the future rural water supply programme in Bangladesh.

1.3 Objectives of the Study

The objectives of the study are: (i) to estimate the water requirements of rural people in Bangladesh for domestic uses (ii) to determine the consumption from tubewells against total requirements (iii) to assess the dimensions of the rural water supply problem in Bangladesh and to find out effective measures to improve the water supply situation. (iv) to establish some basic design criteria like appropriate tubewell site, platform dimension, water quality standard; (v) to design a suitable treatment unit to improve the water quality to an acceptable limit for rural people; (vi) to determine the optimum number of users per well considering various factors; and (vii) to determine the suitability of No. 2 pump for the future water supply programme.

CHAPTER II

LITERATURE REVIEW

2.1 Previous Studies

2.1.1 Fundamental Approach

Research on domestic water supply in developing countries has been limited. In 1973, Richard J. Frankel[14] undertook an evaluation study of community water supplies in northeast Thailand. The study probed into the effectiveness of the water supply systems and found many reasons accounting for the inefficiency of these systems. Sophisticated systems were built neglecting local materials and villagers found them hard to understand and operate. Actual water use was found to be less than half the design quantity. Acceptance of an elaborate system requires a considerable change on the part of the individual before he is in a position to weigh the values of what he is getting for the change. This study provides a sound justification to look for a user-approach by which people with minimum external aid could plan and design an improved water supply system. Carruthers and Brown[15] have stated that in developing countries it is desirable to use simple technology and the scheme must not be complicated. Thanh[16] suggested that since the level of technical expertise in rural areas is very low, all parts of a water supply system must be simple to operate and maintain.

Stainiskawski[17] in his study to determine rural water supply design parameters for conditions in Tanzania, proposed to divide the whole country into uniform water need zones, where the pattern of potable water demand is the same, for greater variability of natural and climatic conditions of Tanzania. In each zone he carried out separate investigations on at least two of the existing rural water supplies to establish the main technical parameters. By technical parameters of potable water demand, the following findings are understood from his work, 1) Mean day water demand per capita or per cattle unit. 2) Co-efficient of daily water consumption fluctuation.

The UNICEF/WHO Secretariat has observed that in planning for water development schemes, socio-cultural information is lacking and investigations are rarely undertaken to ensure that plans are both technically sound and socially justifiable. Thanh[16] has pointed out that in planning and designing for rural water supply programmes, physical factors are often over-emphasized as in urban water supply programmes, where most socio-economic factors are neglected. In addition to physical factors, an understanding of the association between socio-economic factors and water use is very important to determine the dimensions of the rural water supply problem. According to Paramasivam and Sundersan[18] "Rural water supplies in developing countries have to be technologically sound, economically viable, environmentally compatible and socially acceptable". Chainarong[19] has stated that the success or failure of community water supply projects depends largely upon the socio-economic factors prevailing in rural communities.

Wagner and Lanoix[20] have mentioned that one of the most difficult and baffling problems in the planning of a small water supply system for a rural community is the lack of criteria upon which an engineering design can be based. For most rural underdeveloped areas of the world, reliable design guides have not yet been established. They have suggested that a critical analysis of the conditions and problems of the area under study should be undertaken to develop applicable criteria, since certain elements of rural water supply system design are matters of local decision, depending on geography, local economy, custom and other factors.

2.1.2 Water Requirement and Factors Affecting Water Consumption:

There is little knowledge available of water consumption levels in rural areas as compared with urban areas. Generalised estimates of per capita water consumption for selected countries are summarized by White, David and White[21]. For rural areas of West Bengal, India, they have estimated the per capita water consumption as 30-60 litres per day. Adhya[22] mentioned that 6-10 gallon per capita per day water consumption is generally considered adequate for the rural areas of West Bengal, India.

Khurshid[23] and others have reported that the average water consumption in rural areas of Pakistan was 48.1 liters per person per day. Nazir[24] in his study in Faisalabad district of Pakistan found an average water consumption of 9 gallon per capita per day. Household size, number of villagers, level of education and number of sources of water were the most important factors affecting water consumption in Faisalabad district of Pakistan. Azime[25] in a case study in one central province of Thailand observed an average per capita consumption of 41 litres. Factors affecting per capita water consumption were household size, level of education and average household income. The U.S. Joint Committee on Rural Sanitation[26] quoted a water collection of 10 gallon per capita per day from hand pump tubewells. Feachem, et al.[27] in their study on rural water use and collection in Lesotho have suggested a design figure for the mean annual consumption of 30 litres per capita per day. During field investigation they interviewed the households and observed their preferred sources from morning to evening. They have proposed the installation of a tubewell closer to the household than any nearby unprotected surface source to ensure the use of tubewell water.

In water demand studies and related factors, the United States Agency for International Development[28] classified the factors related to community water demand into six categories, namely economic conditions, natural environmental conditions, social conditions of the community, quality of water services, quality of water supplied and cost of water. Cholera Research Laboratory[29] Dacca, in a study at Teknaf observed a direct relationship between the incidence of clinical shigellosis cases and per capita water collection. The incidence of attack rate was 50 percent less when per capita per day water consumption increased to more than 7.9 gallons from less than 4.5 gallons.

White[30] has stated that the volume of water used in the tropical developing countries is chiefly a function of income and material wealth. The highest income group have access to a larger amount of safe water. He found that water consumption is higher in the case of a source situated close to the house. Teller[31] and Lee[32] found that the volume of water used by people who carry it home, seems to be associated with the number of people in the households in a variety of cultures. The larger the household size, the smaller the per capita daily use. One of the major factors affecting the quantity of water used in a household is whether the washing is done at home or not. Warner[33] observed that a major portion of water drawn from a stand pipe in Tanzanian village was used on the spot.

White and others[21] in their study in East African communities observed that size of the family, income level, level of education, cultural heritage, character of water supply, climate and terrain, the size of carrying vessel, distance carried, age and sex-composition of the household size are factors influencing water use in rural areas. Carruthers and Brown[15] have suggested the inclusion of the consumption of both man and cattle together in the determination of a design figure. They found that if people have to walk more than a few hundred metres, they are unlikely to carry more than 10-15 litres per day. Beyer[13] observed the main constraints still hampering the provision of adequate water supply and sanitation are the lack of awareness of benefits and consequently the lack of social acceptance of the present systems.

Islam, Huq and others[34], in analysing the reasons for non-usage of tubewell water for bathing, observed that water use from privately owned tubewells is greater since they are close to the kitchen, whereas Govt. tubewells are generally located at open public places and rural muslim women use such tubewells mainly for collecting water for drinking. For reasons of privacy they do not use tubewell water for other uses. The Rural Studies Project Group[35] in their study of water use patterns have mentioned that the existing spatial distribution of tubewells is generally poor and in favour of the richer households. Improved accessibility is likely to lead to various other uses.

Skoda, Mendis and Chia[8] observed a slight increase in tubewell water use with an increase in socio-economic status. According to their calculation 71.5 percent of the rural people of Bangladesh have floor area less than 350 square feet and only 7.4 percent people have floor area over 700 sft. Water consumption from tubewells of the latter group of people is slightly higher. The main reasons for non-usage of tubewell water as given by the villagers during interviews are distance of the tubewell, water quality, traditional habit etc.

2.1.3 Source Selection and Factors Determining the Choice of Source

In the rural areas of developing countries, it is cheaper to build for a short period of time and plan to make addition as future need demands, because no massive construction like elevated tanks is generally necessary and any alteration and addition may be made without any damage to the present system. Wanger and Lanoix[20] found hand-dug wells very suitable for rural areas, where a supply of a few hundred gallons of water per hour is required and can be drawn from unconsolidated formation through hand pumps or buckets. They have also suggested that primary consideration should be given to the protection of the quality of the natural water, selected in the design of a rural water supply system. For the above reason, according to them, ground water sources are better for rural water supplies. Bangladesh is almost entirely underlain by water-bearing formations, normally at depths varying from zero to fourty feet below the ground surface. Ground water collection through hand pump tubewells is simple in all respects[37]. In bacteriological tests of all types of sources in Bangladesh, tubewell water was found satisfactory in 70 percent of cases, whereas other sources like ponds, rivers, ring-wells etc. all were found to be unsatisfactory. Mendis, Skoda and Chia[8] pointed out that chances of contamination of tubewells can be eliminated by taking appropriate measures.

To determine the factors affecting the choice of source, Feachem[38], in his study in New Guinea in 1973, Lee[32] in Calcutta in 1969, Frankel[39] and Shouvanavirakul in 1973 in Thailand[34] observed that women, who collect most of domestic water, in selecting their source pick what they consider the best quality for their families. A user's criteria may be more likely to include teste, temperature, odour and appearance than considerations of bacteriological quality. Water quality standards differ from community to community. Apparently villagers prefer water which tastes good and looks clean, but they are usually ignorant of the possibilities of contamination[30]. Water for domestic purposes should be free from organisms, from concentration of chemical substances, from turbidity, colour and disagreable teste[37]. The World Health Organization has recommended International Standards of Water Quality[40] for a safe and acceptable water supply. These targets are very sophisticated. Because of diverse economic and social conditions, these standards could hardly be attained in all cases.

According to White[30], distance walked, and time spent waiting in a queue seem to be important factors in the choice of source in an area. It was found that the amount of water carried from a stand-pipe does decrease slightly with distance which possibly indicates the presence of an alternative source. Other considerations regarding choice of a source include technology, need for a bucket and strong arm of pump handle etc. White[30] and Feachem[38] observed that personal relationship also influence the selection of source, if on the walk to get water one might encounter undesirable people such as an irritable landowner or rival group of people.

The Rural Studies Project Group[35] have pointed out that the actual choice of a source and the quantity of water used by a particular household depends obviously on the relative accessibility of the source. They found that use of tubewell water is different in different places depending on the presence of other competing traditional sources near households.

2.1.4 Number of Users per Tubewell

Few reliable data are available regarding water consumption when the source of supply is hand or motor-pumped well or a public tap. There has, however, been great interest in the determination in various areas of the maximum number of persons who should be served by one well or one tap centrally located. This figure may be used to calculate the number of wells required and to select the most convenient locations for these points in a given community. Wagner and Lanoix[20] made personal communication with some investigators in different countries and found that criteria used in different parts of the world vary widely. Ruiz, from Colombia, recommended a figure between 20-50 persons per well. Wood, in Nigeria recommended a figure of 500 persons per well. Lia, from Taiwan reported that in his country, every effort is made to limit the distance for water carrying to 330 ft. Wagner and Lanoix[20] found reasonable to provide a well for a maximum population of 200 persons. DHV consulting Engineers[41] have suggested that consideration should be given to the distance between households and well in addition to the maximum number of people that can be satisfied through one well to determine total number of tubewells required. On determining the locations of wells, existing wells, quality of water, absolute and relative lack of water, development potential, per capita income and settlement pattern should be considered.

White[30] has pointed out that rural concentrated settlements often have access to convenient supplies, but because of the closeness of their neighbours and the larger number of people using one source, their health risk may be fairly high.

Mendis[42] in his study on bacteriological water quality of tubewell waters in Bangladesh observed that the average number of users per tubewell producing contaminated water was 340. On the other hand average number of users per tubewell producing acceptable water was 239.

2.2 Conclusion

The selected literature cited here gives on overview of the research approaches in the area of domestic water supply. In most of the studies on rural water supplies it has been suggested to adopt simple technology. The importance of socio-economic factors in rural water supply is recognised, but little work has been done to understand the influence of these factors quantitatively on rural water consumption.

Per capita water consumption under rural living conditions of the developing countries has been found to be about 8-10 gallon per day. Factors that are known to be associated with water use are size of the family, income level, level of education, cultural heritage, climate and terrain, character of water supply, location and accessibility of the source etc. The studies also revealed that quantity of water available and physical quality of water rather than bacteriological water quality determine the choice of source. Recommendations on number of users per well vary widely between 20 and 500.

CHAPTER-III

THE FIELD STUDY

3.1 General

The study includes visits to concerned organizations, research institutes and government departments of India, Thailand and Bangladesh to study the existing situation, selection of study areas, and extensive field survey. This chapter describes the preparation prior to the field work, the survey questionnaire, the choice of study area, the method of data collection, the sampling method, the field survey, problems encountered in the field and the method of data analysis.

3.2 Preparation Prior to the Field Survey

Discussions were held with teachers of environmental engineering at BUET, AIT, AIIPH and HYGIENE and experienced staff of UNICEF, WHO, NEERI, DPHE, and available documents on the study were collected from the above sources to gain preliminary ideas on the field of study. It was decided to conduct a trial survey (prior to the final field survey) in two places, to collect basic information about the present water supply system, and to prepare a suitable set of questionnaires and to find out the best method of data collection. The proforma and questionnaire which were designed for the field survey were found almost useless during the trial survey in the field. A new proforma and questionnaire were developed on the basis of field conditions.

The proforma and questionnaire were translated from English to Bengali. Ten Sub-Assistant Engineers and about twenty five tubewell mechanics of the Department of Public Health Engineering were engaged and several persons from the locality were hired to help in various stages of the field study.

3.3 Choice of Study Area

In consultation with concerned persons it was decided to conduct the final field survey in different areas of Jessore, Kushtia and Khulna district where the author had good facilities for conducting the work. All three districts are situated in the western and south-western part of the country, but most field conditions typical in Bangladesh exist in Jessore, Kushtia and Khulna areas. There are lowlying areas in Khulna and the eastern part of Kushtia where settlements are scattered. Linear settlements along the levees of dead and dying rivers are observed in Jessore. Clustered homesteads and densely populated areas are observed in the elevated flat land in the western part of Kushtia and Jessore. The socio-economic status of the rural people of the areas is more or less comparable with other parts of the country. There are saline problem areas in Khulna and iron problem areas in Jessore and Kushtia. Sample areas were selected from different Sub-Divisions.

3.4 Sampling Method and Sample Size

To study the effect of various factors on rural water use and collection, different villages were selected for

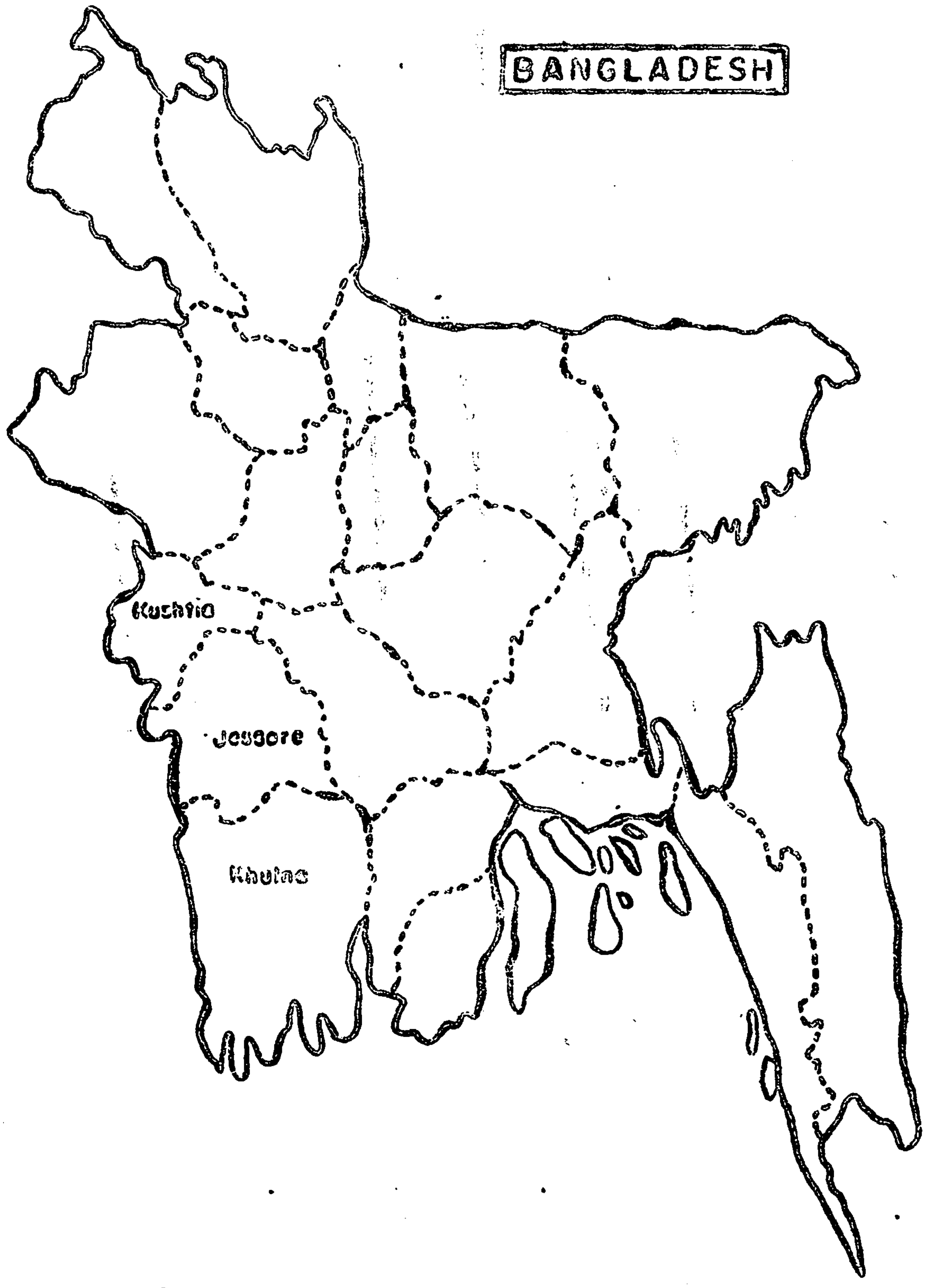


Fig.3.1(a) Map of Bangladesh

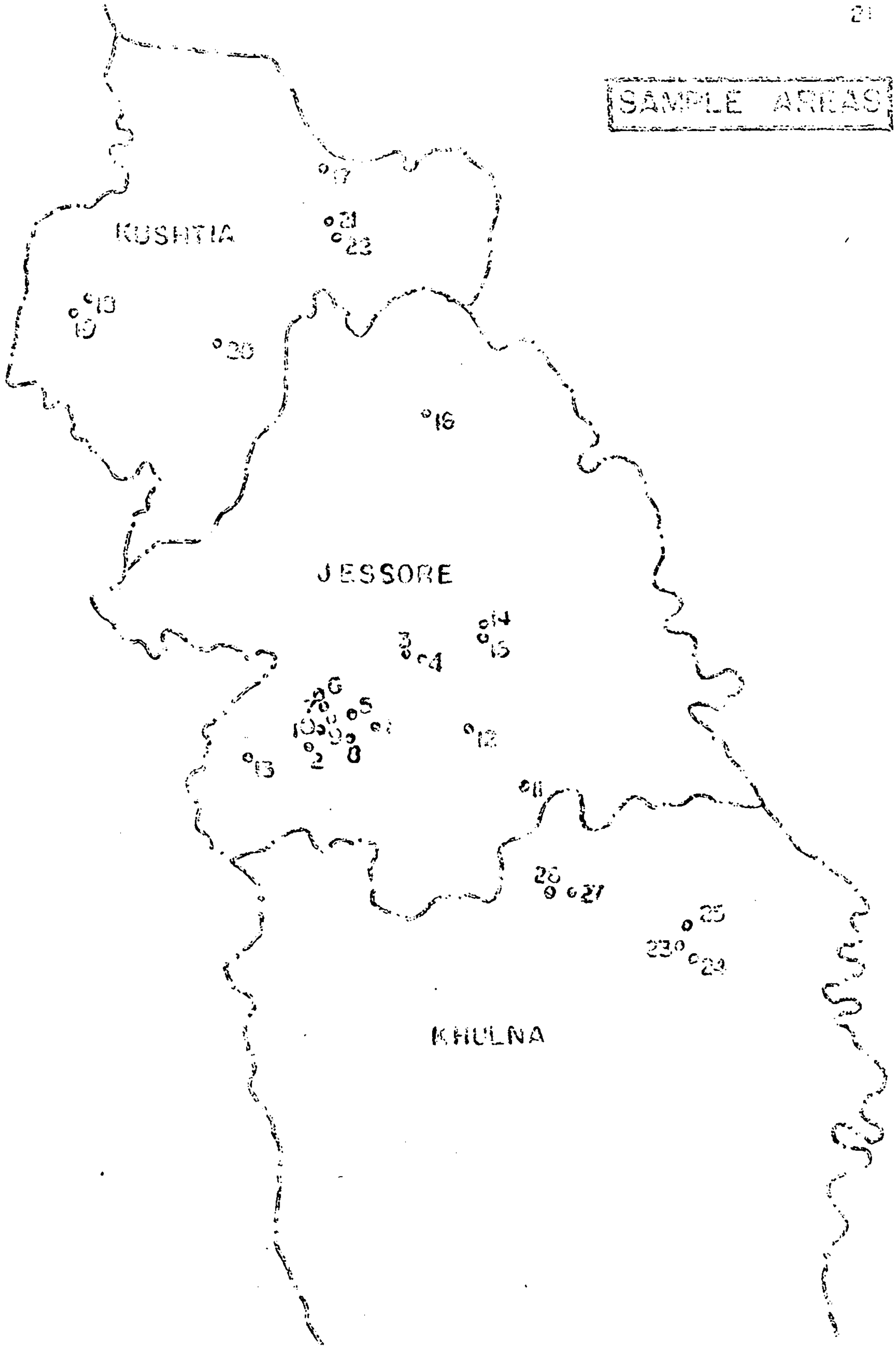


Fig.3.1(b) Location of the Sample Areas in Jessore Kushtia and Khulna District

different types of study, after conferring with Sub-Assistant Engineers of the Department of Public Health Engineering of the area. Villages were selected to ensure that all types of supply were present with different types of field conditions and problems. In each village a hand pump tubewell was chosen arbitrarily, and some 10-15 households using it, and living at various distances from it, were taken as the sample.

The field study was carried out in 27 areas of Jessore, Kushtia and Khulna. A total of 409 households were interviewed which covered about 3000 people. In order to get general information on villages and water use characteristics, one respondent was interviewed from each of the 409 households. To collect specific information on water use and collection from tubewells and other sources, 253 households were observed for 703 household-days in different areas, composition of samples has been presented in Table 3.1.

3.5 Method of Collecting Data

Data on water collection and use were obtained in two ways. First, the preferred tubewell of the household was observed between 5.00 A.M. and 8.00 P.M. for 2-3 days and a record was kept of all water collection. The proforma which was used for data collection has been presented in Appendix A-2. In some places other sources were also observed and use of water by the household was recorded. In cases of water collection and use without any fixed container, to estimate volume,

TABLE 3.1

Composition of Samples

Sample area	LOCATION			Month of obser- vation in 1979	Special characteristic of the area/type of tubewell observed	No. of house- holds inter- viewed	Number of household- days water consumption recorded
	Village	Thana	District				
1	Meghla	Kotwali	Jessore	March	Few surface sources present	25	31
2	Beneali	Jikar.	"	March	Exposed tubewell site	15	15
3	Noapara	Kotwali	"	Apr & Oct	Beside river	10	50
4	Biranpur	"	"	Apr & Nov	Beside river	10	50
5	Kirtipur, E	Jikar.	"	May	Unexposed tubewell site	10	30
6	Jikargacha	"	"	March	Observed private tubewell	1	1
7	Jikargacha	"	"	Nov	Iron problem area	10	40
8	Kirtipur, W	"	"	May	Observed private tubewell	1	1
9	Moralpara	"	"	May & Nov	Very exposed tubewell	10	30
10	Barakpur	"	"	May	Exposed tubewell site	10	30
11	Avoynagar	Avoynagar	"	May	Iron problem area	100	15
12	Narendrapur	Kotwali	"	Oct Nov Dec	Iron problem area	10	40
13	Sharsa	Sharsa	"	Nov	Many surface sources present	10	20
14	Bagharpara	Bagharpara	"	Nov	High dry land, densely populated	10	20
15	Bagharpara	"	"	Nov	High dry land	10	20
16	Modhupur	Jhenaidah	"	Nov	Area with extremely poor majority	12	30
17	Mongolbari	Kotwali	Kushtia	May	Beside river	10	20
18	Amjhupi	Meherpur	"	May & Nov	Family pump tubewell	15	90
19	Senbili	"	"	May	Family pump tubewell	10	30
20	Mominpur	Chuadanga	"	Nov	High dry land	30	20
21	Jogoti	Kotwali	"	Nov	Iron problem area	6	-
22	Alampur	"	"	Nov	Iron problem area	9	-
23	Patharghata (West)	"	Khulna	May	Low marshy land	10	30
24	Patharghata (South)	"	"	Nov	Low marshy land	10	30
25	Kasdia	"	"	Nov	Very scattered settlement	10	30
26	Daulatpur	"	"	Nov	Saline problem area	15	30
27	Daulatpur	"	"	Nov	Saline problem area	30	-
					TOTAL:	409	703

the number of strokes applied for collecting water was counted. Containers used for water collection were observed and the number of times used was recorded. The capacity of the containers was measured from time to time.

Secondly, the household was interviewed in the evening (and sometimes at noon) and information was obtained about water use over the previous 24 hours. At this interview, data were collected not only on the total volume used but on the type of use, both within and outside the home, and on the use of sources other than the preferred source which had been observed.

Data on general information with respect to the household and on present rural water supply facilities were obtained through interviews with one respondent from each household.

Information on water collection and use from private tubewells was obtained with the help of a reliable family member of the household.

3.6 Survey Questionnaire

The survey questionnaire used in the interview of members of households consists of two parts. The first part was concerned with general information of the household and the second part dealt with water use characteristics of the household. A sample of the questionnaire, is presented in Appendix-A-1.

3.7 Field Survey

The field survey was conducted with one guide from each village. He was responsible for introducting each interviewer to the respondent of the household. In most cases the housewife was the respondent. The guide also helped in identifying the water collectors during source observation.

Some assistants were given training on interview methods and recording water collection data. The author visited the entire study area and an effort was made to guide and check the work of the field assistants everyday.

3.8 Major Problems

The problems encountered in the field study are summarized as follows:

- Women were reluctant to present themselves before an interviewer.
- Villagers did not allow observation of sources from a very close distance, to maintain privacy.
- Normal operation of tubewells and water collection were slightly stilted because of our presence in the area.
- Containers of different sizes were used in water collection. It was difficult to estimate precisely the quantity of water collected.
- Observation of the source after sunset was not easy.

- Recording of all particulars on water use and collection at the peak demand period was extremely difficult.
- Water collectors sometimes changed sources and it was difficult to trace them.

3.9 Method of Data Analysis and Presentation

Simple descriptive statistics were used to analyse the data to present the pattern of rural water consumption. Total water consumption of a household from a source was divided by the household size to obtain the per capita consumption. It was observed that about one minute is required to complete the round trip travel distance of 200 feet, where the source is located 100 feet distant. It was found more appropriate to represent travel in terms of travel time for the round trip, rather than distance covered . Fig. 4.19 represents the variation on water collection of households from tubewells with distance to respective sample areas.

CHAPTER-IV

FIELD OBSERVATIONS, DATA ANALYSIS AND DISCUSSIONS

4.1 Settlement Patterns and Density of Population:

In Bangladesh, settlement patterns vary widely from place to place. The following are the major different settlement patterns, observed in the field:

(A) Scattered in the swampy depression areas where the houses are built on artificially raised lands, dispersed and isolated in thick bush areas.

(B) Linear along the levees of dead and dying rivers or along the main thoroughfares.

(C) Nucleated and clustered with highly dense homesteads on high flat land. Figure 4.1 represents the typical settlement patterns of the above types.

Density of population depends on settlement types in habitable areas. Density of population of some habitable rural areas has been presented in Table 4.1, which indicates that density of population varies widely. Maximum densities are observed in the sample areas of Meherpur, Kushtia, where people are mostly poor labourers. Each family has only one or two rooms made of clay and straw. Houses are built on high land. Two to three households share a common yard and each household is very close to the adjacent household.

Field observation shows that expansion of the present habitable area is unlikely in the next 6 years. Therefore, present population densities are likely to increase.

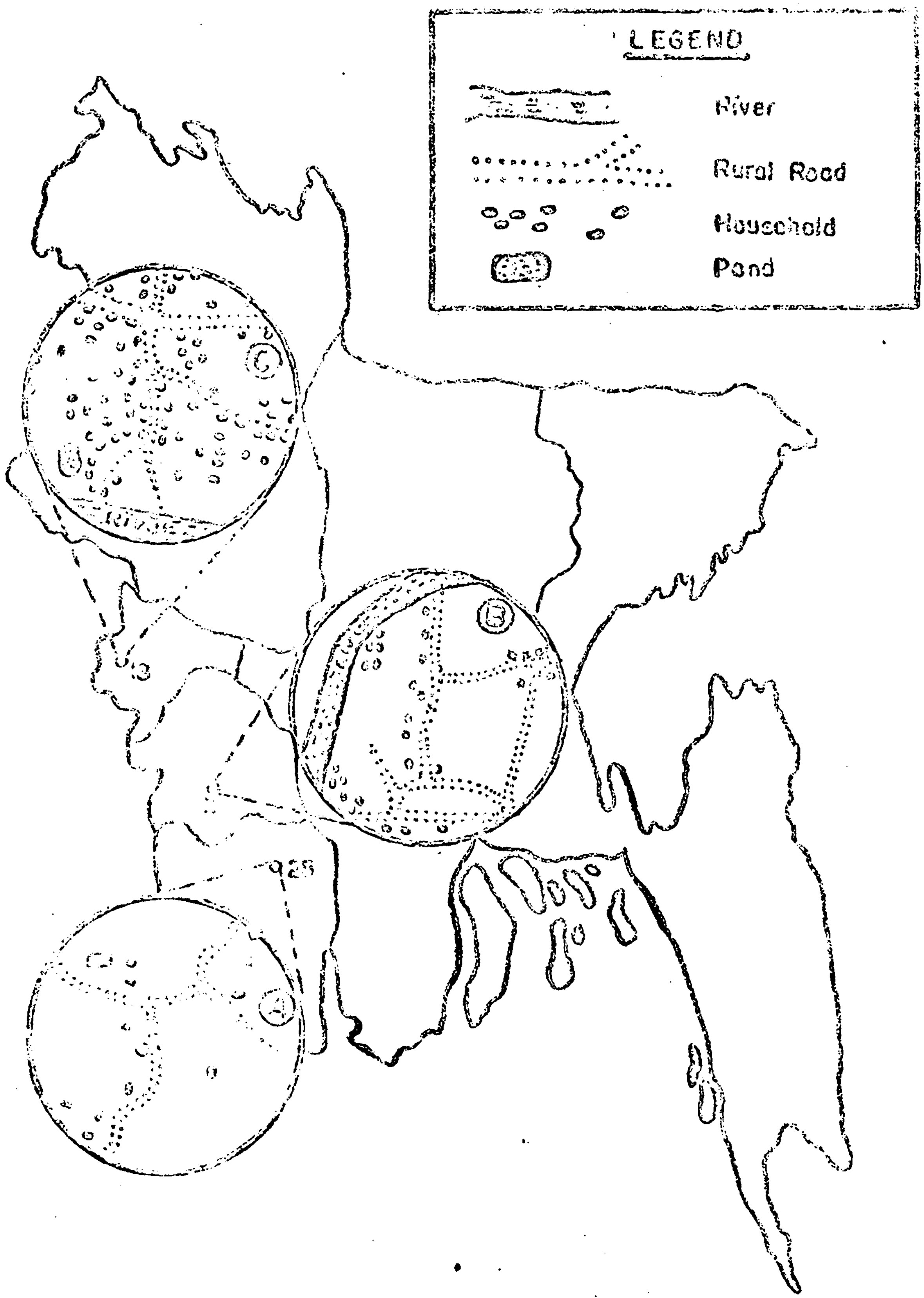


Fig. 4.1 Typical Settlement Pattern of Three Sample Areas

TABLE-4.1

Density of Population of some habitable rural areas

Sample area	District	Type of settlement	Density of population in habitable rural area (persons/acre)
25	Khulna	A < 13.068 persons/acre	6.0548
23	Khulna		6.5340
13	Jessore		8.2328
7	Jessore		8.7991
5	Jessore		10.2801
11	Jessore		8.7120
26	Khulna		13.0680
2	Jessore	28.314 > B > 13.068 persons/acre	14.0263
12	Jessore		14.0263
20	Kushtia		16.2478
9	Jessore		16.2478
10	Jessore		17.0755
3	Jessore		17.4240
1	Jessore		17.8596
4	Jessore		18.8179
16	Jessore		27.4428
14	Jessore	C > 28.314 persons/acre	31.5374
15	Jessore		33.9768
19	Kushtia		42.1660
18	Kushtia		47.9160

Ref: Different values of density of population have been classified into three groups approximately on the basis of scattered, linear and clustered settlement.

Table 4.2 represents the density of population of the sample areas of Jessore-Sadar Sub-Division only, where linear settlement was observed in most of the area.

Assuming a design period of 6 years and an average 2.5 percent rate of population increase per year in the rural areas and considering the source as a centre, estimated distance-population curves for the year 1985 have been drawn in Fig. 4.2 on the basis of average density of population of the sample areas of Jessore Sadar Sub-division.

The curves in the Fig. 4.2 give an approximate idea of the total number of people living at various distances from a source for various average densities of population. Therefore the curves can be used in determining the total number of people that can be served by one well, for a given maximum distance of tubewell from households in different types of settlement areas. For example, if we assume that people should not have to travel more than 300' from their house to a tubewell, then it is possible to calculate the theoretical minimum number of tubewells to effect this in the Jessore Sadar Sub-division. Each tubewell will, theoretically, serve an area 300' in radius surrounding the tubewell. Table 4.3 indicates that the Jessore Sadar Sub-Division would thus require, to serve a 1985 population of 1,640,000, some 10,838 tubewells. This represents 1 tubewell for each **126** persons.

TABLE-4.2

Density of Population in the Sample areas of Jessore Sadar Sub-division

Sample area no.	Density of population persons/acre	Type of settlement	Average density of population in 1979 = P_p (persons/acre)	Average density of population in 1985 = P_f (persons/acre) 1)	Observed area No.
13	8.232	A	9.005	10.443	4
7	8.799				
5	10.280				
11	8.712				
2	14.026	B	16.496	19.130	7
12	14.026				
9	16.247				
16	17.075				
3	17.424				
1	17.859				
4	18.817				
14	31.537	C	32.7569	37.986	2
15	33.9768				

1) $P_f = P_p \times (1+.025)^6$, assuming a 2.5% annual increase.

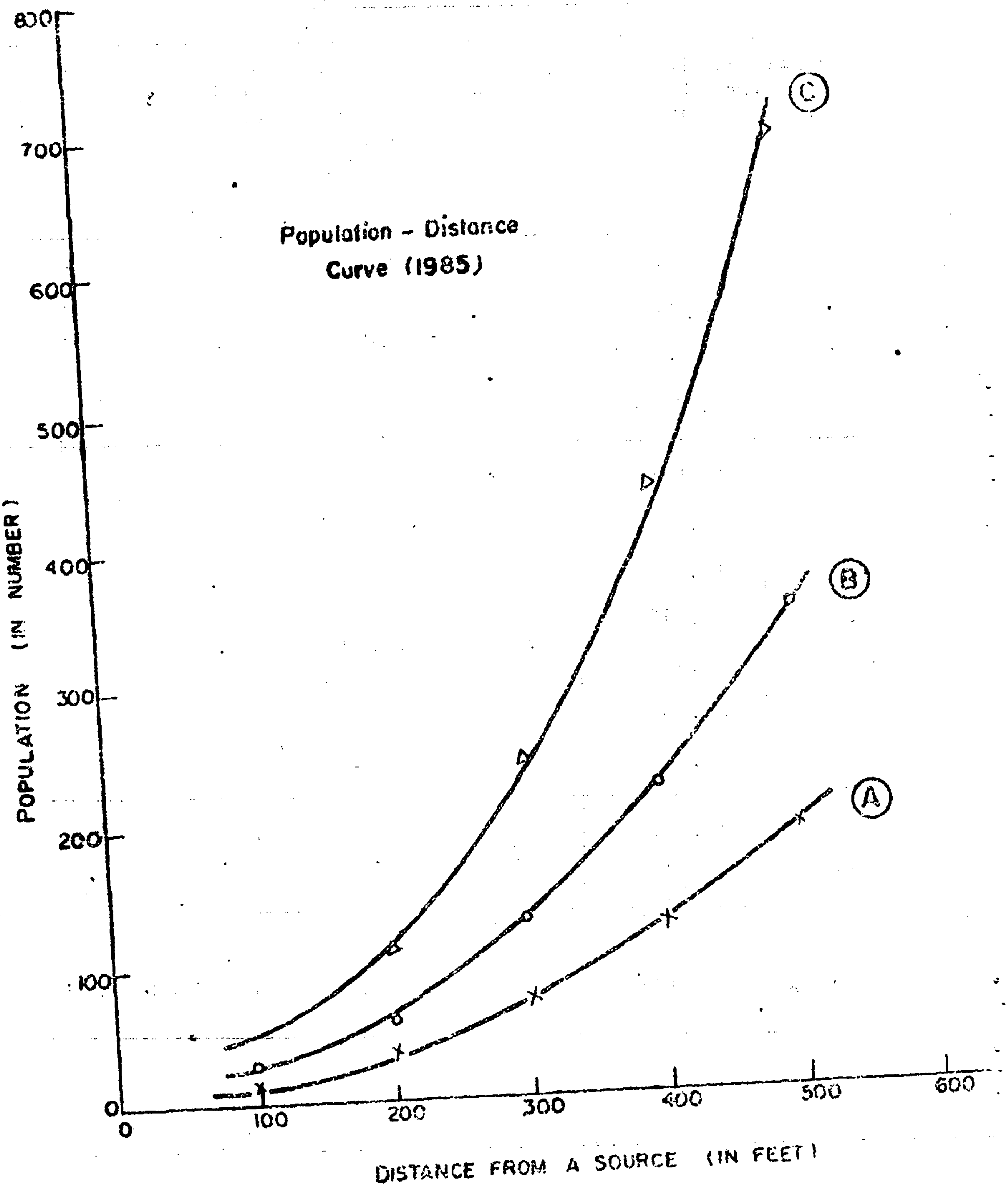


Fig. 4.2 Population Distance Curve for Various Average Density of Population Jessore Sadar Sub-Division

TABLE 4.3

Determination of total number of tubewells required (1985) for a given maximum distance of 300' from tubewell to households considering density of population and population figure of an area

Type of settlement	Average density of population in 1985 (persons/acre) 1/	Number of area observed 1/	Percent observation covered by the type of settlement	Percent population covered by the type of settlement	Maximum distance of tubewell from households (in feet)	Number of person could be served by one tubewell 2/	Number of tubewells in the area considering max. 300' distance between T/WL and each household	Total tubewell required (1985 population) 4/
	a	b	c $= \frac{b}{\Sigma b} \times 100$	d $= \frac{a \cdot c}{\Sigma a \cdot c} \times 100$	e	f	g 3/ $= \frac{\text{Total populn.}}{f} \times \frac{d}{100}$	$h = \Sigma g$
A	10.443	4	30.77	16.583	300	67.784	4012	
B	19.130	7	53.95	53.264	300	124.17	7035	13053
C	37.986	2	15.38	30.151	300	246.56	2006	

1/ From Table 4.2

2/ From Figure 4.2

3/ Population in the rural areas of Jessore Sadar Sub-Div. according to 1974 census = 1,249,947. Estimated population in 1985 = 1,249,947 x $(1 + .025)^{11}$ = 1,640,000 (approx.)

4/ This represents an average of 126 persons per tubewell in 1985.

4.2 Average Domestic Water Requirement/Consumption

In the rural areas of Bangladesh water requirement is affected by domestic consumption together with the consumption by domestic animals. Domestic requirements of the rural people means water requirement for drinking, cooking, washing clothes and utensils, batheing, sanitary purposes, house cleaning and polishing. Occasionally a substantial quantity of water is used for the preparation of rice from paddy. Water is also used for kitchen gardening. Among domestic animals, cows and goats are the most common. A reasonable quantity of water is required for their drinking and food preparation.

Water use and collection from public and private tube-wells of 10 households at different places were observed for three consecutive days. The tubewells were within the inner compound or very close to the households. Those households used tubewell water for all domestic purposes. Households were also interviewed at noon and in the evening to gain information about their water usage in the house.

The total average daily collection of households has been divided by the population of the households to get the daily average per capita water consumption under rural living conditions. Table 4.4 represents the per capita water consumption under various socio-economic and other field conditions. An average of 10 gpcd consumption may be considered normal under rural living conditions. Floor area, construction materials of the house, approximate monthly income and occupation of the

TABLE 4.4

Per Capita Water Collection by Socio-Economic Status and Sanitary Facilities

Sample area	Floor Area of all roofed dwellings (sft)	Wall made of	Roof made of 1/	Approx. average monthly income (Taka)	Occupation of the househead	Religion	Tubewell	Sanitary facility	Average Total collection (gallon/day)	Household size (Persons)	Per capita collection (gpcd) 2/
18	<350	Mud	Straw	450	Labourer	Muslim	Family pump	No	31.3	5	6.26
18	<350	Mud	Straw	450	Labourer	Muslim	Family pump	No	38.2	6	6.37
4	350-700	Mud	Straw	800	Farmer	Hindu	Public	No	47.16	5	9.43
4	350-700	Brick	Tali	1000	Farmer	Muslim	Private	No	68.18	7	9.74
3	350-700	Mud	Straw	1000	Farmer	Hindu	Public	No	30.75	3	10.25
4	350-700	Brick	Tali	1500	Farmer	Hindu	Public	No	107.78	10	10.78
4	350-700	Mud	Tin	800	Service	Hindu	Public	Yes	60.00	5	12.00
3	350-700	Mud	Straw	1000	Farmer	Hindu	Public	Yes	77.24	6	12.87
4	350-700	Brick	L.C.	1500	Business	Muslim	Public	Yes	54.05	4	13.51
8	>700	Brick	L.C.	1500	Business	Muslim	Private	Yes	105.03	9	11.67
										Average:	10.29 gpcd

Average domestic water requirement of 10 gpcd may be considered for design purpose in tubewell water supply.

1/ L.C. = Lime concrete
Tali = Local name for tiles

2/ gpcd = gallon (U.S.) per capita per day head of the house have been taken as indicators of socio-economic status. The field observation found that 70% of the rural households have floor area less than 350 sqft and a house made of mud. Water consumption of this class of people is comparatively less than the others. This may be because they have fewer clothes to be washed, less food to be cooked and a smaller floor area to be cleaned. Average water consumption of the people of the villages of Amjhupi and Senbill under Meherpur sub-division is approximately 25 percent less than people of other observed areas. People of those places are very poor labourers. They have only one or two small thached houses. Water consumption for cooking, washing clothes and utensils, and washing houses is comparatively less than the people of other area. The exact variation of water consumption of various socio-economic cleasses of people is difficult to measure, because other factors also influence water consumption. It has been found that 86 percent of the rural people have only primary education or none at all and only 4 percent have more than secondary education. The level of education may have some effect on water consumption, but it is also difficult to measure this under rural living conditions.

Sanitary facilities increase the per capita water consumption. Approximately 1 gallon additional water per capita is required for hand flushing water seal latrines.

Table 4.4 represents that Hindu people use comparatively more water than Muslims for washing their kitchen and other room floor twice daily; once in the morning and once in the evening, with water and cowdung.

Per capita consumption varies inversely with household size as represented in Table 4.5. This is because some quantity of water is always used for washing, cleaning and cooking, which is independent of the number of family members.

Water consumption varies with seasons of the year. During hot days of summer more water is used for batheing. The data in the Table 4.4 represents the water consumption during the month of April. A water consumption survey was also conducted during winter in some places to determine the variation of water consumption with the season. Water collection from tubewells also varies with the season. About a 20 percent decrease of water collection from tubewells was observed in between summer and winter in some places. Table 4.6 and 4.17 represents the water consumption for various domestic purposes.

4.3 Patterns of Rural Water Supply

4.3.1 Types of Sources Used

The type of water sources are identified as follows:

(a) Unprotected:
- Pond and ditch,
- River and Stream, and
- Ring Well or Dug-well.

(b) Protected:
- Hand pump tubewell (shallow, deep, Deep-set pump, Family pump tubewell)

TABLE-4.5

Per Capita Water Consumption by Household Size

Sample area	Distance of the household from tube well (ft)	Household size (no. of members)	Per capita consumption (gpcd)
3	375	7	7.28
	400	4	10.00
9	200	10	1.24
	200	6	2.06
10	270	13	7.32
	250	7	11.04
11	150	11	1.80
	175	6	3.00
16	150	8	3.50
	120	4	9.61
18	100	13	2.70
	92	7	3.92
23	263	5	4.3
	237	2	8.0
23	315	9	3.78
	300	5	5.00
25	430	9	1.65
	430	4	2.99
26	455	16	5.10
	520	8	10.20

TABLE-4.6

Average per capita per day water consumption for major domestic purposes considering 10 gallon per capita per day total consumption

Purpose of use / Quantity	Drinking	Washing Cloths	Washing Utensils	Cooking	Bathing	Others
In gallon	0.5-0.7	2.0	1.5	1.0	3.0-4.0	2.0-3.0
Percent of total requirement	5-7	20	15	10	30-40	20-30

TABLE-4.7

Water consumption for some specific domestic purposes

Purpose of use	Unit	Quantity in gallon
Rice preperation from paddy	per 100 kg	20-25
Polishing floor and wall with mud and water (Muslim houses)	per 100 sft once or twice per week	2.0
Wash the body of cow	per cow/week	5.0
Cow (used in cultivation) feeding	per cow/day	5-7
Cow(not used in cultivation) feeding	per cow/day	3-4
Goat feeding	per goat/day	0.5
Washing legs and hands after working in field	per person per trip	0.5-1.00
Washing pitcher (Kalsi)	per pitcher per trip	0.3-0.5
Rice washing and cooking	per capita per day (twice a day)	0.8-1.00

In all the sample areas, most of the households have access to both protected and unprotected sources, although the distances to the sources are different for different households. Table 4.8 shows the average distance of the sources from the households in different sample areas. In Kushtia, the use of ring wells to tap subsurface water is very common and its average distance from the households in comparison to other sources is less, because people always construct ring wells within their inner compounds. Moreover, since it is cheaper to construct, wherever it is feasible, there may be several ring wells in a locality.

The pond is the main traditional source competing with gr water collection through handpump tubewells, which is seen in almost all areas. Figure 4.3 represents the comulative relative frequency distribution of travel time of the households to preferred water sources, which indicates that average distance of the households from a pond is nearly equal in comparison with a handpump tubewell. On an average 40 percent of the rural households, have a tubewell within 200 ft; the figure in 1976 was 300 ft. Within the last 4 years, the total number of tubewells has increased by about 50 percent. Only 20 percent of the rural people have a tubewell within 100 ft of their houses. The time required to go and return from a source situated at a 100 ft. travel distance is approximately 1 minute. Table 4.9 shows the types of sources used for various domestic purposes, which indicates that large quantity of water is collected from ponds and other unprotected sources. For washing clothes and

TABLE-4.8

Typical average distance of various sources from the households (in feet)

Sample area	Average distance of the source from the households (in feet)			
	Protected	Unprotected		
	Tubewell	Pond	River	Ringwell
25	296	330	-	-
26	378	62	-	-
23	310	300	-	-
20	161	340	-	-
18	178	482	500	78
17	265	-	Over 1000	150
16	195	315	380	-
12	313	247	-	-
7	175	279	Over 1000	142
13	258	190	-	
14	130	152	-	101
4	205	-	300	-
1	210	500	-	-
11	175	237	500	-
10	195	-	200	-
Mean (in feet)	230'	278'	More than 550'	110'

Foot note: Table 4.8 only represents typical information.

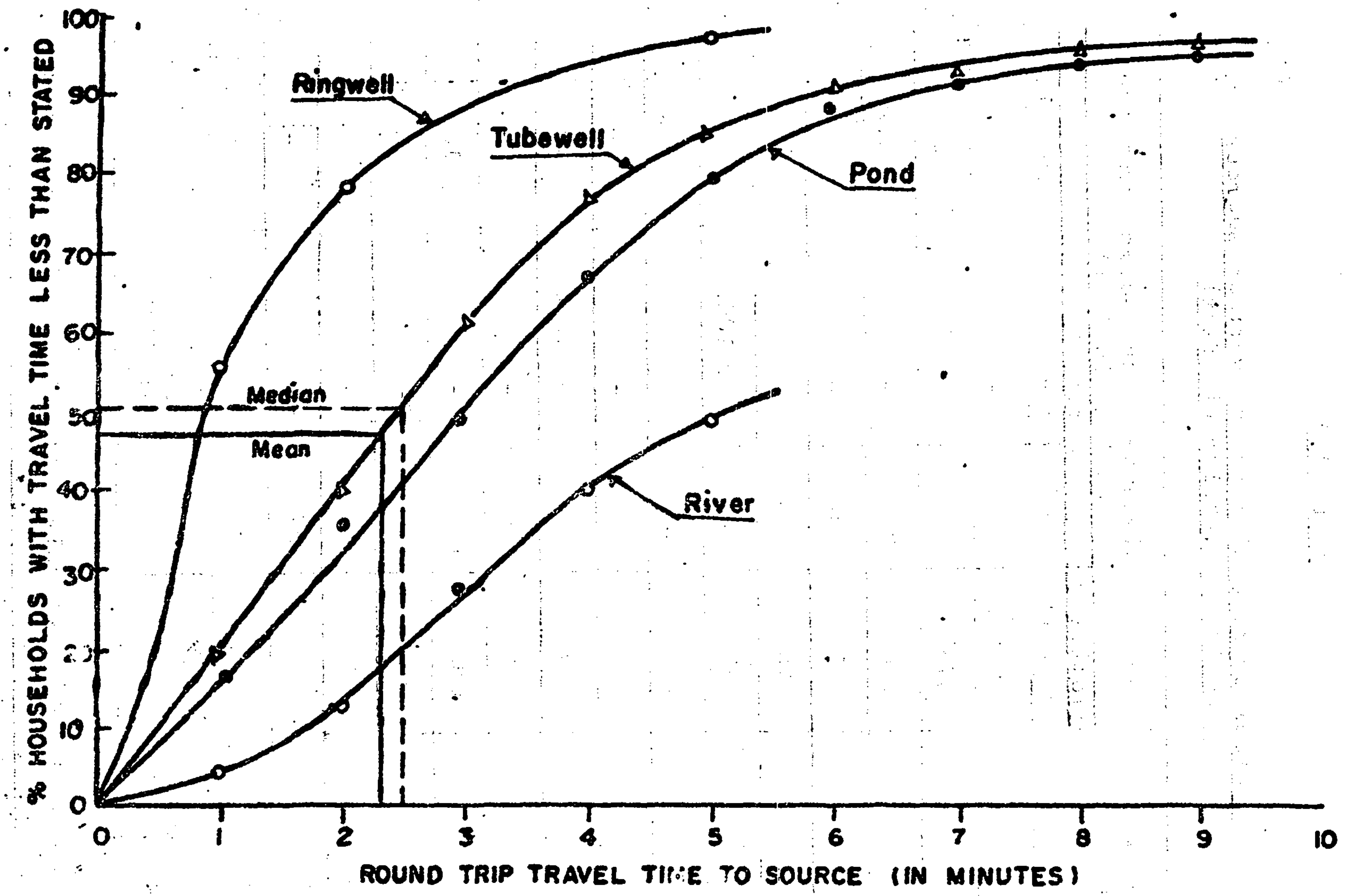


Fig. 4.3 Cumulative Relative Frequency Distribution of Travel Times to Preferred Water Source of the Households

TABLE 4.9

Water Sources used by the Househol ds (in percent) for Various Domestic Purposes

Sample area	Season	Drinking		Cooking		Washing				Bathing		For cattle		Sanitary and other purposes	
						Clothes		Utensils							
		T/WL	Other	T/WL	Other	T/WL	Other	T/WL	Other	T/WL	Other	T/WL	Other	T/WL	Other
3	Dry	100	-	67	33	45	55	85	15	20	80	50	50	70	30
	Rainy	100	-	50	50	12	88	80	20	15	85	40	60	60	40
7	Dry	97	3	80	20	48	52	80	20	38	62	54	46	72	28
	Rainy	95	5	70	30	20	80	75	25	32	68	50	50	60	40
12	Dry	100	-	-	100	-	100	35	65	12	88	-	100	28	72
	Rainy	100	-	-	100	-	100	10	90	10	90	-	100	20	80
13	Dry	100	-	85	15	61	29	50	50	30	70	15	85	30	70
	Rainy	100	-	90	10	35	65	35	65	23	77	10	90	25	75
14	Dry	100	-	65	35	30	70	55	45	20	80	40	60	65	35
	Rainy	100	-	40	60	12	88	40	60	15	85	25	75	60	40
16	Dry	100	-	90	10	15	85	85	15	10	90	90	10	100	-
	Rainy	100	-	80	20	8	92	80	20	5	95	80	20	95	5
18	Dry	95	5	90	10	40	60	65	35	15	85	21	79	50	50
	Rainy	92	8	80	20	18	82	55	45	-	100	20	80	40	60
20	Dry	95	5	58	42	30	70	55	45	30	70	-	100	40	60
	Rainy	90	10	40	60	5	95	50	50	20	80	-	100	35	65
25	Dry	100	-	10	90	15	85	25	75	15	85	10	90	15	85
	Rainy	100	-	10	90	5	95	10	90	10	90	5	95	10	90
26	Dry	100	-	15	85	6	94	15	85	10	90	-	100	10	90
	Rainy	100	-	10	90	5	95	5	95	-	100	-	100	5	95
Mean	Dry	98.7	1.3	56	44	29	71	55	45	20	80	28	72	48	52
	Rainy	97.7	2.3	47	53	12	88	44	56	13	87	23	77	41	59

Foot Note: The sample areas used in Table 4.9 are not fully compatable, since data for the areas were collected during different periods.

utensils and for bathing purposes, unprotected surface water sources are preferable to rural consumers. But due to the absence of sanitary disposal of excreta and non-hygienic practices in the rural areas, most of the unprotected sources are dangerously contaminated. Moreover, water levels fluctuate widely with seasons of the year. During summer, when these sources in many places become almost dry, tubewell water use increases. In the rainy season, surface water use increases again. Chemical treatment or sanitary protection of these exposed sources will involve a high cost and it is impracticable in the rural areas. Ground water collection through handpump tubewell is generally considered a safe and reliable supply of water in rural areas as the chances of contamination are few. Except the hilly areas of Chittagong and Sylhet and the western part of Rajshahi district, the water table lies presently within the suction limit of handpumps. In the above mentioned places and where the water table goes beyond the suction limit of the normal hand pump, deep-set pumps are used. Deep-tubewells are installed where sweet water is not available at a reasonable depth. Tubewell water is mainly used for drinking in almost all these areas. Where tubewell water does not contain high concentrations of iron, it is also used for cooking, washing utensils and some times it is used for batheing and washing clothes. Tubewell water usage decreases by 17% in the rainy season, according to the interviews.

Table 4.10 represents the average per capita water collection from tubewell both in dry and winter seasons as

TABLE 4.10

Average per capita water collection from tubewell in dry and rainy season

Purpose of use →	Drinking		Cooking		Washing: Clothes		Washing: Utensils		Bathing		Sanitary and other	
Season →	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy
a) Present water collection from tubewell source in percent for the purpose 1/	98.7	97.7	56	47	89	12	55	44	20	13	48	41
b) Avg. water requirement for the purpose in percent of the daily per capita requirement 2/	5-7		10		20		15		30-40		20-30	
c) Avg. water requirement for the purpose in gallon per capita per day 3/	0.5		1.0		2.0		1.5		3.0		2.0	
d) = $\frac{axc}{100}$ Amount of water collected from tubewell source for the purpose in gallon per capita per day	0.494	0.49	0.56	0.47	0.58	0.24	0.82	0.66	0.60	0.39	0.96	0.82
e) = $\sum d$ Total per capita per day collection from tubewell (in gallon)	Dry		4.02 gallon/capita/day				Mean collection from tubewell = 3.54 gpcd					
	Rainy		3.07 gallon/capita/day									

NOTE: 1/ From Table 4.9 2/ From Table 4.6 3/ Average domestic per capita per day consumption has been considered = 10 gallon obtained from interviews of the households. Mean per capita collection from tubewell is only 35% of the total daily consumption. Tubewell water collection decreases by 23 percent in the rainy season, which has been calculated from the observations, which is close to the 17% noted from interviews.

Figure 4.4 indicates the 50 percent households have tubewell water collection less than 3.3 gpcd. Observation of water sources have shown a mean tubewell water collection of 3.9 gpcd, i.e 39% of the total daily consumption. The balance i.e 61% of the total daily consumption is being collected from unprotected sources like ponds (Plate-1), rivers, ringwells, etc.

4.3.2 Types of Collection System

In rural areas of Bangladesh about 90 percent of the ground water is being lifted by handpump tubewells. Depending on the depth, handpump tubewells are classified as shallow or deep tubewells. Normally hand pump tubewells are $1\frac{1}{2}$ inch dia. and they are fitted with a "No.6 handpump" at the top. Recently some 1" dia. very shallow tubewells have been installed on an experimental basis in some selected places, which are fitted with a "No.2 hand pump" (Plate-2). This type of tubewell is known as "Family pump" tubewell. Some of the salient features of these pumps are briefly tabulated in Appendix-B. Both types of pumps are able to pump water from ground water source where the water table is within about 25' of the seat valve of the pump. Two separate designs of the No. 6 hand pumps are available;

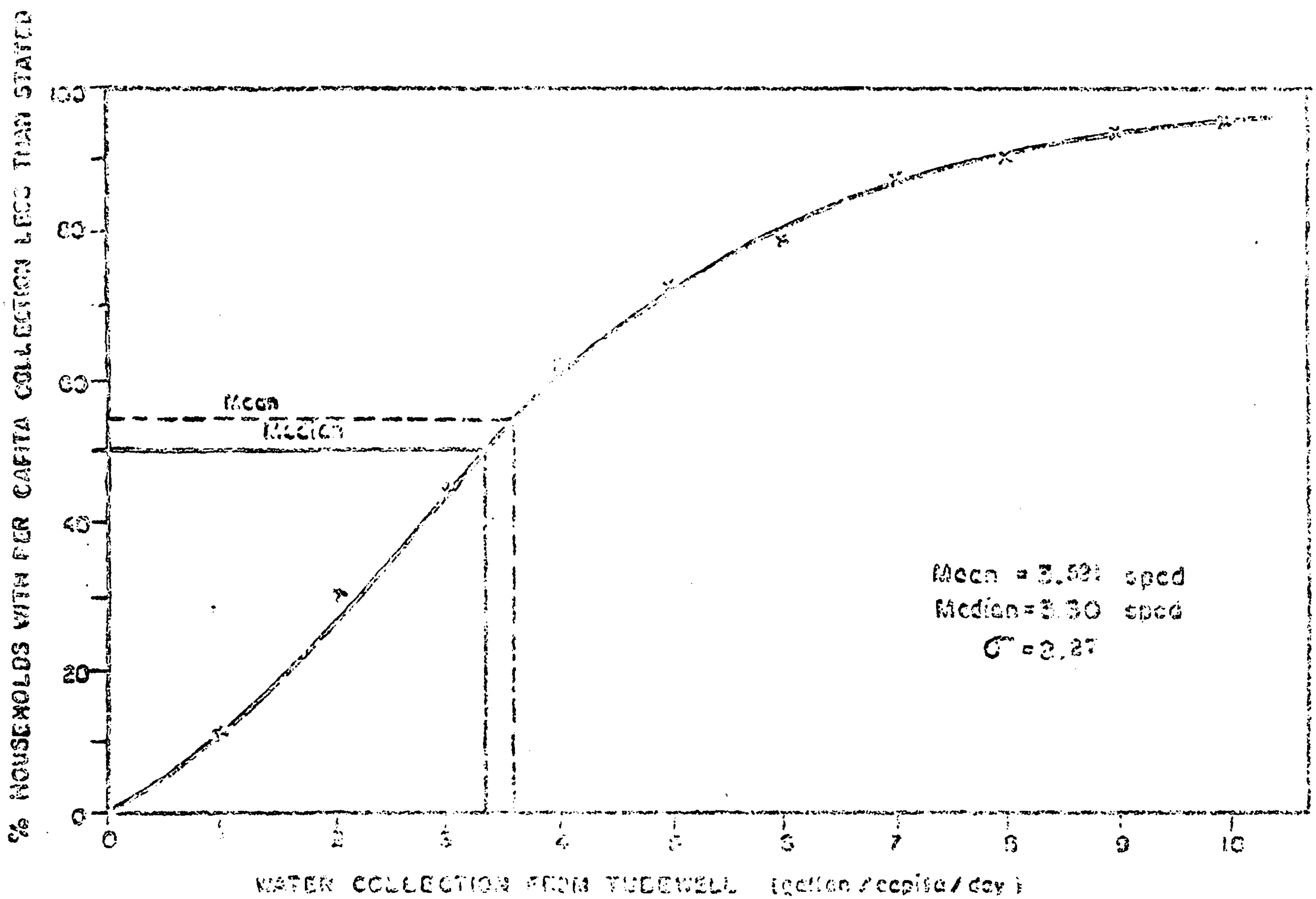


Fig. 4.4 Cumulative Relative Frequency Distribution of Household-day Tubewell Water Collection

Plate-1 Water consumption from unprotected pond.

the local type known as the "Maya No.6" and the UNICEF type. The latter has been developed by the UNICEF local office. Yield capacities of the pumps are different. Other major factors which affect the yield of a pump are condition of the pump and type of operation. Table 4.11 represents the average yield of the pumps excluding average loss and waste in collection. Loss and waste is high in Family pump tubewells. This loss can be minimised if the distance between the spout of the pump and container is reduced. Table 4.12 shows the various types of containers (Plate-3) used for the collection of water in the sample areas. Generally, medium or a small pitchers and buckets are used to fetch water when water is brought to the house. Households living close to a source make more journeys and collect less volume of water per trip than the households living some distance away from source. Average volume of water collection per trip lies between 2.00-2.50 gallon. Figure 4.5 represents the effect of travel time to source on volume of water collected per journey.

The cost of installation of a Family pump tubewell is less than the traditional handpump tubewell, but referring to Table 4.11, the average yield capacity under medium operating conditions is nearly the same. The total cost of construction of a Family pump tubewell is lower for two reasons - low cost of materials and low installation cost. However, a No. 6 pump is about three times heavier and thus more robust than a No.2 pump. In Family pump tubewells 1 inch dia. pipes are used in place of $1\frac{1}{2}$ inch dia. pipe. Cost of installation of a Family pump tubewell is about half ....

TABLE 4.11

Average Capacity of No.6 and No.2 Pump

Pump Number	No. 6						No. 2		
Type of Pump	LOCAL (Maya Type)			UNICEF (Bangladesh New No.6)			Experimental 1/		
Type of Operation	Heavy thrust	Medium	Slow	Heavy thrust	Medium	Slow	Heavy thrust	Medium	Slow
Average strokes/ minute	15-18	25	20	15-18	25	20	50	55	40
Average yield (gallon)/stroke	0.30	0.13	0.06	0.41 2/	0.16	0.08	0.07	0.06	0.03
Average yield (gallon)/min.	4.50-5.50	3.5	1.5	6.0-7.50	4.0	1.5	3.5	3.0	1.0

1/ This was designed in Bangladesh, and is a modified, scaled-down, version of the Maya-type pump.

2/ The theoretical "swept volume" at a full 8½" stroke will yield 0.35 US gallons. It is assumed that the energy imparted during a heavy thrust will create momentum sufficient to allow flow to continue after the stroke is complete.

TABLE 4.12

Containers used by 100 households for the collection of water

Type of container	Pitcher (Kalsi)			Bucket (Balti)			Others
Size of container	Big	Medium	Small	Big	Medium	Small	-
Average capacity of containers (gallon)	3.6-3.0	2.75-2.0	1.5-1.0	-	1.5	1.0	Badna - 0.25 Jug - 0.50
Percent of water collections made	11	34	24	0	7	8	20

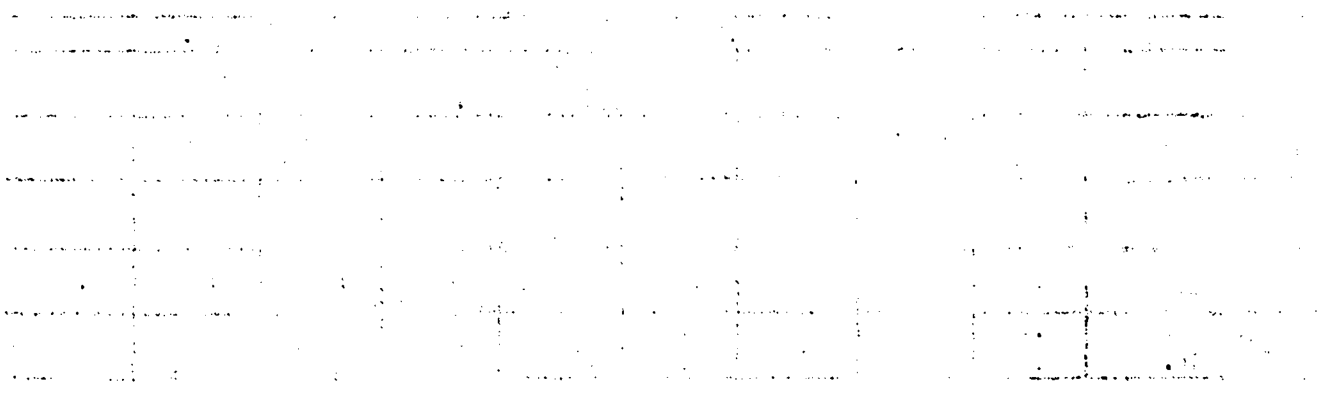


Plate - 2 various type of pumps

Plate-3 Major containers used for water collection from tubewell.

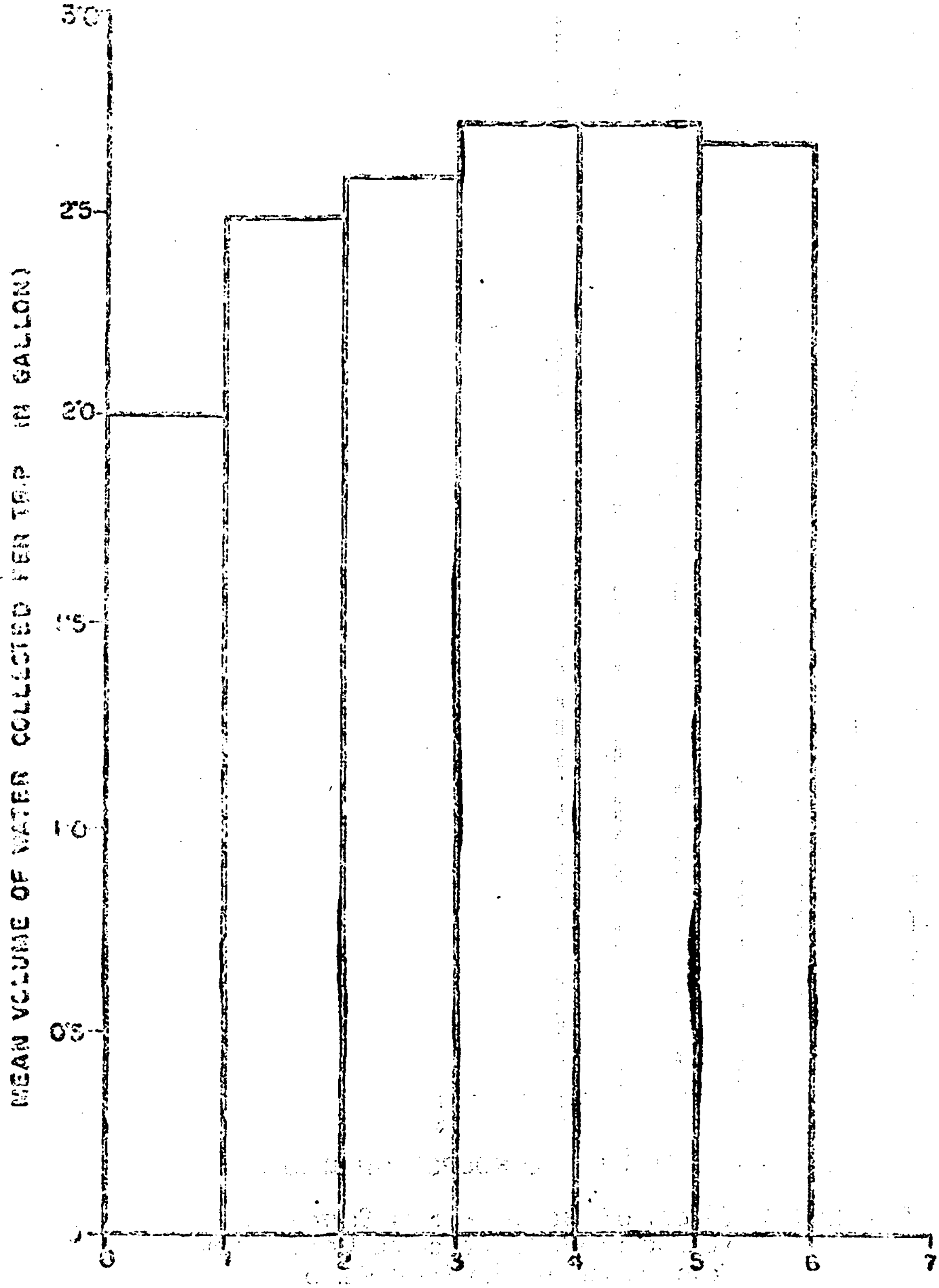


Fig. 4.5(a) Effect of Travel Time to Source on Volume of Water Collected Per Journey from Tubewell with No.6 Pump

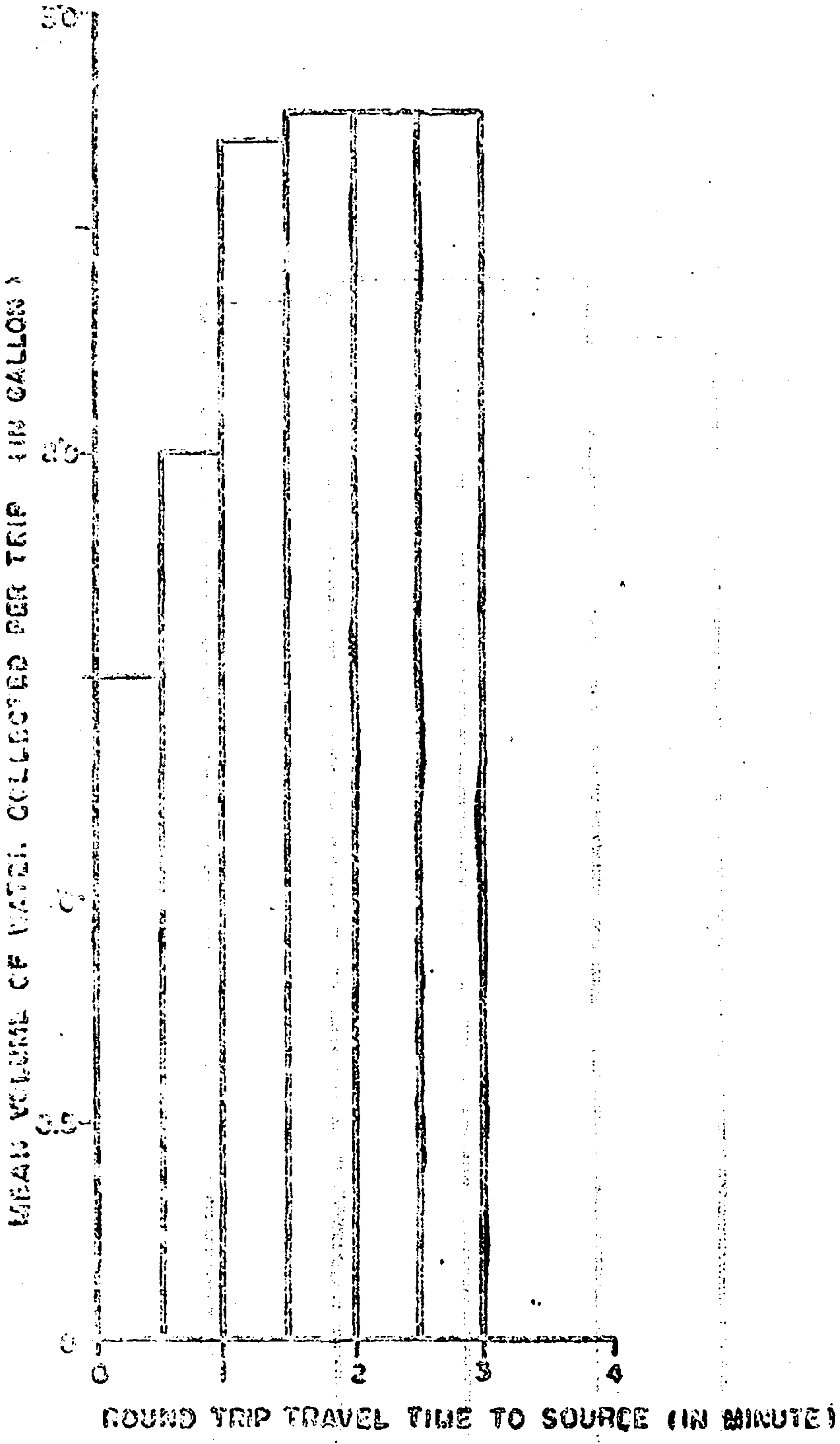


Fig. 4.5 (b) Effect of Travel Time to Source on Volume of Water Collected Per Journey from Tubewell with No.2 Pump.

that of a traditional tubewell. The maintenance cost of a Family pump tubewell is also less because spares are less costly. Only a few buckets have been replaced in the Family pump tubewells of Amzhupi, Meherpur in the first year after installation, the costs of which are less than taka 20/- per tubewell. Although the tubewells have been installed for one family, in most of the places 5-15 households use one well.

Figure 4.6 shows that the maintenance cost of a tubewell varies directly with number of users. The maintenance cost of a traditional hand pump tubewell is about taka 45/- per annum where approximately 160 people use the tubewell. Maintenance costs are optimum for approximately 60 users for a Number 6 type well.

A rough estimate from the above indicates that the cost of construction and maintenance of a Family pump tubewell does not exceed 50% of that of a traditional hand pump tubewell. However, where a "Number 6" tubewell will serve possibly 150 people, a "Number 2" tubewell will only serve 20-30 adequately. This makes the per capita cost of the "Number 2" somewhat higher than the "Number 6".

4.4 Factors Affecting Rural Water Use Habits

It has already been observed that the major portion of water for various domestic purposes is being collected from unprotected sources. In all sample areas households were interviewed to findout the reasons for non-usage of tubewell water. The main reasons are identified as follows:

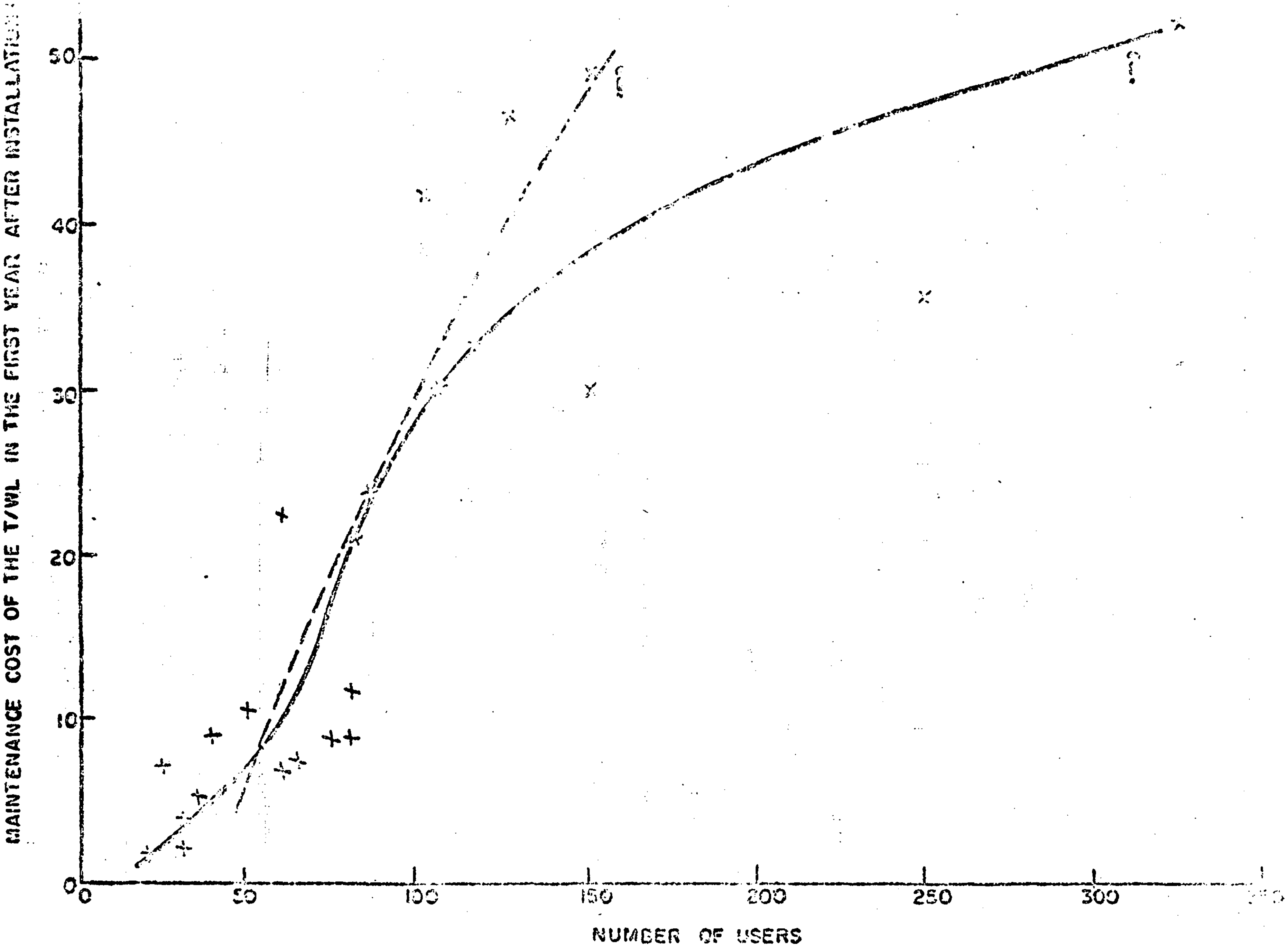


Fig. 4.6 Variation of Maintenance Cost with Number of Users

Description	Type of problem
- Sufficient quantity of water is available from surface sources (15%) - Feel comfort in taking bath and washing cloths in pond and river(95%)	Traditional habit
- Tubewell is too far away (29%) - Ringwell or pond or river is closer to the house (49%)	Distance of the source
- More time is required in fetching water from a tubewell particularly for bathing and washing - Washing and bathing not possible at peak demand period (37%)	Time spent in collecting water and its use
- Tubewell water tastes bad and has a cloudy appearance (36%) - Cooked food and clothes become coloured (29%) - Take more time in boiling rice and dal (27%) - Hair becomes sticky (58%)	Water quality
- Taking bat and washing cloths on small platform is difficult (40%) - Tubewell site becomes flooded and contaminated by waste water (19%)	Washing and bathing facility at T/WL site
- Tubewell is situated in an exposed place; more time can not be spent for washing and bathing by the women for lack of privacy (60%)	Privacy of the tubewell site

Rural people have an idea that tubewells are not for all purposes. The fear of damage to the pump through over use prevents them from using tubew..lls for all purpose. Sometimes caretakers do not permit oth rs to use tubewell water for purposes other than drinking.

4.4.1 Traditional Habit and Lack of Awareness about the Causes of Water Borne Diseases

Traditional habits passed down through the ages lead rural people to use unprotected wate from ponds, ditches, rivers etc., particularly for bathing and washing clothes. Most people during interviews replied that they get personal satisfaction in submerging themselves in rivers or pond water for bathing. Some have the idea that tubewell water is mainly for drinking and not for all purposes.

Field observation indicates that most, if not all, use tubewell water at least for drinking. At present they have an idea that if they use unprotected water from ponds and rivers for drinking. they may be attacked by germs of cholera or diarrhoea.

However, they are totally ignorant about the dangers resulting from the use of unprotected water for other domestic purposes. A lack of health education is responsible for this.

A centuries old traditional habit cannot be changed rapidly. Better facilities such as a tubewell water supply should be provided to encourage them to using tubewell water.

In addition, an extensive general education programme is needed. People should be motivated through health education activities. A long term appropriate programme should be planned.

4.4.2 Time Require in Fetching Water from the Source (T/WL)

Water consumption from a source varies with the time of day. A peak demand period between 7.00 and 10.00 A.M. is observed in most places. Figure 4.7 represents that on an average, 14 percent of the total water collection journies are made between 7.00 A.M and 8 A.M. It can be also seen from figure 4.8 that 50 percent of daily total collection journies are made within the first five hours. Since at peak demand period, comparatively more people attend a tubewell within a short interval of time (Plate-4), it takes several minutes to fetch water from tubewell. In one place 19 collection journeys were made within 8 minutes and soma water collectors waited 10-15 minutes at tubewell site. The maximum time required to fetch water from tubewell at peak demand period depends on, how many users there are to the tubewell. Table 4.14 represents the variation of waiting times.

Long delays at tubewell site naturally discourage a water collector, who often prefers to use nearby unprotected sources instead.

Field observation indicates that households living close to a tubewell use it more frequently but collect less water per trip than households living some distance from the tubewell. Variations in numbers of collection journies and volume of water collected against distance have been presented in Fig. 4.9 and Column (e) of Table 4.13, which indicates that the per capita daily collection decreases with distance of household from tubewell.

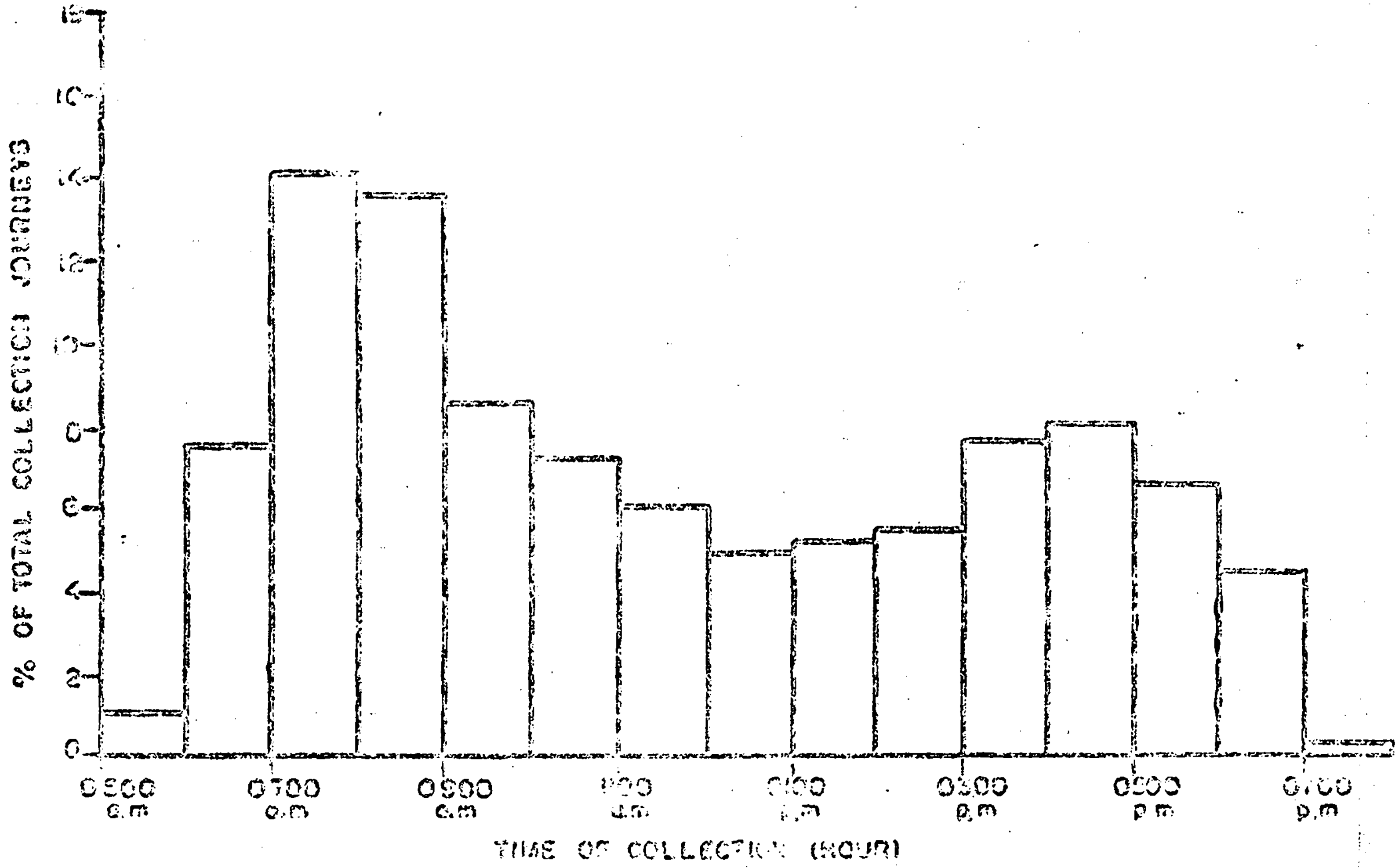


Fig. 4.7 The Variation of Water Collection with Time

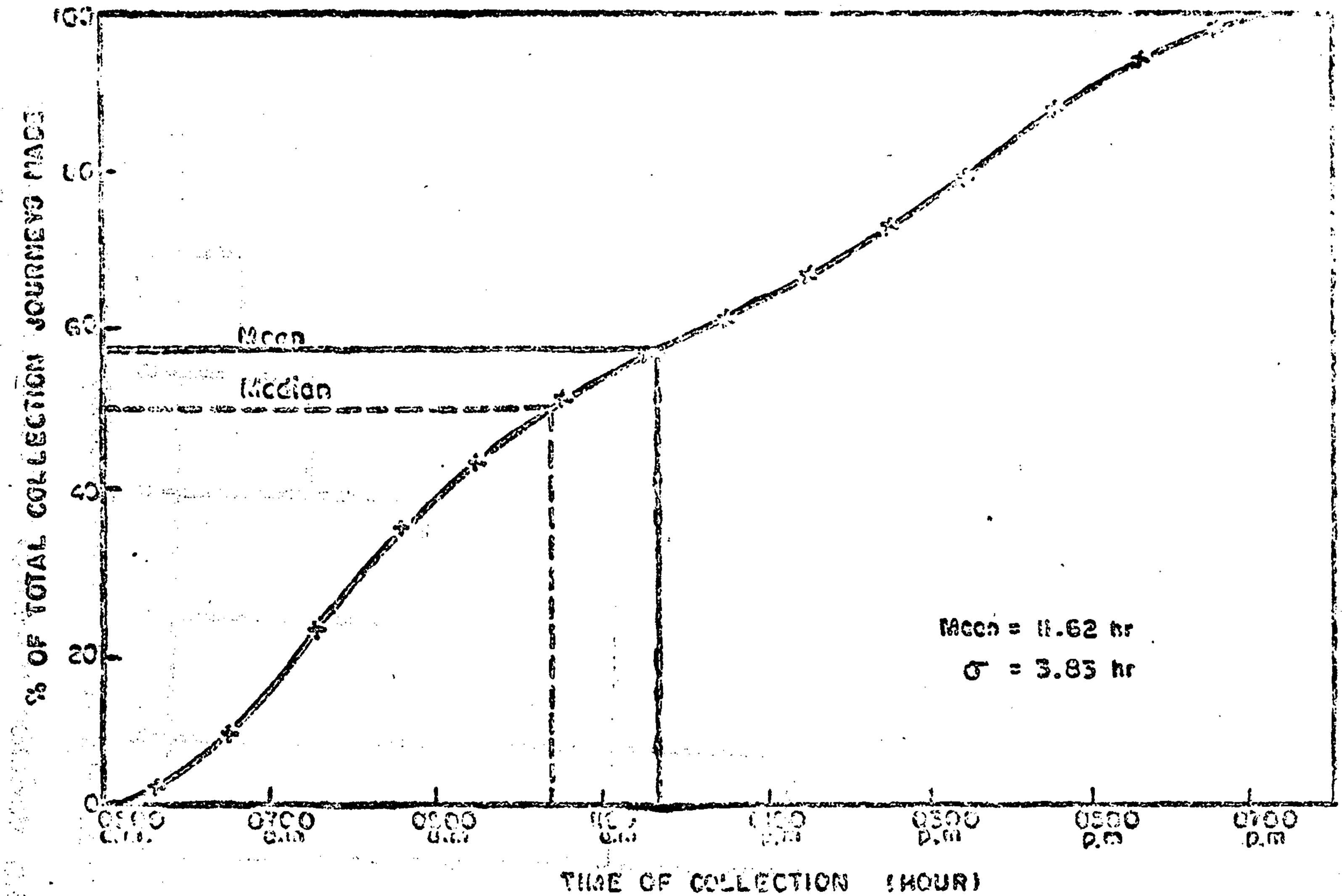


Fig. 4.8 Cumulative Relative Frequency Distribution of Collection Journeys Made with Time of the day

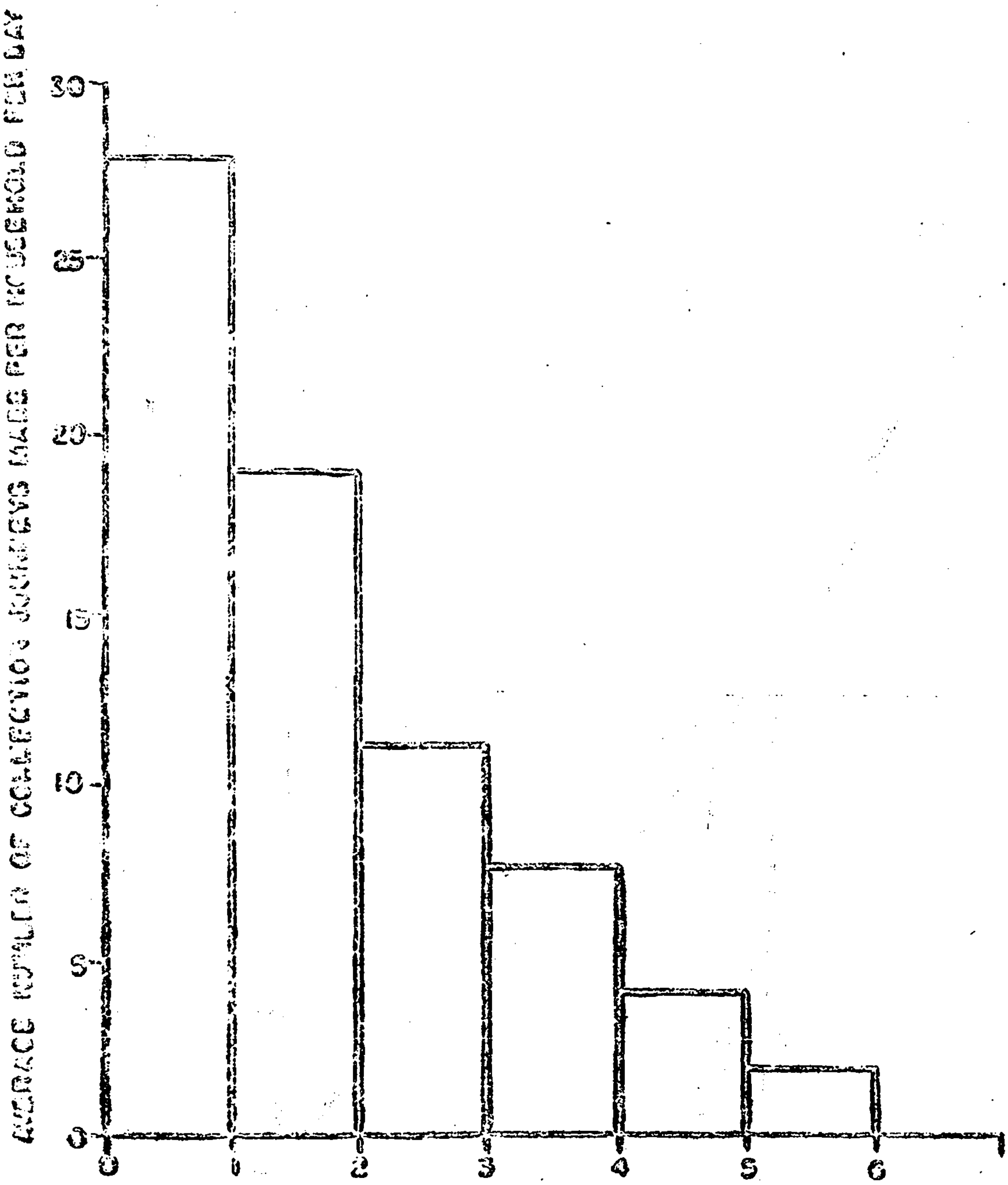


Fig. 4.9 Variation of Average Number of Collection Journeys Made by the Household with Round Trip Travel Time to Source

TABLE 4.13

Effect of travel time to source on per capita collection, volume and on total time of collection

(a) Distance of the household from tubewell (feet)	(b) Average number of collection journies per household/day	(c) Average volume of water collected per trip (gallon)	(d) Total volume of water collection per household per day (gallon)	(e) Average per capita collection per day (gallon) 1/	(f) Average round trip travel time to source (min) 2/	(g) Time required to fill the container with water (in c) per trip (min) 3/	(h) Time spent in washing and placing the container per time (min) 4/	(i) Total time spent per trip = f+g+h (min)	(j) Total time spent per household per day = i x b (min)	(k) Time spent in percent of the available working day 5/
0-100	28	2.00	56	8.00	0.5	0.50	0.66	1.66	46.48	5.16%
100-200	19	2.50	47.50	6.79	1.5	0.625	0.66	2.29	43.51	4.83%
200-300	11	2.60	28.60	4.07	2.5	0.650	0.66	3.78	41.58	4.62%
300-400	8	2.75	22.00	3.14	3.5	0.688	0.66	4.85	38.80	4.31%
400-500	4	2.75	11.00	1.57	4.5	0.688	0.66	5.85	23.40	2.60%
500-600	2	2.70	5.40	0.78	5.5	0.680	0.66	6.75	13.50	1.50%

1/ Considering average household size = 7

2/ Round trip travel time for a travel distance of 100' is approximately = 1 min.

3/ Considering average yield from a T/WL = 4 gall/min.

4/ About 40 second is required to wash and placing the container at T/WL site.

5/ Available working day is from 5.00 a.m. to 8.00 p.m. = 15 hours

Table 4.13 also indicates that total time spent in collecting water from a tubewell per day per household living within 400' from a tubewell does not vary significantly. A household living some distance away from a tubewell makes fewer collection journeys, collects less water but spends more time in round trip travel to source than the households living close to the tubewell (Plate-5). The total time spent in collecting water is only a fraction of the daily available working day.

As presented in Appendix-C-1, if people collect their entire domestic requirement of water, 10 gpcd, from a tubewell, then only to collect 2.5 gallons of water per trip, approximately 1.30 minutes will be required at the tubewell site. Under such conditions 160 people cannot be satisfied by one tubewell. Moreover since people never visit a tubewell regularly throughout the peak demand hour, they will have to wait for some time in fetching water even if the number of users is kept limited to 80, say.

To avoid any long delay at the tubewell site for fetching water, users per tubewell may be kept limited to half or less than half of the above figure.

Plate-4 Heavy rush at tubewell site at peak demand hour.

Plate-5 Water collectors from long and short distances to a tubewell.

TABLE 4.14

Effect of number of users on maximum delay at tubewell site at peak Demand period for one trip

Number of users of a tubewell	Average maximum delay at tubewell site (in minutes)
About 40 households (280 persons)	15 - 20
30 " (210 ")	10 - 15
20 " (140 ")	5 - 10
10 " (70 ")	Less than 5 minutes

The table above represent the present field conditions.

4.4.3 Water Quality

The physical quality of water plays an important role in the selection of source and water use from it in rural areas. Bacteriological quality carries little importance to the rural people, since they prefer water which tastes good and is odourless, and which does not change the colour of food or stains clothes.

Iron and chloride content in ground water collected through handpump tubewells in Bangladesh is generally high and in some places the concentration is at a much higher level than the limit acceptable to the rural people. People of those areas generally refuse to use tubewell water and opt for pond and river waters.

Detail studies on water use patterns were carried out in some iron and chloride problem areas of Jessore, Kushtia and Khulna districts. In one iron problem area of Jessore, one hundred households were interviewed about their water use habits. There were 8 public and 2 private tubewells, 3 ponds and one ring well in the area. In addition, the river "Bhairab" runs very close to that place. The average iron content in tubewell water was 6 mg/l and 77% of the total households surveyed had a tubewell within 700 ft. Most of the people of that locality were farmers or labourers. The water use habits of the people of the locality have been presented in Table 4.15, which indicates that other than for drinking, pond and river water uses are prominent in iron problem areas.

In one saline problem area of Khulna twenty households around three tubewells were interviewed about their water use, which have been presented in Table 4.17. Chloride contents of the tubewell water were 618 mg/l, 1900 mg/l and 2300 mg/l respectively. There are about 10 ponds and ditches in the locality. The first tubewell is a deep tubewell and all people of the locality use its water at least for drinking. People from over 3000' distance come to the tubewell for collecting water. Per capita water collection by the households from the tubewell have been presented in Figure 4.10. Water collection from the other two tubewells is very low. Only four households living very close to the tubewell use its water for some sanitary purposes.

TABLE 4.15

Water sources used by the house holds (per cent) for various domestic purposes in an iron problem area

Water use	Seasons	Tube-well	Ring-well	Pond	River	Rain water
Drinking	Dry	99.5	0.5	-	-	-
	Rainy	99.5	0.5	-	-	-
Cooking	Dry	8.	1	22	69	-
	Rainy	8	1	23	68	-
Washing clothes	Dry	4	2	20	76	-
	Rainy	3	1	23	73	1
Washing Utensils	Dry	19	1	19	62	-
	Rainy	18	1	20	62	-
For cattle	Dry	4	2	22	80	-
	Rainy	4	2	22	80	-
Sanitary purposes	Dry	17	1	20	65	-
	Rainy	17	1	20	65	-

TABLE-4.16

Reasons (percent) for non-usage of tubewell water in an iron problem area

Aesthetic (colour)	Stains clothes and utensils	Odour	Teste	Causes constipation
90	68	28	38	1

TABLE 4.17

Water Sources used by the households (in percent) for various domestic purposes in saline problem areas

Source	Drinking	Cooking	Laundry	Washing utensils	Bathing	Sanitary and other
Tube-well	100	16.6	5.5	5.5	0	5.5
Other	0	83.4	[illegible].5	94.5	100	94.5

During the interview of households, people expressed their opinion about the causes of the non-usage of tubewell water in iron and chloride problem areas. The reasons mentioned by the people of iron problem areas are presented in Table 4.16.

The main reason for non-usage of chloride content water is its bitterness in taste.

In different iron and saline problem areas of Jessore, Khulna and Kushtia, some households were interviewed about their general opinion on overall water quality. Their opinion has been plotted in Fig. 4.11 and 4.12, against the chemical content of the tubewell water they use. It is observed that rural people use handpump tubewell water having an iron content less than 2 mg/l and chloride content less than 400 mg/l without raising any specific objection and they consider such water as good.

In addition to the interview of the households, four tubewells at different sites which yield water with iron concentrations of about 8 mg/l were observed between 5.30 A.M.

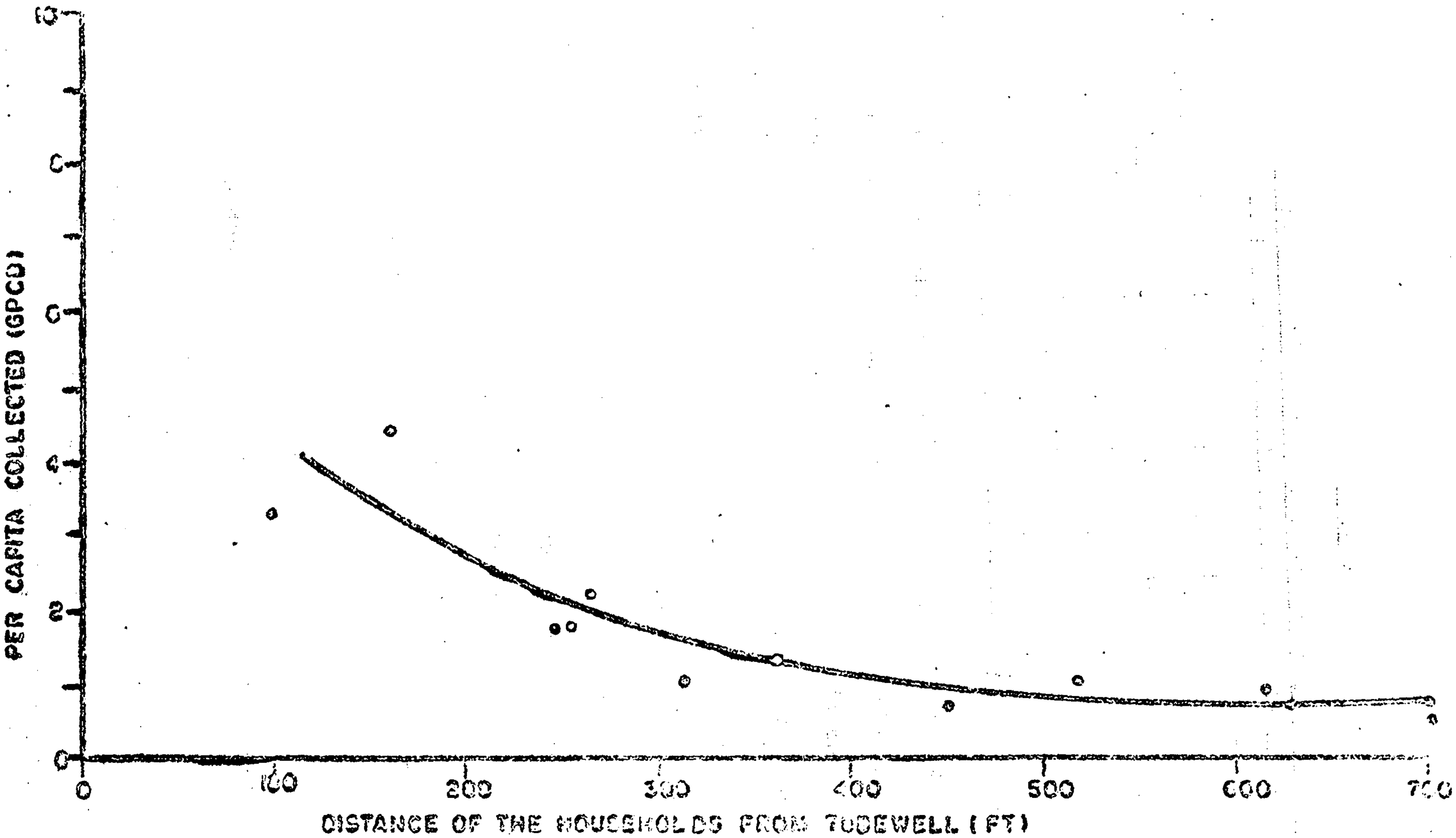


Fig. 4.10 Water Collection from Tubewell by the Households in Saline Probem Areas

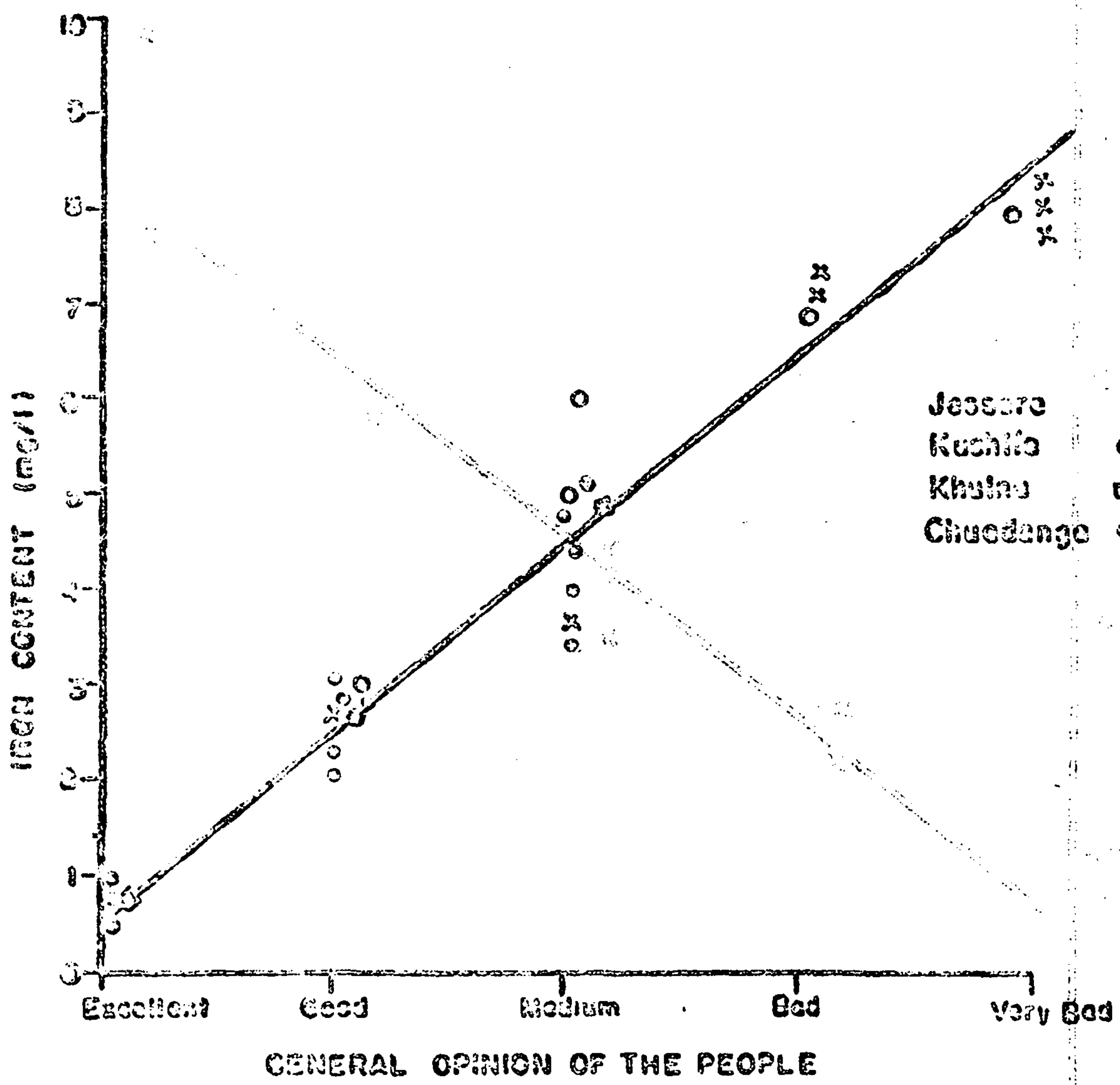


Fig. 4.11 Iron Content and People's General Opinion About Water Quality

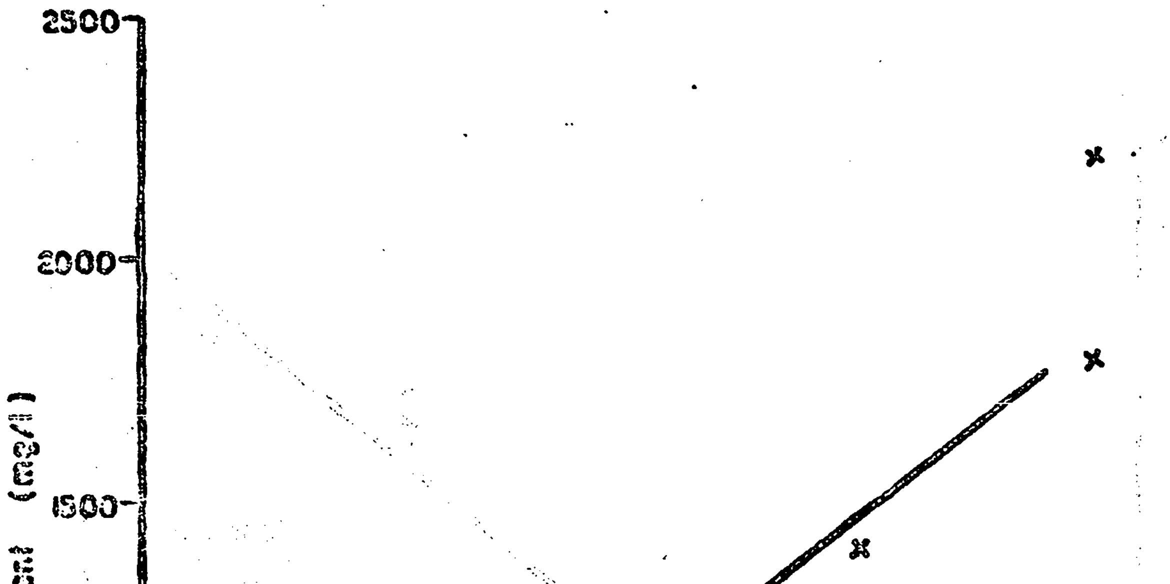


Fig. 4.12 Chloride Content and People's General Opinion About Water Quantity

and 7.30 P.M. The rate of water collection from the four tubewells at two places has been plotted against distances in Fig. 4.14. The curve indicates that the maximum average per capita per day collection from the four tubewells in iron problem areas was only 2.5. gallon as against an average of 10 gallon per capita per day consumption under normal rural living condition.

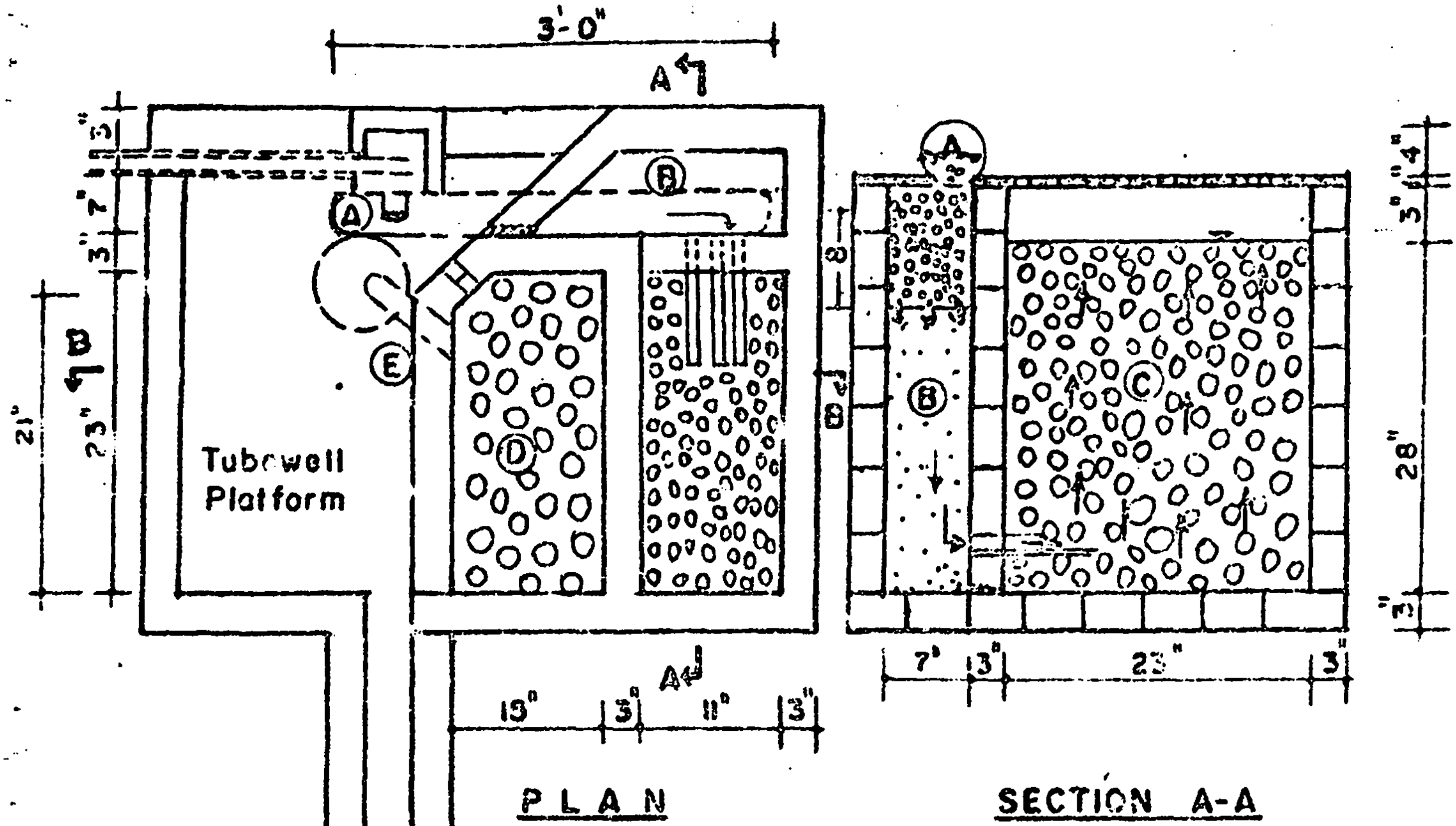
In order to determine the effect of improved water quality on water collection, some Community Type Iron Removal Plants have been designed and constructed at two tubewell sites, (Plate 6 and 7), out of the four previously observed tubewells which originally yielded water with iron concentration of around 8.00 mg/l.

The detail design of the iron removal plant has been shown in Fig. 4.13 and the performance of the plant has been presented in Table 4.18 and 4.19.

The plants shown in Figure 4.13 consists of four units-aeration channel, sedimentation, adsorption and filtration chambers. The aeration channel (A) is made 4" PVC pipe partially filled with brick chips (called khoa locally) and is slotted at its upper side. Water discharge through the mouth of the tubewell passes over the khoa becoming partially aerated, and than drips in the sedimentation chamber (B). In the sedimentation chamber water falls on the charcoal bed at the top, which provides further aeration. Some portion of preciptated iron flocculant settles at the bottom of the sedimentation

Plate-6 Iron removal plant No. 1.

Plate-7 Iron removal plant No. 2.



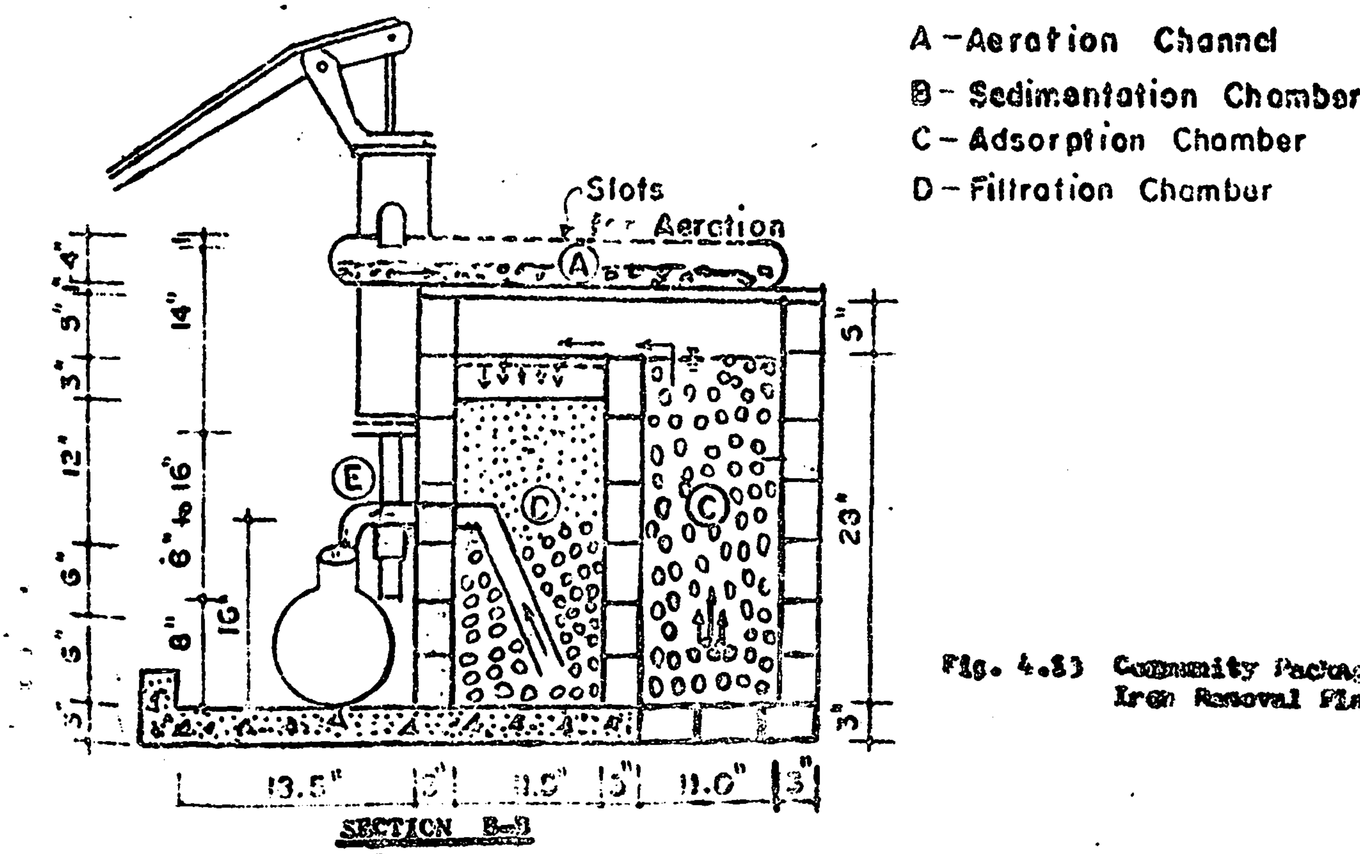


Fig. 4.13 Community Package Type Iron Removal Plant

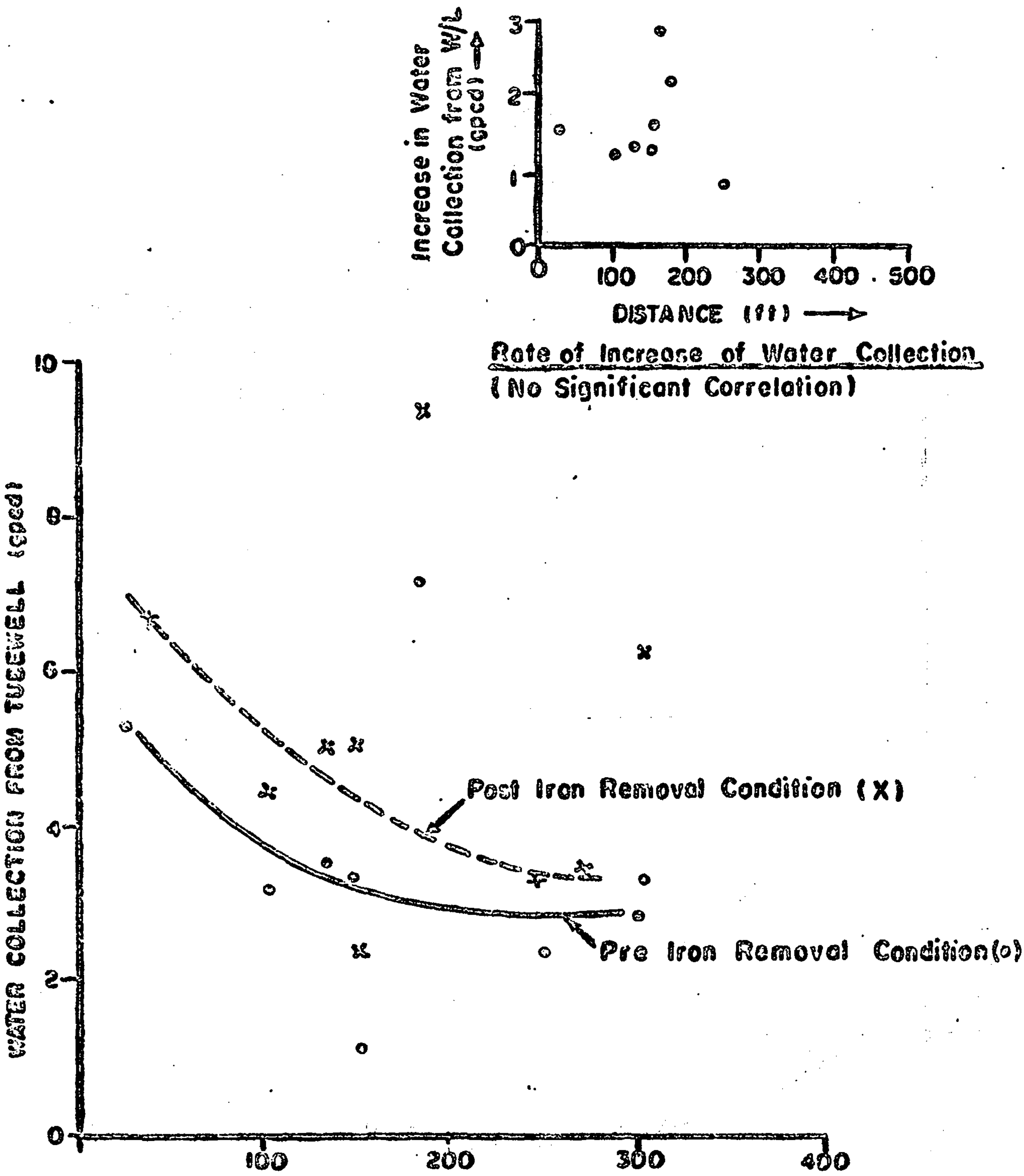
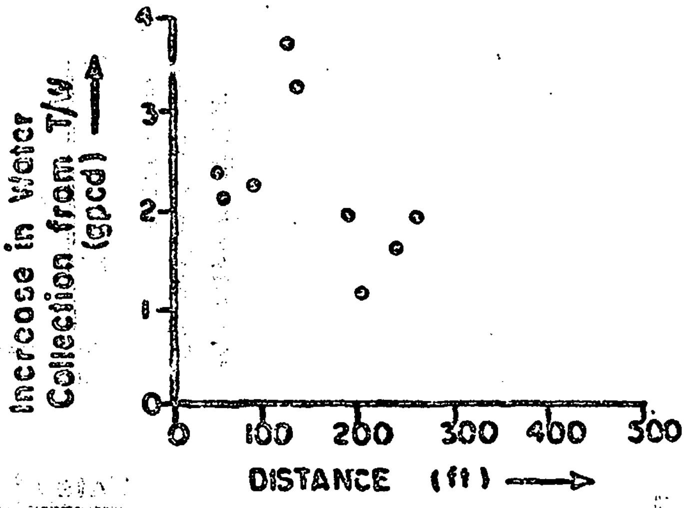


Fig. 4.14 (a) Effect of Water Quality on Tubewell Water Collection in Sample Area-7



Rate of Increase of Water Collection
(No Significant Correlation)

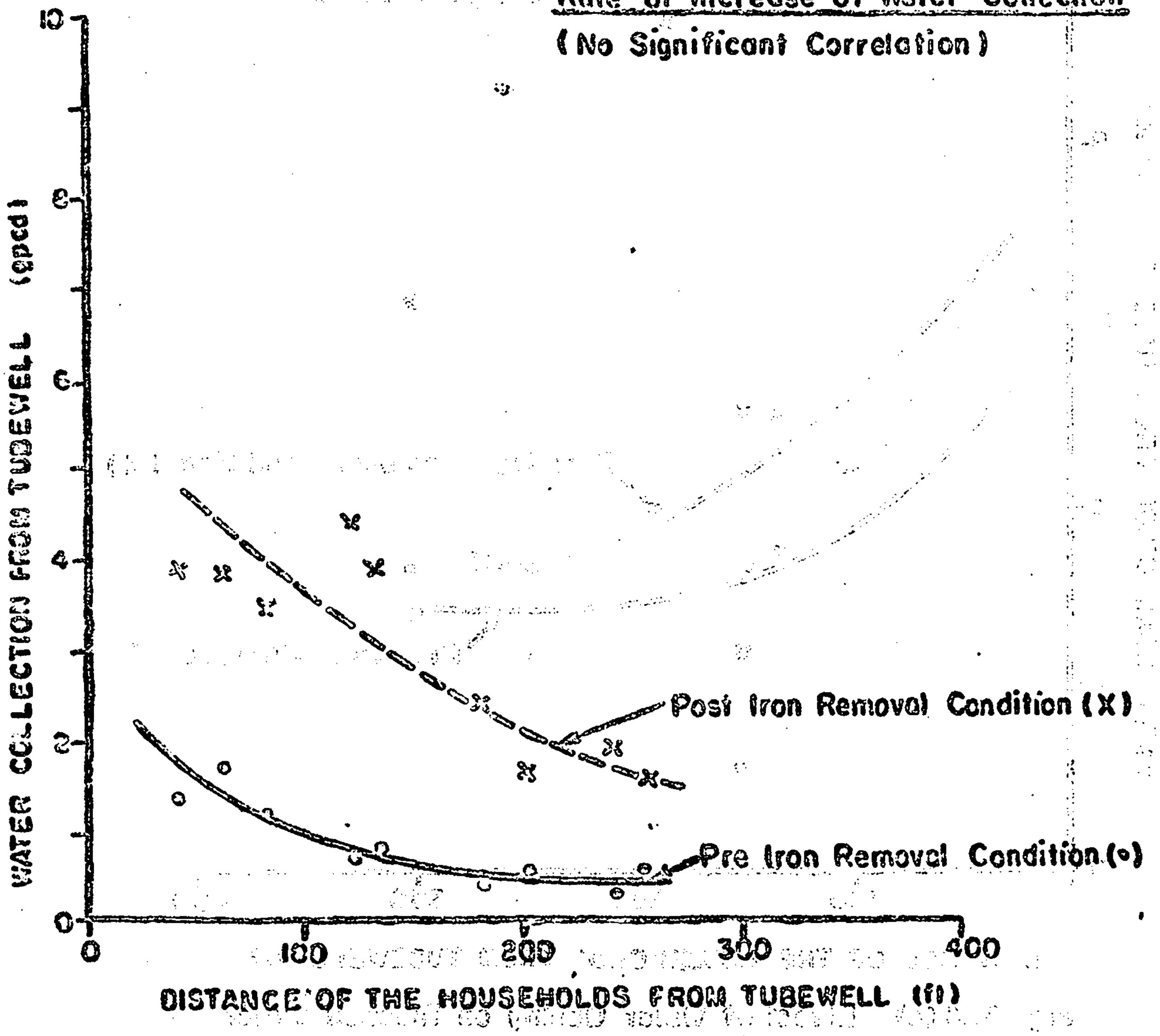


Fig. 4.14 (b) Effect of Water Quality on Tubewell Water Collection in Sample Area-12

TABLE 4.18

Field analysis of water samples and performances of iron removal plant

Sample area	Plant no. with filter materials	Iron Content (mg/l)			Yield (galls/min) from			Average increase in water collection (gpcd)	Length of run between cleaning (days)
		Raw water	Treated Water: Continuous pumping	Treated Water: Intermittent pumping	Tubewell	Iron removal plant: Initial	Iron removal plant: Final		
7	1 khoa only	7.6	2.0	1.4	5	3.5	2.5	1.61	20
12	2 sand gravel khoa	7.6	0.6	0.4	5	2.5	1.5	2.25	15

TABLE 4.19

Laboratory analysis of water samples in Plant No. 2
(with intermittent pumping)

Type of water	Iron (mg/l)	Dissolved CO_2 (mg/l)	Total Alkalinity (mg/l)	Manganese (mg/l)	Total hardness (mg/l)	Chloride (mg/l)	DO (mg/l)	pH value
Raw water	8.00	130	418	nil	444	100	3.2	6.8
Treated water	0.40	60	428	nil	410	100	2.4	7.3

NOTE: The Dissolved Oxygen (DO) level is lower in the treated water because of dissolved CO_2 being driven off. This has the effect of allowing Ferrous iron in solution to precipitate with the help of DO and absorbed oxygen in the process.. See Ahmed, Farooque and Ahmed, Feroze, "Iron Problems in Rural Water Supply in Bangladesh", presented to 24th Annual Convention of Institution of Engineers, Dacca, 30 December, 1979.

chamber. Water from the sedimentation chamber enters into the adsorption chamber (C) at the bottom through small holes and flows upward. Small particles of precipitated iron floc adhere to the surface of the khoa in the adsorption chamber and assist in further removal of the iron from tubewell water. Water from the adsorption chamber flows over a weir and enters into the filter bed (D), where most of the remaining precipitated iron is filtered and water which is almost iron free is discharged through a 1½ inch diameter bent PVC pipe (E).

About 90% removal of iron has been achieved from the plant. The approximate cost of construction is about taka 400/- which is about 11% of the total cost of a new tubewell. Post construction water consumption from the plants were observed and these have been presented in Table 4.20. An average increase of just under 2.0 gallon per capita per day water collection has been observed. The rate of increase depends on initial consumption. This water is generally utilised for cooking, washing clothes and utensils etc. Therefore, by spending about 11% more in the tubewell project in iron problem areas, about an 80 percent increase in water collection from tubewells will occur.

If in future per capita collection increased to 10 gallon, then in order to maintain the present length of runs between cleaning of the plant, users per tubewell must be kept limited to 30 person as indicated by Appendix C-2. Alternatively, the plant will require more frequent cleaning.

TABLE 4.20

Variation in water collection from tubewell due to reduction of iron concentration

Sample area	Distance of househeolds from tube-well (ft)	Water collection from tubewell		Increased water collection	
		Before iron removal (gpcd)	After iron removal (gpcd)	Per household (gpcd)	Average (gpcd)
7 (Jikargacha)	33	5.22	6.78	1.56	1.61
	100	3.23	4.46	1.26	
	150	1.17	2.42	1.25	
	182	7.29	9.43	2.14	
	250	2.48	3.33	0.85	
	300	3.47	6.24	2.77	
	132	3.62	5.00	1.38	
	145	3.43	5.10	1.67	
12 (Shakarigati)	60	1.67	3.87	2.20	2.15
	80	1.15	3.43	2.28	
	40	1.38	3.84	2.46	
	120	0.75	4.45	3.70	
	130	0.76	3.89	3.13	
	180	0.42	2.30	1.88	
	200	0.50	1.61	1.11	
	240	0.21	1.87	1.66	
	255	0.61	1.55	0.94	

Average increase of tubewell water collection = 1.90 gpcd.

4.4.4 Platform Dimensions (Bathing and Washing Facility at the Source)

For drinking, cooking and generally for sanitary purposes, water is brought to the house by container from the source. But for bathing and for most of the time for washing purposes, water is utilised at the source. A sufficient quantity of water, about 50 percent of the daily domestic total consumption, is used for these purposes as indicated in the Table 4.6.

Rural people do not get the opportunity to utilise this large volume of water at present on a small tubewell platform (Plate-8), which has inside dimensions of 2'-9"x2'-9" only. If some one wishes to bathe or wash clothes on the present type of platform, water splashed makes the tubewell site muddy, for which reason most of the tubewell caretakers forbid bathing on the platform to keep the tubewell site clean and dry. In addition, at the peak demand period when several people attend a tubewell within a short interval of time, people do not get the opportunity to spend time for bathing and washing on the tubewell platform, because only one person can use the tubewell at a time and bathing carries a lower priority than drinking. This situation forces the users to use unprotected sources for bathing and washing. Further, a sufficient quantity of water can be obtained from other sources at the same time as drinking water is being collected.

In one sample area where there is no tubewell platform (Plate-9), water use at tubewell site was observed to be only

Plate-8 Washing and bathing is difficult on present small platform.

Plate-9 Washing and bathing is very difficult at tubewell site where there is no platform.

10 percent of the total collection, by the households around the tubewell.

To allow people to have more space for washing and bathing, an extension of the present platform has been effected in two sample areas (Plate-10), as per the drawing presented in Fig. 4.15. Water collection of some households around the tubewells were observed for several days both in summer and in winter before and after constructing the extented platform. Distance-tubewell water collection curves for both conditions have been plotted in Fig. 4.16.

Post construction condition shows an average increase of 1.51 gallon per capita per day of tubewell water collection within 500 feet radius from the tubewell, as indicated by the Table 4.21.

The rate of water collection increase with distance has also been presented in Fig. 4.16, which indicates that the rate of increase is higher for households living closer to the tubewell. This additional water was sometimes utilised for bathing and sometimes for washing clothes. It was observed that on occasions people washed clothes at the pond or river first, and then final washing was done with tubewell water.

The cost for the extension of the present platform is approximately Taka 175/-. Therefore, by spending about 5% more in a tubewell project, an increased tubewell water use of 12 percent of the daily water consumption may be achieved in many places.

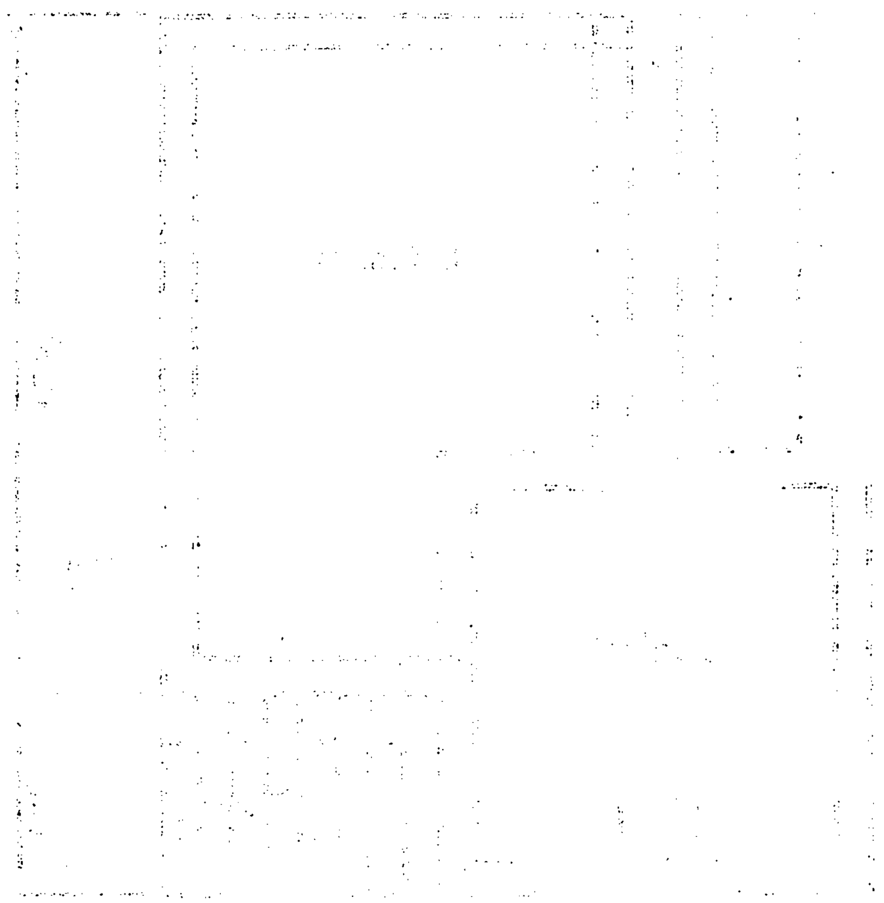
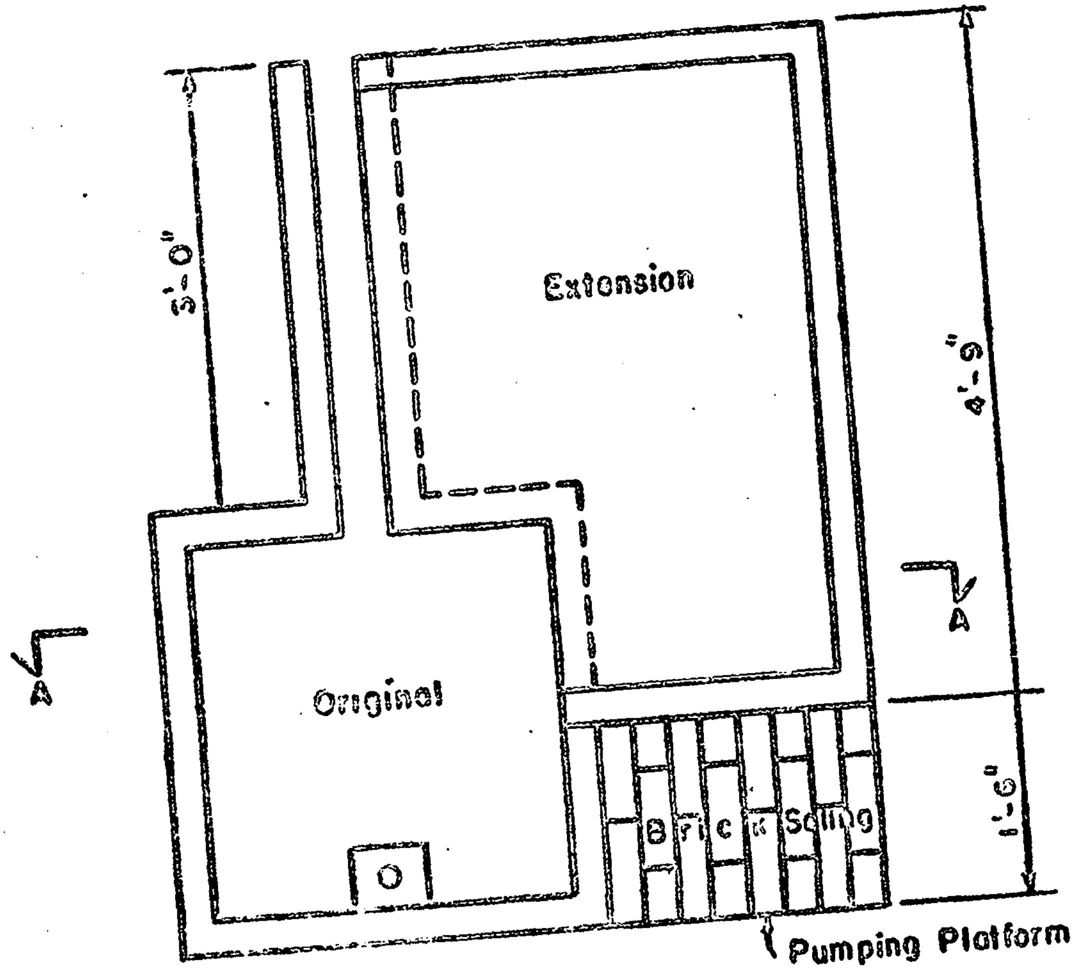


Plate-10 An extension of the present tubewell platform.



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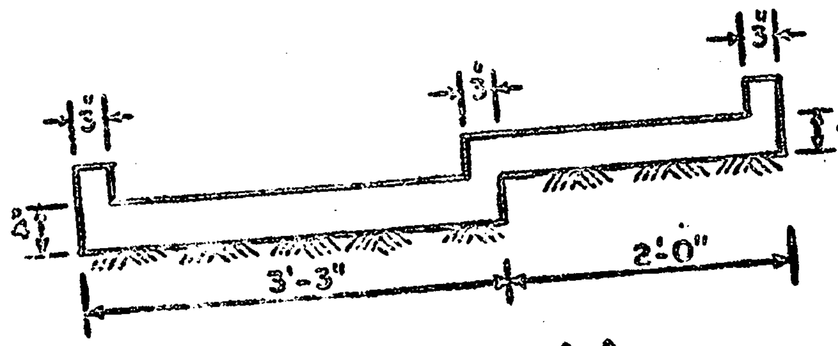

SECTION A-A

Fig. 4.15 Showing the Detail Drawing of Existing and Extended Platform.

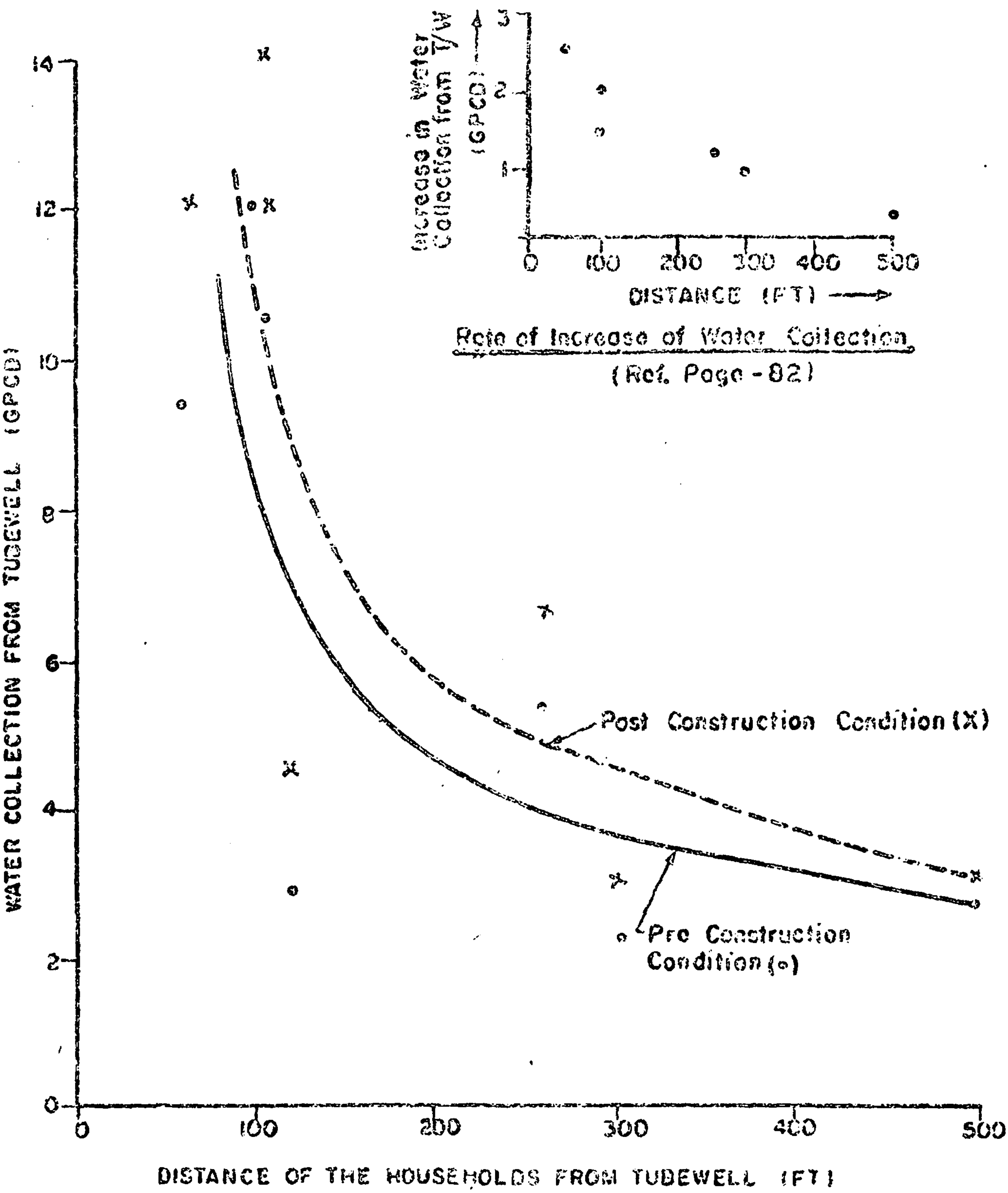

Fig. 4.16 (a) Effect of Platform Dimension on Tubewell Water Collection in Sample Area-3

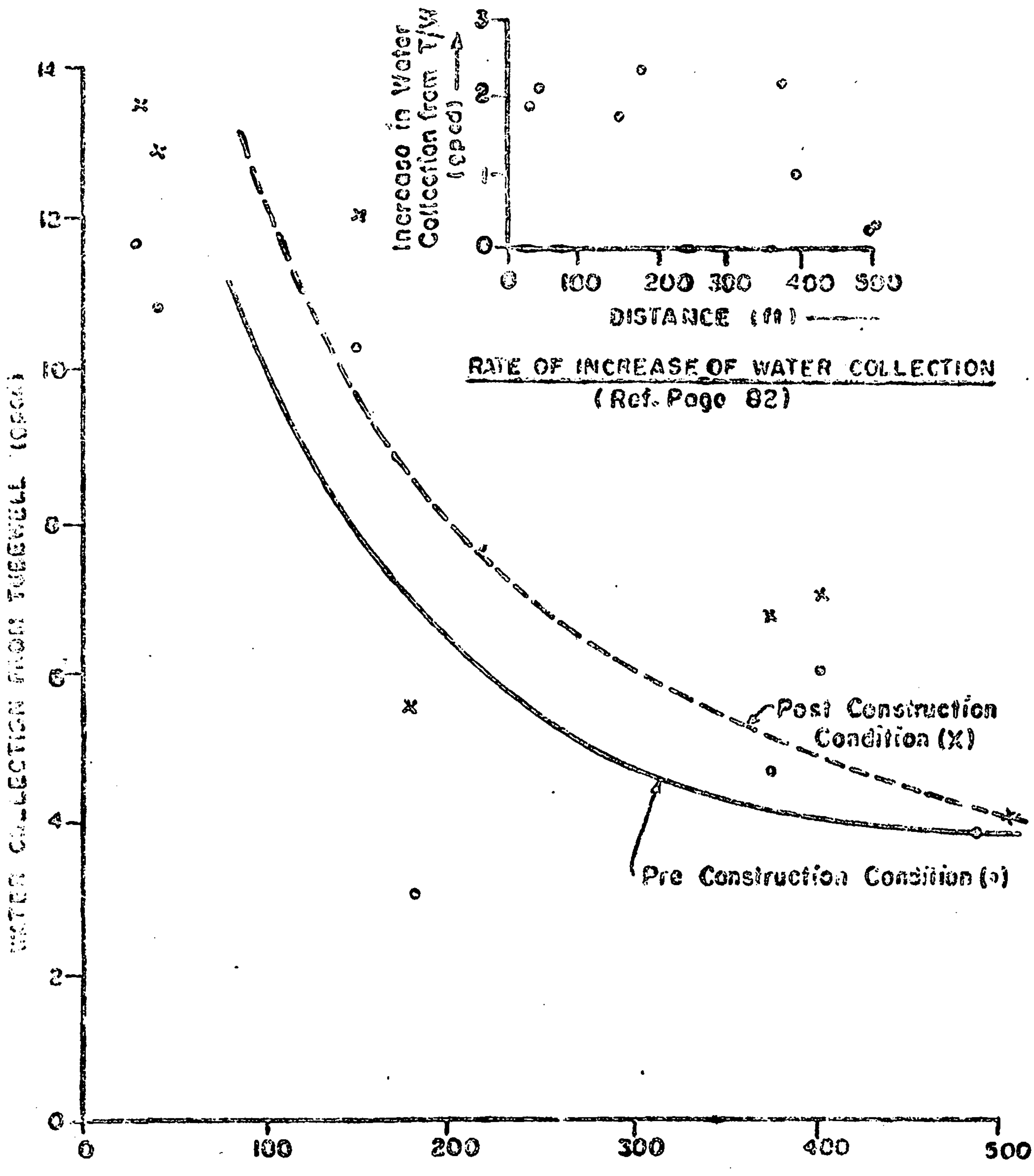

Fig. 4.16 (b) Effect of Platform Dimension on Tubewell Water Collection in Sample Area - 4

TABLE-4.21

Variation in water collection from tubewell before and after constructing bigger platform

Sample area	Distance of househoIes from tube-well (ft)	Water collection from tubewell		Increased water collection	
		Before constructing bigger plat-form (gpcd)	After constructing bigger plat-form (gpcd)	Per house-hold (gpcd)	Average (gpcd)
3 (Site-1, Noapara)	60	9.43	12.00	2.67	
	100	12.00	14.00	2.00	
	100	10.50	12.00	1.50	
	120	2.92	4.50	1.58	
	260	5.33	6.53	1.20	1.42
	300	2.20	3.00	0.80	
	500	2.70	3.00	0.30	
4 (Site-2, Biranpur)	30	11.72	13.50	1.78	
	40	10.79	12.86	2.07	
	150	10.25	12.00	1.75	
	180	3.10	5.50	2.40	1.60
	375	4.60	6.70	2.10	
	400	6.00	7.00	1.00	
	505	3.75	3.86	0.11	

Average per capita increase of water collection(Q) = 1.51 gpcd

An important phenomenon is that on this new bigger platform, one person can operate the tubewell for collecting water by container and another can take his bath or wash something at the same time with previously collected water; i.e two people can utilise the tubewell platform at the same time (Plate-11 and 12), which is not possible with the traditional platform.

To allow people more time for bathing and washing, the number of users per tubewell must be kept limited, in addition to the construction of a bigger platform. As presented in Appendix-C-3, 20-25 users could be served by one tubewell, if bathing and washing are done on the tubewell platform of the present type. If the modified type is used, some 55-60 people could be served adequately.

4.4.5 Location and Surrounding Environment of the Source

Women are the main water collectors in rural Bangladesh. They fetch water for the house from the source by containers mainly for cooking, drinking and sanitary purposes. They do most of the work of washing clothes and utensils. Classification of the water collectors of five sample areas have been presented in Table 4.22.

Plate-11 Two persons utilizing the tubewell site at a time.

Plate-12 Bathing on the extended tubewell platform.

TABLE 4.22

Classification of water collectors in five sample areas in percent of water collection journeys made

Male		Female	
Adult	Minor	Adult	Minor
11	4	64	21

Note: Minors are 15 years and under.

The table indicates that in 85 percent of cases water collectors are female. They do not like to expose themselves to strangers on their way to the source. Particularly women of respectable families of the rural areas do not like to come out of their house in open or public places for collection of water. Field observations indicate that water collection from tubewells located in open or public places is much lower than from the tubewells located in unexposed covered places or from private tubewells. On an average to provide one tubewell for 160 people, presently public wells are generally installed by the side of main road, in a road junction or in an open public place (Plate-13 and 14). Rural women usually fetch one pitcher of drinking water only in the early morning and another in the late evening hours from such a well situated at a public place and hardly use it for any other purpose than drinking. Water collection from such tubewells reduce significantly on weekly market days when more people move along the road (Plate-15).

Plate-13 Very exposed tubewell site.

Plate-14 Tubewell site by the side of a main road.

For lack of privacy at an exposed tubewell site, rural conservative women do not like to spend time for washing clothes and utensil. Bathing is actually impossible for women at exposed tubewell sites.

The environment surrounding the source, i.e whether the tubewell site is muddy or dry, has an influence on water collection from it.

In order to determine the effect of privacy of the source on water collection from tubewells, an arrangement was made to create partial privacy at three exposed tubewells by constructing tarja fencing (Plate-16). Water collection of some households around the tubewells were recorded for four days before and after constructing the fencing. Figure 4.17 represents the effect of privacy of the source on water collection from it. Water collection data have been presented in Table 4.23. Post construction condition of the fencing shows an average increase of about 0.75 gallon per capita per day water collection, within 500 feet radius of the tubewells. This excess amount of water was utilised mostly for washing utensils and sometimes for washing clothes (Plate-17).

The actual privacy of the source can only be maintained where the tubewell is located in an unexposed or screened place. Water collection from such a tubewell will naturally be more (Plate-18). To maintain privacy, one tubewell should be installed for each household or in a suitable central place between two to three households, where the households occur

Plate-15 Rural women hesitate to go to exposed tubewell site when many people move along the road.

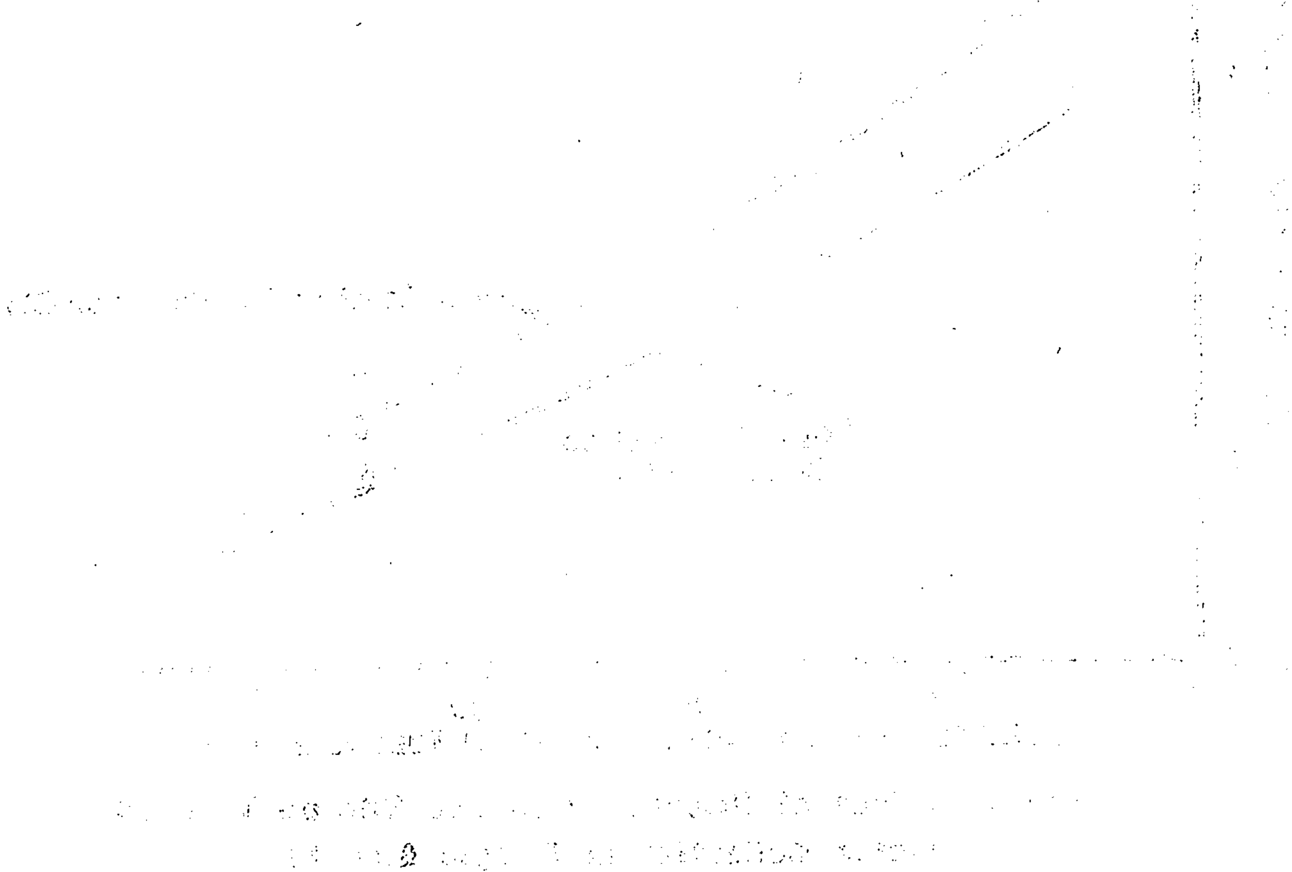

Plate-16 Arrangement for partial privacy at tubewell site by constructing tarza fencing.

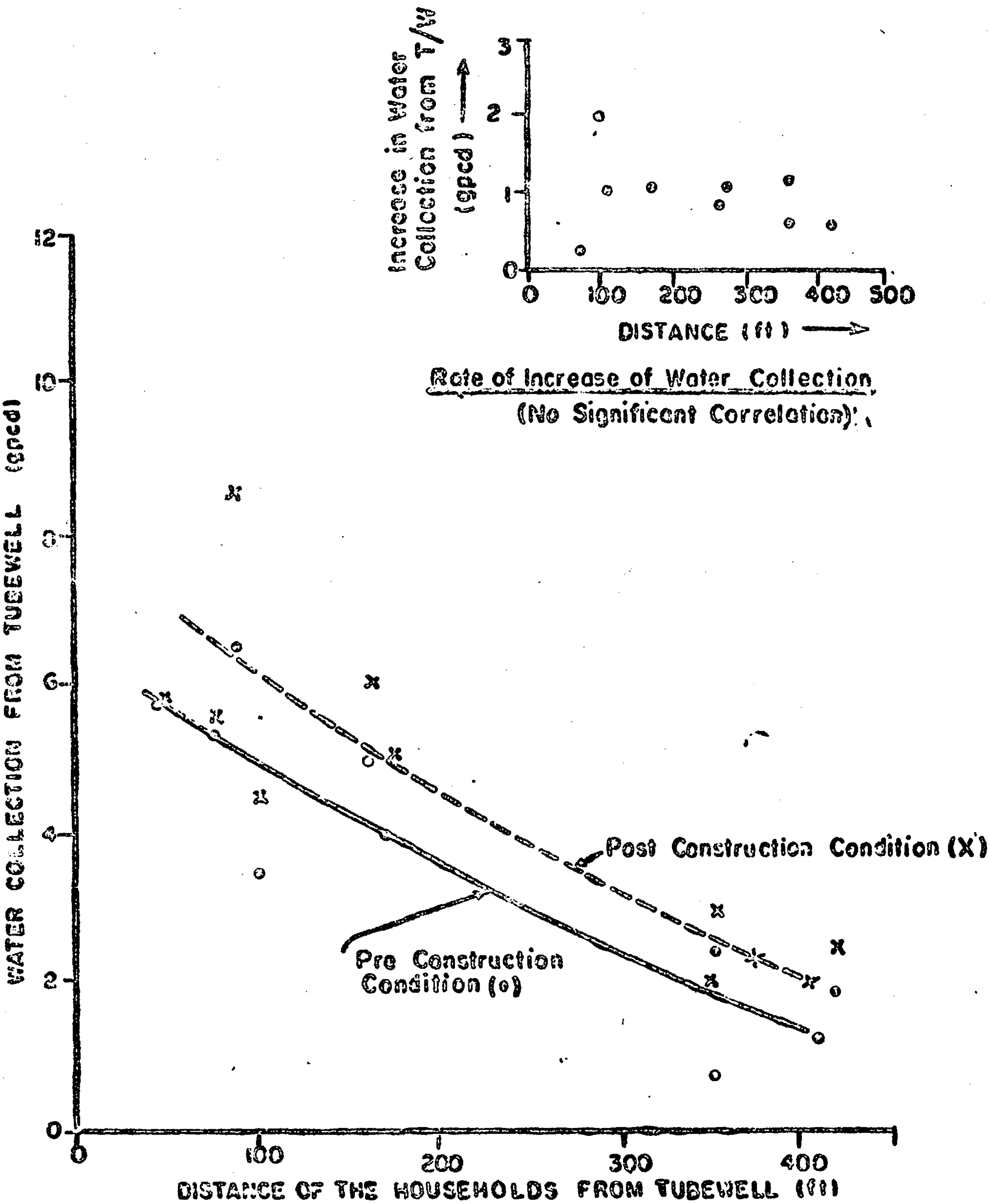

Fig. 4.17 (a) Effect of Privacy of Source Site on Tubewell Water Collection in Sample Area-13

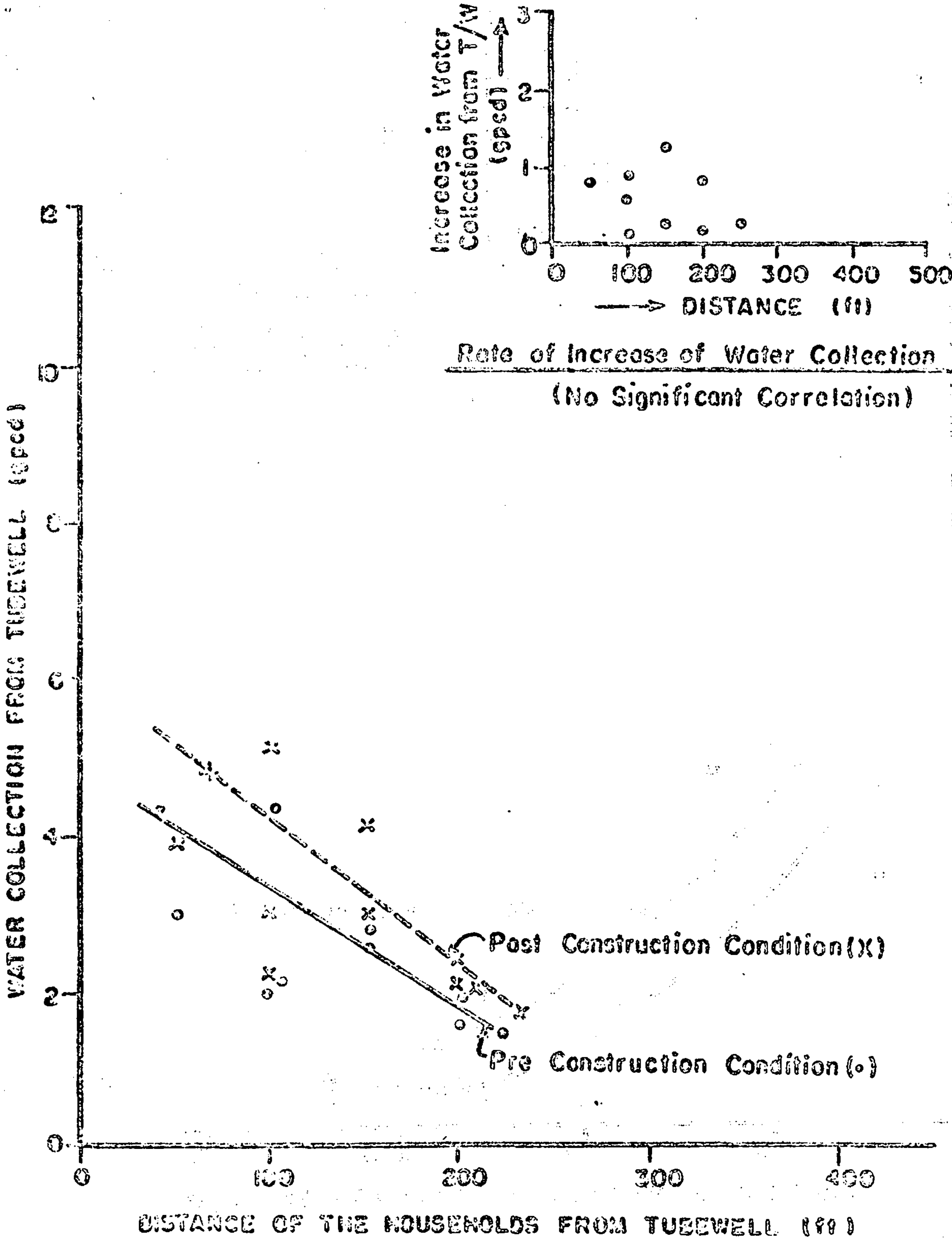

Fig. 4.17 (b) Effect of Privacy of the Source on Tubewell Water Collection in Sample Area - 9

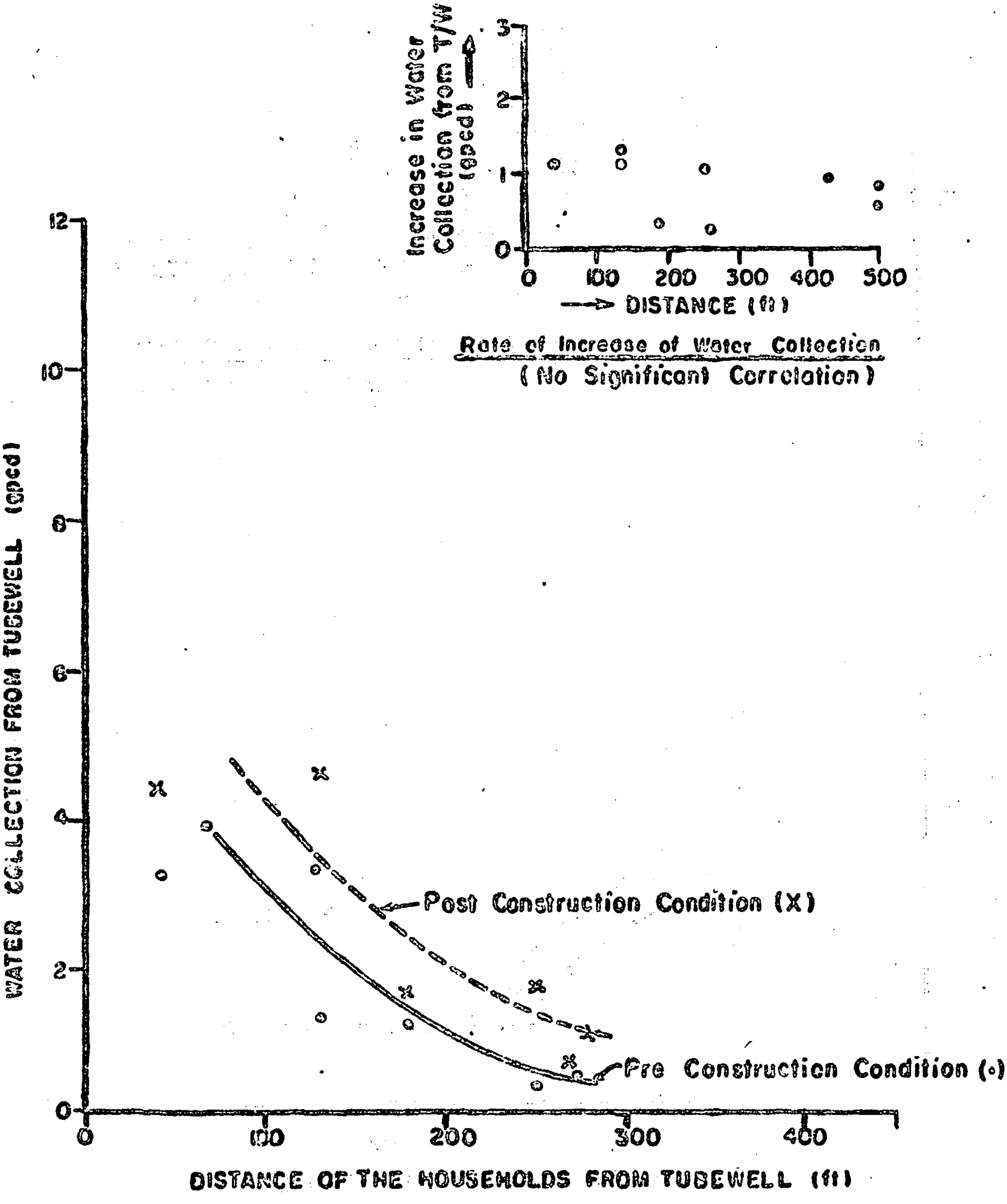

Fig. 4.17 (c) Effect of Privacy of the Source on Tubewell Water Connection in Sample Area - 2

TABLE-4.23

Variation in water collection from tubewell before and after creating partial privacy at source site

Sample area	Distance of households from tubewell (ft)	Water collection from tubewell: Before constructing fencing (gpcd)	Water collection from tubewell: After constructing fencing (gpcd)	Increased water collection: Per household (gpcd)	Increased water collection: Average (gpcd)
	45	5.75	5.75	0	
	85	6.50	8.50	2.00	
	77	5.30	5.50	0.20	
	100	3.50	4.50	1.00	
13	160	5.00	6.00	1.00	0.745
	260	3.50	4.25	0.75	
	270	4.00	5.00	1.00	
	350	0.75	2.00	1.25	
	355	2.50	3.00	0.50	
	380	1.00	1.00	0.00	
	420	2.00	2.50	0.50	
	50	3.00	3.80	0.80	
	100	2.10	3.00	0.90	
	100	2.06	2.20	0.14	
	100	4.40	5.10	0.70	
9	150	2.80	4.10	1.30	0.602
	150	2.54	2.90	0.36	
	200	1.60	2.40	0.80	
	200	1.90	2.06	0.16	
	250	1.80	2.06	0.26	
	42	3.28	4.44	1.16	
	130	1.28	3.49	2.21	
	130	3.40	4.52	1.12	
	180	1.31	1.59	0.28	
10	250	0.47	1.68	1.21	0.913
	270	0.51	0.61	0.10	
	425	1.94	2.80	0.86	
	505	2.43	2.96	0.53	
	506	5.90	6.65	0.75	

Average per capita increase of water collection(V)=0.753 gpcd

Plate-17 Woman washing utensils at fenced tubewell site.

Plate-18 Woman bathing at protected tubewell site.

in a cluster. Based on three to four households, at 6-7 per household, and tubewell site being fenced, than 20-25 people at the most could be satisfied by one tubewell.

4.4.6 Distance of the Source From Households

Figure 4.14, 4.16 and 4.17 clearly indicate that per capita collection from a tubewell decreases gradually with increasing distance of the households from tubewell and users are inclined to use nearby unprotected sources to meet their daily domestic water needs. The most important factor which controls the amount of water collection from a tubewell is the presence of other competing traditional unprotected sources like ponds, rivers or ring wells etc. near the households. It has already been mentioned that most rural people use tubewell water at least for drinking. But usage for other purposes is affected by many other factors like water quality (Q), privacy of the source (V), washing and bathing facility at the source (P) etc. Figure 4.19, indicates that the more acute the various problems are, the more unprotected water sources will be used. The absence of an alternative source in the vicinity, however, compels the users to use tubewell water. Water collection from alternative sources not only depends on various problems in the tubewell water supply but also on its availability i.e the average distance of unprotected sources from households. Fig. 4.18, indicates that the closer the unprotected source is from household, the lower is the amount of water collected from the tubewell.

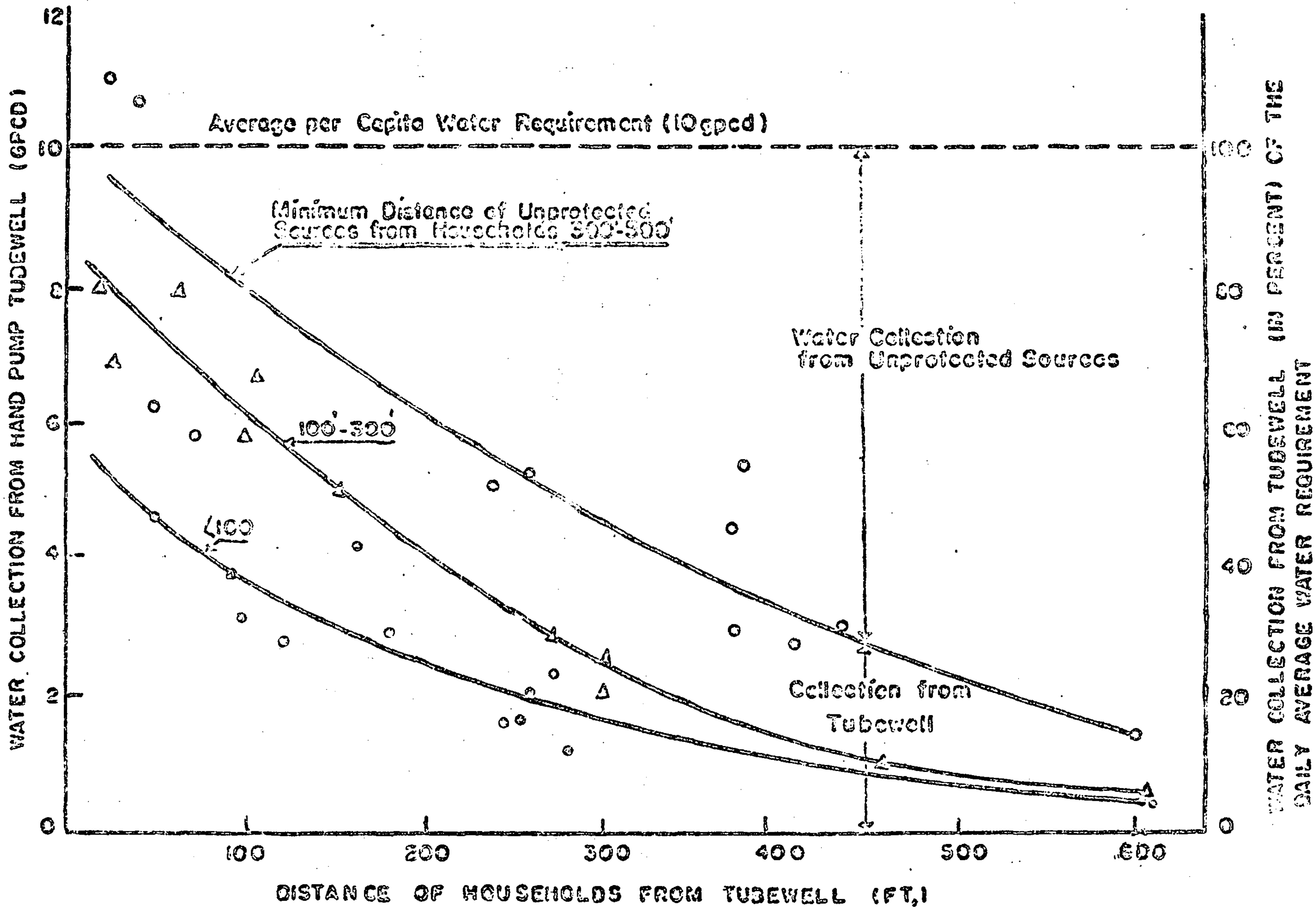

Fig. 4.18 Effect of the Distance of Unprotected Water Sources From Households on Water Collection From Tubewell

The ratio between "distance from house to unprotected source" and "distance from house to tubewell" also plays an important role in the selection of source. When the ratio is less than one i.e the unprotected source is closer to the household than is the tubewell, then water collection from the tubewell is less than the collection from other sources as indicated by the curves 2, 11, 24 and 25 of Fig. 4.19(a), 4.19 (b). Figure 4.18 indicates that when the distance of both types of sources from households are the same, only 35-40% of the daily domestic requirement of water is being collected from the tubewell. Water consumption from both tubewell and pond of some households for three consecutive days have been recorded and presented in Table 4.24 and Table 4.25. Average distance of both types of sources from the households are nearly the same. Table 4.24 indicates that 34% of the total daily per capita consumption was made from tubewell and the rest from the pond.

Quantity and physical quality of water, in addition to distance from an unprotected source determine the amount of water collection from it. It has been observed in most of the cases examined that among the unprotected sources, ponds and rivers are preferable to the ringwell for users, since a large volume of water is readily available from the former. Curves 7,14,18 of Figure 4.19(b),4.19(c) indicate that although ringwells are closer to the households than tubewells, water collection from tubewells has been found greater since the ponds are not closer than tubewells.

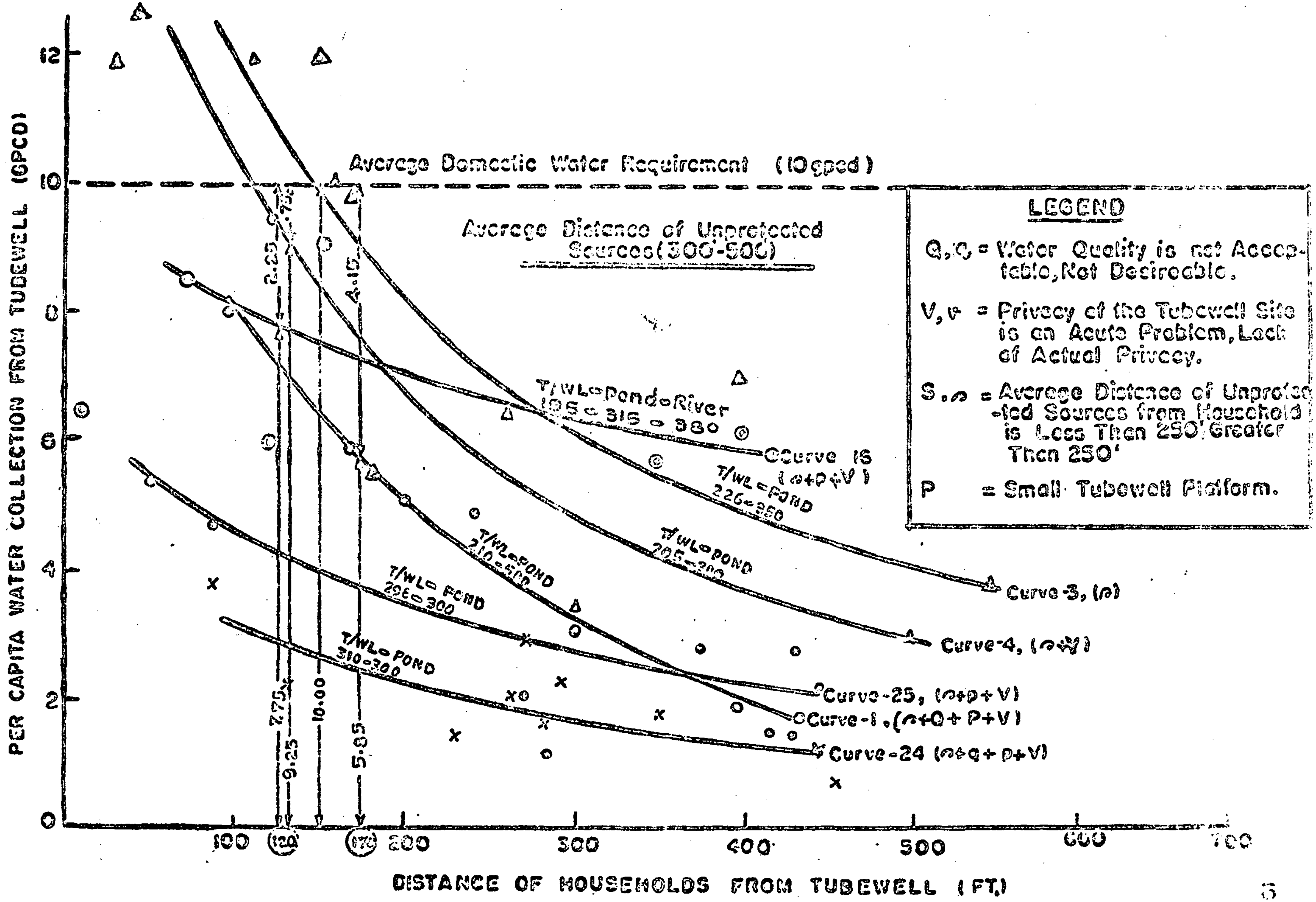

Fig. 4.19(a) Effect of Various Factors on Tubewell Water Collection When Average Distance of Unprotected Sources are 300'-500' From Households

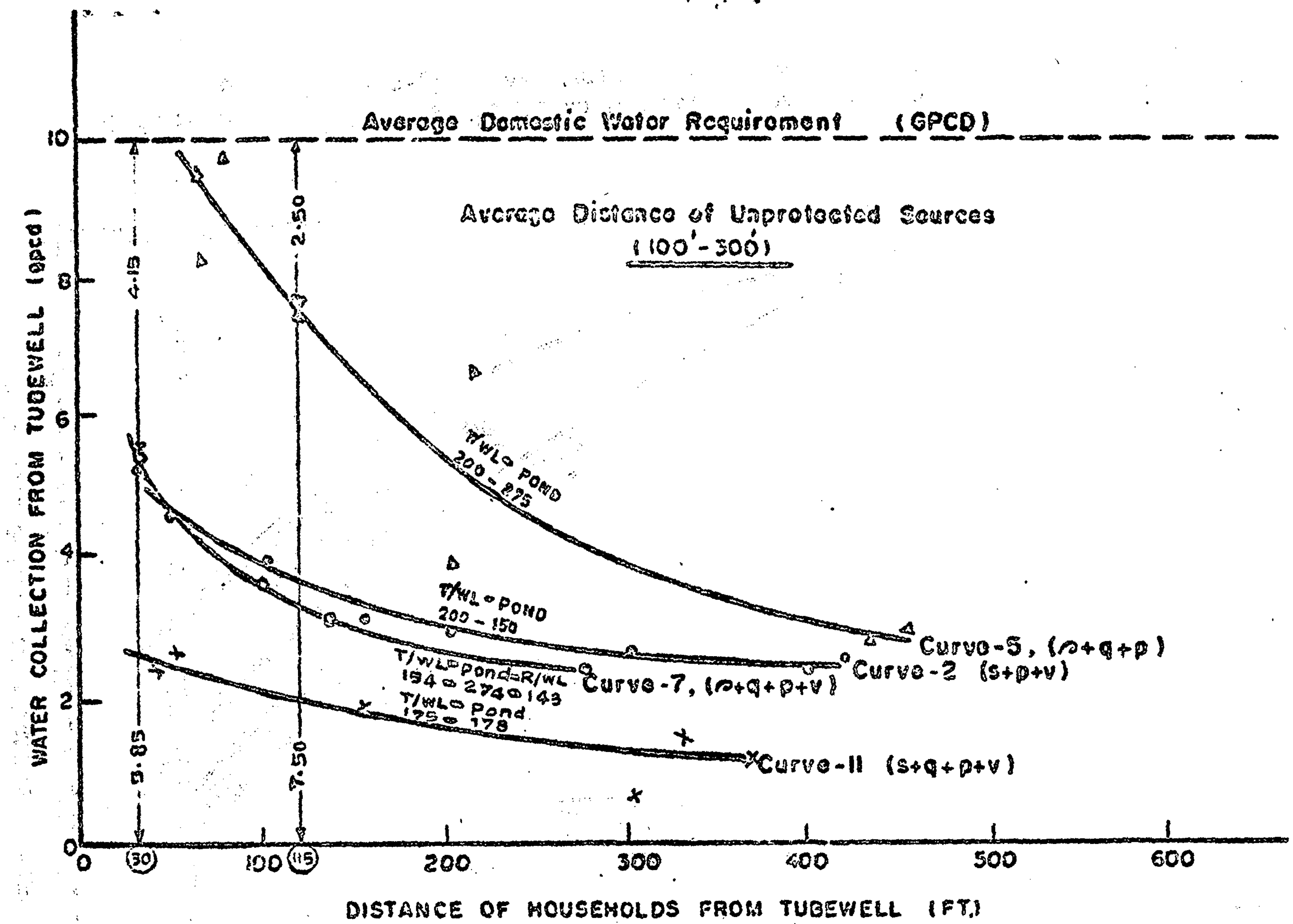

Fig. 4.19(b) Effect of Various Factors on Tubewell Water Collection When Average Distance of Unprotected Sources are 100'-300' from Households

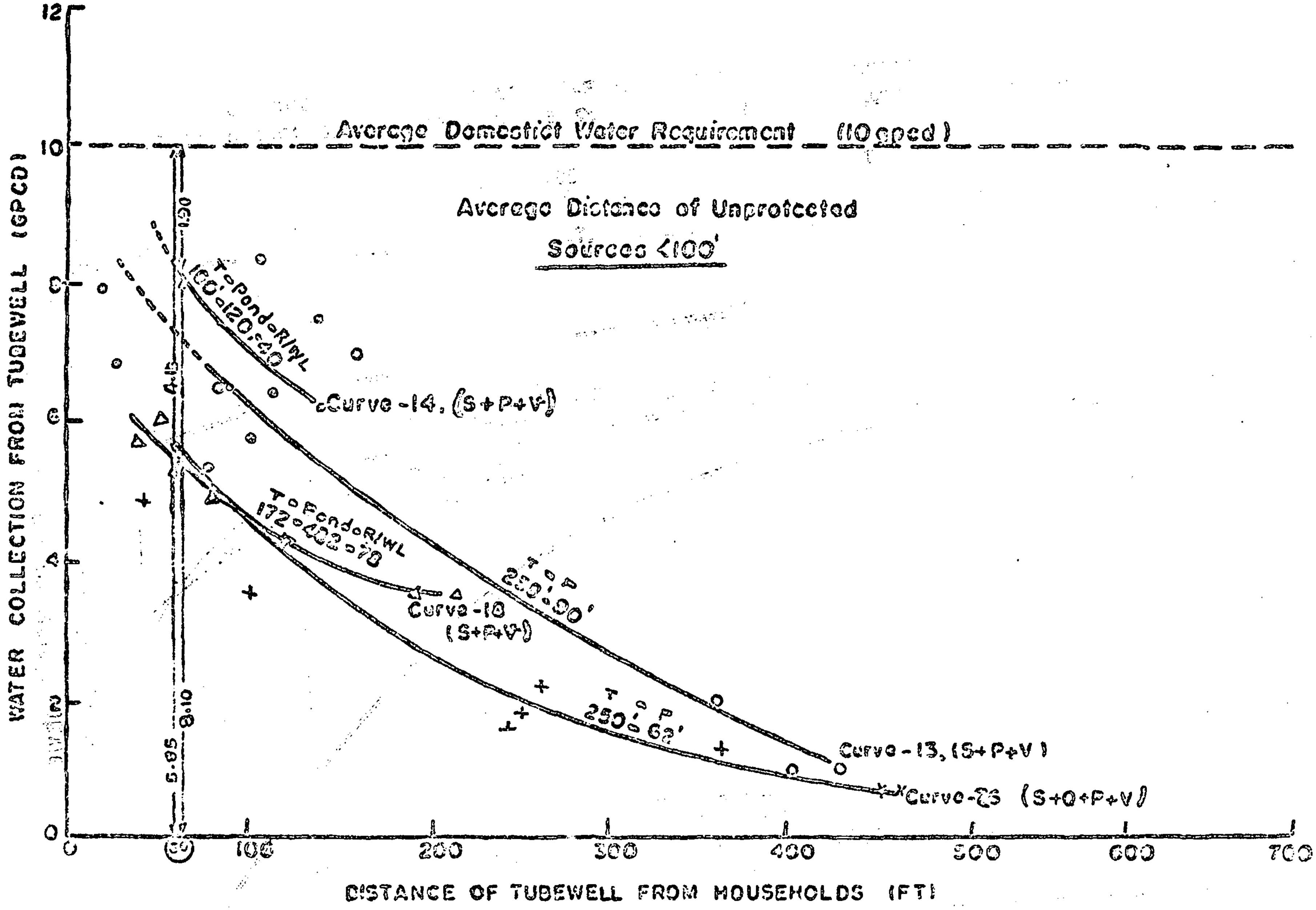

Fig. 4.19 (c) Effect of Various Factors on Tubewell Water Collection When Average Distance of Unprotected Sources Are <100' From Households.

TABLE 4.24

Water collection from both types of sources by the households of Kasdia, Khulna

Distance of tubewell from households (ft)	Per capita per day collection from tubewell (gpcd)	Distance of nearest unprotected source (pond) from households (ft)	Per capita per day collection from pond (gpcd)	Total collection (gpcd)
50	5.40	360	4.86	10.25
90	4.80	360	4.58	9.38
240	5.00	500	4.50	9.50
375	3.05	325	4.93	7.98
380	6.00	330	4.70	10.70
270	2.35	75	8.93	11.28
280	1.30	65	9.79	11.09
420	1.69	400	8.20	9.89
430	1.65	410	8.11	9.76
430	2.99	410	8.08	11.07
MEAN =296'	3.42	324'	6.67	10.09
In percent of total collection	34%		66%	

TABLE 4.25

Water consumption (in percent of total requirement) for various purposes and the source and place of use by the households of Kasdia

Source used	At source site	At home
Tubewell 34%	4% = Washing hands and face 2% = Washing utensils 6%	5% = Drinking 10% = Washing utensils 13% = Sanitary and others 28%
Pond 66%	30% = Bathing 20% = Washing clothes 3% = Washing utensils 53%	10% = Cooking 3% = Sanitary and others 13%

Curves 13,26 of Figure 4.19(c) indicate that although there are several problems in tubewell water supply in the areas studied and the unprotected sources are very close to the households, yet tubewell water consumption has been found comparatively greater than in other areas, as the water quality of the unprotected sources are not as acceptable to the consumers.

Curves 3 and 4 of Figure 4.19(a) indicate that where there are fewer problems concerning water quality, privacy and platform dimensions of the tubewell water supply, where average distances of the unprotected sources are more than three hundred feet away from households and the tubewell is closer than the unprotected source, water consumption from the tubewell is at a maximum.

It has already been observed that, where quality (Q) of tubewell water is associated with acute problems, then by improving the water quality, on an average, tubewell water consumption may be increased by upto 1.90 gpcd. Where privacy (V) of the source is an acute problem, by creating partial privacy, on an average, 0.75 gpcd increase may be achieved. Where there is small tubewell platform, by providing bathing and washing facility at the source through constructing of a bigger platform, then an average 1.5 gpcd increase of water consumption from the tubewell may be achieved. Where the problems are not so acute, increased water consumption for better water quality (q) better privacy (v) may be consider less than the above mentioned values.

Now, to provide for the collection of a 10 gpcd water requirement from a tubewell, the above mentioned problems in tubewell water supply must be eliminated; moreover there must be a tubewell within 120 to 170' from each household where the average distance of unprotected sources from the household lies between 300 and 500', within 115' where average distance to unprotected source from the household lies between 100' and 300', and within 60' for less than 100' average distance to the unprotected source from the household as represented in Table 4.26. As per Figure 4.2 in the first case 20 to 40 people, in the second class on an average less than 20 and in the last case less than 10 people will be benefied by one well. Table 4.26 also indicates that where there are many unprotected sources, more tubewells should be installed and the tube-wells must be closer to the households than other sources, for there to be a greater use made of tubewells.

From Table 4.8, the average distance of ponds from households is about 300' and average distance of rivers from households is over 550' in the study area. In the rural areas generally pond water use is very common. Therefore, according to Table 4.26 and Figure 4.2, to ensure more utilization of tubewell water, a tubewell should be in the range 120'-170' from each household in most places and on an average one tubewell is required for 20-40 persons, for optimum use.

TABLE 4.26

To provide 10 gpcd tubewell water supply, maximum distance of tubewell from households under various field conditions

(Average distance of unprotected sources 300'-500')

Curve No. (Sample area)	Average distance to unprotected water sources (S, s)	Ratio of average distance of unprotected source to tubewell	Expected increased water collection tubewell for following improvement (gpcd): Water Quality		Platform dimension	Privacy of source site		Total gpcd)	Present minimum collection from tubewell to meet 10 gpcd requirement	Corresponding distance of households from tubewell (ft) 1/	Maximum distance of tubewell for 10 gpcd collection from tubewell (ft)
			Q (1.90 gpcd)	q (1.00 gpcd)	P (1.50 gpcd)	V (0.75 gpcd)	v (0.40 gpcd)				
1	500	1:2.38	1.90	-	1.50	0.75	-	4.15	5.85	170'	120'-170'
3	350	1:1.55	-	-	-	-	-	0	10.00	142'	
16	315, 380	1:1.61, 1:1.95	-	-	1.50	0.75	-	2.25	7.75	125'	
4	300	1:1.46	-	-	-	0.75	-	0.75	9.25	120'	
25	300	1:1.1	-	-	1.50	0.75	-	2.25	7.75	-	
(Avg. distance = 100'-300')											
5	275	1:1.37	-	1.00	1.50	-	-	2.50	7.50	115'	<115'
7	279, 143	1:1.81, 1:0.93	1.90	-	1.50	0.75	-	4.15	5.85	30'	
2	150	1:0.75	-	-	1.50	0.75	-	2.25	7.75	-	
(Avg. distance <100')											
26	62	1:0.25	1.90	-	1.50	0.75	-	4.15	5.85	60'	<60'
14	120, 40	1:1.1, 1:0.36	-	-	1.50	-	0.4	1.90	8.10	60'	
13	90	1:10.34	-	-	1.50	0.75	-	2.25	7.75	35'	
18	482, 78	1:2.15, 1:0.40	-	-	1.50	-	0.4	1.90	8.10	-	

1/ From Figure 4.19

4.4.7 Stepwise Regression analysis of factors affecting per capita water consumption.

The physical factors affecting per capita water consumption are now incorporated into stepwise linear regression model for rural water consumption. The model represents average conditions of fourteen sample areas. Using average per capita water consumption as dependent variable,one might postulate that Q_1 varies with Distance ratio of protected source to unprotected; X_1, Water Quality; X_2, Platform Quality; X_3, Location of source site; X_4, and number of users per pump; X_5.

The model may be expressed symbolically as follows:

$$Q = f(X_1, X_2, \ldots\ldots\ldots X_5)$$

In linear form above equation can be expressed as

$$Q = a + bx_1 + CX_2 + dx_3 + ex_4 + fx_5$$

where Q_1 is the dependent variable. X_1, X_2, ... X_5 are independent variable'a'is the intercept. b,c,d, e and f are the regression coefficients.

Model is subjected to stepwise multiple linear regression analysis using the PSS package program on the IBM 370-115 system at BUET Computer Centre. The input data for model is presented in Table 4.27.

The resultant equation of model after five steps is

$$Q = -6.32705+1.97584X_1+.02394X_2+.09741X_3$$

$$(3.289)\quad(3.393)\quad(2.715)$$

TABLE- 4.27

Input Data for the Model

Variable No. / Sample area \ Parameters	1 Q	2 X1	3 X2	4 X3	5 X4	6 X5
3	8.25	1.55	100	75	50	085
4	7.40	1.46	100	70	25	080
16	7.40	1.75	100	50	25	084
14	5.80	1.10	100	50	30	100
1	5.50	2.38	025	50	12	150
5	5.40	1.38	050	50	75	085
13	4.40	1.00	100	50	05	090
25	3.70	1.10	100	50	35	070
18	3.50	0.40	100	35	75	160
2	3.00	0.75	100	50	10	080
26	2.70	0.50	010	50	20	105
7	2.60	0.93	025	50	25	070
24	2.50	0.96	050	50	25	080
11	1.70	1.10	010	50	25	070
Calculated Mean($\bar{x}$)	4.56071	1.16857	69.28571	52.14285	31.21428	93.50000
Standard deviation (σ)	2.09249	0.51415	38.47360	9.55033	21.53412	28.06514

Q = Per Capita Water Consumption in gpcd.

X1 = Distance ratio of protected source (T/WL) to unprotected source.

X2 = Water Quality, expressed as % acceptable to consumers.

X3 = Platform Quality, expressed as % acceptable to consumers.

X4 = Privacy/Location of source (T/WL), expressed as % acceptable to consumers.

X5 = Number of users per Tubewell.

(The coefficients in parenthesis are the T-values)

Multiple correlation coefficient = .906, R^2 = .820

F-value = 11.340

Only three of five independent veriable were entered significant in the model. They are Distance ratio of protected source to unprotected; X_1, Water Quality; X_2 and Platform Quality; X_3.

Distance ratio; X_1, has a simple correlation coefficient of 0.6441, water quality; X_2, has a simple correlation coefficient of 0.5376 and platform quality; X_3, has a simple correlation coefficient of 0.6348 with per capita water consumption as presented in Table 4.28.

The results of the model are summarized in Table 4.30.

4.5 Discussion:

Unlike for urban water supply systems, the determination of water requirement, selection of a source and determination of a collection and distribution system are not the only major steps in the design of a rural water supply system. Since simple technology is applied, marked difference between per capita water requirement for health and per capita water collection from the selected source is observed in the rural areas. An understanding of water consumption patterns and various related factors influencing it, provide a sound basis in establishing some fundamental design criteria for the future water supply programme in this country.

TABLE-4.28
CORRELATION MATRIX

Variable No.	1	2	3	4	5	6
1	1.0000	0.6441	0.5376	0.6348	0.1749	0.0634
2	0.6441	1.0000	-0.0263	0.4213	-0.1536	0.0671
3	0.5376	-0.0263	1.0000	0.1929	0.1483	-0.0210
4	0.6348	0.4213	0.1929	1.0000	-0.1165	-0.4247
5	0.1749	-0.1536	0.1483	-0.1165	1.0000	0.2502
6	0.0634	0.0671	-0.0210	-0.4247	0.2502	1.0000

TABLE-4.29

Regression Coefficient and Computed T-value

Variable number	Regression coefficient	Std. Error of Reg. coefficient	Computed T-value
2	b = 1.97584	0.60077	3.289
3	c = 0.02394	0.00705	3.393
4	d = 0.09741	0.03587	2.715
5	e = 0.01853	0.01285	1.442
6	f = 0.01351	0.01118	1.208

Intercept (a) = - 6.32705

TABLE-4.30

Stepwise Regression Analysis of Factors Affecting Per Capita Water Consumption

Avg. per capita water consumption Q	Intercept a	Regression coefficient of Independent variables					Multiple R	Multiple R^2	F-value	Se
		X_1	X_2	X_3	X_4	X_5				
For Fourteen sample areas	-6.32705	1.97584 *** (3.289)	.02394 *** (3.393)	.09741 ** (2.715)	.01853 * (1.442)	.01351 * (1.208)	0.906	0.820	11.340	1.127

Note: F-value is the variance ratio

Se is the standard error of estimate of the multiple regression equation (Adjusted for D.F.)

The coefficients within parentheses are the T-values of the regression coefficients

*** Significant at 0.01 level

** Significant at 0.05 level

* Not significant at 0.10 level

R is Multiple correlation coefficient (Adjusted for D.F.)

R^2 is the coefficient of Determination.

TABLE 4.31

Table of Residuals

Case No.	Y Value	Y Estimate	Residual
1	8.25000	8.50929	-0.25929
2	7.40000	7.31365	0.08635
3	7.40000	5.99252	1.40748
4	5.80000	5.01699	0.78301
5	5.50000	6.09263	-0.59263
6	5.40000	5.00462	0.39538
7	4.40000	4.22110	0.17890
8	3.70000	4.70443	-1.00443
9	3.50000	3.81704	-0.31704
10	3.00000	3.68471	-0.68471
11	2.70000	1.55943	1.14057
12	2.60000	2.38800	0.21200
13	2.50000	3.18075	-0.68075
14	1.70000	2.36484	-0.66484

For design purposes for the present time, an average of 10 gallon per capita per day domestic water consumption may be considered acceptable under rural living condition of Bangladesh. Water consumption of the rural people of India, Pakistan, Thailand and many other developing countries have also been found around 10 gallon per capita per day. Moreover, this consumption figure lowers the incidences of diarroheal attack according to the former Cholera Research Laboratory, Dacca.

Rural people collect only 30-40 percent of their present daily requirement of water from tubewells and the remaining amount is being collected from unprotected sources like ponds, rivers etc. which is not desirable to attain the objectives of the water supply programme.

The main reasons for non-usage of tubewell water are the traditional habits of the rural people and their lack of awareness about the causes of water borne diseases. The only solution to this problem is a massive compaign on health education. But motivation about health education alone cannot change the situation. Other physical facilities must be provided on the basis of cultural demand, which is feasible and contributed to health.

The present tubewell platform dimensions are not adequate enough to allow bathing and washing on it. Moreover, a sufficient quantity of water cannot be yielded at a time for the purpose. Construction of extended platforms has yielded increased consumption as indicated by the Table 4.21. Benefit achieved in comparison with additional cost is satisfactory. Construction of small brick water reservoir (turnkey) or supply of earthen pots for the purpose of storing water may provide extra benefit. As indicated by Table 4.23 and Fig.4.17, location of the source has definitely some effect on water consumption, since women are the main water collectors. Arrangement for partial privacy of the source resulted in increased tubewell water collection. If tubewells are installed in protected and fenced places, tubewell water collection will increase. This site selection will not involve extra cost. Some tubewells are also required by the side of roads, in road junction or in public places for male collectors. Physical and chemical quality of water determine the choice of source. To ensure more use of tubewell water, quality must be within the acceptable limit of the rural consumers. The world Health Organization's standard for drinking water quality can not be followed strictly in rural water supply. Rural people accept tubewell water having iron content upto 2-3 mg/l and chloride content upto 400 mg/l without any objection in many places. Where iron content exceeds this value, removal of iron through constructing iron removal plants is essential to increase tubewell water consumption, as has been seen in two places. The extra cost involved for this is small, in-comparison with the benefit. Construction of deep tubewells or infiltration galleries in search of water with lower chloride content may provide a similar benefit. Distance of the source from households determines the amount of water collected from it. As indicated by Table 4.26 the presence of other convenient unprotected sources reduces the use of tubewell water significantly, where the tubewell water supply is associated with various problems. The absence of other suitable sources in the vicinity compels the users to use tubewell water as indicated by curve of Fig. 4.19.

To ensure more use of tubewell water, tubewells must be closer to the household than other unprotected sources, i.e. more tubewells are required where there are many unprotected sources. As indicated by Table 4.26, to allow the collection of 10 gpcd water requirement from tubewell various problems in the tubewell water must be eliminated; moreover, there must be a tubewell within 120-170' from each household where the average distance of unprotected source from households lies between 300'-500'. The number of people that could be served by one tubewell under this condition can be calculated from Fig. 4.2. When tubewells are located close to the household, more collection journeys are made and a smaller volume of water is collected per trip as represented by Fig.4.5 and 4.9. Therefore, greater accessibility to the tubewell eliminates the necessity of intermediate water storage and thereby reduces the possibility of contamination during storage.

If we were to provide all the above physical facilities, the theoretical calculation as presented in Appendix-C-4, indicates that 20-40 persons should be served by one tubewell. Therefore, for some 90 million rural people by the end of 1985 about 3×10^6 total tubewells would be required for the whole country i.e an additional 2.5×10^6 tubewell sinking program should be completed by 1985, which is simply impossible for economic and various other reasons. Even if the money were available; implementation of such large program needs a massive expansion of the responsible organizations. In addition, maintenance of those tubewells would be a major constraint.

But the theoretical value reflects the magnitude of the rural water supply problem of the country, and it indicates the necessity for external help and people's participation to share the responsibility with the Government.

Since the density of population in habitable rural areas varies from place to place, the allocation of tubewells on the basis of population figures in an area will result in an uneven distribution of tubewells. Moreover, limiting the distance between tubewell and households cannot be maintained in many places. For a wide variation of density of population, they may be classified into some groups. After the distance-population curve has been drawn on the basis of average density of population and an area classified into one or other group, then the population figure may be used in the determination of number of tubewells required in an area, as has been calculated in Table 4.3.

Where few people use a tubewell such as scattered communities, the family pump tubewell is a less costly option. Table 4.3 indicates that one tubewell will serve less people in scattered communities than dense communities, i.e more tubewells per capita are needed in scattered communities where generally comparatively richer people live; which implies that richer people get better service.

Results obtained from the regression analysis are not fully conclusive, since input data for the model are based on few sample areas.

CHAPTER - V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary of Findings:

- Density of population in habitable rural areas varies widely from place to place and it is high in clustered settlement areas. Local topography and socio-economic status have some influence on settlement patterns. Poor people live in closer association of houses than the rich.

- Average per capita water consumption in the rural areas is found about 10 gallon/day. Household size, sanitary facilities, socio-economic status are the most important factors affecting water consumption in the rural areas. About 50 percent of the daily requirement of water is utilised for bathing and washing at the source. Cows used in cultivation consume about 5-7 gallons of water per day.

- Accessibility to the source, quantity of water available at a time, physical and chemical rather than bacteriological quality of water determine the choice of source. Presently only 30-40 percent of the daily domestic requirement of water is collected from tubewells and the rest comes from unprotected sources. Among unprotected sources pond water is used more frequently and its average distance from households in many places is nearly equal to that of the tubewell. Water collection from tubewells decreases by 10-20 percent in the rainy season when unprotected sources remain full of water.

- Yield from the "Bangladesh New No.6 Handpump" is more than the local type. Performance of Family pump tubewell has been found quite satisfactory in some places. Where few people use one tubewell family pump tubewell be suitable for economic reason. Maintenance costs of traditional hand pump tubewells are optimum for users around 60 in number.

- Main reasons for non-usage of tubewell water are traditional habit of the rural people, lack of awarness about the causes of water borne diseases, its water quality, lack of privacy of source site, small platform dimension and distance to the source.

People prefer water which testes good, looks clean and does not change the colour of food and clothes. Iron concentrations less than 2-3 mg/l, chloride concentrations less than 400 mg/l in tubewell water have been found acceptable to rural consumers. Reduction of iron concentration from tubewell water through an iron removal plant increased the tubewell water consumption by an average 1.90 gpcd in two places. Arrangement of partial privacy increased the tubewell water consumption by average 0.75 gpcd in three places. Construction of bigger platform increased the tubewell water consumption by average 1.51gpcd in two places.

- Water collection from a tubewell decreases with increasing distance of household from tubewell. This problem is more acute where tubewell water supply is associated with various other problems and where alternative sources are closer to the households than tubewell. Households living close to a tubewell make more collection journey to a tubewell but collect less volume of water per trip than other households.

- The regression analysis shows that of the factors affecting per capita water consumption, distance ratio of protected source to unprotected source from household, water quality and platform condition emerged as the important variables in explaining variations associated with per capita water consumption.

- Water collection from tubewell varies with time of the day. At the peak demand period, 13-14 percent of total daily collection jurneys are made in one hour.

- Considering various factors a maximum of 20-40 persons can be served satisfactorily by one tubewell under ideal water consumption conditions.

5.2 Conclusions:

The following conclusions are drawn on the basis of results obtained from field investigations:

(a) Small diameter tubewell with No.2 pump is suitable under certain conditions if the number of users per tubewell is reduced.

(b) To obtain the maximum utilization of hand pump tubewells, i.e. to increase safe water use; in addition to a health education and motivation programme, the following physical facilities should be provided -

b-1. Allowable upper limits of iron and chloride in tubewell water should be 3 mg/l and 400 mg/l respectively. Where iron concentration exceeds this value in an area, ground water exploration should be conducted in search of low iron content aquifers. If the above attempt fails, small iron removal plants should be installed. Where chloride content exceeds the above allowable limit, construction of a deep tubewell or shrouded well or infiltration gallery is needed to ensure acceptable low chloride concentrations.

b-2. An extension of the present platform is needed as per modified design. A new design platform should be constructed where there is no platform.

b-3. Arrangement for partial privacy should be made whereever possible. In the future tubewell sinking programme, attention should be given to proper tubewell site selection. Where women are the main water collectors, location of the tubewell should be in a protected, fenced place, but must be accessible to all users. Some tubewells are also needed in road junctions or other suitable public places.

(c) Since it is not possible in the near future to provide one tubewell for 20-40 persons for various reasons, every effort should be made in selecting proper sites for tubewells in localities so that the distance of a tubewell from all households is the minimum possible. Present site selection criteria to provide one tubewell within 500' of every household should be strictly followed; moreover, this distance should be reduced gradually with time and opportunity which is absolutely necessary for more use of tubewell water i.e of safe water as observed in the study.

Reduction of that distance can only be achieved through people's whole hearted participation and through more extensive external help and co-operation. It is also thought that government could allocate somewhat more resources to this sector than present planning documents indicate.

(d) Density of population in habitable rural areas must be taken into consideration in addition to population in the allocation of tubewells in an area.

5.3 Recommendation for Future Study:

Rural water supply problems have been studied to some extent in only three districts in the south-western part of the country and the results which have been obtained from the investigation may not be applicable to other parts of the country.

It is not feasible to conduct field investigation in all areas, nor it is practicable to apply general design criteria for conditions throughout the country. It is therefore suggested that the whole country may be divided into some uniform water need zones on the basis of patterns of rural water consumption and local conditions. In each zone a similar type of study should be conducted. Specific study of the major parameters like water quality standards, distance factor, settlement patterns, importance of privacy etc. should be conducted to establish applicable design criteria for the particular zone.

A long term study on the performance, suitability, people's acceptability and structural durability of the iron removal plant is recommended in order to improve the design of low cost iron removal device.

APPENDIX A-1

INTERVIEW QUESTIONNAIRE

1. Village .... 2. House No. .... 3. Date ....

4. Informant (relation with house head): 5. Religion ....

6. Population served by own kitchen:

<1 yr.		1-10		>10 years		Total	
M	F	M	F	M	F	M	F

7. Occupation: .... 8. Total land owned: .... (Bigha)

9. Level of education:

Nothing	Primary	Secondary	Above Secondary

10. Approximate monthly income: (Taka) .... 11. Floor area of all roofed dwelling .... (sft)

12. Estimated value of the family property: (Taka) ....

13. Roof made of: .... 14. Wall made of: ....

15. Distance of nearest water sources and travel time:

	Tubewell	Pond	River	Ring well	Canal	Ditch
(Ft.)						
(Min)						

16. Sources of water for Domestic purposes

Nature of consumption	Season	T/WL	R/WL	Pond	River	Ditch	Rain Water
Drinking	Dry						
	Rainy						
Cooking	Dry						
	Rainy						
Washing clothes	Dry						
	Rainy						
Washing Utensils	Dry						
	Rainy						
Bathing	Dry						
	Rainy						
For Cattle	Dry						
	Rainy						
Sanitary Purpose	Dry						
	Rainy						

...../

17. Reasons for non-usage of tubewell water for all domestic purposes:

	YES	NO
(a) Tubewell is too far away -	☐	☐
(b) Pond/River is closer to the house -	☐	☐
(c) Sufficient quantity of water is available from surface sources -	☐	☐
(d) Feel comfort in taking bath and washing clothes in pond and river -	☐	☐
(e) More time is required in fetching water from a tubewell. Washing and bathing not possible at peak demand period -	☐	☐
(f) Tubewell water tastes bad and has a cloudy appearance -	☐	☐
(g) Cooked food and clothes become coloured -	☐	☐
(h) Take more time in boiling rice and dal -	☐	☐
(i) Hair becomes sticky -	☐	☐
(j) Taking bath and washing clothes on small platform is difficult -	☐	☐
(k) Tubewell site becomes flooded and contaminated by waste water; caretaker does not permit-	☐	☐
(l) Tubewell is situated in an exposed place; more time cannot be spent for washing and bathing by the women for lack of privacy -	☐	☐

(m) Other reasons (if any) ....

....

....

....

18. Water usage from various source:

Water collected from tubewell				Water collected from pond/river			
Tube-well No.	Date	Mode of collection and purpose of use	Quantity (gall.)	Pond/River No.	Date	Mode of collection and purpose of use	Quantity (gall.)

APPENDIX A-2

Proforma used in the field to record data collection

Time (Hour)		House No.	Water Collector		Water Collection																	Grand Total
					Water used at tubewell site					Water collected by container and taken back home												
					Strokes applied			Purpose	Total Collection	Kalsi			Balti		Other containers				Purpose	Total Collection	
					Heavy Thrust	Medium	Slow			[illegible]	Medium	Small	Medium	Small	Badna	Jug	Glass				
Arrival	Departure		Age	Sex	..... gall./stroke	..... gall./stroke	..... gall./stroke			..... gallon	..... gallon	..... gallon	..... gallon	..... gallon	..... gallon	..... gallon	..... gallon	..... gallon			
										Number of time used											

APPENDIX-'B'

Some Features of Pumps used in Bangladesh

Model Name	Weight (pounds)	Cylinder diameter (inch)	Stroke Length (inch)	Discharge Minimum (gallon) 1)	Specific use
New No.6 (UNICEF)	65	3.5	8.5"	6.00	Most common type in use all over the country
No.4 very shallow	46	3.0	6.0	3.00	Very shallow wells used only in salinity problem areas. Smaller capacity to prevent salt water intrusion by depletion of fresh water
No.2 Family Pump	22	2.5	4.0	1.4	Is used in areas where potable aqufer is available at reasonable shallow depth (30-45'). Meant for use by a single family.
Deep Set Cylinder with No.6 Head	5 + 65	2.5	8.5	3.00	Used where water table goes below suction head (25'-0") during dry season.

1) Discharge for twenty strokes under 5'-0 static suction lift corresponding to mean sea level at a temperature of 86 ^{o}F.

APPENDIX-'C-1'

Maximum number of users per tubewell on the basis of time required in fetching water from the tubewell

If it is considered that people will collect entire domestic requirement of water, i.e 10 gpcd from tubewell, then number of trip required per person per day is four assuming 2.5 gallons average collection per trip.

Now if 160 people use a tubewell, total number of trips to a tubewell is 640 trips per day.

About 0.625 minute is required to pump 2.5 gallon of water from a tubewell having yield capacity of 4 gpm and approximately 0.67 minute is spent in cleaning and placing the container in proper place during water collection. Therefore, total time spent at tubewell in water collection per trip is equal to 1.30 minute.

Since about 14 percent of the total collection journeys are made per hour at peak demand period, total number of trips per hour at peak demand period $= \frac{640 \times 14}{100} = 90$ collection journeys in one hour.

Total time required to make 90 collection journeys is equal to $1.30 \times 90 = 117$ minutes, i.e 160 people can not be satisfied by one well under ideal water collection conditions.

If the collection jurneys are made uniformly throughout the peak demand hour, then maximum number of person could be satisfied by one well $= \frac{60 \times 100}{1.30 \times 14 \times 4} = 82$ persons. Since at peak demand hour several collectors attend a source within short interval of time, maximum number of users per tubewell may be 20-30 to avoid any long delay in collecting tubewell water.

APPENDIX-'C-2'

Users per tubewell and length of run between cleaning of the iron removal plant

The length of run between backwashes of an iron removal plant is a function of total removal of iron, i.e amount of iron removed per unit volume of water and total volume of water pumped. In plant No.2, raw water iron content is 8 mg/l and treated water iron per litre is 0.4 to 0.6 mg.

About 100 users use the plant and average per capita collection from the plant is 3 gpcd, which is only 30% of the daily domestic requirement. Daily yield from the plant is therefore, 300 gallon. If in future per capita collection from the plant increased to 10 gallon, then in order to maintain the present length of run between cleaning of the plant, users per tubewell must be kept limited to $\frac{3 \times 100}{10}$ = 30 person.

Present length of run between cleaning is 15 days. Since the method of cleaning is a truble some matter, a short length of run between cleaning of the plant is not desirable.

APPENDIX-'C-3'

Maximum number of people who could be satisfied by one tubewell if Bathing and washing are done on tubewell platform of the present limited area (2'9"x2'9")

If on an average 5 minutes is spent per trip for washing utensils, clothes and other purposes then a maximum 12 collection journeys could be made in one hour, with the present type of platform, because the user will occupy the main platform for the whole time.

Since about 14 percent of the total collection journeys are made at peak demand hour, maximum total collection journeys per hour is equal to $\frac{12 \times 100}{14}$ = say 85. As per Fig. 4.2. households living within 100' from a tubewell on an average made about 28 collection journeys per household per day.

Therefore, about $\frac{85}{28} \approx$ 3 households could be served by one tubewell and maximum 20-25 persons will be benefited if bathing and washing are done on the present tubewell platform.

On the other hand where there is an extended new type platform, one person who wants to wash his utensils or clothes, can collect water from the well and then can do his washing on the extended platform leaving the main platform completely free for others. And by that time one or two users can easily use the tubewell for any purpose. Therefore if on an average 2 minutes is spent per trip, about 30 collection Journeys could be made in one hour, i.e $\frac{30 \times 100}{14 \times 28} \approx$ 8 households could be served by one tubewell and about 55-60 persons will be nefited.

APPENDIX-'C-4'

Optimum number of users per hand pump tubewell

	For the condition	Maximum permissible number of users per hand pump tubewell
a.	To have the facility of bathing washing on new tubewell platform (Appendix-B-3)	55-60 person
b.	For the maintenance of better privacy of the source site (Art. 4.4.4)	15-25 person
c.	To avoid any rush at tubewell site at peak demand hour (Appendix-B.2)	20-30 person
d.	To maintain a long length of run between cleaning of the iron removal plant (Appendix-B-1)	20-30 person
e.	To provide a tubewell within 120-170' from each household (Art. 4.4.6)	20-40 person
f.	To maintain a optimum maintenance cost of traditional hand pump tubewell (Art. 4.3.2)	50-60 person
g.	To reduce the chances of Bacteriological contamination of tubewell water (Ref.42)	less than 239 person
h.	Recommendation of Ruiz of Colombia (Art. 2.1.4, Ref.20)	20-50 person

Therefore one tubewell may be provided for 20 person in scattered populated area and for 40 person in densely populated area.

APPENDIX D-1

Calculation of mean and standard deviation from different value of maintenance cost with variation of users

Number of users x	Maintenance cost of tubewell in Taka y	Step deviation from arbitrary value (Ax) = dx	Step deviation from arbitrary value (Ay) = dy	dxdy	dx^2	dy^2	ydx	ydx^2
20	2	-60	- 6	360	3600	36	- 120	7200
25	7	-55	- 1	55	3025	1	- 385	21175
30	2	-50	- 6	300	2500	36	- 100	5000
30	4	-50	- 4	200	2500	16	- 200	10000
30	5	-50	- 3	150	2500	9	- 250	12500
40	9	-40	1	-40	1600	1	- 360	14400
50	10	-30	2	-60	900	4	- 300	9000
60	6	-20	- 2	40	400	4	- 120	2400
60	22	-20	14	-280	400	196	- 440	8800
65	7	-15	- 1	15	225	1	- 105	1575
75	8 = Ay	- 5	0	0	25	0	- 40	200
80=Ax	8	0	0	0	0	0	0	0
80	12	0	4	0	0	16	0	0
80	22	0	14	0	0	196	0	0
80	23	0	15	0	0	225	0	0
115	20	+ 35	12	420	1225	144	700	24500
115	30	35	22	770	1225	484	1050	36750
115	43	35	35	1225	1225	1225	1505	52675
120	33	40	25	1000	1600	625	1320	52800
125	46	45	38	1710	2025	14440	2070	93150
150	30	70	22	1540	4900	484	2100	147000
150	50	70	42	2940	4900	1764	3500	245000
250	35	170	27	4590	28900	729	5950	1011500
320	50	240	42	10080	57600	1764	12000	2880000
		+ 345	+ 292	25015	121275	22400	27775	4635625

Mean:

$$\bar{x} = 80 + \frac{345}{24} = 94.38 \text{ users}$$

$$\bar{y} = 8 + \frac{292}{24} = 20.16 \text{ Taka}$$

$$\sigma y = \sqrt{\frac{22400}{24} - \left(\frac{292}{24}\right)^2}$$

$$= 28.02 \text{ Taka}$$

$$\sigma x = \sqrt{\frac{121275}{24} - \left(\frac{345}{24}\right)^2}$$

$$\sqrt{5053.12 - 206.64}$$

$$= 69.61 \text{ users}$$

...../

Calculation of mean, standard deviation from different value of per capita water collection by observed households (See Figure 4.4 also)

Per capita water collection (gpcd) X	Percent household (%) y	Mid value of X (gpcd) x	Step deviation from arbitrary value (Ax) = dx	Step deviation from arbitrary value (Ay) = dy	dxdy	dx^2	dy^2	ydx	ydx^2
0-1	10	0.5	- 4	0	0	16	0	- 40	160
1-2	20	1.5	- 3	10	- 30	9	100	- 60	180
2-3	15	2.5	- 2	5	- 10	4	25	- 30	60
3-4	17	3.5	- 1	7	- 7	1	49	- 17	17
4-5	10=Ay	4.5=Ax	0	0	0	0	0	0	0
5-6	7	5.5	1	- 3	- 3	1	9	7	7
6-7	8	6.5	2	- 2	- 4	4	4	16	32
7-8	3	7.5	3	- 7	- 21	9	49	9	27
8-9	3	8.5	4	- 7	- 28	16	49	12	48
9-10	2	9.5	5	- 8	- 40	25	64	10	50
SUM	95		+ 5	- 5	-143	85	349	- 93	+ 581

(a) Mean $= \bar{x} = Ax + \frac{ydx}{y} \times c = 4.5 + \frac{(-93)}{95} \times 1 = 3.521$ gpcd

(b) Standard deviation $= \sigma = c \sqrt{\frac{\Sigma ydx^2}{\Sigma y} - \left(\frac{\Sigma ydx}{\Sigma y}\right)^2} = 2.270$ gpcd

Calculation of Mean, Standard Deviation from different value of collection journey (%) with variation of time (hr)

(See also Figure 4.7 and 4.8)

Time in (hour) X	Percent collection journeys y	Mid value of X x	Step deviation from arbitrary value (Ax) = dx	Step deviation from arbitrary value (Ay) = dy	dxdy	dx^2	dy^2	ydx	ydx^2
0500-0600	1.0	05.50	- 7	- 4.0	28.0	49	16.0	- 7.0	49.0
0600-0700	7.5	06.50	- 6	+ 1.5	- 9.0	36	2.25	-45.0	270.0
0700-0800	14.0	07.50	- 5	+ 8.0	+40.0	25	64.0	-70.0	350.0
0800-0900	13.5	08.50	- 4	+ 7.5	-30.0	16	56.25	-54.0	216.0
0900-1000	8.20	09.50	- 3	+ 2.2	- 6.6	9	4.84	-24.60	73.8
1000-1100	7.0	10.50	- 2	+ 1.0	- 2.0	4	1.0	-14.0	28.0
1100-1200	6.0=Ay	11.50	- 1	0	0	1	0	- 6.0	6.0
1200-1300	5.0	12.50=Ax	0	- 1.0	0	0	1.0	0	0
1300-1400	5.2	13.50	1	- 0.8	- 0.8	1	0.64	5.20	5.20
1400-1500	3.5	14.50	2	- 0.5	- 1.0	4	0.25	11.00	22.0
1500-1600	7.8	15.50	3	+ 1.8	+ 5.4	9	3.24	23.4	70.2
1600-1700	8.0	16.50	4	+ 2.0	+ 8.0	16	4.0	32.0	128.0
1700-1800	7.0	17.50	5	+ 1.0	+ 5.0	25	1.0	35.0	175.0
1800-1900	4.1	18.50	6	- 1.9	-11.4	36	3.61	24.6	147.6
1900-2000	0.2	19.50	7	- 5.8	-40.6	49	33.64	1.4	9.8
SUM	100%		0	11.0	-15.0	280	191.72	-88.0	+1550.6

(a) Mean $\bar{x} = Ax + \frac{\Sigma ydx}{\Sigma y} \times c$

$= 12.5 + \frac{-88.0}{100} \times 1.0$

$= 11.62$ hr.

(b) Standard Deviation $= \sigma = \sqrt{\frac{\Sigma ydx^2}{n = \Sigma y} - \left(\frac{\Sigma ydx}{n = \Sigma y}\right)^2}$

$= \sqrt{\frac{1550.6}{100} - \left(\frac{-88}{100}\right)^2}$

$= \sqrt{14.73} = 3.83$ hr.

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