Household Water Supply and Factors Affecting Consumption Level: The Case of Mekelle Town, Tigray

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DEDICATION

To all academic and administrative staff members of Mekelle University.

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ACRONYMS

CSA	Central Statistical Authority
MDGs	Millennium Development Goals
MDWCPHH	Mean Daily Water Consumption per Household
MDWCPC	Mean Daily Water Consumption per Capita
MWCPHH	Monthly Water Consumption per Household
NGOs	Non-Governmental Organizations
MWR	Ministry of Water Resources
UNICEF	United Nation Children's Fund
WHO	World Health Organization
WSSA	Water Supply and Sanitation Authority
WSP	Water and Sanitation Program

ABSTRACT

This research tries to assess household water supply and factors affecting consumption levels in Mekelle town. It is with the main objective of assessing the water supply problems and major factors that affect household per capita water consumption in the town. To achieve this, relevant data were gathered from both primary and secondary sources. The major primary instrument of data for the study was household questionnaire survey. A sample of 200 households was selected using systematic random sampling method from four "Tabias' and responses of the questionnaire survey were entered into SPSS and STATA Software for analysis.

As found out, mean daily per capita water consumption of sample households with private connection (group 1), households with out private connection (group 2), and households with private connection and water vendors (group 3) is 49.5 l/c/d, 11.9 l/c/d and 83.9 l/c/d respectively. Daily per capita water consumption of those households who do not have their own private connection is 11.9 liters. This is lower than the amount specified by Ministry of Water Resource (1996) which was 20 liters of water per person per day and far lower than the WHO standard (45 l/c/d).

The result of regression analysis indicated that average income of household heads, household size, presence of meter connection, and flush toilet are statistically significant to explain the variation in daily per capita water consumption among households in the town.

Hence, income, presence of meter connection and flush toilet are positively related to mean daily water consumption per capita (Y). On the other hand, household size is negatively related to mean daily water consumption per capita (Y). Therefore for appropriate water supply projection, a detail study on the physical and socio-economic factors affecting per capita water consumption are desirable.

Key words: *Supply, Physical, Socio-economic, Household, Per capita, Consumption, Daily.*

CHAPTER ONE

INTRODUCTION

Water is one of the precious and vital resources that need proper management and use. Zewdie (1994) stated that water will have to be managed sustainably, taking into account environmental concerns, such as population pressure, drought, excessive evapotranspiration, desertification, deforestation, land erosion, over application of water, safe disposal and processing of waste water, water pollution, salinisation of water resources and soil, the degradation of living conditions, and poverty.

"While global water resources may be finite, the same can not be said of water demand" (Sullivan, 2002: 1196). Hence, growing population and continued economic progress, which have been increasing the demand for water to be shared among residential, commercial, industrial and public users, have increased the competition for water. But, as to supply scarcity, prioritizing of needs is to be taken to allocate the available water. Zewdie (1994) stated that, whenever there are no alternative sources of drinking water, needs of human beings and animals should be the first to be supplied on any available water.

Following the debates at the second world water forum in the Hague in March 2000, it has become clear that, there are still millions of people world wide without access to sufficient water for domestic use (Sullivan, 2002). This further elaborated by the World Bank report (2004) that, about 1.7 million deaths worldwide were attributed to unsafe water, sanitation and hygiene, mainly through diarrhea in 2002. Therefore, adequate and safe drinking water facilities should be provided to the entire population both in urban and rural areas.

The inadequacy of safe drinking water in both rural and urban areas.across the world has attracted the focus of many world summits. For instance, according to the World Bank Water and Sanitation Board (2004: 9), in recent years the challenge of reducing poverty by improving the efficiency and sustainability of water supply and sanitation services has found focus in the Millennium Development Goals. The Development Goals have specified the proportions of urban and rural areas to have access to safe water. The Board further states that the targets aimed to reduce by half the proportion of people without sustainable access to safe drinking water and basic sanitation by the year 2015.

According to Zewdie (1994), Ethiopia has signed the UN assembly's declaration on the international drinking water supply and sanitation decade and joined the program in 1985. During the decade, the target was to serve a total population of 11.3 million people.

In the case of domestic water demand, expansion in water systems should match town's rapid population growth. To do so, as stated by Zewdie (1994: 83), "national plan for investment in the development of water resources is essential to provide comprehensive and coordinated direction to the water sector agencies and to prioritize projects and expenditures".

Taking only population growth to water supply and demand projection is, however, not sufficient. Many other socio-economic and physical factors such as income, education, accessibility of water tap, possession of water using appliances, possession of domestic animals and garden plots have positive or negative influence on household water demand and consumption.

1.1. Problem Statement

Adequate and safe water supply is one of the basic urban services, which highly influence economic progress of towns and the health of their dwellers (Yimer, 1992). This means that water resource availability, or its lack is linked to economic and social progress, which suggests that development is strongly influenced by water resource availability and management (Sullivan, 2002).

Various studies have been made on water service coverage of different African countries. Accordingly, a study on across-country synthesis (Ethiopia, Kenya, and South Africa) WSP (2003) stated that, Ethiopia's level of water service coverage is among the lowest in the world with only 26.8% of the population having access to basic services.

In line with this, a report by Mekelle water supply service office (2004/05) indicates that the existing water supply sources for the town of Mekelle are 15 boreholes with a total yield of about 2,827,487m^3 per year. But this amount is not enough to the town, which is showing a tremendous change in population growth, industry, and commercial establishments.

In addition to this, other boreholes, which were drilled in different times, are not currently operational. Among those boreholes that are not operational are two boreholes at Mai Shibti, PW12, PW4A, PW6, and PW7A. But most of them, which dried up, were planned to serve until 2015.

In relation to the population growth, a study by WSSA (1992) stated that the town's population was projected to be 140,400 in 2005. Thus, the projected maximum and average daily demand for water was 11,440 m^3/d (132 l/s) and 9530 m^3/d (110 l/s) respectively. But the actual population size of Mekelle town in 2005, unlike the projected one, was 219,179 (Mekelle City

Administration, 2005) and the maximum well production is only 7750 m^3/day (89.7 l/s).

Moreover, the yield of water wells is found to be below their designed capacity because of water shortage, technical problems of pumps, and drying up of some of these boreholes. As a result, it is common that the water delivery service in some 'Tabias'[1] is quit often interrupted for days or even for a week. The town's water supply service office also admits that there is an unequal distribution of water in the town, especially between low lying and hilly areas.

Water loses or wastages are other problems of great concerns. According to the 2004/05 annual report of the town's water supply service office, the age of the water distribution system is 54 years, and five years for the new expansion projects. It is also accepted that system problems (old lines) are the major problems. If this is so, the water lose that is estimated by Mekelle water supply service office, 19 % is underestimated. Water Supply and Sewerage Authority's, five towns water supply and sanitation study (1992) reported that, water production and sales from January to June in 1991 indicated a water loss of about 50 % in the town. Moreover, the existing distribution network doesn't cover many newly developed areas of the town. This creates additional pressure on the supply of water.

Most of the studies made on the town water supply system focus only on the development of new supplies to deal with water scarcity. But along with new supplies, demand management that is oriented towards changing the behavior of consumers is very important. To this end, a detailed study of physical and socio-economic factors affecting household per capita water consumption should not be ignored. This means, along with population growth of a particular town, the overall change of their life style towards

[1] The lowest officially recognized administrative units

water consumption should be studied. This helps to have a complete picture of the supply system needed in the town.

1.2. Justifications and Rationale for the Study

The population of Mekelle is growing at an alarming rate. Its size is rapidly expanding towards the north, northwest, and west (except to the cliff of Messobo). The urban economic activities (commercial and industrial) are expanding and creating an increasing demand for water supply. "Growth in human population is creating an increasing demand for water, and if, at the same time, standard of living is to rise, water consumption per capita is likely to rise" (Sullivan, 2002: 1196).

These phenomena call for immediate efforts to improve the existing water supply and promote the construction of new supplies so as to cope up with the increasing demand for water. Hence, to have complete information about the total amount of water demanded by consumers, a study on the physical and socio-economic factors affecting per capita water consumption is important. Thus, household units are the focus of this study. This is because households are the greatest number of consumers and whose water concerns are most prioritized.

With regard to its significance, the study will give an insight into the physical and socio-economic variables that influence per capita water consumption of households in the town. These variables could serve as a practical guide for water supply planners and policy makers to design a comprehensive water supply and management plan.

1.3. Objectives of the Study

1.3.1. General Objective

The general objective of the study is to identify the water supply problems and major factors that affect household per capita water consumption in Mekelle town.

1.3.2. Specific Objectives

Specifically, the study has the following objectives:

- ✓ To assess the existing water supply situation in terms of:
  - o availability and accessibility
  - o yields of boreholes
  - o distance of public stand pipes, pressure maintained in pipe lines
- ✓ To assess if there is any alternative means of water supply system used by consumers (seasonal variability)
- ✓ To assess the extent of influence of some physical and socio-economic factors on household per capita water consumption level.
- ✓ To recommend the importance of incorporating some physical and socio-economic factors in managing water supply and demand projections and resolve the imbalance problem.

1.4. Research Questions

The purpose of this study is to identify and analyze the water supply problems and major factors that affect household per capita water consumption in Mekelle town. Based on these objectives, the major questions to be answered are:

- ✓ What is the extent and magnitude of the existing water supply problems in terms of availability and accessibility?
- ✓ What are the major influencing factors to the yield of boreholes?
- ✓ Is there any seasonal variability of household or Per capita water consumption from piped water source?

- ✓ What are the main physical and socio-economic factors that influence household per capita water consumption?

1.5. Research Hypotheses

- Household per capita water consumption is positively correlated with:
    i. the presence of water using appliances in the household.
    ii. household head level of education
    iii. household income level.
    iv. Frequency of body washing or bathing.
- Private connection (private meter) water supply service encourages household water consumption more than other types of supply services.
- Household per capita water consumption decreases as the family size of households and distance from home to water sources increases.
- The occupation in which household heads are engaged influences per capita water consumption.
- Possession of garden and domestic animals increase per capita water consumption of households.

1.6. Methodology

1.6.1. Data Sources

Relevant data on geology, hydrology, climate, type of water supply service, and population growth were collected from secondary sources. Documents from different organizations such as monthly and annual well production report of Mekelle water supply service office, documents from Tigray Water Resource Development Bureau, Mekelle City Administration, Tabia Administrative Unit, the Ethiopian Institute of Geological Survey, Mekelle Master Plan Project Office and Ministry of Water Resources were also consulted.

The major primary source of data for the study was questionnaire survey of households. For the survey, this questionnaire was translated to the local language and responded by household heads. In particular, water consumption and management related questions were answered by women. In the absence of household heads, the possible respondents taken were any adult member of the family. The questionnaire was made to focus on the existing water supply system and household per capita water consumption in relation to their socio-economic characteristics.

Eight enumerators were selected on the basis of their experience and knowledge of the selected 'Tabia' administrative unit to handle the questionnaire. They were given training for a day on how to approach the interviewees, fill the questionnaire as well as on various issues of research ethics. In addition to these, the researcher conducted close supervision. The enumerators had also worked in different studies conducted by different organizations such as Central Statistics Authority (Tigray Branch), Relief Society of Tigray, and others.

1.6.2. Sampling and Survey Design

According to the recent administrative set up, the city of Mekelle consists of 10 ' Tabias' which are grouped into North and South districts. According to Mekelle City Administration (2005), Mekelle town has a total population of 219,179 and total household size of 44, 731. In conducting this study, therefore, four 'Tabias' were selected. To ensure representativeness, two 'Tabias' were from the highest private meter connection to total household ratio and two 'Tabias' with the lowest ratio (Table1). This categorization is supported by different studies, as one of the best water supply services provided to households is possession of private meter connection.

After the 'Tabias' were selected, sample size from each 'Tabia' was proportionally determined from the total household in the sampled 'Tabias'. Finally, to select respondent household heads, a list of each 'Tabia' was used as a sampling frame. From the sampling frame, the first household was selected based on lottery method. After the selection of the starting household, the remaining households were selected based on systematic random sampling method. Based on the total number of households in four 'Tabias' and proportional allocation of sampled households from each 'Tabia', the interval was determined. Based on the specified interval respondents from each 'Tabias' were selected.

Table 1: Population, household size and number of private meter connections by 'Tabia'.

NO.	Tabia	Population Size(*)	House hold Size(*)	Number of private meter connections (**)	Private meter connection to household size ratio (***)
1	AdiHaki	25,650	5235	3745	0.72
2	Hadnet	26,106	5328	1173	0.22
3	Kuha	25,716	5248	1598	0.30
4	Aider	24,300	4959	2232	0.45
5	Aynalem	3,468	708	500	0.71
6	Hawelti	31,501	6429	1792	0.28
7	Addis Alem	18,000	3673	3121	0.85
8	Kedamay weyane	27,157	5542	1609	0.29
9	Sewhi Niguse	19,000	3878	1471	0.38
10	Industry	18,281	3731	1475	0.40
	Total	**219,179**	**44,731**	**18,699**	**0.42**

Source:

Mekelle City Administration (2005)

*****Mekelle Water Supply Service Office report (unpublished)***

***** *Computed from the given data.***

Table1 indicates that two Tabias, Addis Alem (85%) and Adihaki (72%) represent the highest relative water supply service provided to consumers. The remaining two Tabias, Hadnet (22%) and Hawelti (28%), represented the lowest water supply service provided to consumers. Then, after the four

Tabias were identified, sample size from each Tabia was calculated as shown in Table 2.

Table 2: Number of sample households from each 'Tabia'

No.	Tabia	Total household number	Number of sample households	Number of questionnaires collected
1	Addis Alem	3673	35	35
2	Adihaki	5235	51	51
3	Hadnet	5328	52	50
4	Hawelti	6429	62	61
	total	**20,665**	**200**	**197**

As indicated in Table 2, only three questionnaire out of 200 were found invalid. The type of water supply service for two respondents was skipped and a respondent is found to be a local beer ('Suwa') seller. In general, 98.5% of the questionnaire were responded and collected properly.

1.6.3. Explanatory Variables used in the Study

Household's Monthly Income (INHH) – This variable is measured in terms of the Ethiopian currency (Birr). A monthly salary of heads of households was taken as a major factor in determining households' income. Where there were other members of a household who earn income, then total household income per month was considered. Moreover, other means of income other than the basic income such as income from rent of property, supports from relatives, and others were also taken (if any). These are the reasons why average income (**AINHH**) of a household was taken in regression analysis.

The sample households were classified into three groups. These groups are high, medium and low-income groups. It was also expected that households' monthly income had a direct relationship with household per capita water consumption.

Family Size of Households (SIHH) – This refers to number of persons per dwelling (household) unit. It was expected that a larger household require more water than a smaller household unit. On the other hand, number of persons per household was expected to be inversely proportional to per capita water consumption.

Education Level of Household Heads (EDHH) – This variable was measured in terms of the number of years that the respondent had been to school. To group the sampled households into their respective educational attainment, four educational levels were generated and used for descriptive statistics. These were:

EDHH=1, if illiterate

EDHH=2, if 1-8 grades only

EDHH=3, if 9-12 grades only

EDHH=4, if tertiary level

In order to use education in regression analysis, a dummy variable is generated as follows:

EDHH=0, if illiterate

EDHH=1, if literate

Here, educational level was expected to have a direct relationship with household per capita water consumption. It was because, as the level of education of a household head increased, there would be more awareness of the health benefit of water and consequently, frequent bathing and washing in the household unit.

Occupation of Household Heads (OCHH) – This variable refers to the main occupation of household heads. For the sake of descriptive analysis, occupation were classified into five categories:

OCHH=1, if government, private or NGO employed or retired (GOPRNGRI)

OCHH =2, if private business

OCHH =3, if farming

OCHH =4, if daily laborer

OCHH =5, if unemployed

In order to use occupation in regression analysis, a dummy variable is generated as follows:

OCHH =0, if unemployed

OCHH =1, if others

Per capita water consumption of households who were employed was expected to be higher than unemployed households. This was based on the assumption that employed household heads were expected to be more educated than unemployed households.

Accessibility of Water Tap (ACCESS) – This refers to whether the supply service is private connection or not. This variable was measured in terms of round trip time taken to fetch water from public stand pipe estimated by households.

0, if private meter connection (in-house or yard) and neighbor/ vendor

Time, if public standpipe users (water fetching time in minutes)

Water-using appliances (WATAP) - In the case of water using appliances shower and flush toilet were found to be determinant facilities in the town. The sample survey also indicated that, numbers of households having bathrooms and/or dishwashers were almost negligible. Thus, numbers of showers and toilet of households were taken.

To observe the impact of these fixtures on daily water consumption, a dummy variable for SHOWER and FTOILET are generated.

SHOWER=1, if the household is having shower(s)

SHOWER=0, if otherwise

FTOILET=1, if the household is having toilet(s)

FTOILET=0, if otherwise

NONUSAGE- This is a dummy variable generated to distinguish households who are water venders from non-vendors.

NONUSAGE=1, if the household is non-vendor.

NONUSAGE=0, if the household is water vendor.

PREM - This is a dummy variable generated to distinguish households who have a private meter connection system or sharing a common yard tap from neighbors and public standpipe users.

PREM =1, if the household is having private meter or sharing a common yard tap.

PREM =0, if the household is using from neighbors or public standpipes.

FREQUENCY OF BODY WASHING (FRWA)- This indicates body washing frequency of household members coded as, daily (1), every two days (2), every three days (3), every seven days (4), and every fourteen days or more (5).

POSSESSION OF DOMESTIC ANIMALS (PREDO) - The presence of domestic animals in the dwelling unit is expected to raise daily water consumption per capita of households. Thus, a dummy variable is generated to differentiate households with or without domestic animals.

PREDO=1, if the household is possessing domestic animals

PREDO =0, if otherwise

POSSESSION OF GARDEN (PGAR) - Possession of garden plot is expected to raise daily water consumption per capita of the households. Thus a dummy variable is generated to differentiate households with or without garden.

PGARD=1, if the house is with garden plot

PGARD=0, if otherwise

MISSING VALUES (55 and 99)- Two missing values are generated to represent:

55, if the information for that particular variable is not available.

99, if the information for that particular variable is unrelated (private meter connection focused questions are unrelated to public standpipe users).

1.6.4. Methods of Data Processing and Analysis

Responses of the questionnaire survey were entered into SPSS and STATA Software for analysis. In the analysis of data, averages and percentages were used. To determine relationships of the dependent variable with some independent variables, various quantitative methods of data analysis were employed. Some of these quantitative methods of analysis were descriptive statistics, and linear regression of all explanatory variables using SPSS and STATA software.

To use the quantitative methods of analysis, the identified dependent and independent variables are:

1. Dependent variable

Y = amount of daily per capita water consumption.

2. Independent variables

INHH = Household Monthly Income

SIHH = Family Size of households

EDHH = Educational Level of Household Heads

OCHH = Occupation of household Heads

PREM = Presence of private meter connection

ACCES = Accessibility of water tap.

WATAP = Presence of water using appliances (fixtures)

FRWA = Frequency of body washing or bathing.

PREDO = Presence and number of domestic animals

PGAR = Possession of garden plots

Then, the functional notation of the dependent and independent variables is:

$$Y = \beta_0 + \beta_1 InHH + \beta_2 SIHH + \beta_3 EDHH + \beta_4 OCHH + \beta_5 PREM + \beta_6 ACCES + \beta_7 WATAP + \beta_8 FRWA + \beta_9 PREDO + \beta_{10} PGAR + U$$

Where:

β_0= intercept of the model (parameter)

$\beta_1, \beta_2, \ldots \beta_{10}$ = slope coefficients (parameters)

U= disturbance or error term. This error term represents all factors that affect the amount of daily per capita household water consumption which are not taken into account here explicitly.

1.6.5. Limitations of the Study

Households may use water from their own connection, from water vendors and/or public standpipes. In the case of households without private meter connection, there was no tangible sources that could be referred for the actual water consumption of the household. Thus it was based on the respondents' estimation that their daily water consumption has been taken.

The other limitation encountered in this study was lack of adequate information due to improper document handling by the town's water supply service office. It was difficult to get source documents in an organized manner.

Moreover, the study covered only 200 households from a total of 44,731 households of the town. Thus, time and financial constraints limited the sample size.

1.6.6. Organization of the Paper

The thesis consists of six chapters. The first chapter, the introductory part, has sections that deal with background, problem statement, justification and rationale of the study, objectives, research questions, research hypothesis, methodology, limitations and organization of the study. Chapter two provides literature review and then followed by the third chapter entitled as background of the study area. The fourth chapter deals with the existing water supply system in the town. The fifth chapter is devoted to the analysis of determinants of water consumption levels in the town. Finally, chapter six presents conclusions and recommendations of the study.

CHAPTER TWO

LITERATURE REVIEW

2.1. Water Supply Issues

Water is plentiful but 97% of the total water is seawater and of the 3% that is fresh, two-third is confined in glaciers or ice or snow around the poles (Khan, 2003). This indicates that the remaining fresh water left to the world population is only 1%. But availability of fresh water resource varies from country to country. Because of the differences in availability of fresh water and financial capacity of governments, number of people who have access to adequate and potable water varies through out the globe. Along with these figures, as water is essential for life, adequate and safe water supplies are prerequisite for human and economic development.

Urbanization that is an increasing concentration of people, economic activities, public services, institutions, offices of different types strongly influence the amount of water supply (Yimer, 1992). In addition to this, WHO (2000:28) further articulated the rate of urbanization and demand for service in Africa as follows:

> *Urbanization in Africa currently exceeds 5% per year, the most rapid of all the regions of the world, and the largest cities tend to exhibit the most serious problems resulting from this growth rate. Among other problems, water and sanitation services can be hard pressed to meet the needs of expanding population.*

Thus, over the years, increasing population, growing industrialization, and expanding agriculture have pushed up the demand for water extremely high. Moreover, lifestyle change of urban dwellers and an increase in their standard of living have created additional limitation on the water supply system.

According to WHO (2000), global water coverage in 1999 for urban and rural centers was 94% and 71% respectively. The total global water supply coverage was 82%. Furthermore, the same source indicated that, the proportion of population in urban and rural areas of Africa accessed to potable water in 1999 were 83% and 42% respectively. The total urban and rural water coverage in Africa was only 56%.

The overall water supply coverage of Africa was 46% lower than global water supply coverage. Moreover, rural water coverage in Africa was 69% lower than global water supply coverage.

2.2. Water Resource Development and Management

"Water management can be considered as a man-environment system that transforms inputs of natural resources into desired outputs of water services" (Porter, 1978:3). This is to be done by harvesting rainwater, extracting groundwater, diverting, and storing running water.

In general, Water resource development and management can be grouped into supply-oriented and demand-oriented management techniques.

2.2.1. Supply-oriented Management Techniques

Supply-oriented management focuses on considering a range of water supply options which are cost effective to meet the over all water requirements. Hence, it mainly strives for water supply increment.

2.2.1.1. Rainwater Harvesting

Rainwater harvesting is the collection of raindrops. In most cases, a roof is used for this purpose. The rainwater then flows through a channel, into a collection tank. The size of the tank is dependant upon the amount and purpose of the water but also of the annual rainfall and the size of the roof.

Rainwater harvesting is also used as a supplement to other water. supply schemes. This is mainly applicable to situations in which boreholes and piped water systems are unreliable, or in situations where other water sources such as rivers and lakes are too distant or too polluted.

Furthermore, rainwater is valued for its purity and softness and is free from infection by-products, salts, minerals, and other natural and man-made contaminants.

2.2.1.2. Groundwater Resources Development

"The portion of the earth through which the lateral movement takes place is known as the zone of saturation, and its water is ground water " (Steel and McGhee, 1979: 55). This water bearing formation is called an aquifer.

Groundwater is an important source of water supply that has a number of advantages. It may require no treatment, has uniform temperature throughout the year, is cheaper than impounding reservoirs, and amount of water available is more certain because it is not affected by drought in the short run (Steel and McGhee, 1979).

However, groundwater can become contaminated through infiltration from the surface or injection of contaminants. Furthermore, the volume of water added to the groundwater source (recharge rate) can vary from year to year, depending on climatic conditions. Extraction of groundwater requires an initial investment that includes the drilling of boreholes, development, casing, filling with gravels, and installation of the pump.

2.2.1.3. Surface Water Resources Development

Surface water resources such as rivers, streams and lakes are other important sources of water. However, Surface water is often susceptible to pollution and contamination. Animal and human wastes within a watershed will often find its way into surface waters. Although some cities are able to collect safe water from uninhabited regions and thereby reduce water born disease to a low level, many others found that their supplies were polluted and that the risk was increasing as population increased up on watersheds (Steel and McGhee, 1979). Moreover, contaminated surface water may interact with ground water and spread contamination. Thus, as surface water is vulnerable to contamination, it requires filtration and disinfection before it is safe to drink.

2.2.2. Demand-oriented Management Techniques

Demand-oriented management is complementary to engineering solutions that seek to supplement water supplies. It ensures that available water is used efficiently and wisely.

2.2.2.1. Water Conservation

Water shortages are placing increasing pressure on communities to conserve their water supplies. Focusing on the supply side only could not solve water scarcity. Thus, consumers are required to use all the means to conserve their water. These conservation steps include coating reservoirs to protect leakage; covering reservoirs to reduce evaporation; industrial and agricultural re-use of water; regulation of lawn sprinkling; and the installation of water meters (International City Managers' Association, 1957).

2.2.2.2. Water Tariffs

Pricing can be a powerful disincentive for more efficient use of water. A relatively high tariff can encourage conservation. But if water prices are kept too low the demand for water would increase and consumers could afford to be wasteful. Thus, raising water prices seems to make sense for several reasons. That is higher water prices not only encourage all users to use water more efficiently, but also could generate funds to maintain existing water infrastructure and to build new infrastructure. This is because production and provision of clean water to consumers entails cost both in terms of initial capital outlay and in ongoing operation, maintenance, and extension of service.

Cost recovery is also important for ensuring sustainability of operations as well. According to Khan (2003), the provision of cost recovery must be made a vital element of all water related projects, without however, comprising the social objective of providing accessibility of water to the poor.

There are also different perspectives with respect to issues of cost recovery and pricing of water. Regarding this, the International City Managers' Association (1957: 279) argues that, "any rate policy must recognize the need for ensuring sufficient revenue to provide for operation and maintenance costs, to repay bonded indebtedness and to provide a safe operating margin to cover contingencies".

Another argument is the one that has been indicated by Khan. Khan (2003: 7) has stated these different views, as follows:

> *Some argue that water is a nature's gift and, therefore, should be provided free. However, some also argue that, "God provided the water, but not the pipes".*

It is often said that water should be free; it is a gift from nature. That is true if the user of that water collects it as it falls from the sky before it has been treated or delivered, because it is the treatment and transport of water that have associated costs. These days water tariff is raised to meet the costs of water supply that will continue increasing due to more advanced treatment and greater distances to be channeled to reach final consumers.

Besides, one of the objectives of MDGs is accessing water to the poor. It is also a fact that most people in the lowest income bracket are unable to afford the initial investment for safe water. To access the poor to safe potable water, therefore, subsidizing the water service by public expenditure could be an inevitable solution. But, at present, there is a paradigm shift that could be viewed against subsidizing services provided to consumers, including water service.

In the water supply service, there is a visible paradigm shift from supply-driven to demand-driven approach to drinking water supply. According to Kleemeir (1995: 1), "the previous approach to drinking water supply would most fairly and aptly be termed a basic needs approach, because it formed part of assistance programs which were targeting aid at directly meeting the basic needs of poor people". To provide clean and convenient water supply to as many people as possible, therefore, was the main objective of this approach. The welfare school advocators have also supported this approach. Khan (2003: 7) stated that, "the argument of the welfare school is that the poor are too poor to pay and, therefore, water basic necessity of life, should be given free to them".

On the other hand, the new paradigm shift is, the demand-driven approach to drinking water supply. This approach cancels subsidies made and favor market forces to operate without any intervention. Regarding this, the World Bank in Kleemeier (1995) indicated that, to restore growth, structural adjustment is to made by governments, which would include measures such as limiting public expenditure, removing subsides, and letting the private sector and market forces take over many functions from government agencies.

It should be noted here that many argue for full private participation and water can be owned and commoditized. Yet, others fear that, full private participation and market-oriented provision of water will not address the needs of the poor. Thus, the challenge is to determine the best mix that could lead to achievement of social objectives of providing people with water.

2.2.2.3. Reducing Unaccounted-for-Water

Unaccounted for water is due to meter and water pump leakage, unauthorized water connections and leaks in the main distribution lines (Steel and McGhee, 1979). Water is wasted mainly through poor plumbing in homes, leakage in distribution systems, and over storage or overflow, which is related to users' attempt to adjust to irregular water supplies.

Managing leakage is a key means of delivering water to consumers in an efficient and cost-effective manner. The amount of water needed from the supply sources is reduced and the possibility of supply restrictions minimized when leakages are timely found and repaired.

According to the International City Managers' Association (1957: 270), "water loss can be reduced to a minimum through metering and through an effective system of leak detection". Wasteful usage of water by customers can be reduced if all water services are metered. Since some body is charged for what is measured by the meter, the effect is to reduce usage when the water bill becomes intolerable. It is important, therefore, that a system of charging be supported by volumetric charges on consumption.

In general, detecting leakage is not a simple task because many of the leakages are underground where no body can observe them. But, since leakages in the main distribution system and domestic lines are substantial, integrated effort to solve these problems is crucial.

2.2.2.4. Pollution Control

Rapidly growing cities, increasing of industries, mining, soil erosion, and the increasing use of chemicals in agriculture are progressively degrading water quality in many rivers, lakes, and aquifers.

Industries damage water through pollution, discharge of raw sewage, and disposal of garbage. This reduces water usability, increases water treatment costs and aggravates the spread of waterborne diseases. Moreover, there are places where ground water source is located close enough to nearby surface water, such as a river or lake, to receive direct water recharge. This recharging process of ground water from surface water creates a high risk of contamination. As polluted water sources are unsafe for human use, other source of water might be needed to satisfy the existing need. Thus, for an efficient utilization of available water, pollution from all sources should be protected and actions should be more focused on pollution control at the source instead of simply building more and more advanced water treatment plants at high cost.

2.2.2.5. Recycling of Water and Waste Treatment

Water reuse refers to the practice of reprocessing water of spoiled quality and using it after suitable levels of treatment for beneficial purposes. Thus, reusing of polluted urban water maximizes the existing water resources. Urban wastewater, which includes used water generated by residences, commercial establishments, and industrial facilities, are the most generally available sources of reusable water, following a suitable degree of treatment. Uses of reclaimed water could be for landscape irrigation, agricultural irrigation, groundwater recharge via percolation ponds and fire protection.

2.3. Water and Poverty

Sullivan (2002: 1195) stated that, "without adequate and efficient water supplies, where there is water poverty, any measures to reduce income poverty are unlikely to be successful". That is why the importance of adequate and safe water supplies for poverty reduction has attracted the attention of governments and different world organizations.

It is important, therefore, to see the relationship between water and poverty. According to Khan (2003), lack of access to clean drinking water exposes the poor to a variety of water borne diseases that affects their ability to participate actively and fully in the income earning works. He further stated that medical expenses incurred in the treatment of the water-borne diseases further deplete the already low level of income earned by the poor.

According to Khan (2003), in the Millennium Development Goals (MDGs), goal number 7 and target 10 relate in particular to water- "Halve, by 2015, the proportion of people without sustainable access to safe drinking water". To achieve the MDGs and solve the challenge of water, due attention should be given to disadvantaged areas and sections of society. With this respect, it is the urban poor and rural areas that mostly lack access to adequate and safe water.

However, in practice, it is noticeable that in many countries, there is a significant variation with respect to urban and rural water development activities. As indicated by many studies, this variation is because of the existence of urban-biased water sector development. In line With this, Dessalegn (1999:14) has stated that, "in Ethiopia water supply services are among the lowest in Africa and the strong urban bias of successive governments since the early 1970s has kept water supply investments in the rural area quite low".

Statistical evidences of many studies conducted support the urban bias argument. For example, Ministry of Water Resource (1996) in Dessalegn (1999) has stated that, 19% of the rural and 80% of the urban population have access to safe water, and the overall coverage is 26%. Further more, the same source has indicated that the high urban figure is because of the high coverage for Addis Ababa. If Addis Ababa is excluded, the average water supply coverage for urban settlements is 31.3%. Khan (2003) also indicated the urban bias as for the entire Asia the average coverage for urban water supply is 93% whereas the rural coverage is only 75%.

As indicated by many sources, in Ethiopia, access to safe water does not mean access to adequate water. Thus, inadequacy of water for domestic use, in both urban and rural areas of Ethiopia, is a common phenomenon. Dessalegn (1999: 15), further elaborated the inadequacy of water as follows:

> *Ministry of Water resource defines "adequate" water supply to mean 20 liters of water per person per day and accessibility within a range of 0.5 to 1.0 kilometers from a dwelling place (MWR, 1996). The WHO standard, which was once adopted by WSSA, is 45 liters per person per day.*

It is also important to consider that inadequate water is one of the several problems facing women as water carriers in many societies. Women are also responsible to use the available water wisely. Kibra (1997) stated that, women could play a vital role in water management, as they are primary water fetchers, managers, end-users and family health educators.

Moreover, inadequate water could lead households to use unprotected sources of water, which is often polluted. This unprotected source of water is another problem facing women that could expose them to water-borne diseases. According to UNICEF (1981: 8), "the group most vulnerable to water related diseases, are perceived to be women, who according to statistics by the WHO, accounted for 30% of all diseases in the developing world".

From the previous discussion, it is apparent that access to safe water and adequate water is very essential. But scarcity of potable water is becoming a major problem of many countries around the globe. Consequently, Atnafe (1997) suggested that, using whatever means is available, the world has to defend itself from entering into water crises.

2.4. Explanatory Variables for Household Water Consumption Levels

Household (domestic) water consumption is the water used in or around a house. According to Samuel (1986), water utilized in households can be grouped into 'person-related' and 'dwelling-related' consumption. Under person-related consumption of water are: water used for drinking, toilet flushing and water used for hygiene (bathing or showering). The dwelling-related consumption is water for laundry, dishwashing, cooking, gardening and car washing.

The amount of water used in or around a house varies from country to country, community to community and household to household. Hence, a variation in per capita water consumption is observable in different countries and even at household level. According to Tesfaye (1984: 25), "these differences largely emanate from differences in the level of living of a population, i.e. differences in level of economic development." Because of this, different studies conducted in different countries or areas mostly come up with different household per capita water consumption figures.

According to a study by Steel and McGhee (1979) in Singapore, living conditions of consumers determine domestic water consumption level, the range usually being between 75 and 380 liters per capita per day, averaging 190 to 340 liters per capita per day. The International City Managers' Association (1957: 264) also indicated that, "in America each member of a family for all purposes consumes approximately 50 gallons per day".

Zephania (1988), in his study in Iringa town, Tanzania, found the following per capita water consumption figures as shown in Table 3.

Table 3: Per capita Consumption Figures, Iringa Town, Tanzania.

Consumer	Consumption (l/d)	Remarks
People using stand pies	25	Minimum service
People with house connections	70	Low income housing
People with house connections	130	Medium income housing
People with house connections	200	High income housing

Source: Zephania (1988: 3)

Tesfaye (1984) in his study conducted in Addis Ababa also found that per capita water consumption was on average 41 liters per day.

Moorsom (1997) indicated that in urban households with a reasonably high per capita consumption of 150-200 liters per day, on average, 3-6 liters would go to cooking and drinking, 15-20 liters to washing and personal hygiene, 3-10 liters to house cleaning and a large amount to toilet flushes, showers and baths and the garden.

Efforts to assess household water supply situations and main socio-economic factors that affect per capita water consumption are desirable. Such studies are helpful in understanding current and projected water supply and demand for the population in focus. According to Yimer (1992) and Mequenent (1998), the factors affecting water consumption levels can be grouped into physical and socio-economic factors. Based on this grouping, the major physical and socio-economic factors are discussed below.

2.4.1. Physical Factors

Various physical factors determine household water supply and consumption levels. The major physical factors affecting household water supply and consumption are rainfall, temperature, pressure maintained in pipelines, yield of boreholes and accessibility of water.

2.4.1.1. Rainfall

One of the key factors affecting household water supply and consumption is rainfall that is the main source of potable water. With this regard, Steel and McGhee (1979) stated that, the primary source of water in streams, lakes, springs and wells is rainfall. Hence, water resource assessment needs, among other things, information on the spatial and temporal distribution of rainfall (Tufa, 1997). This implies that, if there is no reliable rainfall, water becomes a very scarce resource.

Every year human beings use a large quantity of ground and surface water for different purposes. Rainfall refills these ground and surface water resources. According to Steel and McGhee (1979: 38), "infiltration is the entrance of rainwater into the ground and it is by infiltration that groundwater in its various forms is replenished".

According to Porter (1978), with the aim of increasing the amount of usable water and modify its patterns of occurrence, people interfere in the natural hydrologic system. But it is a reality that human's control of the natural hydrologic system is incomplete. With this regard, Porter considers rainfall as one of the inputs that are largely free of influence.

From the above points, therefore, one can easily understand the influence of rainfall on the supply of water and per capita water consumption of households.

2.4.1.2. Yield of Boreholes

Yield of boreholes is another physical factor that affects household water supply and per capita water consumption. Although there are many factors that influence the yield of boreholes, the amount of annual rainfall is the major influencing factor. Hence, during the dry period wells, springs and streams draw water from the ground, which is again replenished by percolation during wet season. The improvement of the yield of boreholes is, therefore, through natural recharge of ground water by rainfall during rainy seasons.

In addition to amount of annual rainfall, yield of boreholes is influenced by the geological formation of the area. In this respect, Steel and McGhee (1997: 57) stated that, the most important aquifers of public water supplies are, sand, gravel, and sandstone, in that order. They further elaborated that igneous rocks in general are not water producers although lava is an exception as it is permeable.

To predict the yield of ground water on a specified time, knowledge of the geological formation is desirable. But, it is so difficult to predict with certainty how much water the yield exactly would be. In line with this, Porter (1978) explained that, ground water is invisible until it is pumped up and there are no simple means of determining how much is stored below ground or how quickly any withdrawal for supply is made good by rainfall percolating to recharge the aquifers.

In developing ground water, there are a lot of questions that need to be answered. One important question, according to Kikawada (1998) is, for how long can the aquifer provide clean water to the people in focus. In fact, an aquifer to serve for a long time, over exploitation should be avoided and the safe yield of the aquifer needs to be calculated. According to Porter (1978: 73), "a safe yield of an aquifer is the quantity of water that can be withdrawn for supply without cumulative depletion and to control abstraction at or below the safe yield".

2.4.1.3. Seasonal Variation and Temperature

These are other important physical factors that affect household per capita water consumption. This is an indication that the total or per capita water consumption does not remain constant but fluctuates with temperature and season. In fact, the two factors are closely related, that is, dry seasons are somewhat hot while wet seasons are not.

Steel and McGhee (1979) stated that in hot and dry seasons much water would be used for watering lawns. Furthermore, domestic use of water will be increased by more bathing, while public use will be affected by parks and recreational fields for watering grass and for ornamental fountains.

Many studies indicated that, week of maximum consumption and greater demand upon water systems are observed during hot and dry weather. But, most of the time, daily per capita water consumption is calculated from annual water consumption. Thus, annual average daily consumption, while useful, does not indicate climatic conditions, working days, etc, that cause wide variations in water consumption.

Some researchers have given due attention to temperature and seasonal variability to assess domestic per capita water consumption. According to Russell, et al (1970: 16), "an important influence in peak hourly and daily demands for water will be air temperature; and the probability of exceeding certain peak demands will be some complicated functions of the probability of exceeding certain atmospheric temperature".

2.4.1.4. Pressure Maintained in Pipelines

The other physical factor that affects daily household per capita water consumption is pressure maintained in pipelines of the supply system. Pressure influences supply capacity of the distribution system. To ensure the efficiency of water supply system, water supplied to consumers should be of adequate pressure. But, because of differences such as topography of an area, pressure maintained in pipelines could be too low or too high. When probing further, it becomes clear that households located on higher elevations are victims of extremely low water pressure. Thus, these households complain that they do not receive any water on some days, regardless of having house connections (Reddy, 1999).

Low water pressure creates a low level of reliability of water users on a water supply system. To win the confidence of users, the water-supplying agency should attempt to ensure optimal pressure in pipelines. In this respect, Zephania (1988) has stated that if pressure system is not adequate to produce adequate pressure in all areas, pressure zoning should be adopted. Zephania has also added that if pressure in some areas is too low, pressure zones should be created by pressure boosting systems and if it is too high, pressure zones should be created by pressure breaking. Furthermore, the International City Managers' Association (1957) indicated that, adequate quantity and adequate pressure are the two twin goals of a good distribution system.

The pressure to be maintained in a distribution system is influenced not only by the topography of the area but also by the height of story buildings that are to be served. International City Managers' Association (1957: 270) stated that, "pressure below 30 lbs. per square inch is too low to supply water at a satisfactory rate to upper stories of three to five story buildings". Hence, the boundaries of the areas to be served by the system are needed to be determined to know the topography and other features contained in the area and to design a proper distribution system.

2.4.1.5. Accessibility of Water

These are other physical variables that influence daily per capita water consumption. They refer to location of water sources and its distance from home to the water point. When the sources of water are located at a distance, individuals incur costs to collect water.

When the water points are far away from home, fetching water is expensive in terms of users' time and energy. As a result, the search for safe water by poor households takes a good deal of women and young girls time and energy in most rural areas and several urban centers of Ethiopia (Fisseha, 1997). According to UNICEF (1981: 6), "since women in many societies are the most concerned with this [water] problem, women of the world may spend as much as one-third of their day locating and transporting water for drinking, agriculture, food production and preparation and family hygiene".

Similarly, Yimer (1992) explained that, long distance traveled to the water points involves considerable energy and time expenditure, which limits the frequency of fetching and the size of containers; hence, reduces daily per capita water consumption.

2.5. Socio-economic Factors

These factors include households' income, size, level of education, occupation, and others. These factors affect per capita water consumption. Hence, to assess the magnitude of shift in demand for water, consideration of socio-economic factors is very important. These factors are helpful in designing water supply projects to estimate the amount of water required.

"This involves determining the number of people who will be served and their per capita water consumption, together with an analysis of the factors that may operate to affect consumption" (Steel and McGhee, 1979: 7).

Under socio-economic factors, the following main variables that affect domestic per capita water consumption are discussed.

2.5.1. Household Income

It is generally argued that the better off a household, the higher is likely to be its water consumption (Tesfaye 1984; Taddese 2001). In addition to this, Yimer (1992) also argued that household income level affects per capita water consumption not only through its influence on possession of water using appliances but also by the possession of privately connected water for households. This is because consumers, in most cases, are required to cover the installation cost of pipelines in addition to the high cost of metered water and rent for the water meter.

Moorsom (1997) reported that the average rate of water consumption of Namib region was 188 liters per person per day for domestic consumers, while the low-income mean residential was only 86 liters/person/day. This was also confirmed in a study conducted to identify key socio-economic factors affecting household water demand in Santa Barbara, Philippines. In this study, Taddese (2001) classified the sample households into low, middle, and high-income levels. The results showed that average consumption of water per household per day was 328.95, 493.42 and 986.84 liters for low, middle and high-income groups, respectively. Thus, these findings reinforce the argument that people with higher income would have a higher consumption of water.

Studies have been undertaken to examine the response of households to increase in water price or the demand elasticity. The price elasticity results can be expected to vary markedly between different domestic uses of water. Concerning this Moorsom (1997) stated that for inside household uses such as cooking, washing and sanitation the result was less than –0.1, but for garden and recreational uses it rose to – 0.2 to – 0.4. Taddese (2001) indicated studies of residential water demand in the United States which showed a long-run price elasticity to fall between-0.3 and-0.7.

2.5.2. Household Sizes

Household water consumption is influenced by family size of a household. Household water consumption is expected to increase with an increase in household size. But, when it is per capita water consumption the reverse is true. That is, as household size increases, per capita water consumption decreases. In other words, a distinction must be kept in mind that while the overall consumption of water increases as household size increases, on per capita basis water consumption decreases as household size increases (Darr et al, 1976; and Taddesse, 2001).

Studies have tried to reason out as to why per capita water consumption decreases as household size increases. Taddese (2001) in his study in Santa Barbara showed that the effort to economize in the case of water would tend to consume water on a joint or simultaneous basis. Hence, household members would set aside one day to do all their laundry instead of any day for any member at his or her convenience. Thus, a per capita water consumption decreases as family size increases is an indication of the advantages of economies of scale.

2.5.3. Educational Level of Household Heads

Household water consumption is also partly influenced by the level of education of household members (mainly household heads). It is believed that education is directly related to household per capita water consumption. The reason is that as the level of education of household heads increases, there would be more awareness of the health benefits of water and frequent bathing and washing in the household.

Moreover, as the level of education of household members increases, there could be an opportunity for better-paid work. This improves the paying ability of households for larger quantities of water consumed. In line with this, Tesfaye (1984: 83) stated that "specifically, higher income groups, who are also more educated, consumed more water both because they can afford to and because of their living standard which involves more cloth washing, bathing, and cleaning the house".

In a study conducted in Tel Aviv, Darr et al. (1976) reported that when family sizes and income level were held constant, in each group, except small, low income families, families in which respondents had at least eleven years of schooling consumed more water per capita than families in which the respondents had ten or fewer years of schooling.

On the other side, there are study results that support the inverse relationship of daily per capita water consumption and educational level of household heads. The inverse relationship between daily per capita water consumption and education level of household heads is explained by the reason that as educational level of household head increases, their attitude towards water conservation also increases. A study conducted by Taddese (2001) confirmed this with a 99% confidence level that respondents with higher educational attainment were aware of the value of water and had a positive attitude towards water conservation practices.

2.5.4. Occupation of Household Heads

It is also believed that occupation of household heads influences household per capita water consumption. But, with this respect, there are different perspectives in different studies. Some studies relate the occupation of the household with the income he/she earns from it and quantity of water consumed. Others relate with the intensity of the activity that an individual performs and the need for water. For instance, Yimer (1992: 24) stated that "the nature and intensity of the activity that an individual performs determines per capita consumption of water, particularly, for drinking and bathing". Hofkes (1986) in Yimer (1992) estimated that water requirement for normal functioning of human body ranges, depending on climate and workload, from 3 to 10 liters per day.

2.5.5. Private (Metered) Connection

As it is mentioned above, location of water sources and its distance from home affects household per capita water consumption. Households fetching water from long distances spend much of their time, which could have been used for other purposes. But, here the focus is on amount of per capita water consumption when there is access to private connection water supply service.

Private water connection saves time and energy. But, for the poor, the initial investment cost for private connection is very high. As a result, poorer households use such alternative sources as public taps, vendors, rivers, springs and hand-dug well. Result of a study by Fisseha (1997) in Meki town indicated that, as a minimum of Br. 200 initial investment cost is required for private water connection. It seems reasonable that those who have the service are the relatively well-off households.

Households who buy water from vendors are those with no private connection and at the same time are unable to get their daily water requirements from the public tap system (Fisseha, 1997). They prefer public standpipes next to private connection rather than vendors. This is because, vended water is far expensive than official tariffs. The much lower water consumption of the poor reflects the differences not only in income but also the 5-10 times higher price the poor pay for vended water (Taddese, 2001).

In a piped water supply, per capita water consumption is usually high and depends on reliability of supply, social and economic conditions, climate and presence of sewerage system (Samuel, 1986). But lack of access to own private connection shows that household water consumption is low. This is because the price of collecting water from outside sources is high in terms of time and money.

2.5.6. Water Using Appliances (Fixtures)

Total household and per capita water consumption is influenced by the presence and number of water using appliances. This is with the assumption that, when households possess water using appliances like washing machines, bath tube, showers, kitchens with faucets, etc, household water consumption will increase.

"The amount of water used by a dwelling unit in a given time period is a function of the number of water using appliances in and around the house and the probability of those appliances being turned on" (Darr et al, 1976: 47). Taddese (2001) also supports this in his study conducted in Santa Barbara, Philippines. He stated that a large size household but with few appliances/ facilities consume less water than households with smaller families but with more household facilities such as showers, bath rooms, toilets, and other appliances involving water consumption.

2.5.7. Possession of Garden Plots and Domestic Animals

Per capita water consumption is also a function of possession of garden plots and domestic animals. Household water consumption increases, as household possesses domestic animals and garden.

Garden watering accounts for most of the outdoor domestic use of water. It is thus very much the norm that for well off households to have watered gardens with trees and bushes and for poor households to have no garden at all (Moorsom, 1997).

According to Moorsom (1997) few householders in the low-income suburbs can afford water for garden because main and backyard structure and that the small open spaces are intensively used. Thus, households on higher incomes are willing and able to pay for a large volume of water required to maintain green gardens.

Through automatic and/or hand watering, gardens consume large quantities of water. "The very high rates of some Western cities are probably caused by much use of water for irrigating gardens and lawns" (Steel and McGhee, 1979: 17).

Possession of green lawns is also justified in terms of their social benefits. A study by Darr et al (1976) in Tel-Aviv revealed that green lawns are aesthetic; that they impute higher land rents on adjacent properties and is particularly more appealing to the elected bureaucrats.

The ownership of domestic animals also influences households' per capita water consumption. In both urban and rural areas domestic animals are important shareholders at household level water budgeting. In rural areas, most frequently, households water their domestic animals at water points. A study conducted by Reddy (1999) in six villages of India showed that an average of 71 liters per day are consumed by domestic animals, that is about a quarter of the total water use in the household.

In our case, since most urban households are expected to water their domestic animals at home, their contribution to household per capita water consumption could be high.

CHAPTER THREE

BACKGROUND OF THE STUDY AREA

3.1. A Brief History of Mekelle

Mekelle town is the administrative capital of Tigray Regional State. It is located 776 kilometers north of Addis Ababa at an average altitude of 2235 m.a.s.l and its geographic coordinates are $99^{0}28'$ East and $13^{0}32'$ North (Mekelle City Administration, 2005). As records indicate, Emperor Yohannes IV founded Mekelle in 1872 (Seltene, 1972).

The city administration currently has a population of 219,179 (Mekelle City Administration, 2005) with its ten lowest officially and formally recognized administrative units called 'Tabias'.

As the population size of the city is rising from time to time, demand for land has increased. Mekelle had a total land area of 16 km^2 in 1984. In 1994 the size of the city reached at 23.04 km^2. By showing a dramatic increase, the city has reached a 74-km^2 area in 2004 by engulfing the vast agricultural lands, neighboring villages and towns (Mekelle City Administration, 2005).

3.2. Geology

According to a study made by Tesfaye, etal (1980), Mekelle town is built on Agula shale, which is the upper most formation of the Antalo Group. Agula shale consists predominantly of shale and some limestone beds that vary both in thickness and in ratio. Dolerite intrusive, mostly found as shelves alternating with shale and limestone, are clearly observed on the cliff east of the town.

Tesfaye, et.al (1980) further stated that regionally, Agula shale is 50. meters to 250 meters thick and at Mekelle it is more than 200 meters. Columnar sections along Illala river forms its junction with Giva River upstream near the institute of Agricultural research, Mekelle.

The study made by Beyth and Shachnai in Tesfaye, et.al (1980:2) indicated that the columnar section shows 55 meters of the upper part of Antalo limestone (black well bedded limestone) overlain by 35 meters of Agula shale (Marl and Shale), 50 meters of Mekelle Dolerite (black diabase) and 280 meters of Agula Shale (black limestone inter-bedded with marl.)

The Mekelle fault is one of the five major fault zones which cut through the Mesozoic sediments of the Mekelle plateau. "The Mekelle fault is a normal fault with down throw on the southern side and it forms a 250 meters fault scrap at a site 10 kilometers North of Mekelle" (Tesfaye, 1980:3)

Poorer water quality that is attributed to the very nature of the water bearing formation is the common feature of the wells located in the town. However, the existing wells at Aynalem have by far better water quality than the rest of the wells.

According to Mohammednur (2005), the main aquifer of Aynalem well field is the fractured dolerite. Table 4 shows the characteristics of aquifers around the Aynalem well field.

Table 4: Geological log of some of the boreholes

Well Index	Depth (M)	A aquifer type
TW2	72	Sand stone Limestone Dolerite
TW3	69	Dolerite
PW3	120	Limestone Dolerite
PW4	120	Limestone Dolerite
PW6	75	Limestone Dolerite
PW11	75	Dolerite Sandstone
PW12	80	Dolerite Marl
BHU	170	Dolerite

Source: Mohammednur, et al. (2005: 27)

According to WSSA report (1992), dolerite is generally fractured and jointed and it has good potential for ground water storage and movement. The same source indicated that Agula Shale is inter-bedded with marl and black limestone and thin layers of gypsum bed. The yield of the boreholes drilled in the Agula shale is low and generally saline.

The Agula shale formation around Mekelle has a relatively high proportion of limestone and it has a moderate to high permeability due to the limestone in it. The dolerites are generally massive and have a low permeability except at places where they are highly joined and weathered. Some springs emerge at contacts between limestone and shale as well as between limestone and dolerite.

3.3. Physical Setting

3.3.1. Topography

According to Mekelle City Administration (2005), Mekelle is situated at the foot of a steep cliff, Endayesus Escarpment on the east side. At a distance, of 10 kilometers north from the center of the city there is also a steep cliff namely Mesebo. The altitude of Mekelle varies from 2150 m.a.s.l to 2270 m.a.s.l.

The same source further explained that the Illala stream flows westward and is the largest in the Illala area and within the Aynalem area. The Aynalem stream is the main one with the same flow direction as the former. However, many tributaries feed both the streams with substantial amount of water during rainy season. These streams are seasonal where the peak discharge is attained during summer.

3.3.2. Climate

According to the Mekelle City Administration (2005), the agro-climatic zone where Mekelle is located is called 'weynadega'[2]. The climate of Mekelle and its vegetation varies from time to time.

The town experiences mild climatic condition with annual average maximum temperature of 24.1°c and annual average minimum temperature of 11.1 °c. There is monthly variation in temperature. June is the hottest month with a monthly mean maximum temperature of 27.1°c and monthly mean minimum temperature of 13.0°c.On the other hand, December is the coldest month with a mean monthly maximum temperature of 21 °c and monthly mean minimum temperature of 8.51°c (Mekelle City Administration 2005). Mekelle City Administration further stated that, there is one short rainy season that comprises months of June, July and August. The growing period consists of 120 days per year and this rainy season is characterized as erratic, unreliable and unevenly distributed throughout the year. The city has annual average rainfall of 618.3mm/year of which July and August comprise the lion's share, i.e. about 436.7mm (70.6%). The highest amount of rainfall occurs by the month of August with a monthly rainfall of about 229 mm (37%) and July is the second largest rainy month with a monthly rainfall of about 207.7mm (33.5%).

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[2] Sub-tropical climate

3.4. Groundwater Sources

It was concluded that due to high sediment content of surface run-off during flash floods, erratic nature of annual flows, long season dry period (9-10 months) surface water source development does not seem a plausible alternative for the water supply of Mekelle town (WSSA, 1992). Therefore, the proposed source of water for the town by the private consulting firm was ground water. Currently, its water supply is mainly from Aynalem well field, which is about 5 km southeast of Mekelle. Aynalem Valley has been found out to be the best potential site of ground water for Mekelle water supply compared to Chelekot, Illala, and Agula-Giba valleys (WSSA, 1992). According to Mohammednur, et al (2005:3), the Aynalem Valley is regarded to be the best well field due to:

- ✓ proximity to the town
- ✓ better water quality (less mineralized) than the rest
- ✓ better ground water potential
- ✓ higher elevation than Mekelle town

However, due to population growth and significant decrease in the yield, the existing water supply is becoming inefficient. Some of the main causes for the decline of the yield, according to Mohammed, etal (2005) is the internal factors such as over estimate for the ground water source potential, inference of wells, construction problems of the wells (uncased wells), and management of the wells.

A report on the hydrology of Mekelle (Beyth and Shachnai as cited in Tesfaye, et al 1980) stated that ground water moves to the synclinal axis and then to the east-southeast opposite to the general topography because the fold plunges that way. It also suggested that Mai Dollo spring probably emerges from the ground water that travels along the syncline axis. However, Mai Dollo is a simple gravity spring discharging at a contact between limestone and dolerite (Tesfaye, et al, 1980). Lower permeability beds would imbed ground water that flows along the synclinal axis and the regional ground water movement is probably in the direction of the general topography.

CHAPTER FOUR

THE EXISTING WATER SUPPLY SYSTEM

4.1. Sources

The present water supply source for the town of Mekelle is ground water. WSSA (1992) proposed ground water for Mekelle town from Aynalem well field located about five kilometers south of the town near the Airport. The main reasons mentioned for ground water proposal were the high sediment content of surface run-off during flash floods, and erratic nature of annual flows made surface water source development uncertain.

Currently, its water supply is from 15 boreholes. Out of these boreholes, ten are found at Aynalem, two at Kebele 07 (Tabia Sewhi Nugus), two at Kuha and one at Lachi (Tabia Industry).

There are a number of boreholes that dried up for various reasons. Two boreholes at Mai Shibti, PW5, PW7A, PW10 are dried up. Another borehole PW12 with a total depth of 80 meters that was drilled in 1998 has also dried-up. PW4A has collapsed after serving only for a year.

According to the water well drilling Enterprise report (1998), since the under lain layer was hard, the well was left uncased. But if casing had been installed, this borehole could have been protected and productive. Another borehole, PW6 with a depth of 75 meters, did not provide any service from the very beginning because of hardness. In general, a report from Mekelle water supply service office has indicated that so far 14 boreholes are out of operation.

4.2. Production

The present production of water depends on 15 operational boreholes. These boreholes are administrated by Mekelle water supply service office. According to the annual report of the office, the production, consumption and water loss of different years are given in Table 5.

Table 5: water production, consumption and loss.

Year	Production (M^3/year)	Consumption (M^3/year)	Water loss (M^3/year)	Proportion of water loss to production (%)
1994/95	841,348	577,709	263,639	31.4
1995/96	829,990	596,944	233,046	28.1
1996/97	1,017,390	683,040	334,350	32.9
1997/98	865,639	700,616	165,023	19.1
1998/99	1,076,560	809,370	267,190	24.8
1999/00	1,293,107	929,629	363,478	28.1
2000/01	1,497,888	1,172,396	325,602	21.7
2001/02	2,199,212	1,730,974	468,238	21.3
2003/04	2,750,000	2,227,500	522,500	19
2004/05	2,827,487	2,290,264	537,222	19

Source: Annual report of Mekelle Water Supply Service Office.

As can be seen from the town's water supply service office report for 2004/05, the total production is 2,827,487 m^3. The report took 19% water loss that is similar to the 2003/ 04 and the amount of water reached to customer was 2,290,264 m^3. From this we can understand that the total water production capacity of the boreholes in 2004/05 was only 89.7 liters per second.

The office in its report (2004/05) also stated that the water supply needed was at least 50 l/c/d and total amount of water was calculated to be 10,500m^3 /day. However, the population of Mekelle town in 2005 was 219,179 (Mekelle City Administration, 2005). So, as the total yield of boreholes is 7746.5m^3/day, water supply per capita basis is 35.3 l/c/d.

When the water lost in the distribution system (water loss) is deducted, the actual water consumed was 6274.7m^3/day and on per capita basis it is 28.6 l/c/d.

According to a study made by WSSA (1992), the town's population was projected to be 140,400. This population size is almost 56% lower than the actual population size in 2005 that was 219,179. Nevertheless, the maximum daily demand and average day demand of water was projected as 11, 440 m^3 /day (132 liters per second) and 9530 m^3/day (110 liters per second) respectively.

A recent eight months report of the office (Table 6) showed that, the average total yield of boreholes was only 7974.42 m^3/day. Hence, the amount of water supplied to the town is less than the projected amount for 140,400 population size of the town.

Table 6: Actual monthly and daily production of water, expected production per month, number of wells on service and their yield (2005/06).

Month	Actual production of water (m^3)	Expected production of water (m^3)	Number of well on work	Actual yield (m^3/day)*
July	220,714	339,216	15	7119.81
August	230,738	395,752	13	7691.27
September	220,673	339,216	13	7355.77
October	272,946	339,216	14	8804.71
November	258,839	339,216	14	8627.97
December	257,023	339,216	14	8291.06
January	241,152	339,216	14	7779.10
Feb.	227,725	339,216	14	8133.04
Total/AVE.	**1,929,810**	**2,770,264**		**7974.42**

Source: Mekelle water supply service office, monthly well production report

** Computed from the given monthly data.*

As indicated in Table 6, monthly-expected production of water from all boreholes was 11,447.37m^3/day (2,770,264 m^3/242 days). However, because of technical problems of water pump and water shortage, the actual production of the boreholes was only 7974.42 m^3/day. Among the boreholes, for instance, borehole TW3 was operational in July only. From July onwards, because of shortage of water, no yield is obtained from it.

Moreover, actual production in July, August and September is lower compared to the remaining months. The relatively low yield during rain season could not be explained in terms of water shortage. It is on the wet season that the ground water is recharged and has a better production rate. So, low yield during the wet season might be explained by the existence of other alternatives such as rainwater harvesting. Thus, customers could use rainwater for cloth washing animal and garden watering instead of using piped water. The hardness of water from boreholes encourages consumers to use rainwater other than drinking and cooking.

Because of the drawn down of water levels and technical problems of pump, discrepancies are observed between actual and expected yield of each wells. Hence, to assess the gap, considering each bore hole's yield is vital.

As indicated in Table 7, actual production of wells from July 2005 to February 2006 is compared with the expected production of each well on daily basis.

Table 7: Actual and expected production capacity of each well.

Name of Boreholes	Actual production (242 days)	Actual production (M^3/day)	Expected production (M^3/day)	Proportion of actual to Expected production
PWl1	37,742	155.10	360	0.43
Enda Yesus (Arid)	69,642	287.78	512	0.56
TW2	215,250	889.46	982	0.91
Sewhi Nugus	41,739	172.48	536	0.32
PW4B	121,983	504.06	605	0.83
PW3	114,280	472.23	1084	0.44
PW8	442,460	1828.35	2116	0.86
PW7B	274,831	1135.67	1571	0.72
PW2	287,109	1186.40	1276	0.93
Makel Sewhi	42,605	176.05	336	0.52
Lachi	13,173	54.43	103.2	0.53
Endabo Tarkegn	132,439	547.27	553	0.99
TW3	5,555	22.95	553	0.04
Kuha Gomata	94,774	391.63	480	0.82
Kuha EndaMariam	36,228	149.70	240	0.62
Total	**1,929,810**	**7974.42**	**11,307.2**	**0.71**

Source: *Mekelle water supply service office, monthly well production report (unpublished).*

**Computed from the given data.*

As it can be observed from Table 7, proportion of actual production to expected production of each borehole was found different in the past eight months (July to February). The proportion of actual to expected production ranges from a minimum contribution of borehole TW3 (4%) to maximum contribution of Endabo Tarekegn (99%). In general, the overall actual production is nearly 71% of the expected production.

Mekelle Master Plan Project Office also calculated the annual and daily water demand of Mekelle town. In its unpublished report, the total water demand in 2005 was calculated to be 1,048,212.2 l/d (i.e. 10,482.12 m^3/d). Annual water demand was calculated to be 3,812,594.768 m3/annum. If the then un-accounted-for water (water loss) which was 19% is assumed, total water demand considering loss was 4,556,027.774 m^3/annum. If water demand calculation of Master Plan Project Office is compared with the actual delivered amount of water in 2005, a wide gap between supply and demand is observable. The water supply service office supplied a total of 2,547,274m^3 in 2005, which is 55.9% of the calculated demand by the Master Plan Office. Thus, additional supply of 2,008,753.774m^3 /annum (44.1%) was needed to satisfy water requirement of the town in 2005.

4.3. Distribution

Distribution is a process of transporting water through the supply system (ground or surface) to the final users. As most of the accounted-for-water occurs in the distribution system, its improvement helps in solving water scarcity and narrowing the gap between production and actual consumption.

In Mekelle town, the distribution system extends from the farthest borehole site to the reservoirs at Endo-Gabriel. Pipelines, which are connected to each source borehole, take raw water to the larger pipe called a main line. The main line is also connected to water meter and dosing pump for chlorination. Finally, mixed with chlorine, water reaches to Enda-Gabriel reservoir. According to WSSA (1992) the Aynalem well field site average ground level is 2270 m.a.s.l and the reservoir is located at 2280 m.a.s.l.

4.3.1. Pipeline Network

The pipes from the boreholes to the main reservoir are arranged in different stations and sizes (WSSA, 1992). These pipes are:

-DN 150 mm, length 4500m collection pipes
-DN 150mm, length 580m from station 1-5
-DN 200mm, length 840m from station 5-10
-DN 250mm, length 1180 from station 10-18
-DN 300 mm, length 2400m from station 18 to the Enda-Gabriel reservoir.

From the sources to the first reservoir, 9.5 kilometers of pipes with different sizes are connected. In addition to this, the water supply office in its 2004/05 annual report stated that the overall distribution system is 330 Kilometers.

4.3.2. Reservoirs

Because of different reasons, water production and/or water distribution could be interrupted. To solve this problem, and to provide continuous water supply to consumers, reservoirs are needed. The capacity of these water reservoirs depends on the total amount of water needed by industries, commercial establishments, public entities and house hold units on specified time.

The water supply system of Mekelle town consists of four reservoirs. One of these reservoirs is located at Enda- Gabriel with a capacity of 2000 m^3. This reservoir receives automatic gas chlorination and it serves zone one which is directly connected to it.

Another reservoir called kebele 17 reservoir is also connected to Enda-Gabriel reservoir that has a capacity of 500 m^3. Kebele 17 reservoir that supplies water to zone two serves as a break pressure tank.

Another reservoir, which is situated at Endamariam, has a capacity of 2000 m^3 and it is connected to kebele 17 reservoir. This water reservoir feeds water to zone three. There is also near Mekelle University. This reservoir contains 230m^3 and supplies water to Mekelle University Arid campus. .

This reservoir, unlike that of Enda-Gabriel, gets chlorine treatment, which is chlorine powder, manually. Another reservoir is the one with a capacity of 230 m^3 and which serves zone four and at Lachi there is a reservoir with a capacity of 50 m^3. Kuha also has its own reservoir with a capacity of 200 m^3.

4.3.3. Connection Type

Customers could have their own private connection, which is considered as better and improved accessibility to water service. Further more, those customers having private (meter) connection could be households, industrial and commercial establishments, and governmental and non- governmental offices.

According to Mekelle Water Supply Service Office 2004/05 report, the total numbers of connections were 18,792. At present the privately connected households have reached 18,699.But, this figure is not still to be considered as satisfactory because when we look up to the proportion of private connection coverage in terms of town's total households, it is only 41.8% (18,699/44,731). Thus, 58.2% of households are using other alternatives such as public standpipes, neighbors and/or water vendors.

4.3.4. Public Standpipes

As mentioned earlier, when households are unable to get private meter connection one of the alternative water supply sources is public standpipe. Most of the time consumers prefer this source rather than water vendors/neighbors, because it is relatively cheaper.

To some households, private meter connection could be unaffordable. There are different payments to access this convenient water supply service.

According to the town's water supply service office report 2004/05, to get private meter connection the following payments are to be made:

-Permission fee	10 birr
-Cost estimation fee	15 birr
-Deposit	50 birr (for residential connection)
-Service charge	40% of the cost of the material.
-Transport charge	25% of the cost of the material.

If the cost of material is estimated to be 400 birr, the customer is required to pay 735 birr. This makes public standpipes the preferred source for those in low-income brackets.

However, public standpipes that are currently operational are small in number. Last year (2004/05) the office reported that there were 34 public standpipes but their number is currently (2005/06) reduced to 28 standpoints.

In the town, around 14,226 households do not have access to house or yard connection. Thus, one standpipe, on average, is serving 508 households. On the average, a household also consists around 4.9 family members. Hence, one public standpipe is serving for 2,489 users. But according to WSSA (1992) one public standpipe should serve for every 800 to 1200 public tap users depending on the local population density and physical situations.

Moreover, the presently serving standpipes are not evenly distributed throughout the town. Even there are 'Tabias' such as Hadnet and Hawelti with out public standpipes. The largest numbers of standpipes, which are 9 in number, are found in Kuha.

CHAPTER FIVE

DETERMINANTS OF HOUSEHOLD WATER CONSUMPTION LEVELS

Household and per capita water consumption levels are affected by various socio-economic and physical factors. Thus, the amount of water used for domestic purpose varies from country to country, community to community and household to household. Because of this, studies conducted in different areas or same area at different times demonstrate different household per capita water consumption levels.

In this chapter, variables that are thought to have an influence on household and per capita water consumption level in Mekelle are discussed. For the analysis, surveyed households were classified into three groups. The first group of households is those with private meter connection and do not sell water to others (120 households). The second group is households without private meter connection (46 households). The third group is households who have private meter connection and water vendors as well (31 households). In order to assess the actual amount of water consumed by households, water vendors are separated and excluded in most computations. But, in reality, these may not be the only water vendors from the sample households.

A technique of calculating the simple correlation coefficient matrix for the dependent and selected independent variables was used to test multicollinearity. The results (Appendix 3) show that multicollinearity is not a serious problem. Variables flush toilet and shower resulted in a coefficient of 63% because all households who have flush toilet also have shower facility.

As indicated in Appendix 4, regression analysis is made taking all independent variables with respect to the dependent variable. Thus, the analysis of variance (ANOVA) indicates that the total sum of squares (SS) is 211,449, of which 63,063 is explained by the model and 148,385 is left unexplained (in the residual).

Moreover, the multiple coefficient of determination (R^2) is 0.2982. The R^2 value indicated that all explanatory variables together account for about 30% of the variation in the daily water consumption per capita of households in the town. The adjusted R-square, which is adjusted for degree of freedom is 0.2530.

The overall significance test of multiple regression was also made and the computed F-value (7.74) is greater than the critical value (1.96). Thus, the null hypothesis that all slope coefficients are simultaneously zero was rejected. This shows the overall significance of the regression.

5.1. Occupation of Household Heads (OCHH)

Occupation of household heads is believed to have an influence on per capita water consumption. As stated in the literature review part, there are different perspectives in different studies. Some studies relate the occupation of the household with the income he or she earns from it and quantity of water consumed. Others relate with the intensity of the activity and the need for water.

To assess the influence of occupation on daily per capita water consumption, the sample households were grouped into four types of occupation. The first group consists of household heads that are employees of government, private business, and NGOs, as well as those who are retired

(GOPRNGRI). Then private business, farming, daily laborer and unemployed are the second, third, fourth and the fifth group respectively.

Table 8: Mean daily per capita water consumption by occupation, total sample (water vendors excluded)

Occupation	No of HH with private meter	MDWCPC (liters)	No. of HH without private meter	MDWCPC (liters)	Total no. of HH	Mean (liters)
GOPRNGRI	52	43.29	19	11.05	71	34.66
Private business	23	50.35	12	10.25	35	36.6
Farming	3	45	0	-	3	45
Daily laborer	9	47.44	5	14.4	14	35.64
Unemployed	33	59.57	10	14.4	43	49.07
Total/ mean	**120**	**49.48**	**46**	**11.93**	**166**	**39.07**

Source: Survey result

As indicated in table 8, the first group comprises 43.8% of the sample households. This is the largest proportion of occupation followed by unemployed household heads (25.9%). The third group is the lowest proportion in which only 1.8% of the sample household heads are engaged in.

In the fifth group (unemployed), there is a high variability that the standard deviation is 43.4. The minimum observed water consumption in this group is 6 l/c/d and the maximum is 177 l/c/d. In contrary, the lowest variability is observed in the third group (farming) in which the minimum water consumption is 30 l/c/d and the maximum consumption is 65 l/c/d.

In the case of privately connected (in-house or yard) households, the highest per capita water consumption rate is observed among unemployed household heads (59.6 l/c/d) followed by private business owners (50.4

l/c/d). Furthermore, the lowest per capita water consumption is observed in the first occupational group (43.3 l/c/d).

In the case of households who do not have their own private meter connection, the water consumption trend is almost the same as the privately connected households. The only exception is that daily water consumption per capita for private business owners is now the lowest of all occupational groups.

The influence of occupational differences on mean daily water consumption for the whole sample (vendors excluded) has shown a similar trend. The highest daily water consumption is exhibited among unemployed household heads (49.1 l/c/d). This may be because of unemployed household heads engagement on water vending task as a means of income. In the other extreme, the lowest daily water consumption is observed in the first group (34.7 l/c/d).

Regression results (Appendix 4) indicated that occupation is not statistically significant. Thus, the influence of occupation on the rate of daily per capita water consumption is insignificant to accept the hypothesis that the type of occupation in which the household heads are engaged influences per capita water consumption.

5.2. Accessibility of Water Tap (ACCESS)

It is expected that the daily per capita water consumption of households who lack access to own private connection is to be low. Furthermore, the daily water consumption of households decreases if the water points are located at a distance from residence. Accessibility of water tap refers, therefore, to the location of water sources and the time taken to fetch water.

From the total of 46 households who did not have access to private meter connection, 35 households who use public standpipe were taken to estimate the time of fetching water. To see the association between the daily water consumption per capita and water fetching time, four categories were generated and their daily water consumption per capita was computed.

Table 9: Mean daily water consumption per capita and round trip time taken to fetch water of households without private meter connection (public stand pipe users)

Time (minutes)	Number of households	MDWCPC (liters)	Standard deviation	Minimum	Maximum
≤15	2	26.5	27.58	7	46
>15 and ≤ 30	30	13.13	5.47	3	27
> 30 and ≤45	1	9	-	9	9
> 45	2	6.5	0.71	6	7
Total/ mean	**35**	**13.4**	**7.84**	**3**	**46**

. ***Source: Survey result***

Table 9 indicates that, the majority of households (85.7%) travel a round trip time of between 15 and 30 minutes. It is also clearly observed that as distance increases the daily per capita water consumption of households decreases. The first group that travels almost 15 minutes consumes 26.5 l/c/d. Then, after a continuous decline, the fourth group who travels more than 45 minutes consumes 6.5 l/c/d on the average.

The highest variability of daily per capita water consumption is observed in the first group where the coefficient of variation is 104.1%. The observed minimum and maximum daily per capita water consumption among households are 7 and 46 liters respectively.

However, regression result (Appendix 4) indicates that accessibility of water tap is not statistically significant. Therefore, there is no sufficient evidence to the hypothesis that household per capita water consumption decreases as distance from home to water sources increases.

5.3. Frequency of Body Washing or Bathing (FRWA)

Household and per capita water consumption is not only influenced by the presence of water using appliance but also by the probability of these appliances being turned on. This also depends on the socio-cultural factors, climate, workload and other local conditions of the area under study.

Table 10: Mean daily water consumption per capita (MDWCPC) by frequency of body washing

Household batching frequency	Number of households	MDWCPC (liters)	Standard deviation	Minimum	Maximum
Daily	1	126.00	-	126	126
Every two days	5	51.40	48.37	10	121
Every three days	33	39.21	36.96	7	169
Weekly	125	38.32	34.57	2	223
Every two weeks or more	2	9.50	4.95	6	13
Total/ mean	**166**	**39.07**	**35.80**	**2**	**223**

Source: Survey result

Table 10 shows that the households who take bath once a week, every three days, every two days, every two weeks or more and every day are 75.3%, 19.9%, 3%, 0.6% respectively. The dusty environment of Mekelle could have been a reason for a frequent bathing of some households. On the other hand, the hardness of ground water, which discourages bathing and inadequate water, may be the reason for infrequent bathing of the majority of households.

Table 10 also indicates that as the frequency of body washing increases, the mean daily water consumption per capita increases. In other words, as the interval of body washing increases, the mean daily water consumption per capita decreases. The water consumption rate of household who bathes every day is 126 l/c/d. In the other extreme, for those households who bath every two weeks or more consume only 9.5 l/c/d. Moreover, if households who bath every two days changed their practice to bath every day, then per capita water consumption would increase by 145%.

The regression result (Appendix 4) indicates that frequency of body washing or bathing is not statistically significant to explain the variation in daily water consumption per capita (Y) of households in the town. Hence, the hypothesis that household per capita water consumption is positively correlated with the frequency of body washing is insignificant to accept.

5.4. Presence of Domestic Animals (PREDO) and Garden Plots (PGAR)

The presence or absence of domestic animals and garden plots within a living compound of a household may affect the daily water consumption rate of the household. Thus, water consumption is expected to increase, as the household possesses domestic animals and garden.

Table 11: Mean daily water consumption per capita (MDWCPC) of households with or without domestic animals and garden.

Measured Variable	Domestic animals		Garden	
	With	Without	With	Without
Number of households	16	150	76	90
DWCPC (liters)	44.31	38.51	42.53	36.16
Standard deviation	31.50	36.28	29.77	40.13
Minimum	2.00	3.00	2.00	3.00
Maximum	113.00	223.00	128.00	223.00

Source: Survey result

Table 11 shows the mean daily per capita water consumption in terms of households with and without domestic animals and garden plots. Thus, 9.6% and 45.8% of the households possess domestic animals and garden plots respectively.

Concerning household per capita water consumption rate, both variables have shown the expected trend. The daily water consumption per capita of household with domestic animals is 44.3 liters and while it is 38.5 liters for those without domestic animals. The result is also true for households with garden plots that consume 42.5 l/c/d and households without garden plots consume 36.2 l/c/d.

Moreover, mean daily water consumption per capita of households with respect to the type of domestic animals they possess is also calculated (appendix 1). Households with horse and/or mule consume 65.5 l/c/d. Moreover, mean per capita water consumption of households with domestic animals such as cows and/or oxen is 39.5 liters.

However, the regression result (Appendix 4) shows that the influence of domestic animals and garden plots on household daily per capita water consumption is not statistically significant. Hence, the hypothesis that possession of garden and domestic animals increase the per capita water consumption of households in the town is insignificant to accept.

5.5. Seasonal Pattern of Water Consumption by In-house and Yard Connected Households

The total or per capita water consumption of households is believed to fluctuate with temperature and season. During wet season water consumption bills of households are expected to indicate low consumption rate. But, water consumption bills of households are expected to be high during the dry season because of lack of alternative sources of water.

In order to assess seasonal variation of household water consumption, the water bills of 151 households were taken. From the bill, therefore, the monthly and daily per household as well as per capita water consumption were calculated.

Table 12: Seasonal Patterns of Monthly and daily per household and per capita water consumption in the town (from March 2005 to February 2006)

Duration	Mar. and Ap. (mean)	May and June (mean)	July And Aug. (mean)	Sep. and Oct. (mean)	Nov. and Dec. (mean)	Jan. and Feb. (mean)
MWCPHH (Liters)	9102.5	8307	6231.8	7747	8710	9427.4
MDWCPHH	303.4	276.9	191.7	258.2	290.3	314.2
MDWCPC	55.2	50.3	34.9	47.0	52.8	57.1

Source: Survey result

Table 12 indicates that the lowest water consumption level per household and per capita is to be in July and August. This is an indication that piped water consumption decreases during the rainy season.

According to Mekelle City Administration (2005), Mekelle has annual average rainfall of 618.3mm/year of which rainfall during July and August comprises the lion's share, i.e., about 436.7 mm (70.6%). This is, therefore, the main reason that households use the intensive rain in July and August for cloth washing, animal and garden watering, floor cleaning and other purposes. The relative hardness of groundwater of the town encourages people for rainwater harvesting. During the rainy season, almost all households practice rainwater harvesting for different purposes.

The mean daily water consumption per capita of households in September and October is 47 liters. This may be for the reasons that in the beginning of September households use the already collected rainwater. In the end of June, it is time that the rainy season begins and some rainwater harvesting practices start. However, during the dry season (October – May), when there is no alternative source, per capita water consumption from piped water is high. The highest per capita water consumption level (57.1 l/c/d) is in January and February. This is because January and February are dry months as well as different wedding ceremonies take place in the area.

Thus, the seasonal mean daily per capita water consumption pattern of households from piped water source is lower during the rainy months since households have rainwater to use for domestic purpose.

5.6. Pressure Maintained in the Pipelines

Pressure influences supply capacity of the distribution system. Because of differences in topography of an area, pressure maintained in pipelines could be too low or too high.

However, in the case of Mekelle town, as Anyalem well field is at higher elevation than the town, water shortage is more pronounced than inadequacy of pressure in the pipelines. With this regard, households were asked about the main cause(s) for their water supply interruption and only 6% responded as lack of enough pressure in the distribution system. The majority of the households responded as the main causes of their water supply interruption was water shortage from the source and lack of maintenance. In addition to this, most of the respondents proposed for additional water supply sources to solve the water shortage problems.

Moreover, Mekelle water supply service office in its annual report (2004/05) stated that there was unequal distribution especially on the high lands. The office took zone 1 as a high land facing inadequate pressure in the distribution system. To solve this problem and equalize water distribution there is water rationing. However, to this particular zone, water rationing is not applied and the system is always open.

5.7. Household Size (SIHH) and Water Consumption

Household size is one of the major socio-economic variables that have a significant influence on the amount of daily water consumption per capita and per household. As indicated in various studies and hypothesized in this study, it is expected that as family size increases daily per capita water consumption decreases. With this regard, sample households in the study area had a family size that ranges from single to 12 members and the average was 5.5 members per household.

To assess the relation of these two variables, household sizes were classified into three groups. Each group was made to have the same width. Based on these groups, Table 13 shows the daily water consumption per household (DWCPHH) in relation to family size.

Table 13: Mean daily water consumption per household (MDWCPHH) by size of households (households without private meter connection)

Household size	Number of households	MDWCPHH	Standard deviation	Minimum	Maximum
≤ 4	24	41.54	15.87	20	75
5-8	19	53.42	19.93	20	80
9-12	3	115.00	160.23	20	300
Total/mean	**46**	**51.24**	**41.86**	**20**	**300**

Source: Survey result

Table 13 indicates that the mean daily water consumption per household increases from 41.5 liters to 115 as the household size increases. The grand mean daily water consumption of households without private meter connections is only 51.2 liters per household. This average amount of water consumption per household per day is very low because the amount of water consumed by the household is to be shared among 5.5 family members on the average.

In each group, the minimum daily consumption per household is 20 liters. But the maximum daily consumption varies from 75 liters per day to 300 liters. This indicates the existence of consumption disparities among these households. But, consumption disparity is high in the third group in which the minimum is 20 liters per day and the maximum 300 liters. One possible reason for water consumption variability could be differences in income level and the distance the households travel to fetch water.

Hence, the coefficient of variation of the third group is 139.3% (160.23/115) showing a high disparity among households of the group. In general, the overall mean daily water consumption of the whole group (51.2 liters/day) is low.

The findings of other researchers support the direct relationship of daily water consumption per household with respect to household size. But, because of the peculiar conditions of each study area, the amount of daily water consumption per household may vary to each other. Yimer (1992), in his study in Nazareth, found that the mean daily water consumption per household was 76 liters. This is almost 1.5 times more than the finding of this survey in Mekelle town.

Other important water consumption measurement is the daily per capita water consumption. Unlike the overall consumption of water that increases as household size increases per capita water consumption is expected to decrease as household size increase. To identify this relationship daily per capita water consumption of the sample households is indicated in Table 14.

Table 14: Mean daily water consumption per capita of households without private meter connections.

Family size	Number of households	MDWCPC (liter)	Standard deviation	Minimum	Maximum
≤ 4	24	14.54	8.16	6	46
5-8	19	8.84	3.96	3	16
9-12	3	10.67	14.15	2	27
Total/mean	**46**	**11.93**	**7.55**	**2**	**46**

Source: Survey result

Table 14 depicts that the mean daily water consumption per capita of household with four or less family members is 14.5 liters/day. The per capita water consumption reduces to 8.8 for five up to eight household sizes. But the trend of the third group is not as expected. Even though the change is small, it has shown a slight increment. This trend does not violate the hypothesis that as household size increases daily water consumption per capita decreases. It is because regression result (Appendix 4) indicates the inverse relationship of the two variables. But, this unexpected trend could be explained in terms of the household composition of this particular group and the distance from the water point. In general, mean daily water consumption per capita of those who do not have private connection is 11.9 liters/day. In similar study in Nazareth, Yimer (1992) found the mean daily water consumption per capita was 14.3 liters.

Other group of households is those having their own private meter connection. This group includes households who have in- house or yard connection service, and those households who are sharing a common yard tap. Households in this group are considered to have a better service because the availability of water supply at home creates convenience and encourages water consumption.

Table 15: Mean daily water consumption per household (MDWCPHH) and mean daily water consumption per capita (MDWCPC) of households with private connection and non-vendors

Family size	Number of households	MDWCPHH (liters)	Standard deviation	MDWCPC (liters)	Standard deviation
≤ 4	36	196.36	124.60	66.94	44.83
5-8	71	264.85	188.43	43.63	31.70
9-12	13	318.82	191.79	33.00	19.19
Total/mean	**120**	**250.15**	**175.16**	**49.48**	**36.90**

Source: Survey result

Table 15 shows that mean daily water consumption per household increases as household size increases. Mean daily water consumption per capita consistently decreases as household size increases. The grand mean water consumption is 250.2 liters per day per household. When this consumption rate is compared with households who do not have their own private connection, this group consumes almost five times more water.

The mean daily water consumption per capita of those households who are water vendors is relatively high. Regardless of their income and family size, this group's water bill showed very large water consumption level. There were some water vendors who sold water to ten households. This is the main reason for the separate analysis of daily household and per capita water consumption of water vendors.

There were 31 households who told the fact that they are vending water. Their daily water consumption per capita was 83.9 liters. On the other hand, the MDWCPC for those households who are privately connected and non-vendors is 49.5 liters. The level of water consumption of those water vendors show almost 1.7 times more than water consumption level of non-vendors.

In general, the type of water supply service provided to households has an impact on their water consumption levels. That is why households who do not have access to private meter connection have shown less daily water consumption per capita than privately connected households.

Mean daily water consumption per household and per capita, including water vendors, is 220.8 and 46.1 liters respectively. When the per capita daily water consumption is compared to some other towns, it is low. For instance, Yimer (1992) found that the daily per capita water consumption of Nazareth was 48.4 liters. It is obvious that, in the last fourteen years, there could be a significant life style change, which increases demand for water. But still, the daily water consumption per capita of households in Mekelle town is less than that of Nazareth. Emnet (2005) also found that the per capita water consumption of households in Harar town was 67.3 liters. This is 1.5 times more than the per capita water consumption of households in Mekelle town.

The combined water consumption of the households (excluding vendors) would be the overall daily water consumption per household and per capita. The per capita water consumption for the whole sample is, therefore, only 39.1 liters/day.

The family size of households, SIHH, (β=-4.14, p= 0.001) is negatively related to mean daily water consumption per capita (Appendix 4). It indicates that as the family size of a household increases by one person, daily water consumption per capita of the household decreases by 4.1 liters. Hence, the hypothesis that household per capita water consumption decreases as the family size of household increases is accepted at 1% significance level.

5.8. Household Income (INHH) and Water Consumption

As indicated in Appendix 2, mean monthly income of the sample households is 780.30 birr. The smallest and largest income is 60 birr and 4130 birr per month per household respectively. The standard deviation is 683.80 birr per month.

Households were grouped into eight income categories (Table 16). The width of these income categories was calculated taking the formula, highest income value minus the lowest divided to the number of groups. The range is, therefore, 509 birr.

Table 16: Mean daily household and per capita water consumption by income group, total sample (excluding water vendors)

Income Group (Birr)	Number of households	MDWCPHH (liters)	Standard deviation	MDWCPC (liters)	Standard deviation
60-568	76	140.37	123.40	34.96	36.08
569-1077	53	243.22	228.87	43.98	39.83
1078-1586	19	246.01	163.97	38.95	25.36
1587-2095	12	217.62	146.76	42.25	38.99
2096-2604	1	202.78	-	51.00	-
2605-3113	2	216.67	11.79	34.00	5.66
3114-3622	1	191.11	-	38.00	-
3623-4131	2	351.25	54.80	47.00	2.83
Total/mean	**166**	**195.03**	**174.87**	**39.07**	**35.80**

Source: Survey result

Table 16 shows that the second income group has a high standard deviation. This indicates the existence of consumption disparities among these households. Hence, the calculated coefficient of variation of this group is 90.6% (39.83/43.98) showing a relatively high water consumption disparity among households of the group.

The Table also indicates that, as the income of a household increases, the mean daily water consumption per household also increases up to the third income category. Then, followed without a patterned trend of decreasing or increasing until the highest water consumption in the highest income group households (351.3).

The mean daily water consumption per capita of households in different income categories does not show a clear pattern of increase or decrease. The existence of water vendors and the distance of water points from dwelling units may explain for the inconsistence per capita increase in water consumption of households. However, the overall relation of income to mean daily water consumption per capita is positive as indicated in the regression analysis.

The influence of income on daily per household and per capita water consumption is multidimensional. It influences water consumption through private meter possession, which needs finance to cover installation cost and other expenses. Hence, households who can afford private meter connection consume more because it is easily accessible. Another influence of income on water consumption is through acquisition of water using appliances. These water-using appliances made households to use more water in terms of per household and per capita basis.

Regression result (Appendix 4) also shows that AINHH ($\beta=0.04$, $p=0.071$) is positively related with daily water consumption per capita of households. This is interpreted as, if the average income of a household head increases by 1 birr, daily water consumption per capita of the household will increase by 0.04 liters. Thus, the hypothesis that household per capita water consumption is positively correlated with household income level is accepted at 10% significance level.

5.9. Educational Level of Household Heads (EDHH)

Educational level of household heads is believed to have a direct relationship to daily household and per capita water consumption. It is expected that as the educational level of household head increases, there would be more awareness of the health benefits of water and, as a result, there should be frequent bathing and washing.

Educational level of household heads was classified into four educational levels as illiterate, 1-8 grade, 9-12 grade, and tertiary level.

Table 17: Mean daily water consumption per household and per capita by educational level of household heads and with private meter connection (water vendors excluded)

Household head educational level	Number of households	MDWCPHH (liters)	Standard deviation	MDWCPC (liters)	Standard deviation
Illiterate	46	249.56	178.45	49.72	36.04
1-8 grade	38	256.68	168.79	46.11	29.89
9-12 grade	17	282.69	240.38	60.76	55.49
Tertiary level	19	209.38	102.24	45.53	31.93
Total/ mean	**120**	**250.15**	**175.16**	**49.48**	**36.90**

Source: Survey result

Table 17 indicates that 38.3% of the households were illiterate, 31.7% were 1-8 grade, 14.2% were 9-12 grade and 15.8% were Tertiary level graduates.

Mean daily per capita water consumption decreases from the first to second educational categories. Then, it increases in the third group and finally, decreases in the highest educational level category. In general, except the third group, the result reveals that daily per capita water consumption decreases as the educational attainment of household head increases.

Thus, the decreasing of per capita water consumption as educational level of household heads increase, could be explained by that relatively less educated household heads could be engaged in water vending activities.

In the case of households who were without private meter connections, daily water consumption per capita seems to have a declining trend with an increase in educational level of the household heads.

Table 18: Mean daily water consumption per household and per capita by educational level of household heads (without private meter connection)

Educational level of household heads	Number of households	MDWCPHH (liters)	Standard deviation	MDWCPC (liters)	Standard deviation
Illiterate	17	47.41	17.59	12.88	9.56
1-8 grade	17	57.12	65.59	11.06	7.34
9-12 grade	9	48.89	16.73	12.56	3.64
Tertiary level	3	46.67	30.55	9.67	6.51
Total/ mean	**46**	**51.23**	**41.86**	**11.93**	**7.55**

Source: Survey result

Table 18 indicates that mean daily water consumption per capita of the first group is the highest and more than the grand mean (11.9 l/c/d). In the contrary, the lowest mean daily water consumption (9.7 l/c/d) is computed for the highest educational level category.

Thus, the distance of water sources could explain the decline in daily mean per capita water consumption from home and availability of labor to fetch water. More importantly, the ownership of domestic animals by the relatively less educated household heads increase their daily mean per capita water consumption.

The highest standard deviation is observed in the first educational level group. In this group the minimum observed daily per capita water consumption is 6 liters and the maximum is 46 liters. The lowest standard deviation is seen in the third group where the minimum consumption level observed is 7 l/c/d and the maximum 20 l/c/d.

However, the regression result (Appendix 4) indicates that the influence of education on household daily per capita water consumption is not statistically significant. Hence, the hypothesis that states household per capita water consumption is positively correlated with household head level of education is insignificant to accept.

5.10. Presence of Private Meter Connection (PREM)

As indicated in the literature review part, location of water sources and its distance from home affects both household and per capita water consumption. In line with this, it is hypothesized that, in-house or yard water supply service encourages households for more per capita water consumption than other types of supply services.

Table 19: Mean daily water consumption per household and per capita by type of water supply service: privately connected households (Group – 1), without private connection (Group – 2) and privately connected and vendors (Group – 3).

Group	Number of households	MDWCPHH (liters)	Standard deviation	MDWCPC (liters)	Standard deviation
Group 1	120	250.15	175.16	49.48	36.90
Group 2	46	51.24	41.86	11.93	7.55
Group 3	31	358.67	195.00	83.90	59.65
Total/ mean	**197**	**220.78**	**199.13**	**46.13**	**43.00**

Source: Survey result

Table 19 indicates that out of the total households in the sample survey 76.6% of them had private meter connection. The remaining households (23.4%) were using public standpipes and/or vended water. In the sample survey, it is also observed that there were no households who completely depended on hand dug well, spring or river.

Households in group – 3 (water vendors) are treated separately to arrive at the actual daily water consumption per household and per capita. If this is not done, the household water consumption result will be higher than the actual consumption.

Group 1 and group 3 are both served by private meter connection water supply service. But the daily water consumption per household and per capita of group 3 are 1.4 and 1.7 times the consumption of group 1 respectively.

Water consumption per household for private meter connected households is 4.9 times more than without private meter connected households. In addition to this on per capita basis group 1 consumes 4.2 times that of group 2.

The variation in the daily water consumption per capita in group 1 is 74.6%. The minimum water consumption observed is 5 l/c/d and the maximum being 223 l/c/d. In the case of households in group 2, the coefficient of variation is 63.3% which is less than group 1. In addition to this, the minimum and maximum water consumption exhibited in the group is 2 l/c/d and 46 l/c/d, respectively.

In general, the results show that lack of access to own private connection means that households water consumption is low. An important factor for the low water consumption may be the high price of collecting water from outside sources in terms of time and money.

The regression result (Appendix 4) indicates that presence of private meter connection (in house or yard), PREM (β =25.87, p=0.050), is positively related with daily water consumption per capita of households. The daily per capita water consumption of households with private meter connection is more than those households who do not have this supply service. Thus, the calculated coefficient indicated that as a household gets access to private meter connection, daily water consumption per capita of the household increases by 25.9 liters. Thus, the hypothesis that private meter connection water supply service encourages household water consumption more than the other types of supply services is accepted at a 5% significance level.

5.11. Presence of Water Using Appliances (WATAP)

Total household and per capita water consumption is influenced by the presence of water using appliances. These appliances may be like washing machines, bath tube, shower, kitchens with faucets and flush toilet. But, in the study area, showers and flush toilet are the most dominant water using appliances. Hence, this variable is to be measured and analyzed by taking these two water-using appliances.

Table 20: Mean daily water consumption per capita of households with and without flush toilet and shower.

Households	Number of households	MDWCPC (liters)	Standard deviation	Minimum	Maximum
With flush toilet	14	65.86	42.96	21	128
Without flush toilet	152	36.61	34.19	2	223
With shower	39	56.03	39.51	2	169
Without shower	127	33.86	33.03	3	223
Total/ mean	**166**	**39.07**	**35.80**	**2**	**223**

Source: Survey result

As can be seen from Table 20 households with flush toilet use 65.9 l/c/d and while households who do not have this fixture consume only 36.6 l/c/d. This per capita daily consumption level is almost 80% less than those households having the facility. It is also less than the grand mean (39.1 l/c/d) of group 1 and group 2.

All households with flush toilet also have shower facilities. Therefore, from the total of 39 households with shower, 14 households have both flush toilet and shower and 25 households have only shower facilities. If the households who have both shower and flush toilet are excluded (14 households), the per capita water consumption of those households with and without showers is 50.6 and 33.9 respectively.

From the total sample (except water vendors), 23.5% of the households have shower facility. Their mean daily water consumption per capita is 56 liters. As a result, the consumption rate is 65.5% more than the households who do not have the facility. In general, the mean daily water consumption per capita of households with showers and flush toilet is more than those without it.

To detect the problem of multicollinearity multiple correlation analysis (appendix 3) of suspected variables were made and found that shower and flush toilet are correlated (63%). As stated earlier, all households who have flush toilet also have shower facilities. Therefore, taking flush toilet as one of the independent variables is taking showers as well.

The regression result (Appendix 4) indicates that FTOILET (β=15.78, p=0.026) has a direct relationship with household per capita water consumption (Y). It means, if a household who does not have a flush toilet and shower possess the facility, the household water consumption will increase by 15.9 l/c/d. Therefore, the hypothesis household water consumption is positively correlated with the presence of water using appliances in the household is accepted at 5% significance level.

From Appendix 4, mean daily water consumption per capita (Y) and the four-stastically significant independent variables are summarized in the following regression equation:

$$Y = 44.19 + 0.04\ AINHH - 4.14\ SIHH + 25.87\ PREM + 15.28\ FTOILET$$

The intercept of the regression equation (**β_o**=44.2, p= 0.054) is significant at 10% significant level. It is interpreted as, if all explanatory variables were zero, the mean daily per capita water consumption would be 44.2 liters. "Of course, this mechanical interpretation of the intercept may not make much economic sense" (Gujarati, 2003).

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Adequate and safe water supply is one of the basic urban services, which highly influence economic progress of towns and the health of their dwellers. But over the years, increasing population, growing industrialization and expanding agriculture have pushed up the demand for water extremely high. At the same time, if the standard of living of the population is to rise, per capita water consumption is also likely to rise.

Ethiopia's level of water service coverage is low. As reports indicate, only 19% of the rural and 80% of the urban population have access to safe water and from which the total coverage is 26%. Excluding Addis Ababa, the urban coverage becomes only 31.3%.

The water supply problem of Mekelle town is also growing from time to time, together with its high population growth. The existing production of water from the wells is inadequate to satisfy water demand for domestic and non-domestic requirement of the town. From time to time, many boreholes are out of use and water level of the wells has dramatically dropped. In addition to this, the watershed areas are devoid of trees and greenery. These greatly hamper rainwater percolation and slow groundwater recharge. The production of water is further hampered by power interruption and frequent technical problems of pumps. Old pipes of the distribution system, which have served for almost 55 years, are susceptible to water leakage and pollution.

Moreover, the responsible office, Mekelle water supply service office, is not in the position to tackle all the problems mentioned above. Let alone efforts to improve the yield of boreholes, it was so difficult to get an organized record of the boreholes. In this case the office needs to be proactive rather than reactive.

As indicated in the seasonal variation of piped water consumption of households, there is an already established water harvesting practice in the town. The relative hardness of groundwater of the town encourages people for rainwater harvesting. But, the capacity of tanks households use to store water from the roof is small. As a result, there is no excess stored rainwater that could be used after the wet season ends.

. Presence of private meter connection and water using appliances are directly related and strongly influence mean daily water consumption of households. The calculated mean daily per capita water consumption of sample households with private connection (group 1), households with out private connection (group 2) and households with private connection and water vendors (group 3) is 49.5 l/c/d, 11.9 l/c/d and 83.9 l/c/d respectively. Mean daily per capita water consumption of the majority of the households who do not have their own private connection in the town is 11.9 liters. This is lower than the amount specified by Ministry of Water Resource (1996) which was 20 liters of water per person per day and far lower than the WHO standard (45 l/c/d). As it is indicated in the literature, without adequate and efficient water supplies any measure to reduce income poverty is unlikely to be successful. The poor could be exposed to varieties of water born diseases that affect their ability to participate fully in the income earning works.

For appropriate water supply projection, a detail study on the physical and socio-economic factors affecting per capita water consumption is desirable. Population growth is one of the socio-economic factors that have been mainly taken in future water supply and demand projections. Other physical and socio-economic factors are mostly ignored in water supply projection in the study area.

6.2 Recommendations

Based on the findings of the study, the following recommendations are given:

1. To solve the water shortage problem and improve the yield of boreholes, watershed management activities such as afforestation and terracing should be taken by Mekelle water supply service office. Artificial recharge system should also be introduced by digging of ponds around the water fields.

2. Record handling of the Mekelle water supply service office concerning the boreholes and consumers should be improved to guide future solutions.

3. An integrated effort to solve power interruption and regular maintenance of water pumps should be taken. In the time of power overload, the Electric and Power Authority Branch Office should give priority to the groundwater power lines as it is usually practiced for the hospitals in the town.

4. As a long-term solution to the water shortage problem of the town, ways and means must be sought to develop surface water in combination with the groundwater sources.

5. The Mekelle Water Supply Service Office and other responsible offices should encourage and strengthen the already existing rainwater harvesting practice of the dwellers of the town. The town's water supply office should help and educate households to have greater capacity collection tankers (may be constructed by cement and steel) to complement groundwater supply for a relatively longer period of time.

6. As a short-term solution, Mekelle water supply service office need additional boreholes to be drilled and connected to the system to minimize the existing water supply problems.

7. To increase access of households to house connection the initial costs, which are unaffordable by the low-income bracket group, Mekelle water supply service office should made the payment on longer-term basis. However, this should be done after reliable water supply source(s) is/are developed for the town.

8. The old pipelines should be changed and properly maintained in order to reduce water loss in the distribution system. A new one should also replace old water pumps.

9. Urban water supply system planners and officials should include the major physical and socio-economic factors in their water supply projection. To this end, in addition to the technical knowledge of individuals involved in water supply demand projection, other individuals who are from different fields such as sociologists, chemists, geographers, geologists, economists should be involved.

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APPENDICES

Appendix 1: Mean daily water consumption per capita of household by type of domestic animals (in liters)

Type of water service		Type of animals			
		Cow/ox	Horse/mule	Cow/ ox, sheep, goat donkey	Total
House connection and non-vendors	N	10	2	1	13
	Mean	48.10	65.50	65.00	52.07
	Median	44.00	65.50	65.00	48.00
	St. deviation	23.81	67.18	-	29.30
	% of total sum	67.8%	18.5%	9.2%	95.5%
Without house connection	N	3	-	-	3
	Mean	10.67	-	-	10.67
	Median	3.00	-	-	3.00
	St. deviation	14.15	-	-	14.15
	% of total sum	4.5%	-	-	4.5%
Total	N	13	2	1	16
	Mean	39.46	65.50	65.00	44.31
	Median	30.00	65.50	65.00	35.00
	St. deviation	26.98	67.18	-	31.50
	% of total sum	72.4%	18.5%	9.2%	100%

Appendix 2: The distribution of household monthly income (water vendors excluded)

Percentiles		Smallest		
1%	60	60		
5%	150	60		
10%	200	90	Obs.	169
25%	300	90	Sum of Wgt.	169
50%	600	Largest	Mean	780.2959
75%	960	3055	Std. Dev.	683.7949
90%	1650	3190	Variance	467575.5
95%	2000	4020	Skewness	2.2338
99%	4020	4130	Kurtosis	9.5666

Appendix 3: Correlation of selected explanatory variables

	DWCPC	INHH	SIHH	PREM	EDHH	OCHH	SHOW2.	FTOIL2.
DWCPC	1.0000							
INHH	0.0820	1.0000						
SIHH	-0.2353	0.2383	1.0000					
PREM	0.3718	0.2972	0.1568	1.0000				
EDHH	0.0277	0.5591	-0.0552	0.1360	1.0000			
OCHH	0.1308	-0.1908	-0.0906	0.0216	-0.3576	1.0000		
SHOWER2	0.2670	0.3738	0.0720	0.2713	0.1467	-0.0680	1.0000	
FTOILET2	0.2540	0.2907	0.0111	0.1473	0.1220	-0.0863	0.6340	1.0000

Appendix 4: Multiple regression results between daily water consumption per capita (Y) of households and all regressors.

Source	SS	df	MS	
Model	63063.33	10	6306.33	Number of obs. = 166
Residual	148385.80	155	957.33	F (10, 155) = 6.59
Total	211449.13	165	1281.51	Prob > F = 0.0000
				R-squared = 0.2982
				Adj. R-squared = 0.2530
				Root MSE =30.941

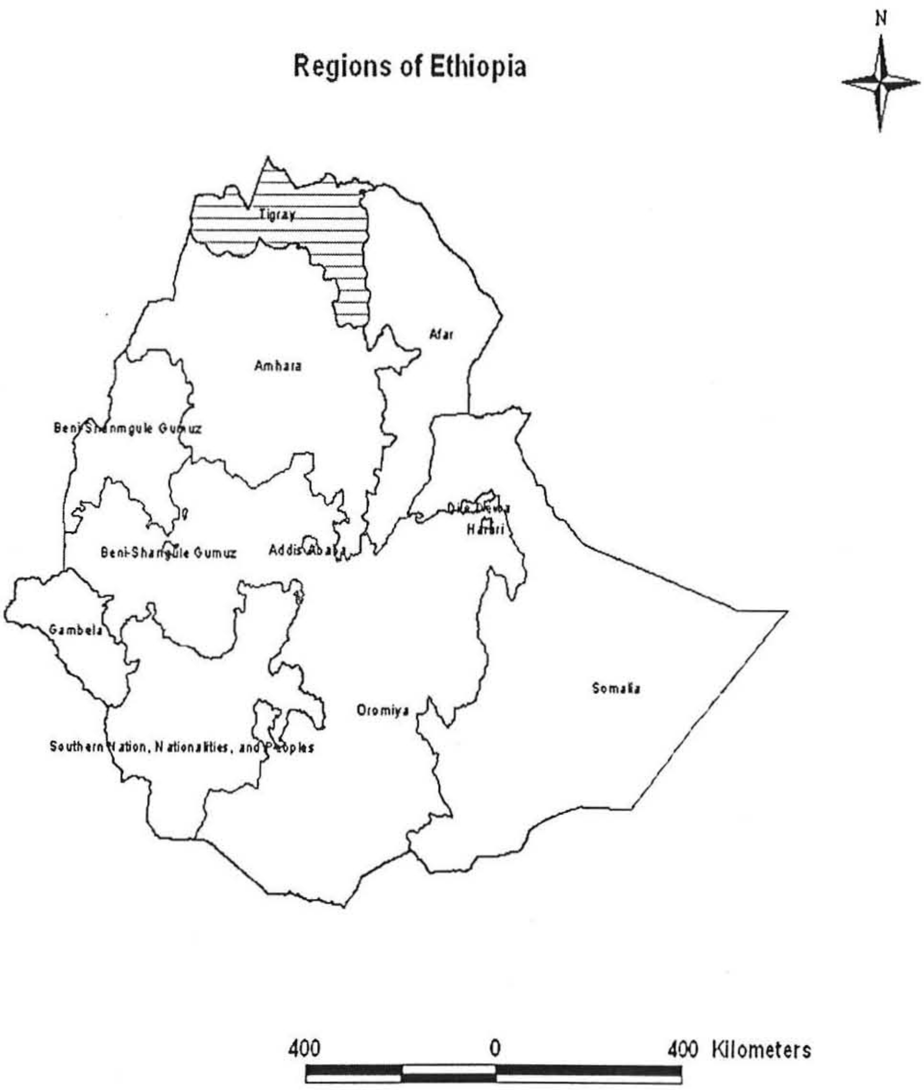
DWCPC	Coef.	Std. Err.	t	P>/t/	[95% conf.	Interval]
AINHH	0.0407	0.0223	1.82*	0.071	-0.0034618	0.0849595
SIHH	-4.1397	1.2310	-3.36***	0.001	-6.571485	-1.707889
EDHH	-2.8180	5.6646	-0.50	0.620	-14.0077	8.371781
FRWA	-0.6070	4.6688	-0.13	0.897	-9.829816	8.61569
PREDO	13.0632	8.6039	1.52	0.131	-3.932817	30.05923
PGARD	1.7557	5.1879	0.34	0.736	-8.00372	8.492342
PREM	25.8707	13.0801	1.98**	0.050	0.0323401	51.70901
ACESS	-0.1795	0.4983	-0.36	0.719	-1.1639221	0.8049384
FTOLET 2	15.7818	7.0176	2.25**	0.026	1.919358	29.64423
OCHH	-8.3841	6.2790	-1.34	0.184	-20..78745	4.019263
Cons.	44.1852	22.7706	1.94*	0.054	-0.7955769	89.16595

*** Statistically significant at 1% significance level

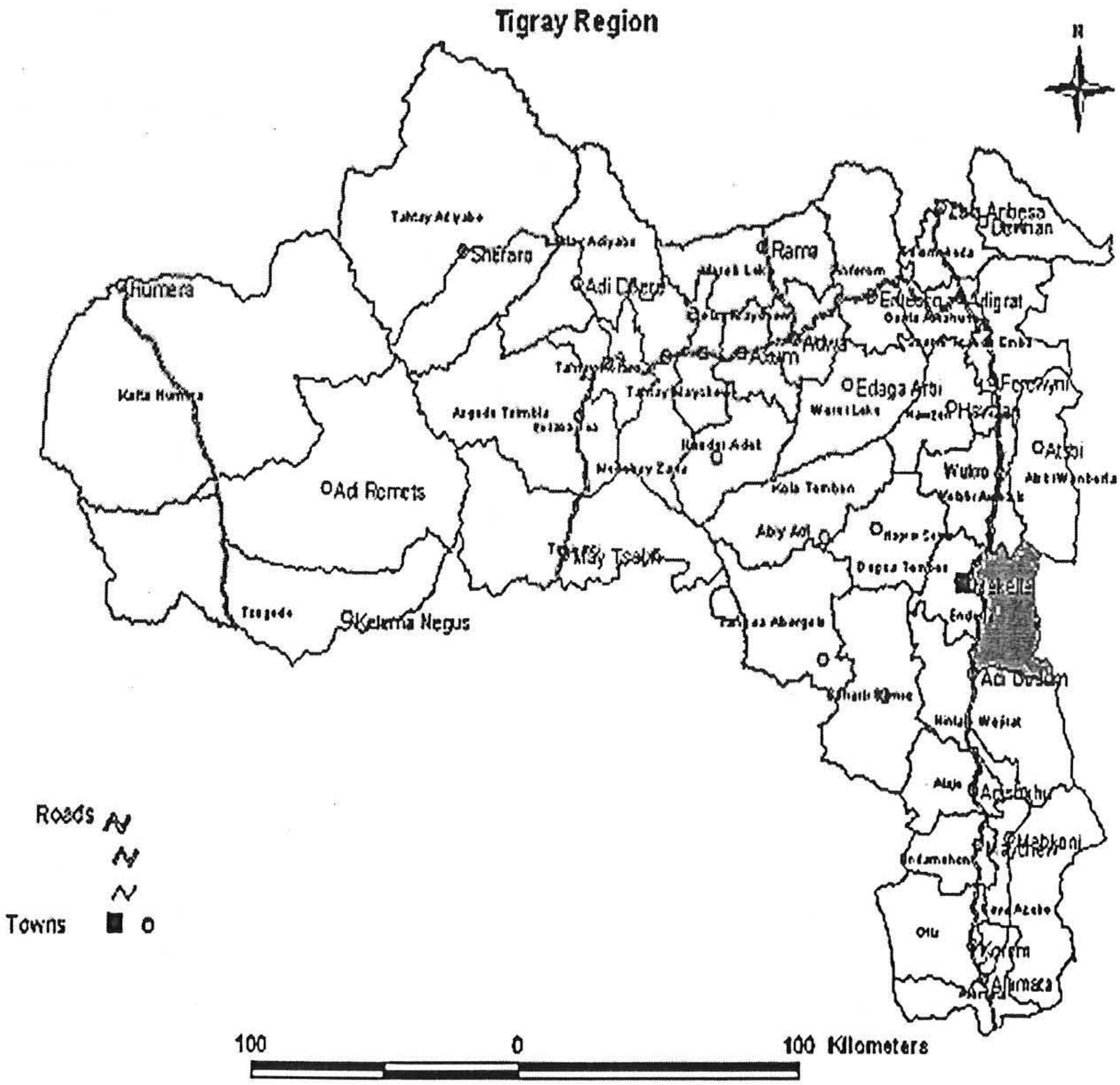
** Statistically significant at 5% significance level

* Statistically significant at 10% significance level

Appendix 5: Map of Ethiopia



Appendix 6: Map of Tigray Region



Appendix 7: Household water supply and consumption sample survey questionnaire

Introduction of the Survey

Bihon Kassa is currently studying at Addis Ababa University. This research is in partial fulfillment for the award of his M.A. in Regional and Local Development Studies (RLDS).

We are asking questions to some households in Mekelle town about the current situation of water supply service and household consumption levels. So your response will be used as important input to policy makers and officials in their attempt to improve the water supply system of the town.

This interview will take a few minutes and is completely confidential, strictly for academic purpose. Therefore, honest discussion is the best way a head.

Name of enumerator ________________

Name of supervisor ________________

A. Socio-economic Characteristics

Q1. Address:

Woreda ____________________

Kebele ____________________

House No. ____________________

Q2. Religion:

☐ 1 Christian

☐ 2 Muslim

☐ 3 Others, specify ____________

Q3. Household size _________ (number)

Q4. Age, sex, educational and employment status of household members.

Sr. No	Age	Sex		Educational status		Employment status		
		M	F	Illiterate	Grade if literate	Unemployed	Employed	Student
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								

Q5. Type of occupation and monthly income of the employed family members.

Sr No.	Occupation						Monthly income (Birr)
	Government	NGOS	business		Agriculture	Daily laborer	
			owner	employed			
1							
2							
3							
4							
5							
6							
7							

Total ______________ (birr/ month)

Q6.a. Does the household have any source of income other than those explained above?

☐ 0 No ☐ 1 Yes

Q6.b. If yes, state the amount (monthly) in birr ____________.

Q7. House ownership status.

☐ 1 private owned ☐ 3 others, specify ___________

☐ 2 rented

Q8.Is there any garden in your compound?

- ▢ 0 No
- ▢ 1 Yes

Q9.Do you have domestic animal living in your compound?

- ▢ 0 No
- ▢ 1 Yes

Q10. Do you have an automobile?

- ▢ 0 No
- ▢ 1 Yes

B. Water supply and demand

Q11. Which source of water supply do you use for household purpose?

- ▢ 1 piped water
- ▢ 4 river
- ▢ 2 hand-dug well
- ▢ 5 rain water
- ▢ 3 spring
- ▢ 6 piped and rain

Q12. a. Do you use the same source of water supply throughout the year?

- ▢ 0 No
- ▢ 1 Yes

Q12. b. If no, what type of water supply do you use during dry seasons?

- ▢ 1 piped water
- ▢ 5 piped and hand-dug well
- ▢ 2 hand-dug well
- ▢ 6 piped and river
- ▢ 3 spring
- ▢ 7 piped and spring
- ▢ 4 river
- ▢ 8 piped, well, and/or spring

Q12. c. If no, what type of water supply do you use during rainy seasons?

- ▢ 1 piped water
- ▢ 5 rain water
- ▢ 2 hand-dug well
- ▢ 6 piped and rain water
- ▢ 3 spring
- ▢ 7 piped water and hand-dug well
- ▢ 4 river
- ▢ 8 piped, hand-dug well and rain water

Q13. a. Do you use the same source of water supply for different household purposes (e.g. cooking, drinking, washing. etc.)?

- ▢ 0 No
- ▢ 1 Yes

Q13.b. If no, indicate your source for cooking and drinking.

- ▢ 1 piped water
- ▢ 5 river water
- ▢ 2 hand-dug well
- ▢ 6 piped and hand-dug well
- ▢ 3 springs water
- ▢ 7 piped and rain water
- ▢ 4 rain water
- ▢ 8 piped, hand-dug well and rain

Q14. What is your source of water other than drinking and cooking (e.g. gardening, car washing, etc.)?

- ▢ 1 piped water
- ▢ 5 river water
- ▢ 2 hand-dug well
- ▢ 6 piped water and rainwater
- ▢ 3 springs
- ▢ 7 piped, hand-dug well and rainwater
- ▢ 4 rainwater

C. Private House Connection (Metered) Water Users

Q15. Where is the location of your water tap?

- ▢ 1 inside the house
- ▢ 3 in both
- ▢ 2 in the compound (yard)

Q16. a. Had there been any water supply interruption from your private connection during the last twelve months(March,2005 up to February 2006)?

- ▢ 0 No
- ▢ 1 Yes

Q16. b. If yes, in which season of the year?

- ▢ 1 dry season
- ▢ 2 rainy season

Q16.c. On average bases, indicate the frequency of this interruption

- ▢ 1 daily
- ▢ 3 monthly
- ▢ 2 weekly
- ▢ 4 seasonally

Q16.d. n average bases, indicate the duration of interruption

- ▢ 1 for a week or less
- ▢ 4 for 1 to 2 months
- ▢ 2 for 8 to 15 days
- ▢ 5 for more than two months
- ▢ 3 for 16 to 30 days

Q17. Where do you get water from at the time of water supply interruption?

- ▢ 1 reservoir
- ▢ 2 buying from neighbors/ vendors
- ▢ 3 buying from public stand pipes
- ▢ 4 hand – dug well
- ▢ 5 river, spring
- ▢ 6 neighbors and river/spring
- ▢ 7 neighbors and well

Q18. What is the approximate round trip time taken to fetch water during tap water interruption? Time: ______ hour_______ minutes

Q19. How much water does the household use per day during water supply service interruption? _____________ liters.

Q20. a. How much water does the household use per day when no water supply interruption? ___________liters.

Q20. b. Do you know the causes for water service interruption?

☐ 0 No ☐ 1 Yes

Q20.c. If yes, what are these causes?

☐ 1 power cut

☐ 2 shortage of water at the source

☐ 3 lack of enough pressure in distribution system

☐ 4 lack of maintenance

☐ 05 lack of water and maintenance

Q21. a. Do you sell water from your private connection?

☐ 0 No ☐ 1 Yes

Q21.b. If yes, for how many households? ______________ (number)

Q21.c. What is their average daily water consumption per household? _________________ liters/ household/ day.

Q22.a. Do you have water well in addition to piped water of your own?

☐ 0 No ☐ 1 Yes

Q22.b. If yes, for which purpose(s) you usually use well water?

☐ 1 garden watering ☐ 4 for watering animals

☐ 2 car washing ☐ 5 for all purpose

☐ 3 for bathing ☐ 6 garden and animal watering

Q23. a. Do you have water tanker?

☐ 0 No ☐ 1 Yes

Q23. b. If yes, what is its capacity in liters?

☐ 1 below 1000 liters ☐ 4 3001-4000 liters

☐ 2 1001-2000 liters ☐ 5 4001-5000 liters

☐ 3 2001-3000 liters ☐ 6 more than 5000 liters

Q24. Would you please show your water consumption bill, which you have covered, from March, 2005 to February, 2006.

Months of the year	Amount (liters)	Cost (Birr)	Months of the year	Amount (liters)	Cost (Birr)
March			September		
April			October		
May			November		
June			December		
July			January		
August			February		

Grand total _______________ liters

Average monthly consumption ___________ liters

D. Households sharing a common yard tap

Q25. If you are sharing a common yard tap, what are the numbers of households? _______________ (number)

Q26. How many taps does the yard connection has? ________ (number)

Q27. How much water per day do you use on the average? _______ liters/day.

Q28. For what purpose is the water from this source used?

- ☐ 1 drinking and cooking
- ☐ 2 washing clothes
- ☐ 3 livestock watering
- ☐ 4 garden watering
- ☐ 5 drinking, cooking and washing
- ☐ 6 drinking, cooking washing and livestock watering
- ☐ 7 for all purposes

E. Neighbors' Private Connection Water Supply Users

Q29. If you consume water from your neighbor's private connection, how do you use it?

- ☐ 1 pay directly in cash
- ☐ 2 on monthly contractual basis
- ☐ 3 sharing the bill with other users equally
- ☐ 4 others, specify ___________________________

Q30. How much water do you use on the average?_______ liters/day

Q31. a. Is there any seasonal variation in the price of water?

☐ 0 No ☐ 1 Yes

Q31. b. If yes, what is the price per container during dry and rainy season?

	Dry season	<u>Rainy season</u>
1 price per bucket	___________	___________
2 price per pot	___________	___________
3 price per barrel	___________	___________
4 price per Jerican	___________	___________
5 others, specify	___________	___________

F. Public Stand Pipe Water Users (Access)

Q32. If you fetch water from public standpipes, what is the approximate round trip time taken? Time: _________ hour_________ minutes

·Q33. What type of container do you use for fetching water?

☐ 1 bucket ☐ 4 barrel

☐ 2 pot ☐ 5 others, specify ________

☐ 3 Jarican

Q34. How many times do you fetch water from the public standpipes? _________ times/day

Q35. How much water does the household consume from the public standpipes per day? ____________ liters/day

Q35. How many taps, on the average, function most of the time? _______(number)

Q36. a. Had there been any interruption of water supply form the public stand pies?

☐ 0 No ☐ 1 Yes

Q36. b. If yes, on the average, how frequent was this interruption?

☐ 1 daily ☐ 3 monthly

☐ 2 weekly ☐ 4 seasonally

Q36.c. On the average, indicate the duration of interruption

- ▢ 1 for a week
- ▢ 4 for 1 to 2 months
- ▢ 2 for 8 to 15 day
- ▢ 5 for more than 2 months
- ▢ 3 for 16 to 30 days

Q37. Whenever there is an interruption, from where do you get water?

- ▢ 1 buying from neighbors/ vendors
- ▢ 2 buying from another public stand pipes
- ▢ 3 rivers, springs
- ▢ 4 others, specify ____________________

Q38. How much time do you spend in queuing at the public standpipes to get water? ________ hours and ________ minutes.

Q39. a. Have you ever placed a request for private meter?

- ▢ 0 No
- ▢ 1 Yes

Q39. b. If no, indicate the major reasons.

- ▢ 1 high installation costs
- ▢ 3 cheaper from stand pipes.
- ▢ 2 near by stand pipes
- ▢ 4 others, specify __________

Q39. c. If yes, indicate the time elapsed since you placed the request?

________ years and ________ months.

Q40. State the reason why you did not get private connection so far?

- ▢ 1 do not know
- ▢ 4 inefficient bureaucracy
- ▢ 2 shortage of meters
- ▢ 5 others, specify __________
- ▢ 3 shortage of pipes

Q41. a. Does the household have bathrooms?

- ▢ 0 No
- ▢ 1 Yes

Q41.b. If yes, how many? ____________ (number)

Q42. a. Does the household have shower room?

- ▢ 0 No
- ▢ 1 Yes

Q42. b. If yes, how many? ______________ (number)

Q43. Does the household have water boiler?

- ▢ 0 No
- ▢ 1 Yes

Q44. a. Do you have toilet room?

☐ 0 No ☐ 1 Yes

Q44. b. If yes, what type of toilet do you have?

☐ 1 flushing toilet ☐ 3 dry pit latrine

☐ 2 flushing by tin ☐ 4 flush and flushing by tin

Q44. c. If you have a flush toilet, indicate the number_______________

Q45. Do you have cloth washing machine?

☐ 0 No ☐ 1 Yes

Q46. Do you have kitchen with a complete water supply service?

☐ 0 No ☐ 1 Yes

Q47. If you have automobile, where do you get it washed?

☐ 1 inside the compound

☐ 2 in a garage

☐ 3 others, specify ________________________

Q48. If the automobile is washed inside your compound state the frequency of washing.

☐ 1 daily ☐ 4 once a week

☐ 2 three times a week ☐ 5 Others, specify____________

☐ 3 twice a week

Q49. How much water do you need to wash the automobile at a time?

__________ liters.

G. Body Washing or Bathing

Q50. Where do the members of your family usually take bath?

☐ 1 inside compound ☐ 3 rivers

☐ 2 near by stand pipes ☐ 4 others, specify ___________

Q51. Please state the frequency of bathing of your household member.

☐ 1 daily ☐ 4 every seven days

☐ 2 every two days ☐ 5 every fourteen days or more

☐ 3 every three days

Q52. Where do you usually wash your clothes?

- ☐ 1 inside compound
- ☐ 3 rivers
- ☐ 2 near by stand pipes
- ☐ 4 others, specify ___________

Q53. On the average, indicate the frequency of cloth washing

- ☐ 1 every week
- ☐ 4 every month
- ☐ 2 every two weeks
- ☐ 5 others, specify___________
- ☐ 3 every three weeks

H. Possession of Domestic Animals

Q54. If you have domestic animals in your compound, please answer the following questions.

Sr. no	Types of animal	Number of animals	Frequency of watering	Amount of water consumed at a time	Place of watering	
					Dry season	Rainy season
·1	Cow/ox					
2	Sheep/ goat					
3	Horse/mule					
4	Donkey					
5	Others					

Total ___________ liters/month

N. B.

1. Write the number of frequency of watering from the following choices.
   1 twice a day
   2 once a day
   3 every two days or more
2. Write the number for place of watering from the following choices.
   1 inside compound
   2 near public stand pipes
   3 troughs
   4 river
   5 others, specify _______

I. Possession of garden in dwelling unit

Q55. a. Do you have any garden in your compound?

- ☐ 0 No
- ☐ 1 Yes