teknillinen korkeakoulu
tekniikan osasto
ympäristötekniikan laitos

Tampere University of Technology
Department of Civil Engineering
Institute of Water and Environmental Engineering
Postgraduate Course in Water Supply and Sanitation 1986-88
in co-operation with
Finnish International Development Agency
FINNIDA

N:o B 33

Mesfin, Tegene

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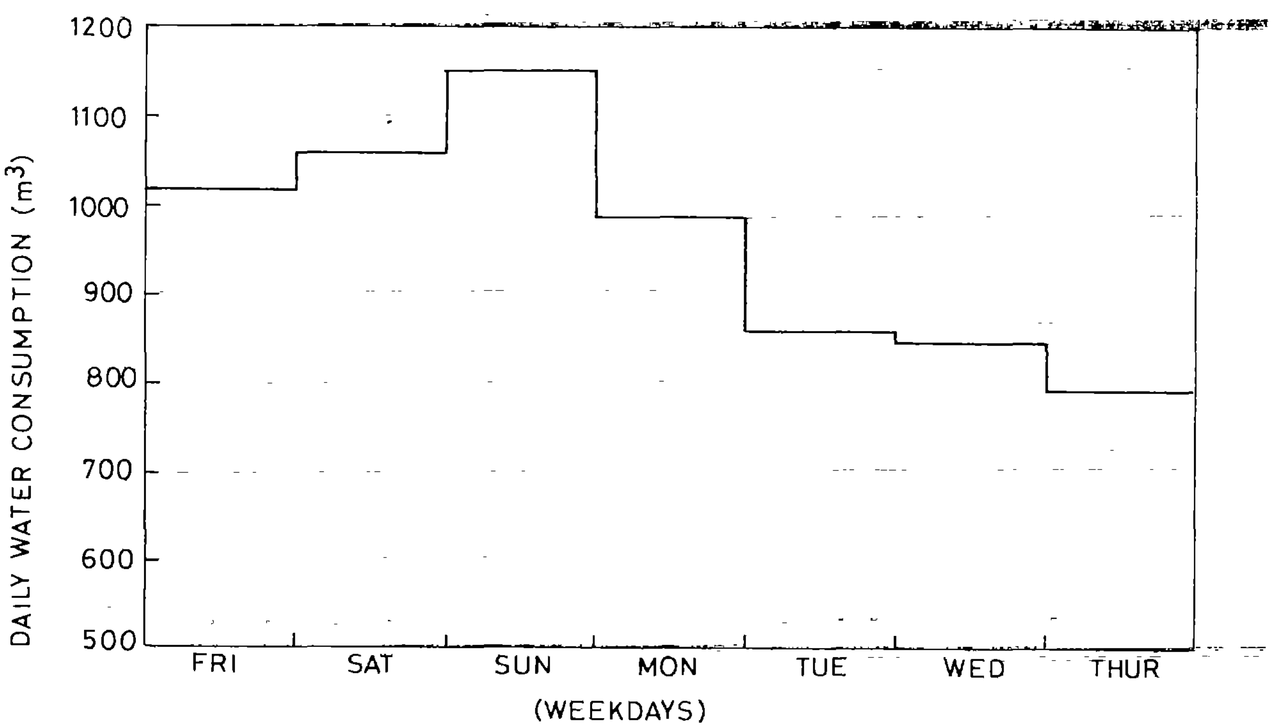

Tampere 1988

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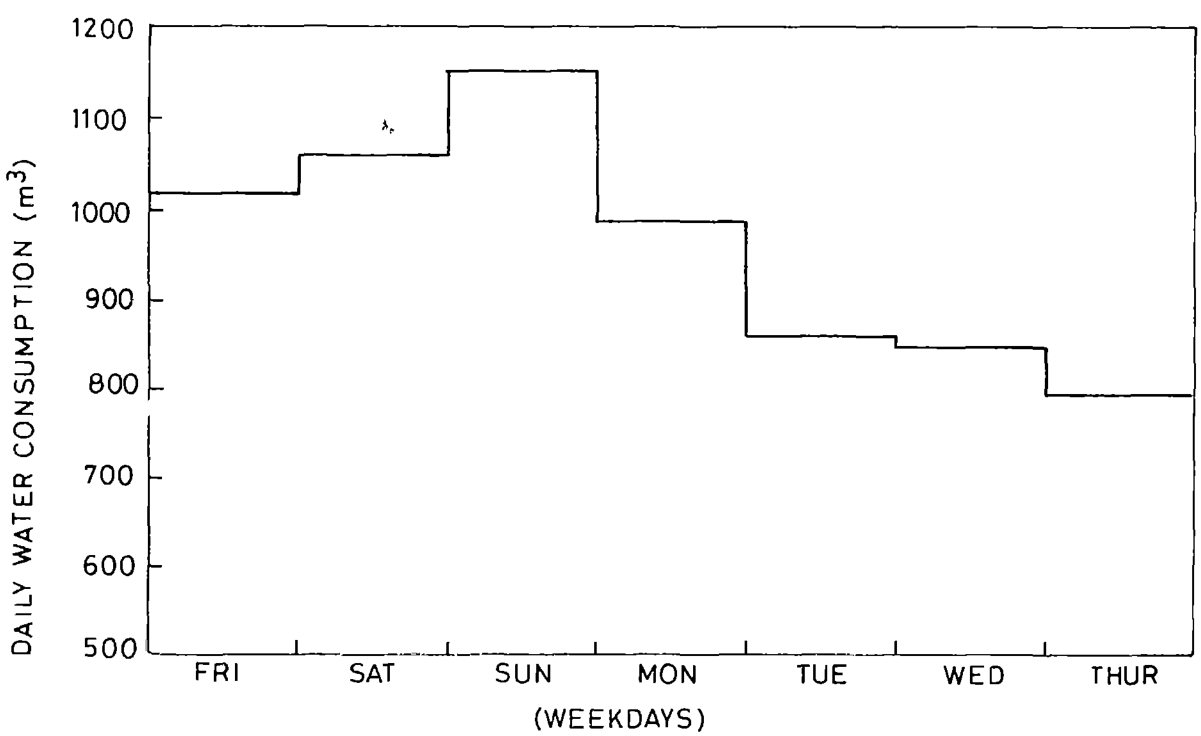


UDK 628.17
ISBN 951-721-254-2
ISSN 0784-655X

Tampere 1988

WATER CONSUMPTION AND PEAK FACTORS WITH REFERENCE TO AWASSA TOWN WATER SUPPLY IN ETHIOPIA

TABLE OF CONTENTS Page

ABSTRACT

1 INTRODUCTION 1

2 WATER DEMAND AND WATER CONSUMPTION 3
2.1 Definitions 3
2.2 Categories for Usage of Water 3
2.2.1 Domestic Consumption 3
2.2.2 Industrial Consumption 7
2.2.3 Public and Commercial Uses 8
2.2.4 Agricultural and Livestock Uses 9
2.2.5 Fire Demand 9
2.3 System Losses 10

3 FACTORS AFFECTING WATER USE 12
3.1 Climatic Conditions 12
3.2 Standard of Living 12
3.3 Household Size 13
3.4 Accessibility and Availability of Water 14
3.5 Level of Education 14
3.6 Pressure of the System 15
3.7 Metering 15
3.8 Price of Water 16

4 PLANNING AND DESIGN ASPECTS OF DOMESTIC WATER SUPPLIES 18
4.1 Forecasting of Water Demand 18
4.1.1 Methods of Demand Forecasting 19
4.1.2 Design Period 20
4.1.3 Population Projection 20
4.1.4 Consumption Projection 21
4.2 Variations in Consumption and Peak Factors 22
4.2.1 Types of Variation in Consumption 22
4.2.2 Methods of Controlling Peak Loads 25
4.3 Distribution System 27
4.3.1 General Layout 27
4.3.2 Pumping and Storage 28
4.3.3 Pressure Requirement 31

5 ANALYSIS OF THE WATER SUPPLY SYSTEM OF AWASSA 32
5.1 Location of the Town 32
5.2 Demographic Data 32
5.3 Existing Water Supply System 34
5.3.1 Intake and Wet Well 36
5.3.2 Treatment Process 37
5.3.3 Reservoirs 38
5.3.4 Distribution Network 39
5.4 Trends of Water Consumption in Awassa Town 39
5.5 Losses in the System 40

6 RESULTS OF THE SURVEY 42
6.1 Period of Survey 42
6.2 Checking of the Meters 42
6.3 Estimation of Per Capita Water Consumption 43
6.3.1 Public Stand Pipes 43
6.3.2 Yard Connections 44
6.3.3 In-house Connections 45
6.3.4 Public and Commercial Uses 47
6.4 Variation of Water Uses 47
6.4.1 Seasonal Variation 47
6.4.2 Daily and Hourly Variation 48
6.4.3 Peak Factors 52

7 DISCUSSION 54

8 RECOMMENDATIONS 57

REFERENCES 58

ABSTRACT

The studies on the patterns of water consumption will help in predicting water demand to an adequate degree of accuracy. This could satisfy the needs of the various users and also optimize the costs of water supply schemes.

The knowledge of the socio-economic factors affecting consumption will not only indicate the reasons for the variations in per capita consumption, but will also improve water demand forecasting.

This study examines the per capita water consumption patterns in a typical urban town named "Awassa" in Ethiopia. The survey indicates average per capita consumptions of 65 l/c/d for modern houses with in-house connections, 28 l/c/d for local houses with yard connections and 9 l/c/d for consumptions from public standpipes. Availability of numerous hand dug wells, larger number of inhabitants per household, higher costs of installation and price of water and shorter duration of opening hours for public standpipes were seen to account for these smaller per capita consumption values.

A maximum daily peak factor of 1.20 and a maximum hourly peak factor of 2.30 are also obtained which closely match with the assumed design values of 1.25 and 2.40 respectively.

1 INTRODUCTION

There has been a continuous interest in the study of water consumption patterns by different user categories in various countries. Apart from conservation of the valuable water resources, these studies will help to build efficient and economical water supply systems.

The rate of per capita water consumption is seen to vary from a few litres per day to hundreds of litres per day. Besides the economic capability of a country, various factors like standard of living, climate , price of water , system pressure, activity of area and other water using habits are seen to influence the patterns of water consumption.

For determining per capita water consumption, two methods are often employed:

- Noting readings of consumption with master meters attached to source outputs or storage tanks and dividing by the number of people estimated to be served.

- Selection of dwellings of different classes, noting individual meter readings and the number of inhabitants residing in each dwelling.

In order to analyze the per capita water consumption, the factors affecting and timely variations of water usage in Ethiopia, a typical urban town named 'AWASSA' has been chosen.

According to the type of dwelling and the water supply system connection, two major categories were studied:

- Modern houses with brick/hollow block walls, cement/plastic floors having in-house connections.

- Local houses made of wooden pole houses with earthen floors and owning yard connections.

The rates of consumptions on some of the public standpipes have also been indicated.

Questionnaires were distributed prior to the survey to assess the number of inhabitants in a household and the opinions they had on the water supply system.

Some of the public and commercial users were also analyzed to see their rates of consumption.

The need for a proper planning and design practice is necessary in any water supply undertaking. The costs of studies and design will be repaid many times over by the reduction in investment and operating costs.

In view of this, the present planning and design practices of the urban schemes of Ethiopia have been given together with the experiences of other similar developing countries.

These practices of developing countries could be tailored to suit the local conditions of Ethiopia and hence guidelines for design criteria could be established.

2 WATER DEMAND AND WATER CONSUMPTION

2.1 Definitions

The terms water demand and water consumption are often used interchangeably. However, the differences should be noted while using them. Water demand refers to the planning value resulting from observation of water consumption as derived from a forecast datum. Water consumption is the value reached in the past and at present as a result of local needs and conditions (Tessendorff, 1972). Hence the values for water demand could fairly be predicated from the analysis of water consumption patterns.

2.2 Categories for Usage of Water

Water is used domestically for household purposes, to maintain hygiene and keep the growth of plants and trees. Apart from this purpose it is used for public uses like in hospitals and schools.

Its use also goes to the manufacture of tools and equipments necessary for life. The main usages of water are listed below and are explained in the context.

- domestic consumption
- industrial consumption
- public and commercial uses
- agricultural and livestock uses
- fire fighting.

2.2.1 Domestic Consumption

Domestic water use includes water used for cooking, drinking, house cleaning, washing of clothes, sprinkling and sanitation. The water used in drinking helps for physiological processes such as blood formation and food assimilation. Prevalent diseases are by far reduced by using water for sanitation and hygienic purposes. Once these essentials are satisfied a householder uses water for sprinkling and other outdoor purposes.

The amount of water used for garden watering and lawn sprinkling is found to be a function of rainfall, average temperature, water price and house value (Danielson, 1979).

Current studies separate domestic water use into in-house purposes (drinking, cooking, ablution) and outdoor purposes (sprinkling and car washing). This is mainly due to:

- The importance of sprinkling demand as a determinant of water system capacity required.
- The significant difference in responsiveness of the two demands to the price of water.

In some countries sprinkling use of water could constitute a major portion of the total water consumption. Surveys in the U.S.A. have revealed that 25 % to 50 % of the total annual domestic demand is for sprinkling use (Twort et al 1985).

Domestic use of water is satisfied by the following means:

- in-house connection
- yard connection
- public standpipes.

An in-house connection provides one or more taps connected with in-house plumbing fixtures. As the number of outlets is higher the consumption from these type of connections is likely to increase as compared with other types of systems. The breakdown of domestic water usage is shown in Table 1 obtained from surveys in Indian towns.

Table 1. Average values for components of domestic water usage (Birdi, 1979).

Usage	INDIA	
	l/c/d	%
Drinking and cooking	10	7
Flushing latrines	30	22
Ablution	55	41
Dish washing and cleaning houses	20	15
Clothes washing	20	15
TOTAL	135	100

A yard connection is similar to an in-house connection the only difference being that one or more taps are placed in the yard outside the house and in-house fixtures are not provided. They are usually installed as an intermediate step towards a fully house connected system, which in turn depends on the designed system and the economic capacity of the people. Figure 1 shows a typical yard connection.

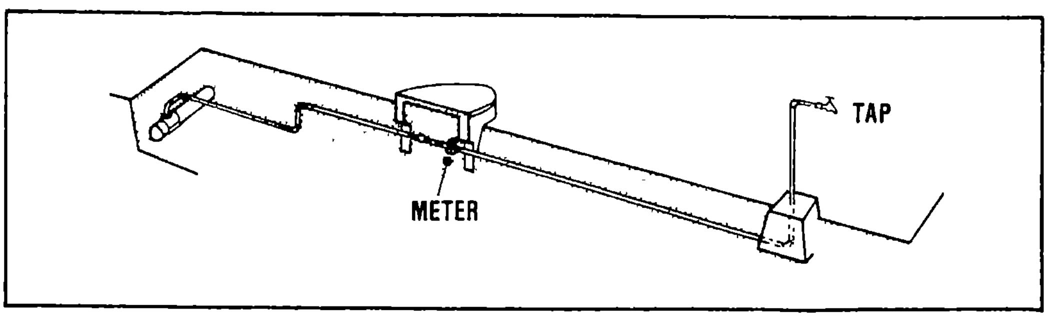


Figure 1. A typical yard connection (Hofkes, 1985).

Public standpipes have long been in use in supplying water to communities owing to their cheap cost and technical feasibility. They are usually made of masonry, brickwork or concrete. A service pipe is built through the structure and is connected to one or more taps. Figure 2 shows a typical cross section of a multiple-tap standpipe.

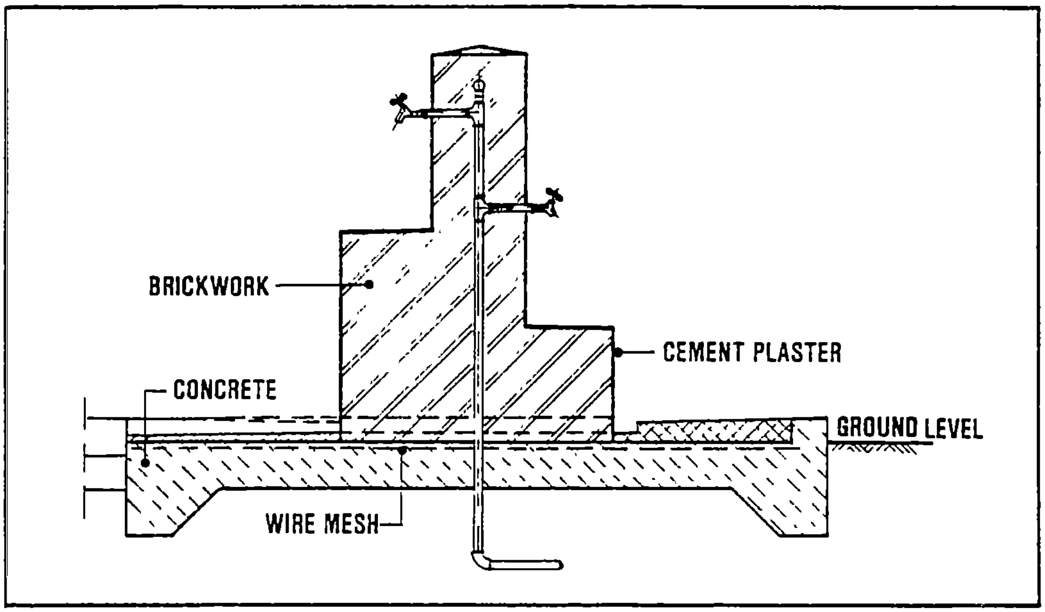


Figure 2. Cross section of a multiple tap standpipe (Hofkes, 1985)

The water used for puposes other than drinking and cooking is limited when the water is fetched from public standpipes. Personal hygiene and sanitation are better encouraged by yard and house connection (Hofkes, 1985). Although reasonable service for 250 - 300 persons could be obtained from multiple tap standpipes, practices indicate higher consumption of users in yard and house connections. Table 2 shows the rates of consumption in three West African countries.

Table 2. Rate of consumption at standpipes (Feachem et al 1980).

Country/city	Average number of persons per standpipe	Average consumption (l/c/d)	Water tariff at standpipe ($ US/m^3)
UPPER VOLTA			
Ouagadougou	1 850	6.5	0.3
Bobodioulasso	1 550	5	0.3
GABON			
Libreville	3 300	7	0.5
Port Gentil	750	10	0.5
Lambarene	1 200	2	0.5
CAMEROUN			
Douala	1 450	8.5	0.2
Yaounde	2 250	7	0.3

Domestic water use is the main factor in predicting the water demand and in some cases it may be the sole parameter to be considered. Table 3 shows the distribution of water consumption by the various user categories in Nairobi, Kenya.

Table 3. Water consumption by user categories expressed as percentage of total supply (Nairobi City Council 1977 cited by Ngari, 1986).

Category	1967	1975	1984
Industrial	8.6	9.7	10.0
Commercial	14.7	14.8	15.5
Public: Government Nairobi city Commission	9.9	8.7	8.7
Domestic	51.1	50.0	52.2
Unaccounted-for	15.7	16.8	16.8
TOTAL	100	100	100

As could be seen from the above table, domestic water consumption forms about half of the total water consumption.

2.2.2 Industrial Consumption

The water used in industries is mainly for the following purposes:

- manufacture of products (textiles, chemicals, paper, food)
- air conditioning
- generation of energy by producing steam
- transport of raw materials or waste products
- rinsing of components or products.

Although the proportions of water used vary according to the type of industry, cooling (in the power industry and manufacturing) is the dominant industrial water use and could constitute as much as 60 % to 80 % of the total demand (UN, 1976), To analyze the important components of industrial water use the terms "gross water requirement" and "consumptive use" should be differentiated and studied.

Gross water requirement constitutes the total intake of water for a specific industry. A portion of it is consumed while the remaining part is discharged as waste. Due care is not usually given to this as the total cost of water supply represents only a very small part (usually below 1 %) of the total production cost of the output (UN, 1976). However the growing demand of water has led to economize and reduce the amounts withdrawn and disposed. Apart from legislation and economic incentives which help in reducing waste loads in the effluent, reuse and recirculation of water are being carried out.

Reuse implies the usage of water in an open system for two succesive but different purposes while recirculation is the indefinite reuse of the same water for the same purpose (Degremont 1979). Recirculation plants should take care of alkaline sulphates, soluble minerals and degradable organic matter to prevent precipitation, minimize corrosion and hinder the growth of bacteria.

Consumptive use is the net amount of water utilized by an industry and is normally much less than the gross water intake. The ratio of the consumptive use to the total intake of water determines the efficiency of the water usage for an industry. Table 4 shows the consumptive use amounts expressed as percentage of intake in different types of industries.

Table 4. Percentage of consumptive use in industries (UN,1976).

Type of industry	Water consumption (percentage of intake)
Automobile	6.2
Textiles	6.7
Food Processing	33.6
Machinery	21.4
Chemicals	5.9
Steel	7.3
Petroleum	7.2
Distillery	10.4

In some countries the demand of water for industries is expressed in terms of the floor area. This is usually determined by discussing with the concerned authorities of industries. In Tanzania, industries are divided into categories for estimation of future water needs and Table 5 indicates the demand of water for industries in the absence of detailed specifications.

Table 5. Industrial Water demand (m^3/ha/d) for future industries (Ministry of Water ... 1982).

Industry type	Water demand m^3/ha/d
Large scale (water intensive)	60
Medium scale (medium water intensive)	20
Small scale (dry)	5

2.2.3 Public and Commercial Uses

The water required for uses in schools, hospitals, day care centres, city halls, public parks, churches and offices is classified as public uses. Commercial water uses include hotels, restaurants, bars, shops and service stations.

The demand for these categories depend on the purpose of buildings built, the number of visitors and/or residents, the floor space and the type of activities. Although the water used for these purposes vary, typical rates of usage are shown in Table 6 for three countries.

Table 6. Water usage for public and commercial purposes.

No.	Usage	Units	Country: England (Twort et al 1985)	Country: India (Birdi 1979)	Country: Kenya (Ministry of Water...1978)
1	Hospitals				
	- regional	Lit/Bed/day			400
	- district	- " -	350 - 500	340 - 450	200
	- other	- " -			100
2	Hotels				
	- high class	Lit/Bed/day			600
	- medium class	_ " _	250	180	300
	- low class	_ " _			50
3	Offices		65	45	25
4	Schools				
	- day	Lit/Head/day	25	45	10 - 25
	- boarding	_ " _	75	135	50

Some countries do not adopt metered connection on public usage of water while others meter these uses and do not charge for the services. Similarly excess sprinkling of public parks is observed in many countries. These conditions should be given due care as enormous amount of water is wasted which could have been utilized for other important purposes.

2.2.4 Agricultural and Livestock Uses

Water is one of the basic necessities for agricultural production and existence of livestocks. In agriculture, the use of water extends from small farm house purposes to irrigation of crops in large areas. Since the demand for these purposes is high, abstractions from public supplies is not economical and hence private sources are normally used to satisfy the requirements of agricultural uses.

The demand of water for livestocks is normally given in livestock units. In Tanzania 25 l/livestock unit/day is recommended for local breed (Ministry of Water ... 1982). On the other hand for rural areas and local/market centres of urban areas of Kenya, 75 l/livestock unit/day is recommended (Ministry of Water ... 1978). It should be noted that in studying the demand of water for livestock, care should be given to the natural water in streams and ponds to enable the livestock to use them.

2.2.5 Fire Demand

The quantity of water required for fire fighting purposes is termed as fire demand. To accomplish this, water is extracted either directly from wells and rivers or from fire hydrants. Fire trucks are normally used to convey and apply the water to the point of interest. Duration of the fire and the design fire flow are the two components upon which the demand for fire fighting depends.

In most urban towns fire hydrants are used to satisfy the demand of fire fighting. Fire hydrants are normally two types, those located below ground level termed as underground hydrants and those ones projecting above ground level are called post hydrants. Table 7 shows design standards for fire hydrants in different countries with the quantities of water required.

Table 7. Typical hydrant properties in different countries
[1] (Bernis and Galan 1976).
[2] (Ministry of Water ... 1982).

Hydrant Characteristics	Country			
	Belgium[1]	Switzerland[1]	USA[1]	Tanzania[2]
Quantity of water required	minimum 50 m^3/hr	minimum 54 m^3/hr	227 m^3/hr to 2725	minimum 36 m^3/hr
Minimum pipe diameter	100 mm and 150 mm	-	150 mm and 200 mm	100 mm
Distance between hydrants	100 m and 200 m	80 - 120 m	100 - 150 m	< 300 m

2.3 System Losses

All the water which goes into the distribution pipes does not reach the consumers. Some portion of it is lost due to leakage in the mains, valves, fittings and illegal water connections. In water supply systems totally metered, the unaccounted for water is the difference between the total metered input into the system and the total supplied as measured by meters of consumers (Twort et al 1985). The quantity of water lost due to the above reasons is uncertain and can not be accurately predicted. However the main factors causing the variation in the amount of losses should be noted and are described below.

High Pressure

Pressure has an effect on the amount of losses, since the higher the pressure the greater the calking effect on pipe joints. This causes rapid wear in the moving parts of water facilities resulting in losses. The increment in water demand leads to extension of new pipes from the existing network and this causes rise of pressure in the existing pipes. The increased pressure may burst the pipes, joint flexes which results in a big volume of water loss.

Illegal Connection

Unauthorized connections are sometimes made by individuals in water supply systems. One of the methods used is connecting a service pipe before the water meter so that consumptions could not be read. Frequent inspection of distribution systems and checking of larger consumptions could help in rectifying illegal connections. Defaulters should also be penalized by court of law to minimize the misuse of water.

Excessive Loads

Pipelines are normally designed to sustain internal and external loads. However in some cases they are seen to be subjected to loads beyond their design capacities. The forces that exceed the pipe strength can occur from excessive internal pressure which causes hoop stress failure resulting in the blow out of the weakest portion of the main wall (O'day, 1982).

In conditions where reinstatement of roads is not properly done, pipelines are likely to be exposed to severe external loads.

Installation of Pipes

One of the major factors resulting in large volume of losses is improper installation of pipes. Loading and unloading of pipes should be done with maximum precaution. Bedding materials free of gravel or stones should be used to minimize damages on pipes. Because of the risk of flooding and caving which could damage the pipes, long stretchs of open trenches should be avoided. The layer to be put immediately on top of the pipes should also be free of rocks which could damage pipes. Depending on the type of the system and on the frequency of leak detection and repair the amount of losses vary in different countries. One method of detecting losses is measuring minimum night flows (MNF). In this method flow measurements are noted during the period of minimum consumption (02 - 04 a.m.) by closing the supply and noting the level drops in reservoirs. In Kenya MNF of 20 % and 30 % were found for Nairobi West and Madaraka estates respectively (Ngari, 1986).

Figures of about 18 % MNF are the best that could be achieved for whole town supplies, and figures in the range of 23 % to 26 % are by no means unusual (Twort et al 1985). Continuous monitoring is necessary to know levels of losses and higher values indicate a need for intensive leakage repair.

3 FACTORS AFFECTING WATER USE

There are various factors which affect the rate of water consumption. Understanding these factors will help to predict the water demand with an adequate degree of accuracy and arrive at an economical and justifiable design of water supply systems. Because of this, these factors should be analyzed and studied before fixing the per capita demand of water.

3.1 Climatic Conditions

The use of water is usually highest in summer, particulary in dry, hot climates. In areas practicing lawn sprinkling, high consumption of water is observed during summer. As a result of differences in water consumption during summer and winter months, prediction of municipal water demands should be analyzed separating the two seasons. The water demand in winter has consistently been estimated to be price inelastic, whereas the summer demand appears to be more elastic (Al-Qunaibet and Johnston, 1985).

It should be noted that high water consumptions in hot climates can be caused by the following (AESL, 1982):

- increased bathing
- increased watering of private lawns and gardens
- increased watering of public boulevards and parks
- water cooling of air conditioners.

On the other hand, water use during winter months in cold climates may be surprisingly high. In some areas consumers run water faucets continuously to prevent water from freezing and bursting the pipes.

3.2 Standard of Living

The measure of the extent to which the value of an owned house is assessed, the ownership of physical goods, tools and equipments determines the standard of living in this context. Houses with separate kitchens, bathrooms, rooms with plaster floors need more water for washing.

Surveys aimed at analyzing factors of water consumption should incorporate the variation of per capita income with water use. One method of estimating per capita income is by dividing the total personal income by the number of population. The major difficulty with this method is obtaining the exact amounts of income in a household.

It should be noted that for residents who depend on private jobs, a prolonged duration is necessary in determining their income amounts as fluctuations prevail in shorter durations.

Cohchran and Cotton (1985) from studies made in Oklahoma City and Tulsa, U.S.A. have proved that income factor was always found to be a significant determinant of water demand and advice planners to incorporate income data into projecting water needs.

The importance of standards of living in influencing water consumption accords with the hypothesis that the need for domestic water supply varies with the level of economic development (Bannaga, 1979).

3.3 Household Size

One of the most important parameters affecting the amount of water use is the size and composition of a household. Various studies have proved that larger consumptions were found in households with smaller number of occupants. In Kigoma region, Tanzania households with 1 - 2 members were found to use 20 litres/capita/day while households with more than 10 members use only 12 litres/capita/day (Lomøy, 1983). Similar cases were also observed in Lesotho and some regions of East Africa (Feachem et al 1978; White et al 1972). Figure 3 shows the relationship obtained between household size and volume of water used per capita per day in Leshoto. As could be seen a markable relation prevails justifying the decrease in per capita water consumption with an increase in size of households.

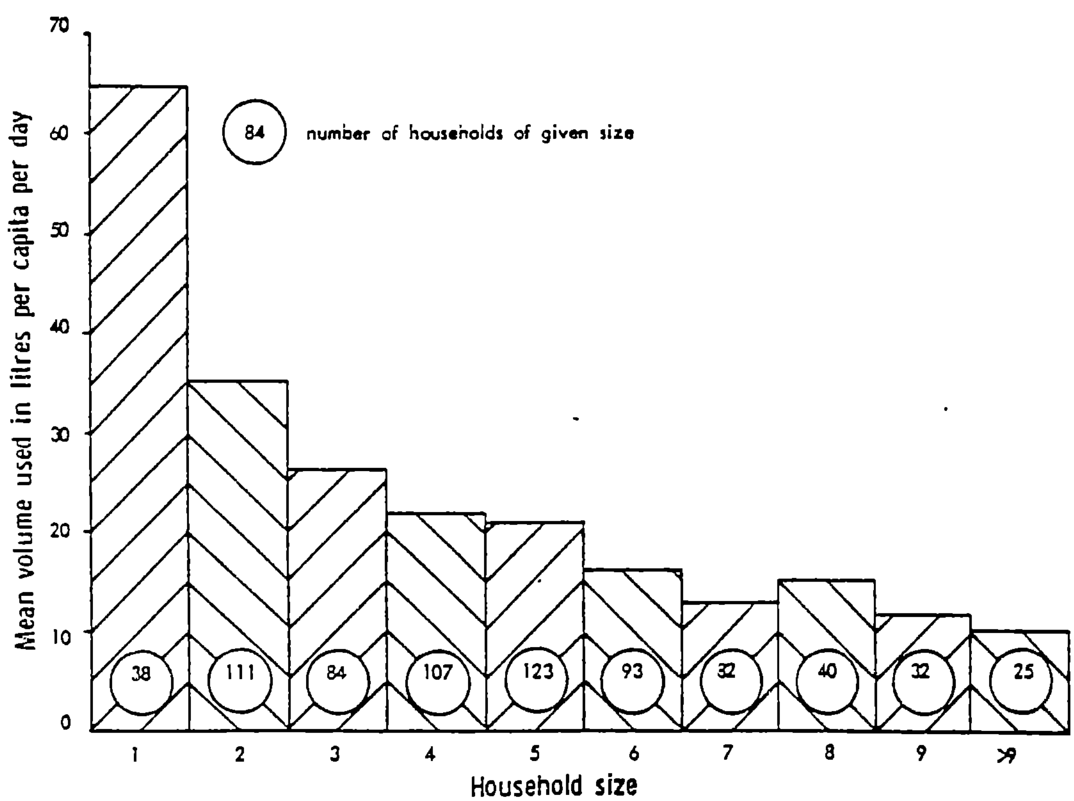


Figure 3. Relationship between household size and per capita water consumption in Lesotho (Feachem et al 1978).

Two possible reasons were given for the decrease in water consumption with household size. One is the common usage of commodities; since items like cleaning of toilets, cooking, washing of clothes and garden watering are shared, the larger the number in a household the less would be the per capita withdrawal. Each additional person needs less additional water. The second reason assumes a fixed time spent on water collection. In larger households there will be more persons to share the same amount resulting in a smaller per capita water consumption (Lomøy, 1983).

The number of children was found to be inversely related to the aggregate use in some East African regions and is suggested as a better measure for predicting per capita use. Although children require less water than adults, the demand of adults are more variable according to their age and occupation (White et al 1972).

3.4 Accessibility and Availability of Water

One of the factors which affects the use of water is the distance from a source to a household. Although surveys conducted in many countries do not indicate a linear relationship between per capita use and distance from the source, the rate of water consumption was found to decrease beyond some critical distances. In East Africa, studies made on some households in Kenya indicate that between 3 to 12 litres per capita per day were used from up to a distance of 1 mile while beyond this none of the users exceeded 5 litres (White et al 1972). A similar result was obtained in some parts of Lesotho where households with a water collection journey time of over 30 minutes tend to use slightly less water. A 30-minute round trip is required to a source about a kilometer away (Feachem et al 1978).

On the other hand, Lee 1969 cited by White et al (1972) showed that in the slums of Calcutta and Delhi, water carried home at distances of less than 30 feet was slightly less than at distances of 30 to 300 feet. Beyond 300 feet, it was 60 % higher.

Availability of water is another factor which affects the amount of water use by a community. Particularly in urban towns where people realize the advantages of potable water, shortage of water is a factor which reduces consumption.

3.5 Level of Education

The level of education attained in a household is found to be related to the total household use of water. Where teachers emphasize the importance of hygiene and sanitation, water consumption is likely to increase. From his studies made in Elobeid, the Sudan, Bannaga (1979) has shown the close relationship of water use to the level of education particularly in areas where people carry water. On the other hand from surveys in East Africa, it was observed that the highest level of education attained in a household did not appear to be related to the per capita use of people carrying water. However, for piped connections educational levels were directly related to per capita and total water use. The main reason being achievement of higher educational levels in areas of piped supplies (White et al 1972).

3.6 Pressure of the System

The rate of water consumption increases with the increase in the pressure of the system. One of the problems of water supply systems is inadequacy of pressure to satisfy the needs of people residing in tall buildings. An increase of pressure from 2 to 3 kg/cm^2 may lead to an increase in consumption to the extent of about 25 % to 30 % (Rangwala, 1986). Because of high pressures the amount of loss through leakages will also be higher. Hence designers should see to provide the lowest pressure that would render satisfactory service.

3.7 Metering

The policy of metering is one of the factors to be considered as it has effects on the rate of water consumption. Some of the advantages of metering include:

- to reduce loads on treatment plants and pumps
- control in wastage of water
- providing fair charges according to the amount used
- simplicity in locating points of leakage
- per capita consumption of households could be determined which helps in predicting future water use.

The main disadvantages of metering are:

- costs of installation, operation and maintenance could be high
- reduction of consumption leading to poor unhygienic practices
- loss of pressure resulting in additional pumping costs
- use of water for gardening is reduced which affects the economy and appearance of the community.

For the efficient operation of a water system, the amount of water entering a system and sold to consumers should be known. At least master meters should be installed which measure the water from the source or storage tanks.

One common aspect in the practice of metering is the reduction in consumption. Surveys indicate that the introduction of meters in houses with multiple taps has accounted for 20 - 40 % reduction in water use within the household (Hanke and Flack 1968). A substantial amount of water is also saved from excess sprinkling practices by installation of meters.

The decision of whether to meter or not should be made considering the above factors, comparing the cost of lost water through not metering against the costs of meters, costs of installation and maintenance. The analysis should be projected into the future for at least twenty years and all costs should be brought to present worth for comparison (Shipman 1966).

In order to reduce the errors in metering, care should be given to positioning, calibrating and maintaining of meters. Reports show that the ordinary small domestic meters tend to under-record consumption by at least 2 % when meters are up to five years old and by 3 % when meters are over five years old (Twort et al 1985).

3.8 Price of Water

The rate at which water is sold to consumers affects the rate of consumption. A water rate is defined as the basis of a system which permits the establishment of charges for water consumed (Shipman, 1966). Three different types of rate structures have been implemented by water authorities namely the flat, inclining and declining block rates.

Flat rate

A rating system where a fixed sum of money is charged for water services during a specific period of time regardless of the actual quantity of water consumed is called a flat rate (Hyle 1971). Some of the advantages of this system include

- simplicity in application and adminstration
- more readily accepted by users
- installation, reading and maintenance of meters is avoided.

During the times when the availability of water was in abundance and cheap, flat rates were widely used. However as this type of rating system leads to wastefulness and since it does not provide a proportional fair base for the water consumed it has given way to other types of rating systems.

Inclining rate system

A system where the rate per volume of water increases as the amount of water used increases is called an inclining rate. This type of system helps in conservation of water as customers will be highly charged for additional water uses.

Declining rate system

In declining type of rates the rate per volume of water decreases as the volume used increases. Plants which have a higher capacity and yet not exhaustively used prefer this system. Another advantage of this type of rating system is encouraging consumers to use a higher volume of water.

Various studies have been conducted to determine the price elasticity nature of water demand. Price elasticity of demand is defined as the relative change in quantity demanded as in response to a relative change in price if one assumes that the quantity demanded is a function of price (Reid 1982). If the absolute value of the elasticity is less than unity, the demand is said to be inelastic and when the elasticity is greater than one the demand is elastic.

One of the reasons for separating domestic use studies into sprinkling and in-house uses is the difference in response to price changes. Danielson (1979) from studies made in North Carolina, U.S.A. obtained price elasticities of -0.305 and -1.38 for in-house (winter) demands and sprinkling demands respectively. This means for a 10 % increase in price, the demand for in-house (winter) purposes will fall by 3.05 % and a corresponding decrease of 13.8 % for sprinkling uses. In-house demands are necessary for survival and consumers will not be responsive to the increase in price and therefore demand is relatively inelastic.

On the other hand studies conducted in Ugandan and Tanzanian towns suggest that domestic use did not change readily with price alteration (White et al 1972). The need to use price of water to regulate demand may, in any case be limited by the need to encourage adequate use by poorer section of the community without imposing too heavy a financial burden on them.

4 PLANNING AND DESIGN ASPECTS OF DOMESTIC WATER SUPPLIES

Planning for domestic water supplies should at least consider demographic changes, provision of water with sufficient quantity and desirable quality and the financial resources for capital investment, operation and maintenance problems. Different alternatives should be prepared to select the optimum system for a community. It should be noted that the cost of a supply system may not necessarily be the best criteria for selection. Flexibility to adjust capacity should also be considered. Development in stages with minimum of additional cost is desirable. Discussions with the community or with the intended users should also be made to assess their needs, opinions and possible suggestions.

Financial resources should be foreseen to make sure that the initial costs are covered and moreover the resulting operation and maintenance problems are properly tackled. Without proper and skilled manpower, any water system is bound to serious difficulties. Consideration should be made to train the necessary manpower to run the system satisfactorily.

The design of water supplies is the interpretation of the planning objectives into actual practice. The various alternatives are thoroughly investigated and selections are made. Cost-benefit analysis, choice of technology and sound engineering judgement are the basic tools to be used in every step of a system design.

In the absence of relevant data for the purposes of design, guidelines on criteria of design are important. Although the wider variation in local conditions could not allow establishment of rigid standards, guidelines which could be modified as per local situations have proved to be beneficial. These could be prepared from investigation of the water use patterns over the country, the general economic conditions and the experience gained from other countries.

With adequate planning proceeding well ahead of design, optimum use of water supplies could be achieved.

4.1 Forecasting of Water Demand

A forecast or prediction is defined as a statement concerning unknown and especially future events. 'Forecast' and 'prediction' may be used interchangeably, but they must be distinguished from a projection which is a type of forecast relying on extrapolation of the past values (Herrington, 1973).

The main purpose of forecasting is to reduce these uncertainties by making use of past and present datas. The two major sources of error in projecting future levels of water use are (UN, 1976):

- errors of measurements and interpretation in the data base and
- structural errors of projection models.

Prediction of water requirements needs special care as the services to be given to the intended users and also the cost of the schemes strongly depend on it. Selection of a suitable and economical design period, estimation of population and consumption projections are the major factors to be analyzed in forecasting water demand.

4.1.1 Methods of Demand Forecasting

Some of the techniques and methods used by designers in the forecasting of demand include (Dekay, 1985):

- judgemental techniques which rely on experience and often using project growth rates of total system use
- per capita methods of data analysis and forecasting rely on estimates of total system water use per person served
- regression models correlating water use with many variables
- time-series analysis, assuming the future water use to be predicted entirely on past water use patterns.

Judgemental methods are often used in the absence of past data. Designers use their experiences of other water supply schemes and make forecasts. However, since this method involves higher uncertainties, it is being replaced by organized analysis.

In per capita methods of forecasting, past trends in water consumption per capita per day are observed over a period of time and projections are carried out.

Modern techniques used in forecasting water demand make use of regression analysis. The method considers various factors which are likely to affect consumption. The relations of the socio-economic factors like household size, standard of living and cost aspects are studied with the variations in consumption from which models are developed. The models help in visualizing the consumption patterns and help in predicting future uses of water.

One of the difficulties in preparing a working model in developing countries is the absence of data related to consumption patterns. The various factors which affect per capita consumption should be analyzed to see their relationship with rates of consumption. Once these conditions are studied, equations could be developed which help in predicting water demand.

In Ethiopia, the present practice of demand forecasting is made by judgement and from the general experiences of some of the service giving schemes. This could result in under or overdesign and care should be given to study the patterns of different schemes and also the factors affecting rates of consumption.

4.1.2 Design Period

Design period is defined as the number of years during which a proposed water scheme including its structural components and equipment is expected to meet the anticipated needs of the future population (Damball, 1981).

Too long a design period results in financial burden while too short a period will obviously fail to meet the increasing demand and hence the scheme becomes uneconomical. Consideration should be given to the following factors in selecting the design period of a scheme (Birdi, 1979).

- funds available for the completion of the scheme and rates of interest on the loans taken to complete it
- life of the pipes and other structural components used in the water supply scheme, also depreciation, wear and tear of the components
- anticipated expansion rate of the town.

Because of the limitations of financial resources, developing countries should examine whether it is cheaper to design for a short term and plan for future extension or assume a longer period now to meet the future demand.

Every water supply system has an over capacity during the early stages of operation. As this conditions lead to high investment costs, designers should be as flexible as possible to expand the system step by step.

It should be noted that components of a scheme which are hard and costly to enlarge like dams and transmission mains should be given ultimate dimensions of design period.

In Kenya, periods of 10 years ahead for "future demand" and 20 years for ultimate demand are normally used (Ministry of Water ... 1978).

In Ethiopia, two phases of design periods are normally used by designers. The first phase is made for ten years and an additional ten years is made for the second phase.

4.1.3 Population Projection

One of the biggest uncertainties in forecasting water demand lies in estimation of the population at the end of the design period. Under normal conditions, population tends to grow according to the logistic or S shaped curve starting with a low growth rate followed by a high rate and then a lower progressive rate at the saturation population (AESL, 1982). The limit for saturation population lies in the economic opportunity but is also influenced by other factors like available land area. Unpredictable death rates decrease population, birth rates increase population and migration could increase or decrease population. The methods applied in predicting population are (Babbitt et al 1967):

- mathematical, either analytical or graphical
- projections based on migration and on natural increase
- forecasts based on estimates of future employment or regional development.

Mathematical methods adjusted by logical considerations are frequently used and give relatively adequate results.

One of the important aspects to be considered in projecting population is estimating the amount of people likely to be served by the system facilities. Due to economical problems a portion of the population may not be able to utilize the water supply system and be forced to use traditional sources. Hence care should be taken in considering the population likely to use the water supply system to be built.

4.1.4 Consumption Projection

One of the factors affecting forecasting of water demand is projection of consumption and estimation of the percentage of people likely to use the water supply system. In urban towns served both by house connections and stand pipes, the percentage of consumers should be differentiated with respect to each system. Standards of living and social habits should be considered in predicting consumption and levels of service.

It should be noted that water consumption may be stabilized after some years. A forecast of consumption was made in Sweden from the years 1960 to 2000 which assumed an increase in domestic consumption by a factor of 2 and the industrial consumption by a factor of 3 (Ulmgren and Westermark, 1976). However, the actual consumption stabilized at a certain level since 1970 and has in some cases even dropped during the last 7 - 10 years.

Two main reasons given were

- the rise in cost of water
- use of water could only be raised to a certain level until the standard is fulfilled.

Some countries adopt guidelines for prediction of levels of service. Table 8 shows recommendations given in Kenya on the use of different systems.

Table 8. Relation between types of connections and percentage of population (Ministry of Water ... 1978).

Type of supply	Individual connections (%)			Communal water points or kiosks (%)		
Demand Period	Initial	Future	Ultimate	Initial	Future	Ultimate
URBAN AREAS						
- population > 5000	60	70	90	40	30	10
- population < 5000	40	50	70	60	50	30
RURAL AREAS						
- high potential	20	35	60	80	65	40
- medium potential	10	25	50	90	75	50
- low potential	5	10	20	95	90	80

4.2 Variations in Consumption and Peak Factors

The design basis for most water supply components is the fluctuating demand for water. Fixing the per capita demand is not only sufficient although useful, for various parts of a scheme. Consumption shows significant alterations in different years, months, days and even in interval of hours.

On the other hand, flow which is significantly determined by consumption results from the fluctuating demand of water. The variations in consumption generate peaks which should be monitored and satisfied. Assessment on past and present consumption patterns could help in estimating peak factors. Prolonged period of observation is necessary to arrive at reasonable values of peak factors.

It should be noted that construction of a water supply system to the absolute peak is not necessary to meet peak consumption at all times. In order to design an economical and reliable water supply system and be able to meet the fluctuations of demand occurring at different times, surveys should be carried out to know the seasonal, annual, monthly, daily and hourly water usage patterns.

4.2.1 Types of Variations in Consumption

<u>Seasonal variations</u>

In countries facing markable changes of seasons, considerable changes in consumption occurs. Generally in dry periods the water demand is maximum as people use more water for bathing, cooling and lawn watering. Where lawn sprinkling is highly practiced the seasonal variations are pronounced to a larger degree. Observations in East Africa show shifts during dry periods. In Dar es Salaam an upward swing during dry periods and in Nairobi decrease of pumping during peak of wet periods were noted (White et al 1972).

Data obtained from most urban schemes of Ethiopia indicate a markable decrease of consumption from the months May to September. This period is rainy for most parts of Ethiopia and people use rain water for most of their activities.

Daily variations

The variations which occur daily depends on the general habits of people, climatic conditions and character of the city. By noting the daily uses of water over a prolonged period of time, the fluctuations of water consumption could be easily seen. The ratio of the summation of the daily consumptions to the number of observation days gives the average day demand. This parameter helps in the planning of raw water supply and in economic calculations related to operation of water treatment plant and water distribution.

The maximum value obtained during the observation days is called the maximum day demand. Installation of master meters at source outputs or storage tanks helps in obtaining the consumptions at different time intervals.

In studies conducted in Utah, U.S.A. (Hughes, 1981) average and peak month demands were found to be highly correlated with price while peak day was not. The possible reason was that consumers had no economic incentives to distribute their monthly consumption more equally over the days in a month since they were billed on a monthly base.

Maximum consumption for a day is usually expressed as percentage of daily supply. Table 9 shows typical ratios of these percentages as obtained from different countries.

Table 9. Ratio of maximum to average day consumption (Twort et al 1985).

Country	Ratio: Maximum day to average annual daily consumption
U.K	
- residential towns: rural areas	122 - 125 %
- exceptional peak due to garden watering in prolonged hot dry weather	150 - 170 %
U.S.A. (domestic demand due to sprinkler demand)	
- western states	215 - 340 %
- eastern states	195 - 295 %
FINLAND[1)]	135 - 200 %
HONG KONG	122 %
SPAIN (Barcelona)	109 %
TANZANIA[2)]	140 %

1) Yletyinen, 1986
2) Damball, 1981

Maximum day demands are used in the determination of the capacities of water treatment plants, pumps and storage of reservoirs. The ratio obtained between the maximum day and the average day consumption is called the maximum daily peak factor. Similarly the minimum daily peak factor is obtained by dividing the minimum day by the average day consumption.

Hourly variation

The amount of water a system delivers for a full hour is called the hourly demand and is normally obtained by noting hourly flow rates from master meters.

The determination of hourly variations is necessary since it indicates the basis for the rate of pumping to meet the demand in all hours. In order to visualize the patterns of hourly variations clearly, values of water consumptions are plotted against hours of a day.

The ratio of the peak hour to the average hour demand gives the maximum hourly peak factor. Peak hour factors are useful parameters in the design of distribution networks.

Depending on the nature of an area and the number of population served, peak factors are seen to vary in ranges. Figure 4 shows these conditions which were obtained from studies in areas of Liverpool, U.K.

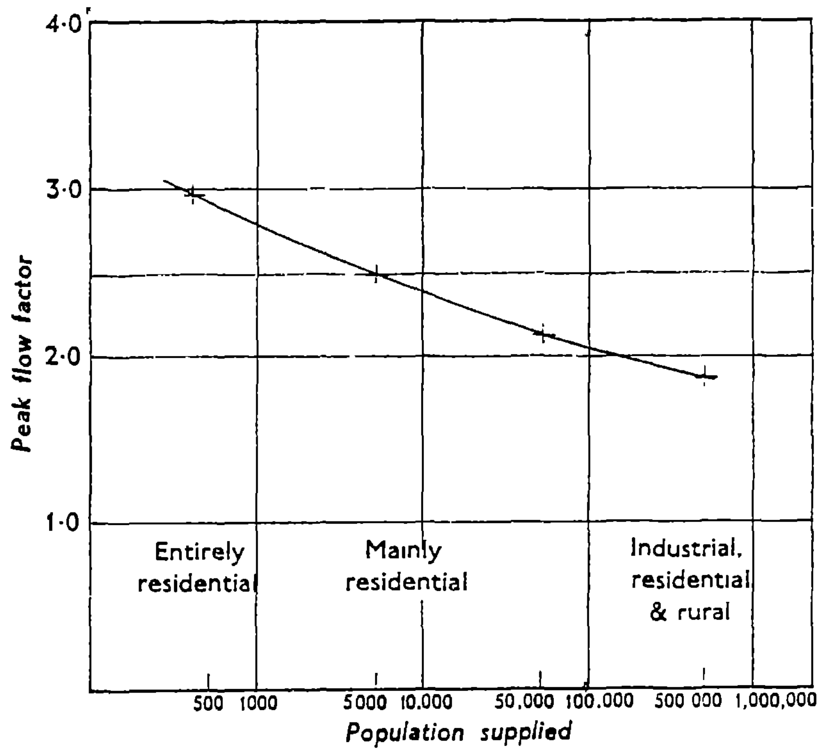


Figure 4. Ratio of peak hourly flow to annual average flow in areas of Liverpool, U.K. (Adams 1955 cited by Twort et al 1985).

4.2.2 Methods of Controlling Peak Loads

The fluctuation of water demand which leads to creating peak values should be examined in any water supply system. In order to minimize the big investments resulting from high peak values and low load on pipe systems, the various factors which affect the magnitude and frequency of peak loads should be thoroughly investigated (Tessendorff, 1974). Some of these factors which influence peak loads are:

- period of observation
- number of inhabitants
- dwelling area
- temperature.

The time extent of measuring peak loads has an effect on the magnitude of peak loads. The smaller the interval of time. the higher the peak demand will be. Shorter time intervals could sometimes be 3 to 4 times the magnitude of one hour peak load (Tessendorff, 1980). Hence designers should analyze and select the period of observation to come up with an economical design of pipelines.

Peak loads are also found to have close relations with number of inhabitants in buildings. Studies conducted in Germany (Tessendorff, 1980) have proved the decrease in peak loads with an increase in number of inhabitants per building. The results obtained from these studies are shown in Figure 5.

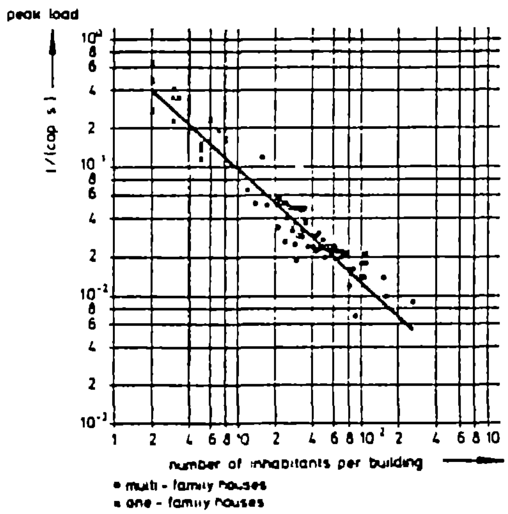


Figure 5. Relationship between peak load and number of inhabitants per building (Tessendorff, 1980).

A similar relationship was obtained from studies conducted on the water supply of The Hague verifying the decrease in peak demand with an increase in number of occupants per dwelling (Wijntjes, 1984).

Although mean consumptions have a stronger influence on dwelling areas, Tessendorff (1980) indicated a slight increase of peak loads with an increase in dwelling areas per capita. A similar result was obtained showing an increase in peak load with an increase in maximum temperature from the same survey conducted in Germany.

There are different methods used for taking care of a peak load. Some of the methods used include

- provision of storage tanks
- increasing the price of water
- installation of fixtures with lower water consumption
- use of a separate peak load plant
- design of treatment units so as to meet peak loads.

The provision of storage tanks in high consumption areas would help in reducing peak loads. The cost of construction should however be compared with the overall saving of line construction. Natural water reservoirs are also used to satisfy peak demands. In Stockhom, Sweden the lake Bornsjön is mainly used during peak load periods and as a stand-by due to resource limitation (Ulmgren and Westermark, 1976).

In domestic premises installation of fixtures of lower water consumption tends to reduce peak loads. One form of it is the replacement of W.C.. flush valves with flushing cisterns. Tessendorff (1972) indicated a reduction in peak loads of about 50 % to 60% by the advance storage of the flushing water in cisterns.

Another alternative used in handling peak loads is by construction of a peak load plant. The plant should preferably be of low investment cost, a compacted unit and simpler in operation.

Designing a plant so as to cover peak loads within the treatment stages is one of the methods used in handling peak loads. Use of mixed media filters to increase rates of filtration, and certain chemicals to speed up treatment process could help in meeting peak loads.

In most Ethiopian urban schemes, peak loads are controlled by the conventional method. The maximum day demand is met by designing the intake and treatment plants for this condition. Storages are provided to reserve the excess during average day demand to be used for peak hour demand. Hence the pipes from the storage leading to the distribution system and the distribution network are designed to meet the peak hour demand.

4.3 Distribution System

In order to convey treated water to the intended users, to be able to balance the variations in demand and pumping rates and to monitor operation and maintenance difficulties, the different components of a distribution system are necessary. This mainly includes pipes, fittings, storages and pumps.

4.3.1 General Layout

The basic aspect in the design of distribution systems is determining the general layout of the scheme. These include choice and location of pipelines, storages and pumping facilities.

Distribution storages should preferably be located near to the area of demand. The best case would be to get a higher ground elevation which is near to the distribution area. Some of its advantages are:

- to minimize the higher construction costs of elevated towers
- to easily control the breakdowns.

However it may not be possible to obtain these advantages in different conditions. In this case, elevated reservoirs could be used.

The other factor to be considered is pressure requirement. The location of storage reservoirs should ensure sufficient and steady pressure to different parts. Depending on the general topography of the town, construction of different storages could be economical. This avoids subjection of low level zones from excessive pressures.

The other problem faced by most designers is the location of the pipelines within a system. The total length of pipeline should be as short as possible and should be laid where construction access is easier.

The problems get worse in developing countries like Ethiopia. Most of the urban towns of Ethiopia have got master plans prepared by the Ministry of Housing and Public Works. These master plans indicate future provision for roads and other public services. Although the layout of pipelines should be made according to the master plans, the actual implementation of these plans may not be practiced during the design period of the schemes. Also following the master plans may sometimes result in destruction of several properties which could not easily be compensated. Hence care should be taken to analyze the situations from different points of view.

Another important consideration to be made is planning for future upgrading of layouts. Future extensions or individual connections should be made easier without much reconstruction works.

4.3.2 Pumping and Storage

In order to meet the periodical fluctuations of demand and lift water to a desired elevation, distribution systems need storages and pumps.

The main purposes of storages are the following:

- to equalize rates of flow due to variation between demand and supply
- to bridge over temporary breakdowns
- allow shifts in rates of pumping
- reserve water for fire fighting
- reduction of pipe sizes in main lines.

To determine the balancing requirements, mass curves are often used. Figure 6 shows such a curve for two different rates of pumping. If a continuous pumping rate of 24 hours is chosen, the summation of the ordinates 'a' and 'b' will result in the required storage capacity. In this case it is 19 % of the total water consumption during the day with the maximum water demand.

On the other hand, if a shorter rate of pumping is assumed, the resulting storage requirement is 16 % of the total water consumption.

Hence by adjusting different pumping situations which have an effect on the demand fluctuations, capacities of storages could be determined.

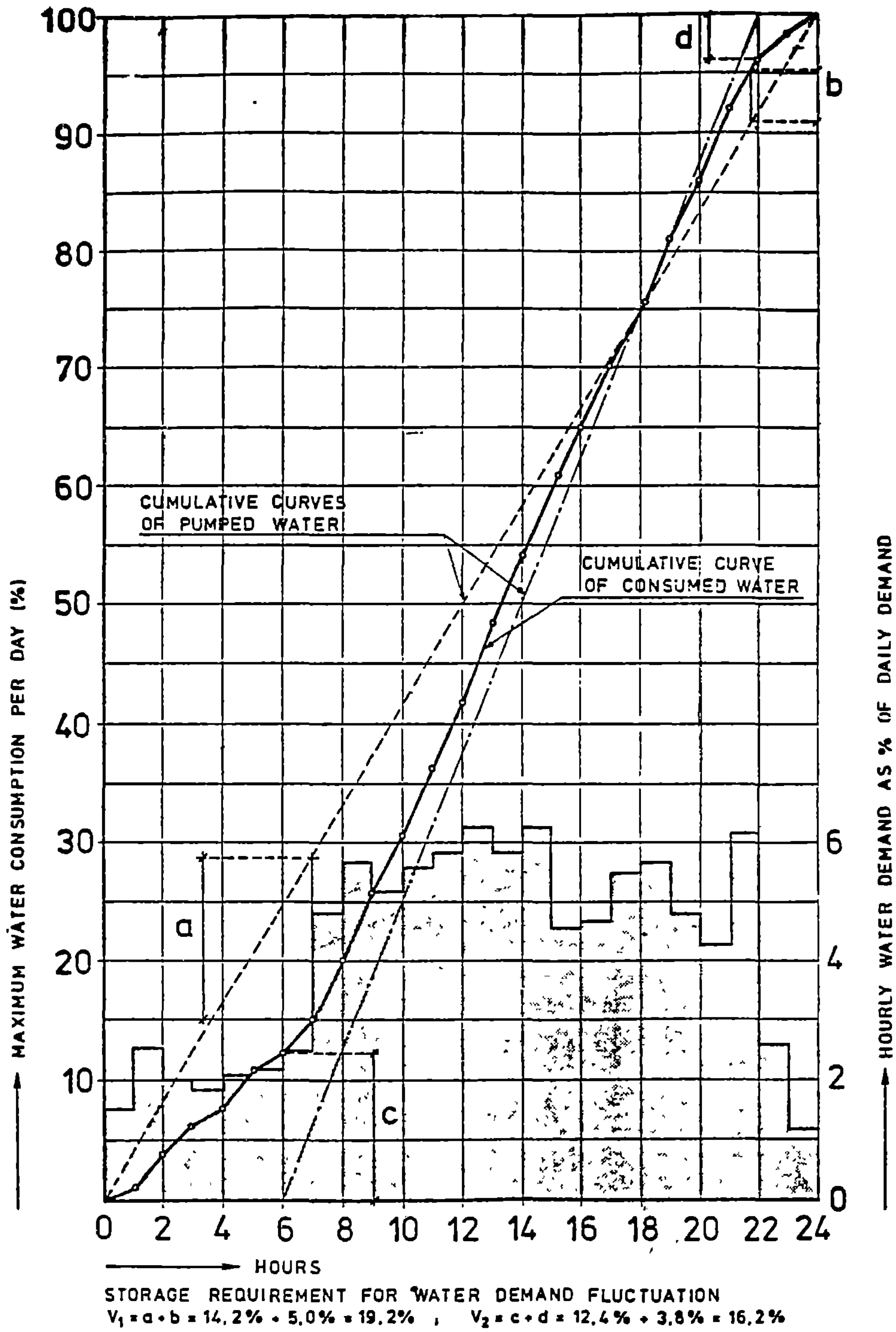


Figure 6. Water demand fluctuation and storage requirement for a community in Finland (Pasanen, 1974).

The storage capacity needed for temporary breakdowns is difficult to estimate as it depends on the time required to handle the breakdowns. Pasanen (1974) suggested a minimum of 10 % of the maximum daily design consumption values for a day. Depending on local situations variations are to be expected and concerned countries should determine suitable rates for their own conditions. The storage capacity required for fire fighting depends on the duration of the fire, the design fire flow and on the local legislation.

Table 10 shows the requirements for duration of fire flow in selected countries.

Table 10. Required duration of fire flow in different countries (Bernis and Galan 1976).

Country	Duration in hours
United States	4 - 10
Belgium	2
France	2
Switzerland	1.5 - 2

A study made in France has revealed that out of 40 000 fire incidents, 75 % lasted less than 2 hours (Bernis and Galan, 1976).

The Kenyan design manual recommends a duration of 2 hours for fire flow (Ministry of Water ... 1978). In Ethiopia, a duration of 2 hours has been chosen in the design of some urban schemes (AESL, 1982).

The total capacities of storages are given as percentages of average or maximum day demands. Hofkes (1985) suggest a storage volume of 20 % to 40 % of the peak day demand to be adequate as capacity of service reservoirs.

In Tanzania, the Ministry of Water and Energy (MAJI) recommends a storage capacity equivalent to 30 % of the peak daily domestic demand or 42 % of the average daily demand (Damball, 1981).

In Ethiopia, most of the urban schemes have 30 % storage capacities of the maximum day demand to balance variations while 10 % of this volume is kept as reserve for fire fighting.

The selection of pumps depends on the discharge and the head requirement of a scheme. Pumping costs are higher if elevated tanks are located relatively higher. On the other hand, the higher the tank, the more head is available for overcoming friction. This in turn allows smaller pipe diameters to be used in a system. One task of designers is to look an optimum balance between pumping and piping cost.

Special attention should be given to the availability of spare parts, supply of stand by and training of personnel for the proper operation of pumps.

In case power for running pumps depends only on electric supply, failures should be expected due to power line damages. Alternative supplies like diesel engines could be provided to run the pumps.

4.3.3 Pressure Requirement

A good distribution system ensures adequate pressure within the scheme. Due to location of storages and topography of the areas, pressure varies within the distribution network.

One of the tasks for a designer is to select a minimum operating pressure for the system. Some of the factors to be considered are (Trattles, 1985):

- preferably low so that high head is available for overcoming friction and small pipe diameters could be used
- should be sufficient to enable water reach top buildings
- adequate enough to meet uncertainties in demand.

Pressure is directly related to distribution system pipe size. Due to the higher costs involved, designers usually select minimum pipe diameters. It should be noted that a small increase in pipe size may cost more, but it could result in better pressure conditions over longer periods (Taylor, 1967).

5 ANALYSIS OF THE WATER SUPPLY SYSTEM OF AWASSA

Among the 23 urban towns of Ethiopia who have adequate and reliable water supply systems, the town of Awassa represents a typical model having a water supply system with modern treatment process, rendering satisfactory service to the inhabitants and to other service giving firms.

In order to carry out the consultancy and construction works, tenders were asked by the client, The Water Supply and Sewerage Authority, and after a thorough evaluation, German Water Engineering (GWE) was selected as consultant to carry out the design and supervision works while a national contractor "BERTA" was given the task of construction works. The start of water selling was on late September 1982.

5.1 Location of the Town

The town of Awassa is located 275 km by road south of Addis Ababa and it belongs to the Administrative region of Sidamo. The Rift Valley encompasses the town and divides the country into two highlands. The Trans-East African highway bypasses the town which links Egypt to Botswana. Its geographical coordinates are as follows

* Latitude 6^{o} 59'N
* Longitude 38^{o} 28'E

It is situated at an average elevation of 1680 m above sea level. Average annual rainfall is 1 103 mm. The minimum average temperature is 7.5 ^{o}C, maximum average temperature is 33.3 ^{o}C and hence the average temperature is about 20.4 ^{o}C (Southern Regional Office ... 1987).

5.2 Demographic Data

The town of Awassa is governed by an urban dwellers association. There are two "HIGHER" associations with fourteen "Kebeles" under them. The association is responsible for community matters. The actual implementation is made by the different Kebeles. Table 11 shows the distribution of houses in each higher association.

Table 11. Housing data in Awassa town in 1986 (Southern Regional Office ... 1987).

Zone	Privately owned	Government	Total
Higher 1	1 582	2 046	3 628
Higher 2	1 188	1 192	2 380
TOTAL	2 770	3 238	6 008

On the other hand the total number of families residing in the town was 6 955. Comparing this with total number of houses which was 6 008, it is seen that about 14 % or a total of 947 families were living either in hotels or jointly with other families.

According to the latest census made in the country during May 1981, the population of the town of Awassa was 36 169. Details showing age and sex groups are shown in Table 12.

Table 12. Population of Awassa town showing age and sex groups (Southern Regional Office ... 1987).

Age group	SEX			Percentage (%)
	MALE	FEMALE	TOTAL	
0 - 14	9 259	9 434	18 693	51.7
15 - 64	7 636	8 619	16 255	44.9
> 64	777	444	1 221	3.4
TOTAL	17 671	18 497	36 169	100.0

As per the growth rate of 4 % estimated for urban towns of Ethiopia, the population of Awassa is expected to reach 51 480 by the year 1990. Regarding industries one cement factory, a flour mill, cicels and oil factory and wood works factory are located in the town together with a tobacco production unit. A number of small scale industries are also available. Other services are listed in Table 13.

Table 13. Number of service giving units (Southern Regional Office ... 1987).

Purpose	Number of units
Kindergardens	5
Schools (elementary to secondary)	10
Institutes	3
Hotels	34
Restaurants	23

5.3 Existing Water Supply System

The Awassa water supply system consists of an intake structure within the river "CADO" which is located 17 km south of the town. The alternative source of Awassa Lake was rejected because of its high fluoride content and its recharge problems, as far as the quantity of water was concerned. Results of flow measurements conducted on Cado river indicated maximum and minimum flows of 540 l/s and 294 l/s respectively. During the design of the system a safety factor of 1.5 was applied to the minimum flow which gave 196 l/s as the usable amount of water. The water demand in the year 2000 was estimated to be 114 l/s which made the water from the source adequate (GWE, 1978). A scheme of the Awassa water supply is shown in Figure 7 indicating the source and the various treatment processes.

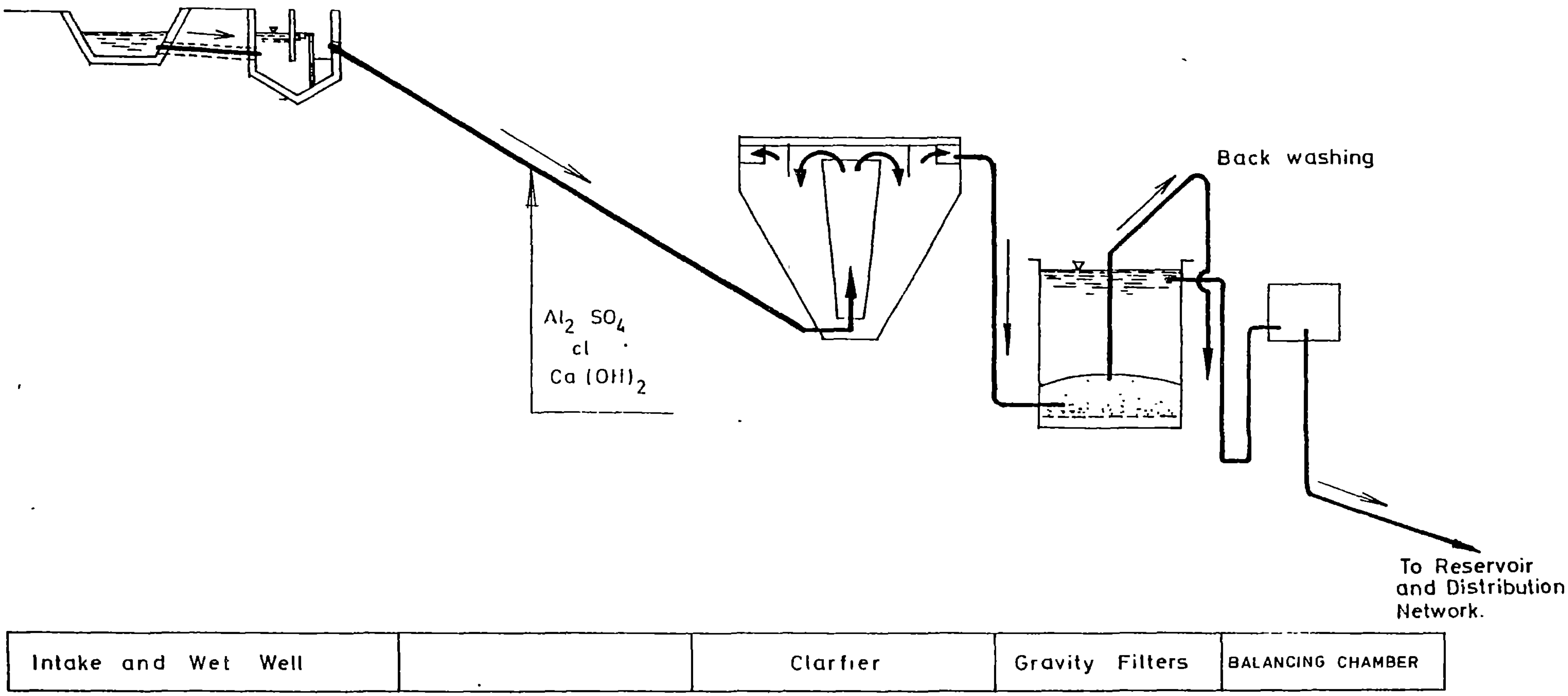


Figure 7. Schematic view of the treatment plant in Awassa (GWE, 1978).

5.3.1 Intake and Wet Well

The water catching on the Cado river comprises a weir 0.80 m high above the river's bed level and 8.50 m long. On the coping of the weir a tyrol intake is built with a length of 4.0 m and a width of 0.50 m. A metallic grid of trapezoidal bars with their length oriented in the flow direction will cover the intake from the entrance of big stones or other materials. The distance between the bars is 3 cm. To cover half of the intake area at least up to the first design period (1980 - 1990) a metallic plate is provided. As the needs of water increase the plate is suggested to be replaced by grids in the second phase of it (1990 - 2000). Figure 8 shows the intake of the Awassa water supply schemes.

Figure 8. A view of the intake of the Awassa water supply system.

On the downstream of the weir a stilling basin with a length of 3 m is constructed with paved blocks lying on a gravel layer in order to withstand a flow velocity of 4 m/s. The water from the intake is then conveyed via a concrete pipe ND 400 mm, with a slope of 2.4 % and a length of 5 m into the collecting chamber which is composed of two compartments:

- A recieving and stilling compartment with plan dimension of 1.5 m x 2.0 m and a central channel in the bottom to allow for settling and discharge of the sand through a pipe downstream into the river.
- Over a spillway 1.5 m high, the water flows into the second compartment where it is made to be conveyed through an ND 400 mm pipe into the treatment plant.

5.3.2 Treatment Process

Due to the raw water quality of the river three chemicals were chosen to be used in the plant. A coagulant aluminium sulphate for removing colour and turbidity, hydrated lime to adjust the optimal pH and chlorine for disinfection (GWE, 1978). A solution of alum is prepared on feeder containers. Although different dosages are used depending on the turbidity of the river water, the average dosage of alum is 90 mg/l. In order to adjust the optimum pH for the floculation process, hydrated lime is injected into the raw water. The average dosing rate of lime is 20 mg/l. Dosing pumps are used to lead the two chemicals to the clarifier. Pre-chlorination is also carried out in the plant. Water for the preparation of this solution is taken from the pump located below the balancing chamber and is led into the chlorinator-ejector for mixing with chlorine.

<u>Clarifiers and filters</u>

The clarifier used in the scheme is an up-flow type. The up-flow takes place by hydraulic pressure which avoids the use of mechanical stirring device. The incoming raw water together with the injected chemicals flows to the mixing zone and the clarified water is collected from the channels installed on top of the clarifier. Figure 9 shows a cross section of the clarifier.

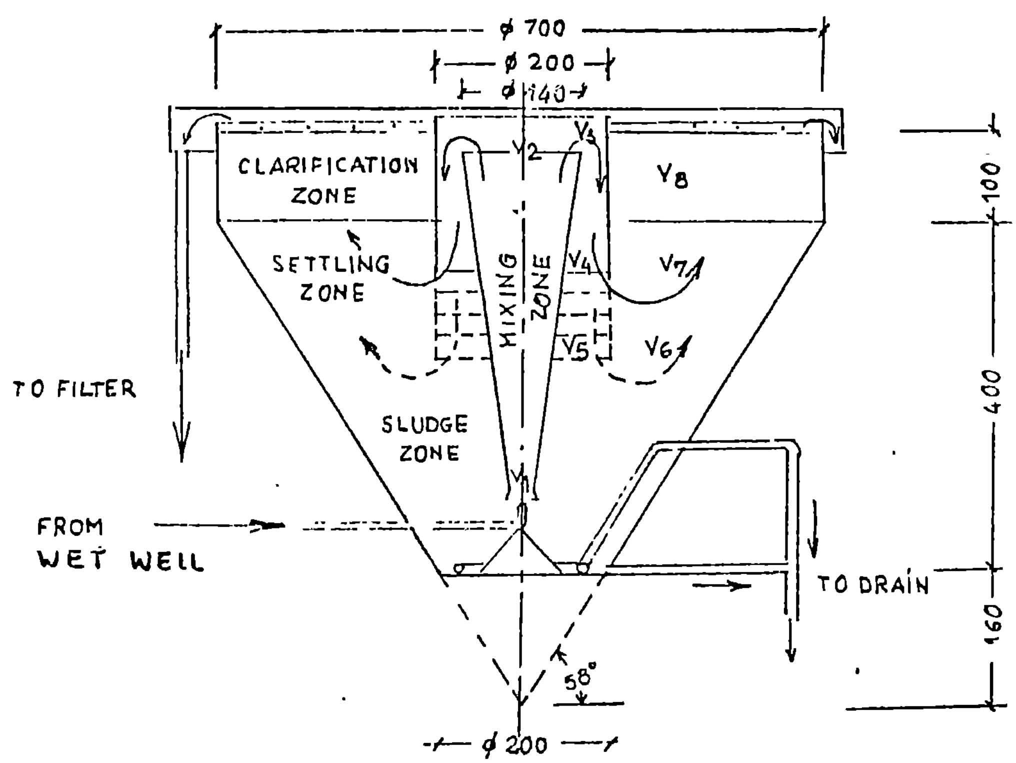


Figure 9. A typical cross section of the clarifier in the Awassa scheme (GWE, 1978).

The sludge which settles at the bottom is drained by using manual operation. In order to dilute the sludge so that the pipes will not be clogged, raw water is led and discharged into the main drain, at the time of sludge removal. For improving the quality of water, by reduction of the number of bacteria and other organisms the water supply scheme consists of two gravity filters. The filter material is quartz sand and the filter operates for a maximum flow rate of 10 m^3/h (GWE, 1978).

5.3.3 Reservoirs

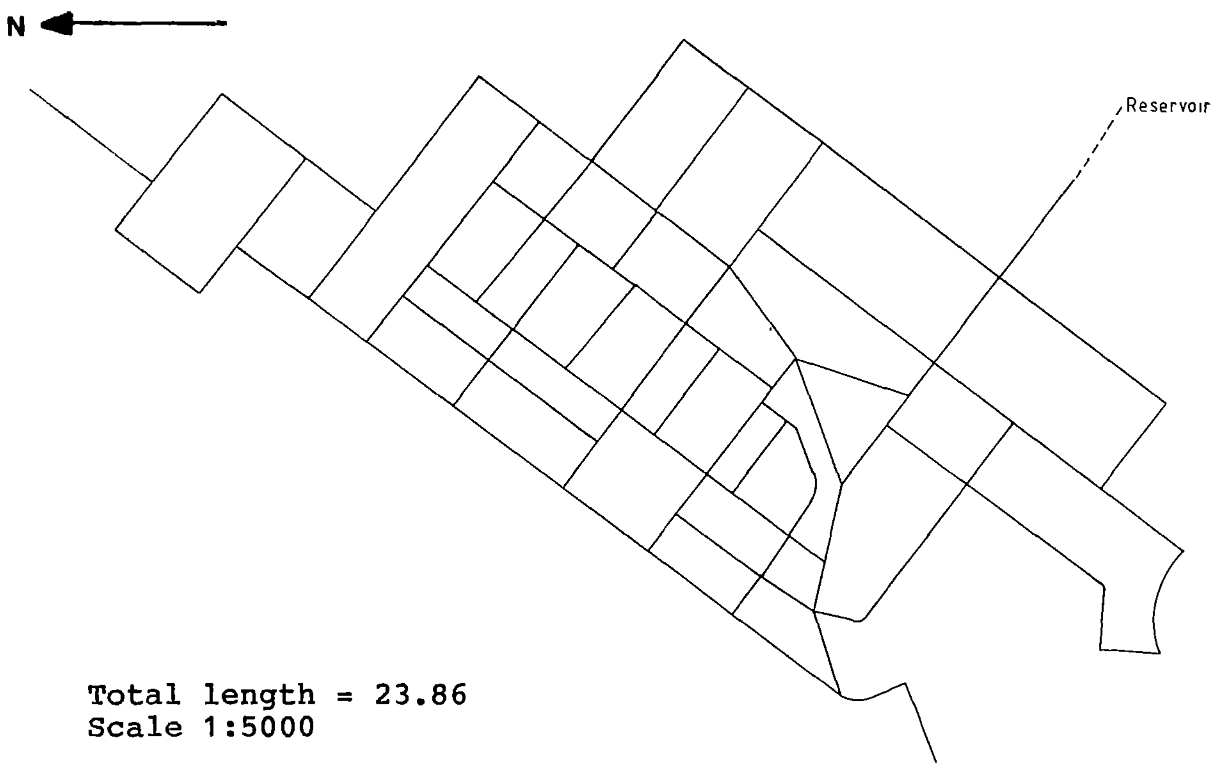
In order to meet the daily fluctuating water consumption and reserve water for fire fighting, two reinforced concrete reservoirs with a total capacity of 1 000 m^3 were built for the first stage design period (1980 - 1990). They are supply reservoirs and located at an elevation of 1 670.8 m. One of the advantages of this system is that water reaches to the reservoirs from the treatment plant situated at 1 700 m by gravity and thus pumps are avoided. Figure 10 shows a rear view of the reservoirs.

Figure 10. A view of the two reservoirs in the Awassa water supply system.

In determining the capacity of the reservoirs, 30 % of the maximum day demand was selected (30 % of 2 785 = 835). For fire fighting purposes 10 % of this volume was accounted (10 % of 835 = 83.5). The final volume turned out to be the summation of the two demands i.e. 835 + 83.5 = 918 m^3. Hence two reservoirs each with a capacity of 500 m^3 were chosen for the first stage design period. In order to meet the increasing demand of water, two additional reservoirs are intended to be built to serve the second stage design period (1990 - 2000).

5.3.4 Distribution Network

The pipe network comprises of PVC pipes with nominal pressure resistances of NP = 6KP/cm^2 to NP = 10 KP/cm^2. DCI pipes of diameters ND 350 mm and ND 400 mm are used as gravity main to convey the water from the treatment plant to the reservoir. The layout showing the distribution network of Awassa water supply is given in Figure 11. A total of 27 public fountains and 11 subsurface hydrants are constructed in the system. Flushing and aeration devices are also located in the scheme. The design values indicate a maximum velocity of 1.6 m/s and the pressure vary from 14.2 m to 69.9 m at junctions (GWE, 1978).



Total length = 23.86
Scale 1:5000

Figure 11. Layout for the distribution network of Awassa town water supply system (GWE, 1978).

5.4 Trends of Water Consumption in Awassa Town

The past water consumption patterns of the town were obtained from the town's water supply and sewerage office. Although the reliability is questionable the different user categories with their respective consumptions are shown in Table 14.

Table 14. Average consumption by different user categories from the Awassa Water Supply System (WSSA, 1987).

	1985		1986	
User category	Consumption (m^3/d)	%	Consumption (m^3/d)	%
Domestic	196	30	214	25
Schools	190	29	167	20
Public	134	21	279	33
Commercial	98	15	126	15
Industrial	26	4	43	5
Others	3	1	15	2
TOTAL	647	100	844	100

5.5 Losses in the System

The only data available concerning the losses at Awassa water supply system come from the regional office of the Water Supply and Sewerage Authority. The amount of losses in each month were obtained by noting the differences between the water actually metered and the amount of water sold. These values as obtained from the regional office are shown in Table 15.

Table 15. Unaccounted water in Awassa scheme (WSSA, 1987).

MONTH	1985		1986	
	Unaccounted water (m^3)	Percentage of total supply (%)	Unaccounted water (m^3)	Percentage of total supply (%)
January	-	-	4 596	14
February	6 347	23	8 357	23
March	5 094	20	2 678	9
April	4 852	23	971	4
May	3 741	16	821	10
June	3 662	20	3 639	15
July	216	2	2 257	9
August	1 685	10	5 277	20
September	5 336	23	1 850	7
October	4 989	20	8 423	28
November	4 440	16	5 216	16
December	5 747	18	6 148	18

* Empty spaces indicate no figures could be obtained.

6 RESULTS OF THE SURVEY

To analyse the per capita water consumption and the variations in the system of Awassa town water supply, two methods were employed:

- The daily and hourly water consumptions were noted from the master meter located in the reservoir which helped in obtaining the peak factors.
- Dwellings were classified with the type of water supply connections and two categories were studied:
  a) modern houses made of brick walls, cement/plastic floors with full internal plumbing facilities and
  b) local houses made of wooden poles with yard connections.

The consumption on some of the public stand pipes were also analyzed. The results obtained from reading of the master meter were not used to determine the per capita water consumption as a considerable percentage of the population still relies on privately owned shallow wells dug in the compounds of the houses. Hence the per capita water consumptions were obtained from the daily readings of individual meters and the number of inhabitants residing in each dwelling.

6.1 Period of Survey

The field works started in late September 1987 and continued up to the middle of November 1987. A total of 450 meters were read which was 38 % of the total connections in Awassa town.Up to the reporting period a total of 1 179 clients were registered as clients of the water supply service.

Questionnaires were distributed to customers to obtain their income levels, to know the number of people residing in each house with their level of age and to assess their opinions about the water supply system.

6.2 Checking of the Meters

In order to ascertain correct flow measurements, water meters should be calibrated before being used. Accordingly household meters were checked and those ones which gave same readings over a period of time were discarded. The master meter at the reservoir was also checked for accuracy. The method used was filling the reservoir and allowing it to drop to a fixed height. In this interval of time the reading on the master metre was noted. The volume of water in the reservoir was checked with the master meter reading. Similar results were obtained verifying accuracy of the master meter. Figure 12 shows the master meter located adjacent to the reservoirs of the Awassa water supply scheme.

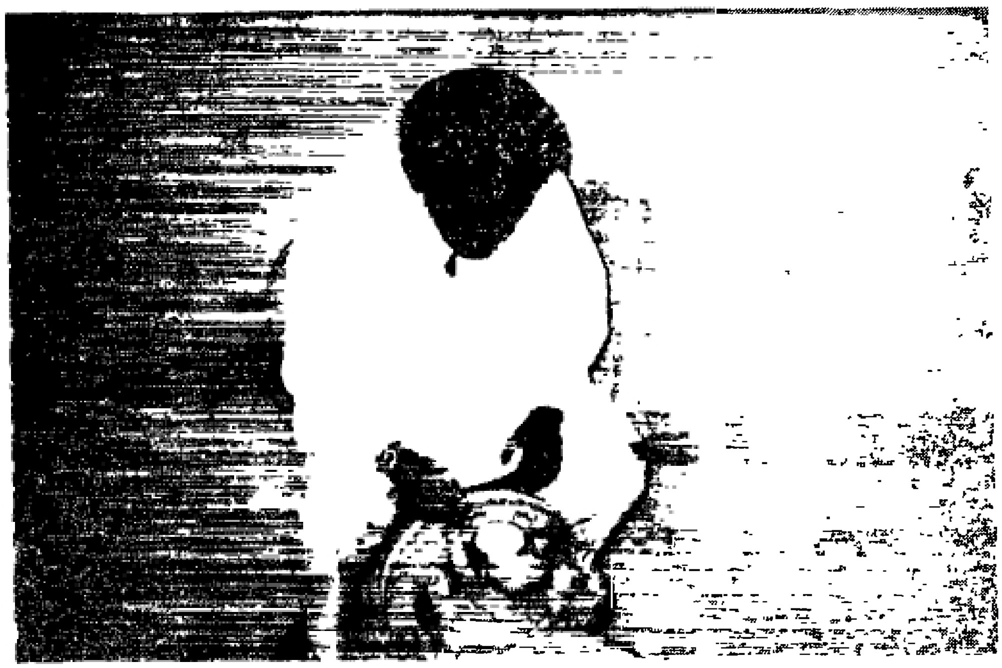


Figure 12. Noting flow patterns from the master meter of the Awassa scheme.

6.3 Estimation of per Capita Water Consumption

6.3.1 Public Standpipes

The water supply system of Awassa has got 27 public stand pipes. They are made of reinforced concrete and contain a built in water meter. During the survey most of them were seen to be working for an average of 3 hours a day. The daily usages were noted for a period of 14 days. Consumers were seen to use tins, jercans, plastic bottles and buckets for collecting water. Apart from the bigger containers whose volume were already known, actual volume measurements were done for the smaller containers. Use was made of a prepared format where the name of consumer, the amount withdrawn and the size of the family were noted. The meters which were enclosed in the standpipes were read both in the beginning when water selling started and in the closure times. The results obtained from the prodecures outlined above are displayed in Table 16.

Table 16. Rate of consumption and tariffs for Awassa town with public standpipes.

no.	Average number of households served per day	Average number of persons served per day	Average consumption (m^3/d)	Average consumption l/c/d	Tariff* (ETB/m^3)
1.	67	403	3.1	7.7	1.00
2.	70	380	2.7	7.1	1.00
3.	75	371	3.4	9.3	1.00
4.	58	360	3.0	8.3	1.00
5.	64	356	4.1	11.5	1.00
6.	55	295	2.0	6.8	1.00

(* 1 ETB = 0.48 USD. Nov., 1987)

From the results obtained on the six public standpipes a minimum average consumption of 6.8 l/c/d and a maximum of 11.5l/c/d were noted. The mean turned out 9 l/c/d which was less than the minimum value of 10 l/c/d set by WHO.

From observation of the users with the least per capita water consumption, it was noted that unprotected shallow wells were used by most of them. The wells were not lined which made the earth material to sink into the well making it easily contamined. The regional office of the Water Supply and Sewerage Authority is trying its best to abandon these wells. As compared to previous years, progress has been achieved and this should continue for the future. In this respect, teaching the public the effects of drinking unhygienic water would be a key factor.

6.3.2 Yard Connections

Most of the dwellings of the town have yard connections. Although these types of systems are available in both the modern type of houses and the local wooden pole houses, it is the later type of housing which is chosen to analyze the consumption from yard connections. In a survey conducted by the Central Statistics Office (C.S.O.) in 1980, it was found that out of the 5 436 houses built in Awassa town, 93 % of them were categorized under these traditional type of houses (Southern Regional Office ... 1987).

As these houses by large depend on yard connections, it was found important to conduct the water consumption survey on them. The results obtained are indicated in Table 17. Household datas were obtained from the questionnaires distributed earlier to each family.

Table 17. Rate of consumption and tariffs for yard connections in selected wooden houses, Awassa town.

Zone	Number of houses surveyed	Total number of people	Total daily consumption (m^3/d)	Average consumption l/c/d	Tariff (ETB/m^3)
1.	72	494	15.3	31	1.00
2.	50	369	8.9	24	1.00
3.	100	669	17.8	27	1.00
TOTAL	222	1 532	42.0	-	-

From the analysis made for each house, average daily consumptions of 11 l/c/d to 40 l/c/d were noted. The mean value was found to be 28 l/c/d. Some of the lower range consumers were seen to use the water from lake Awassa for ablution and also own private dug wells.

6.3.3 In-house Connections

During the survey of the water consumption patterns, most of the in-house connections were seen in modern houses built by the government. In other zones they are few in number and are found to be scattered. For the study, random selection of houses was not used as this could result in an unfortunate bias of the sample towards lower or higher grade properties and because of this test results may have to be adjusted which is unsatisfactory (Twort et al 1985). Hence households were chosen whose number of inhabitants is over a wide range and similarly from different income level groups.

Daily readings were taken from Oct 10, 1987 to Nov 10, 1987 by noting individual meters. The number of inhabitants in each household was obtained from questionnaires distributed earlier. The results of the survey are shown in Table 18.

Table 18. Rate of consumption and tariffs for in-house connections in selected modern houses, Awassa town.

Zone	Number of houses surveyed	Total number of people	Total daily consumption (m^3/d)	Average consumption l/c/d	Tariff (ETB/m^3)
1.	42	276	13.8	50	1.00
2.	53	369	25.7	69.6	1.00
3.	40	225	16.9	75	1.00
TOTAL	135	870	56.4	-	-

From the analysis made for each house, the daily per capita water consumption was found to vary from as low as 30 l/c/d to a maximum of 170 l/c/d. High per capita consumers were observed to use water for gardening and also they had better levels of income. Unlike the majority of the households with 4 - 6 people, the highest consumers were composed of 1 - 3 people in each household. Figure 13 shows the relationship obtained between per capita consumption and household size during the survey period.

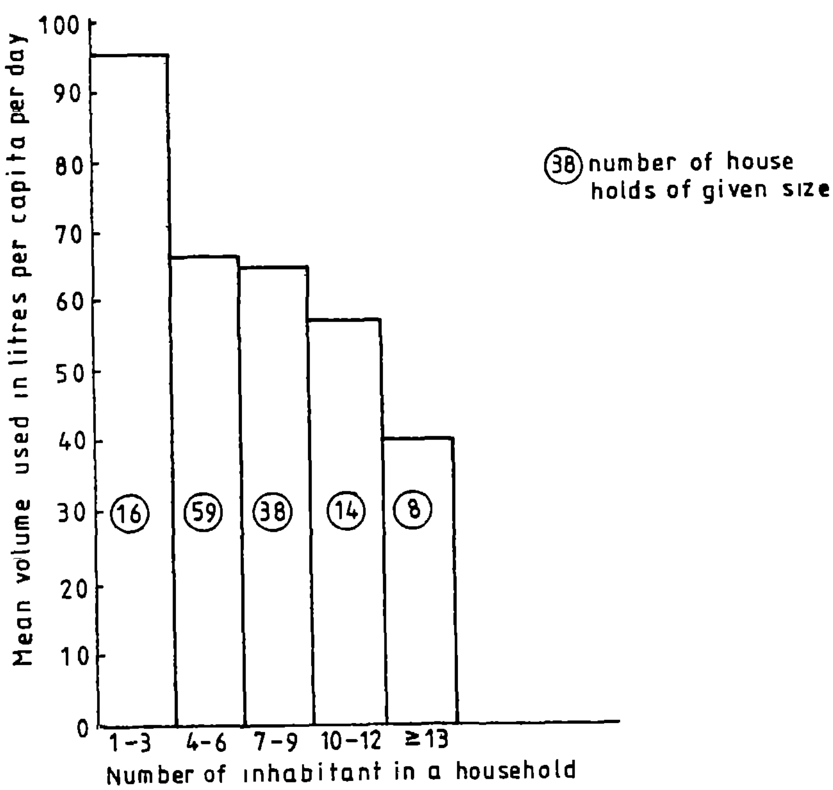


Figure 13. Relationship between per capita water consumption and household size for in-house connections, Awassa town.

The mean per capita consumption in this case was obtained by dividing the total daily consumption by the total number of people and has come out to be 65 l/c/d.

6.3.4 Public and Commercial Uses

Surveys were also carried out to see the water consumption patterns in the major schools and hotels of the town of Awassa. Table 19 shows the average consumption rates during the periods Oct 1, 1987 to Oct 15, 1987.

Table 19. Rate of consumption in some of the public and commercial uses, Awassa town.

Category	Unit	Average per capita consumption
Schools		
- junior and secondary	l/c/d	3
- nursing	l/c/d	70
Hotels		
- major	l/bed/d	390
- medium	l/bed/d	120
- lower	l/bed/d	50

The per capita consumption obtained in the schools was found to be very low. Students usually stay for 3 - 4 hours a day since classes are conducted on shift basis. Even during these hours, limitations on use were noted. This should not be practiced and students should be encouraged to use the water supply system. The hotels were categorized into three parts. The major ones included two large government owned and three other big hotels. They had a well established facility with large provision for dining. Further the medium and the lower categories were separately studied depending on the facilities provided by each of them.

6.4 Variation of Water Uses

As indicated in Chapter 4, the consumption of water varies with time and season. For the analysis of the seasonal variations, past records from the Awassa water supply office were noted while for the daily and hourly variations the master meter at the reservoir was used.

6.4.1 Seasonal variation

The monthly water consumption values are shown in Figure 14 for the whole of 1985 and 1986.

Observation on the two year pattern of water consumption indicates that from June to August, a drop in consumption prevails. A similar fall in consumption is also seen in most urban towns of Ethiopia. The period is rainy and most

people do not take water from their taps but rather make use of rain water for most of their activities.

6.4.2 Daily and Hourly Variations

The patterns of the daily and hourly variations as obtained from the master meter are shown in Figures 15 and 16. As could be seen the maximum day water use was found on a Sunday during the specified study period. As Sunday is not a working day, people use a relatively higher amount of water for baths, clothes washing, gardening and other activities. The average day consumption was calculated to be 963 m^3/day while the maximum day consumption was found to be 1 156 m^3/d.

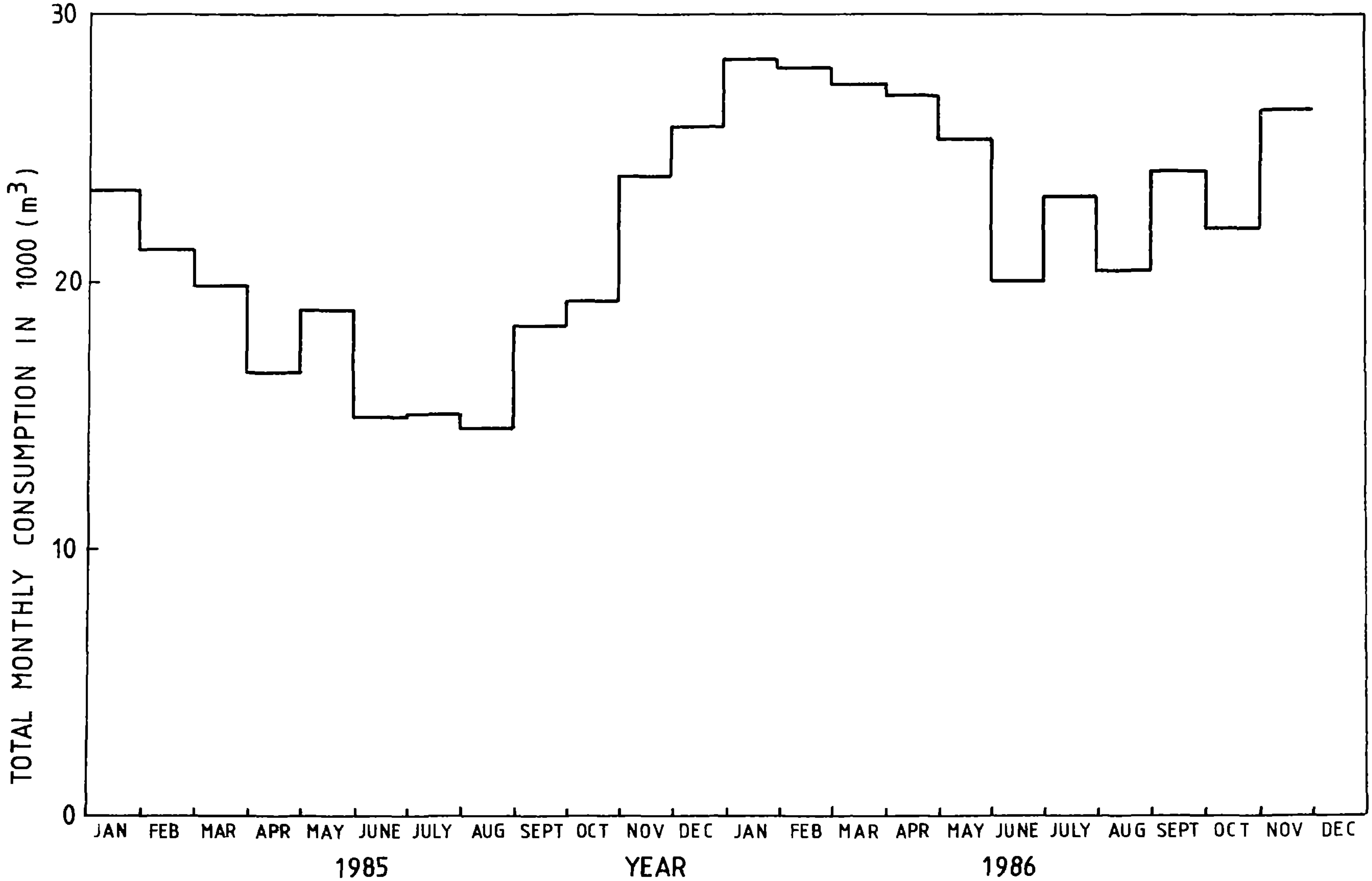


Figure 14. Monthly water consumption patterns in Awassa town (WSSA, 1987).

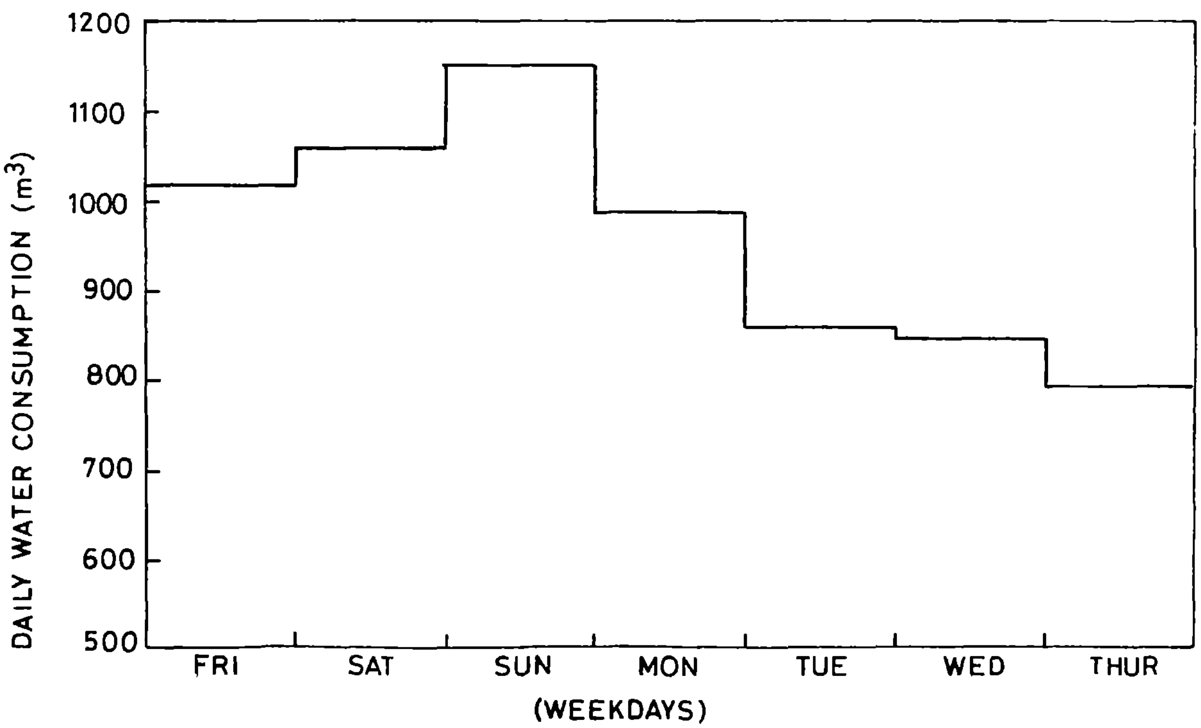


Figure 15. Daily water consumption in Awassa town (Sept. 25 - Oct. 2, 1987).

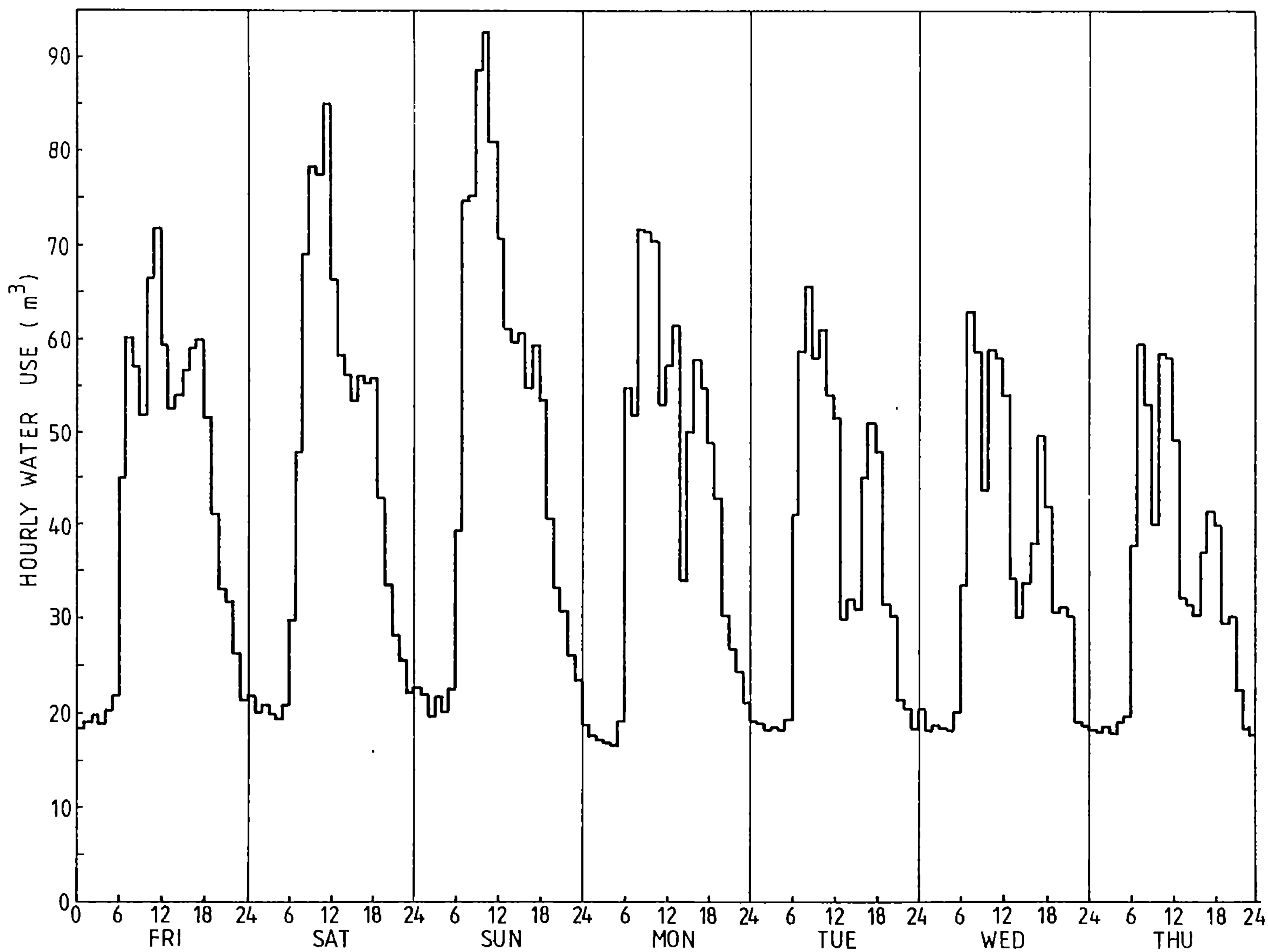


Figure 16. Hourly usage of water in Awassa town (Sept. 25 - Oct. 2, 1987).

Similarly the average hourly consumption was calculated to be 40.1 m^3/h while the maximum hour consumption was seen to be 92.5 m^3/h.

The peak flow hours were observed between 7 a.m. to 8 a.m and 11 a.m to 12 a.m. on working days. The former is the time interval to go to work, hence people use water for washing and preparation of morning meals. The later time is used in lunch preparation. On Sundays peak flow hours were noted between 9 a.m. to 11 a.m. It was also observed that the minimum flow hours were between 2 a.m. to 5 a.m. when most people go to sleep and hence activities get reduced.

6.4.3 Peak Factors

The maximum daily peak factor $C_{d(max)}$ was obtained by taking the ratio of the maximum day and the average day consumptions.

$$C_{d(max)} = \frac{1\,156}{963}$$

$$= 1.20$$

Similarly the maximum hourly peak factor $C_{h(max)}$ was calculated by taking the ratio of the maximum hour and the average hour consumptions.

$$C_{h(max)} = \frac{92.5}{40.1}$$

$$= 2.31$$

The minimum daily peak factor during the study period was calculated by dividing the minimum day demand by the average day demand.

$$C_{d(min)} = \frac{799.3}{963}$$

$$= 0.83$$

By the same method the minimum hourly peak factor was calculated.

$$C_{h(min)} = \frac{17.2}{40.1}$$

$$= 0.43$$

The results are summarized and shown in Table 20.

Table 20. Peak and minimum demand factors (Sept. 25 - Oct 2, 1987).

Location and survey date	Maximum daily peak factor $C_{d(max)}$	Maximum hourly peak factor $C_{h(max)}$	Peak demand factor $C_{(max)}$	Minimum daily peak factor $C_{d(min)}$	Minimum hourly peak factor $C_{h(min)}$	Minimum peak factor $C_{(min)}$
Awassa town	1.20	2.31	2.77	0.83	0.43	0.36

7 DISCUSSION

The investigations carried out on the mode of water usages by different categories will help in predicting water uses with an adequate degree of accuracy. In this respect, measurements on the timely variations of water consumptions and analysis of the various socio-economic factors which affect rates of per capita consumption are the key elements to be given due consideration.

These studies when coupled with sound planning and design practices will result in an economical and efficient water supply system. The timely variations of consumption generate peaks which are important factors in the design of water supply components.

The results obtained from the survey on the water supply scheme of Awassa town are shown below. The designed values and results of other studies are also indicated for comparisons.

Location	Measured per capita water consumption in 1986 (l/c/d) In-house	yard	public standpipes	Design consumption (l/c/d) 1980 - 1990
Awassa town	65	28	9	45

PEAK FACTORS

Location	maximum daily measured (1986)	design (1978)	Ashenafi (1983)	maximum hourly measured (1986)	design (1978)	Ashenafi (1983)
Awassa town	1.20	1.25	1.29	2.31	2.40	2.60

Two factors were noted while comparing the design and measured values of per-capita consumption. One is the importance of separating levels of service into public standpipes, yard connections and in-house connections. Studies on the types of houses existing in the town and levels of income could help in determining the different levels of service.

The second case is estimation of the population likely to use these system connections. As was observed from the town, a considerable number of people were seen to use traditional sources. Although the future modes of living of the people is likely to be better, short term projections should account the effects of these to be able to design an economical water supply system.

The results obtained from the survey indicated lower values as compared to similar urban schemes of other countries. One of the factors which contributed to lower per capita consumption was availability of alternative sources. Most inhabitants own privately dug shallow wells while others use the lake Awassa for various purposes. The shallow wells were not lined properly which led to contamination of the wells and made them unsafe for usage. The regional office of WSSA has succeeded in abandoning some of the wells but continuous effort should be made through teaching the benefits of potable water to the inhabitants.

During the author's field work, discussions were made with householders who do not use the water supply system. The main reasons given were the higher installation cost and the price of water. As compared to Addis Ababa where the price of water is 0.50 ETB/m^3 = 0.24 USD/m^3, the present price of water in the town of Awassa is 1.00 ETB/m^3 = 0.48 USD/m^3. Although prices of water should meet the investment and the operation and maintenance costs, the consumers capacity to afford on the price of water should also be studied. Since a water supply system is built to serve as much users as possible, prices of water should be related to the capability of the various classes of consumers.

In the author's opinion a lower charge should be fixed for a minimum quantity of water which is necessary for the basic needs. Higher charges could then be fixed for the extra consumptions above the basic requirements.

As expected in the survey, variations in the per capita consumptions were obtained. One of the factors noted was the size of a household. Modern households owning in-house connections with 1 - 3 inhabitants had average consumptions of 94 l/c/d as compared with the overall average consumption of 65 l/c/d obtained for these categories. Most households in Ethiopia have 4 - 6 inhabitants in each of them.

The per capita consumptions obtained from the public standpipes of Awassa town were found to be very low. Consumers from these categories were not satisfied with the service hours of public standpipes. Longer duration of operation hours should be practiced to satisfy the needs of users.

The peak factors obtained from the survey were quite comparable to the design values and to the findings in other similar countries. Slight differences were mainly due to measurement periods.

It should always be noted that the primary function of building a water supply system is to supply potable water to the inhabitants. Encouragement should be given to the people so as not to return them to use traditional sources.

The present design practices in Ethiopia differ depending on different designers. Although no detailed guidelines are established, designers should focus on

- flexible and stage by stage systems
- availability of spare parts and
- simpler mechanisms for overcoming operation and maintenance difficulties.

These factors should be analysed together with the economic capability of the inhabitants to build a more efficient and economical water supply system.

8 RECOMMENDATIONS

1. Regardless of the degrees of complexity with which water demand is forecasted, the data base is to be given primary consideration. Without such a reliable basic data, the desired goals can not be achieved with an adequate degree of accuracy. Hence all water utilities should monitor their works and make more data available for any type of research works, which will benefit planners and decision makers in the future.

2. Per capita water consumption is found to vary with different socio-economic factors like modes of living, household size, price of water and accessibility. These factors should be thoroughly studied to analyse their effects on rates of consumption.

3. The percentage of population who use different level of service (in-house, yard and public standpipes) and those who rely on other sources should be identified and studied. The entire population should not necessarily be taken for design purposes. Consumption patterns of various social services like schools, hotels and hospitals should also be investigated.

4. In fixing the price of water, not only the investment, operation and maintenance costs be taken but account should also be given to the affordability of the intended consumers.

5. To handle the variations in consumption, pumps and storage are normally used. Their design should be economical and moreover the supply of adequate spare parts and stand-by pumps should be considered.

6. Designers of water supply schemes in Ethiopia have faced difficulties because of the absence of a design criteria. The experiences obtained from other countries should be coupled with the local conditions of Ethiopia to establish a guideline for design criteria.

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