AN APPLICATION OF TREND ANALYSIS TO MODEL DOMESTIC WATER CONSUMPTION PATTERNS FOR SELECTED RESIDENTIAL AREAS OF NAIROBI

BY

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This Project is my original work and has not been presented for a degree in any other University.

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This project has been submitted for examination with my approval as University supervisor.

I.M. MBECHE

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ABSTRACT

The City residents rely on the Nairobi City Commission for the provision of essential services of which water supply is very important. Provision of such an urban service is very challenging especially with the current population growth rate.

Continued provision of water is only possible if adequate revenue is generated from water sales to cover capital, operation and maintenance costs. Collection of revenue from water sales has been a perpetual problem to the Nairobi City Commission. The major problem in this case is attributable to the delay in reading the water meters, an exercise that has had to be done before billing the consumers. The result has been the delay in billing the consumers promptly and therefore lack of proper enforcememnt for payment.

It has been suggested in the past that the meter reading frequency should be reduced in the case of some domestic water consumers but bill them monthly from consumption estimates. It was the aim of the study therefore to establish whether the past average household water consumption followed a predictable pattern which could form the basis of billing the consumers in the same residential areas.

It was found from the study that the average

water consumption followed a predictable pattern which could form a base of billing consumers in those residential areas where the monthly water consumption does not vary much between households. These residential areas are populous and a lot of time is spent in reading the water meters. Monthly water billing with suitable meter reading intervals would be advantageous to the Nairobi City Commission in very many aspects of which the improvement in revenue receipts is a major one.

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Among other essential services that the Nairobi City Commission is charged with, is the provision of clean water for its residents. The Nairobi City Commission, was appointed a Water undertaker for the Nairobi area in 1959, the area of supply being subsequently extended during the 1960's and again in 1974. This was done through the Water Act.[1]

An area of supply is any area within the City boundary that depends on the Water and Sewerage Department of the Nairobi City Commission for its water supply. There are a few areas within the City boundary that rely on private water undertaker for their water supply.

The City of Nairobi has been divided into water distribution zones. Figure 1.1 in Appendix A shows the existing distribution zones. The proposed future distribution zones are shown in Figure 1.2. Both figures contain information on the bulk transfer of water from the various sources to the storage reservoirs and the direction of distribution to the

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1. Severn Trent Water Authority, Third Nairobi Water Supply Project: Short Term Implementation Plan; Organization, Management and Finance Study, Vol. 1 Report, 1986, pp.29.

zones. Also shown are the ground levels and the top water levels for the various reservoirs which facilitate gravity flow.

1.1.1 Historical Development of Nairobi Water Sources

Nairobi was the choice of the railway builders as the main depot between Mombasa and Lake Victoria mainly because of two reasons (Wagura, 1982; Gupta, 1983). First, there was adequate water available there and secondly because it was the last stretch of level ground before reaching the Rift Valley. Before the arrival of the railway, Gupta (1983) describes Nairobi as follows:

> ... a bleak swampy stretch of landscape devoid of human habitation of any sort, the resort of thousands of wild animals of various species.

Originally Nairobi was a Maasai land. Uaso Nairobi or "a place of cold waters" was the stream bisecting this land. The land later came to be known as Nairobi while the Uaso Nairobi came to be known as Nairobi River. This was the first source of water supply. By 1901 Nairobi had become an important administrative centre with the movement from Machakos of the headquarters of British East African Protectorate. The township of Nairobi was comprised of the area within a radius of one and a half miles from the railway station. The growth of Nairobi led to the extension of its boundaries in 1928 and 1963.

The provision of water in the early part of the century was under the railway authorities who supplied water to Nairobi Township via various standpipes which they erected. This was profitable to the railway authorities who charged a nominal rate of five rupees per month for each stand pipe. This continued till 1921 when the railway authorities sold the water supply to Nairobi Town Council. The agreement was that the railway authorities was to get free water for the first five years and thereafter at a cost price. The Town Council was also required to supply water to Government departments at equitable terms. This then is an indication that payment for water services in Nairobi is almost as old as the City itself.

Demand for water outstripped the supply by 1921 and the Council opened an additional source at Kikuyu springs. It also purchased a private water scheme; Muthaiga Estate supply in 1932. As Nairobi developed and the population grew, additional sources of water were required. Nairobi Dam was completed in 1946 while Ruiru Dam was completed in 1950.

In the early 1940's there existed two schools of thought about the future water supply for Nairobi. One school felt that Nairobi had to rely on surface water drawn from further away. The other school was of the opinion that the best solution to Nairobi's water problems was to rely on ground water which meant sinking large boreholes. With the completion of gauging of the Chania River in 1946, surface water was adopted as the main long term solution for provision of water through the construction of dams.

Plans for Chania-Sasumua scheme were completed around 1948 and this marked the first long distance transmission of water to Nairobi, and the pipeline covered forty miles. The scheme was completed in 1956.

Considerable effort has been put to expand the City's water supply since 1970. Chania phase I water supply became operational in 1974. This was another long distance transmission covering 36 kilometers. Phase II of this project became operational towards the end of 1983. The Third Nairobi Water Supply Project which will involve among other things the construction of a dam on Thika River and the expansion of the treatment plant and storage facilities is supposed to cater for the City's supply till the end of the century. This will make the Water and Sewerage Department of the Nairobi City Commission one of the largest urban water supplier in Africa

1.1.2 The Management of Nairobi Water Supply

The Water and Sewerage Department (W.S.D.) of the Nairobi City Commission was set up in 1970 as a precondition for a loan so that water supply and sewerage services were the responsibility of a separate division from the City Engineer's Department (World Bank, 1977). This brought all the engineering financial and administrative activities concerning water and sewerage under one management for convenience and efficiency in the provision of these services. The Department was to undertake the following tasks:-

(i) To plan its future expansion

(ii) To plan and manage its operations and affairs

(iii) To carry out its operations in accordance with sound business, financial, engineering and public utility practices.

The department is headed by a general manager, who is assisted by two deputies; one for engineering and the other for financial and commercial matters.

The department as mentioned above is supposed to carry out its operations in a commercial manner though of course under the stipulations laid down by the Nairobi City Commission and the Ministry of Local Government. In its pursuit to provide Nairobi residents with water, W.S.D. has been involved in heavy capital investments over the years as mentioned earlier. This is because unlike many major cities of the world (Buky, 1972) Nairobi is not located on a major water course or even close to a significant water resource. The location of Nairobi was chiefly due to the convenience it accorded the railway builders. The problem of provision of adequate water supplies, however, is not unique to Nairobi:

> ...because of the way in which water supply has developed in Britain, the levels of costs varies very greatly between undertakings. Some authorities have been able to exploit abundant water resources comparatively close at hand; others have had to go long distances and construct eleborate and costly structures...In some cases the cost of water is much higher than others...(Sleeman, 1953, pp. 248).

The department has to rely on revenue raised from water charges in order to meet its revenue and capital expenditures. Revenue expenditure has short term consequences and involves meeting operations and maintenance costs. Capital expenditure on the other hand involves the funding of new water supply and sewerage projects (Mwirichia, 1983). If the department has to continue in its operations, adequate revenue must be raised. In the more developed countries water authorities are being encouraged to adopt a commercial outlook of their operations in order to enhance efficient operations. In Britain for example some water authorities are in the process of being converted to Public Limited Companies. There is a general move to privatise water supply services (Turner, 1986, pp. 19).

In its efforts to raise revenue necessary to meet costs of running the water and sewerage services, W.S.D. has to consider social and economic factors in its charging policy. This is reflected in the rate and tarrif structure and consumer categorization. This is necessary especially due to the demographic pattern of the city residents in a developing country like Kenya (Porter, 1983, pp. 354-362).

There are several categories of water consumers. There are industrial consumers who use water as one of the raw materials such as Kenya Breweries Ltd. Commercial consumers use water in their production process but not necessarily as an input. Institutional water is consumed in Public institutions and government offices. Domestic water is water consumed by people in their homes. The biggest consumption is that one for the domestic consumers. This can further be subdivided into those consumers served through private connections, communal water points and licensed water kiosks. In some of the old estates in the Eastlands region like Bahati, the Nairobi City Commission's Director of Social Services is in charge of the meter accounts serving these estates. The charging policy for an urban service like water in addition to cost recovery is to discourage the above consumers from wasting water (Meier, 1983).

Revenue collection has continued to be a major problem for W.S.D. (Severn Trent Water Authority, 1986).

Before a consumer can be billed the meter has to be read to find out the amount consumed. The City is divided into four Billing Groups (BGs). BG1 contains (first two digits of the account number) 01-08, BG2 09-17, BG3 18-29, and, BG4 30-38. Table 1.1 in Appendix B shows some of the areas within the Billing Groups. Currently, all the meters in a BG have to be read before that group can be billed.

Once the meter reading has been done the meter cards are taken to the computer section where punching is done. The computer works out the water charges for the various meter accounts. A tabulation is prepared for those accounts where a mistake in the meter reading is detected or where the current water consumption deviates from the previous one by about 200%.

The number of new connections has consistently grown at a much faster rate than the manpower in the meter reading section. Table 1.2 in Appendix B shows the number of meter accounts in each section of the Billing Groups. Currently there are over 131,000 water accounts in Nairobi compared to the 40,000 in 1973. Though it has not received the attention it deserves, the meter reading section is very important to the department. This is because it is this section that has to provide the meter readings, the only basis of billing the water consumers. Apart from furnishing the readings, the meter readers are supposed to report on the state of the meters so that repair works can be arranged where necessary. It is not surprising therefore to note that as far as payment for water and complaints are concerned, the relationship between the department and the water consumers is very much governed by the performance of the meter reading section.

Meter reading is a taxing job especially when the workforce is small. The situation is aggravated by the rapid expansion of Nairobi. Even if the demand for additional meter readers was to be met, it normally takes a considerably long time before the Ministry of Local Government approves the employment of additional staff at the Nairobi City Commission. Until April 1988 there were 59 meter readers of whom 17 were involved in the administration of the section. An additional figure of 31 new meter readers were employed in May 1988 and it will take quite some time before they become conversant with the City as a whole and the meter reading operations.

There are several problems that hinder smooth operations in the meter reading section. A major problem is transport. The fact that the men do not have adequate transport reduces their productivity. The weather especially during the rainy season affects the number of readings that a man can obtain in a day since most of the meters lie low and get covered by mud or water. When querry sheets are prepared in the case of defective meters, repair work is not carried out promptly. This is evidenced by the meter cards where a meter shows a constant reading for a long time. Some meters are not durable and can be destroyed easily especially when a consumer interferes with a meter to prevent the meter reader from obtaining a reading. Currently, meter cards are vulnerable to destruction. The covers cannot bind the cards properly and there is the danger of not tracing the consumption through an account if its card is lost. Having access to some premises has been a problem due to locked gates and fierce dogs.

With the growth of metered supply which is out of tune with the growth of manpower in the meter reading section it becomes necessary to devise ways of reducing the frequency of meter reading in some areas in an attempt to try and solve the problem of backlog in meter reading and prompt billing. Meter reading is indispendable for a city in a developing country like Kenya where automatic metering has not been introduced. Using ordinary meters is expensive enough. Dann, Feldman and Kamen (1976) have said that telemetering which is an automatic method of metering water consumption, is making the work of the meter reader almost obsolete in some places.

It has been suggested in the past that reduction in the frequency of meter reading to some domestic consumers would lead to improved revenue collection if an appropriate billing procedure is adopted (Mulder, 1982; Severn Trent Water Authority, 1986). The report by Mulder on the proposition for the introduction of a commercial accounting system for W.S.D. considered a monthly billing system based on yearly consumption estimates. The yearly meter readings taken would lead to appropriate adjustments of subsequent water bills depending on whether the consumer had been overbilled or underbilled. The report however doesn't indicate how the annual water consumption estimate would be determined.

The report by Severn Trent Water Authority for Short Term and Implementation Plan on the organization, management and finance study for W.S.D. suggests something different. It suggests a quarterly meter reading and billing of low domestic consumers. The report however is quick to point out the likely problems the department might have from such consumers because of accumulated amounts of money to be paid. It is the monthly billing aspect that makes the suggestion by Mulder more appealing than that of the Severn Trent Water Authority.

The focus on domestic water consumption is due to several reasons. Of the total water supplied in 1986, 61% was taken up by this consumer category.

Presently, of the total 131,011 meter accounts, 114,665 (87.5%) cater for domestic consumption. The implication therefore is that meter reading for these consumers takes a big proportion of the available meter reading man hours. In the year 1985/86 income from this consumer category contributed to 56% of the total income from water charges.

Prediction of domestic water consumption in certain residential areas would go a long way in improving the billing system at W.S.D. This is because it would reduce the delay in meter reading especially for new accounts. Domestic water demand will depend on several factors of which price, income, house occupancy, and house type are important examples (Darr et al, 1976). Water demand prediction has been used in some places where the above factors are used as variables in regression analysis. Studies to establish such factors are quite expensive and often take quite a long time to complete. Time series analysis though not as elegant as the regression analysis can be used to study water consumption pattern from historical data (Darr et al, 1976, pp. 10). It would therefore be appropriate to investigate whether there are any time dependent water consumption patterns within the chosen residential areas which can form the basis of prediction.

An average water consumption pattern that can be used for prediction purposes in given residential areas could be useful to the management of a water supplier like W.S.D. It can form a basis for billing consumers promptly with less frequent meter readings and adjustment made on the consumption estimates after the meter is read. The management, however, requires to decide on a suitable meter reading interval, after addressing itself to such problems as mentioned earlier that might affect the smooth running of the meter reading operation.

1.2 STATEMENT OF THE PROBLEM

The Water and Sewerage Department of the Nairobi City Commission has had a perpetual problem of delay in billing domestic water consumers for the water used. This has resulted in poor revenue collection and lack of proper enforcement for payment.

The delay in billing is also inconvenient to some consumers who find it difficult to pay accumulated amounts of money. There have been major complaints from consumers because in most instances the bills do not match with the monthly consumption.

The core of the problem as previously mentioned is the backlogs in meter readings. Presently the situation is that the consumer can only be billed after reading the meter. As discussed earlier it has been suggested in the past that the problem due to the backlogs in meter reading can be reduced by adopting less frequent meter readings but at the same bill the consumers promptly.

An appropriate starting point towards this end is the determination of water consumption pattern for given residential areas. Such a pattern if suitable for predictive purposes could be used to bill consumers promptly. This is especially useful for those new consumers in the given residential areas. As some housing estates tend to be similar, the pattern for one residential area might be found appropriate to bill consumers in another residential area.

1.3 OBJECTIVES OF THE STUDY

The objectives of the study are as follows:-

1. Identify the domestic water consumption pattern for households in selected residential areas of the City of Nairobi.

2. Investigate whether the pattern can be described by a trend curve.

3. Test whether if objective number 2 is met the curve could be used for billing purposes.

1.4 IMPORTANCE OF THE STUDY

The study will be useful to the following groups of individuals:-

1. To the Water and Sewerage Department,

(a) The consumption pattern so obtained from the study may provide a method of improving the billing of water and collection of revenue.

(b) The planning section of the Water and Sewerage Department may find such a pattern useful in the planning of water provision in the given residential areas or similar ones.

2. Water supply project financiers who fund water supply projects in the department would be interested in a study that could lead to an improvement in revenue receipts in the department.

3. Consumers would favour improved water billing procedure as compared to the present system where they get accumulated bills that do not match with monthly water consumption.

4. Researchers who might be interested in such or a related study.

1.5 AN OVERVIEW OF THE PROJECT REPORT

This management project consists of five chapters. The foregoing discussion in this chapter considered the background, the statement of the problem and the objectives of the study. The significance of the study is also discussed in this chapter.

The second chapter provides a review of the literature relevant to the study. Consideration is given to residential water consumption, forecasting water consumption, meter reading and billing for water.

Research design is covered in the third chapter. In this chapter, the population, sampling method and data collection procedures are considered. An overview of data analysis is also given.

The fourth chapter covers data analysis and the reporting of the findings while the fifth chapter, the last, is a conclusion containing a summary of findings, limitations of the study, and suggestions for further research.

CHAPTER 2

LITERATURE REVIEW

2.1 WATER CONSUMER CATEGORIZATION

Water supply authorities normally categorize their water users into various user sectors. A user sector as Boland et al (Sept. 1982) have put it can be defined as a group of water users or water using activities that are reasonably homogeneous with respect to variables and functions that explain and predict the quantity of water likely to be used by each sector.

Several parameters can be used to define these user sectors. These parameters are time, space, and property use classifications. Traditional property use classification include residential or domestic, commercial and institutional categories. Domestic water is consumed at people's premises and can be divided into sub-categories as will be explained later. Consumption in small factories where water is not used in the manufacturing process is classified as commercial water. This comprises the water used in restaurants, hotels, shops, and private offices. Institutional water is the water used in places like schools, hospitals, and government offices. Industrial water is used in any place where water is used in the manufacturing process. This can be in small engineering workshop, light industry or a big industry.

2.2 DOMESTIC WATER SUPPLY

Most of the efforts of a water supply authority in an area are geared to supplying the residents with adequate water and of a quality that attains given health standards (Singley and Black, 1972, pp. 7-10). A substantial cost of the operating costs in such an authority is in the running of the treatment plant. The treated water so to speak must be 'wholesome' and 'palatable'. Water is wholesome if it contains no pathogens (disease causing micro-organisms). It is said to be 'palatable' if it is clean and clear. Most water authorities will find it uneconomical to supply different waters of different quality for human and industrial use and hence use the same supply for all consumers.

In the provision of water and wastewater services to its customers, authorities incur water costs which are supposed to determine water rates (Woodcock, 1984, pp. 61). Expenses incurred by the authority are separated into three categories: (1) billing costs, (2) capacity costs, and (3) commodity costs. Billing costs result from service costs that include labour, accounting and administrative expenses required for billing and collecting. Capacity costs result from providing the water distribution system and wastewater collection system and keeping them in service. Commodity costs are those that vary directly with the amount of water delivered to the customer and include the cost of chemicals and power used in the treatment process.

A public utility involved in water supply normally has two revenue categories:

(1) capital revenues generated from capacity charges, and,

(2) user charge revenues generated from water and sewer rates.

Water and sewer user charges are the most important revenue sources that support daily operations. The capital revenue charges are separately identified under a general heading of capacity charges and are commonly referred to as connection fees or tap fees. The purpose of the user charges is to support the daily operations and maintenance, whereas capacity charges are supposed to support customer growth through system replacement, improvements, expansions or any other project that will lead to the improvement and expansion of the available capacity in the water and sewerage systems.

Even for domestic consumption, all the consumers are not the same and can be divided into several classes. There are those who have private and individual connections and those who have communal water points. In the latter user class several households draw water from a common tap. In developing countries where dwelling in 'shanties' is common the inhabitants could be supplied through water kiosks.

Metered connections have gained widespread use by water supply authorities which involves charging or administration of the charging system of water on the basis of consumption (Porter, pp. 356). It is also argued that metering comes closest to satisfying the objectives of a good charging system namely:-

(1) adequacy of raised revenue to meet the utility's financial requirements subject to the willingness and ability to pay by the consumers;

(2) fairness or equity so that a customer pays for the constraint he subjects the water supply system but depending on income level;

(3) simplicity as far as operation and administration of the charging system is concerned, and;

(4) enforceability so far as the withdraw of the service is speedy and effective sanction for non-payment of bills.

The above objectives cannot be fulfilled if the installed meters are not read timely. This important exercise of meter reading is covered in the next section.

2.3 METER READING

The importance of meter reading in a water utility like Water and Sewerage Department of the Nairobi City Commission is summed up by Laurence (Nov. 1975, pp. 604) in an article in the Journal of American Water Works Association (AWWA):

> "For most water utilities, meter readings are the foundation of all utility operations. Yet the larger the utility, the harder it is to manage..."

The meter reading aspect is important as far as customer relations is concerned:

> "Knowledgeable water utility managers always have known that their first line of public relations is made up of their outside men, particularly the meter readers - the only utility employees who contact every individual customer at least once a year. Needless to say, the impression these men make on customers help shape the utilities' image." (O'Leary, Journal AWWA, Aug. 1971 pp. 481).

Irrespective of the amount that a water utility has invested in plant and distribution system, its continued operation depends on whether it can raise adequate revenue which depends on meter reading and billing activities. Meter reading however has been recognized as a universal problem (Snider, Dec. 1969, pp. 641-644). In the article to AWWA Journal, he attributes this problem mainly to the fact that most meters are located indoors and adds:

> "While obtaining meter readings is a problem for water utilities of all sizes, it is becoming, if it is not already, a crisis for the larger utilities in the cities."

As the City of Nairobi expands and more residential areas come up the number of people with metered water connections will increase and meter reading poses to be even a more difficult task for W.S.D. The Department should therefore devise ways of alleviating this problem.

2.3.1. <u>Automatic Meter Reading</u>

To counteract these problems some water utilities in developed countries like the U.S.A. are undertaking what is called a meter reading revolution in conjunction with other public utilities. Meter manufacturers, water, gas, and electric utilities, private entrepreneurs, and the telephone companies are said by Snider to have been interested in developing better means for reading both industrial and residential gas, electric and water meters. What is evident however is the fact that money available to read residential meters automatically is so restrictive that a major effort is required on the part of all participants to devise an economically attractive alternative to replace the manual methods.

After several trial tests, several water utilities have adopted automatic meter reading. Snider has described this ability to read meters automatically as "the greatest breakthrough for water supply field since chlorination of water supply." Some systems under development for automatic meter reading are: existing telephone circuits, radio frequencies, and existing power lines. The systems receiving the greatest amount of attention are ones using existing telephone circuits. In this case, special equipment is required in three locations:

(1) utility's data processing centre
(2) the telephone central office serving the subscribers whose meters are to be read, and,
(3) the meter location.

The above development in residential meter reading is appropriate in water utilities in developed countries especially where the utilities are large. In such countries the supportive facilities for such an activity are available, e.g. having most if not all of the consumers owning a telephone. There is synergy as the public utilities co-operate with the manufacturers of the necessary equipment to make the whole exercise economical. What should be realised, however, is that telemetering meter reading has not gained widespread use even in the developed countries and some utilities have to look for alternative ways of improving the exercise.

2.3.2 Manual Meter Reading

Manual meter reading is in widespread use in developed and the developing countries. Meter reading became necessary after most water utilities decided that it was necessary to relate the charge to a consumer to the amount of water consumed. Even where automation has been done it becomes necessary once in a while for somebody to do a check:

> "The increasing difficulty in gaining entrance to homes during normal working hours for meter readers and water servicemen cannot be ignored. Remote reading devices are interesting but they do nothing to the meter serviceman..." (Customer Metering Committee, Journal AWWA, April 1970,pp.220).

One aspect, therefore, that makes manual meter reading a difficult task is the siting of the meter. The above committee goes on to add that initially the meter siting policy did not consider how periodic checks, repair and maintenance could be facilitated.

To make manual meter reading more productive water utilities have to improve the operations of the meter reader and to encourage self reading by the consumers. The operations of the meter reader can be improved in several ways. Proper transport is very essential. Extraneous work like carrying very heavy meter books or physical searching of a hidden meter should be avoided. Motivation is a very important aspect and the meter readers should be encouraged to do their best. Proper zoning of the area and the arrangement of the meter sheets in a logical order makes meter reading easier. Wilson (Sept. 1979) recommends that meter readers be rotated regularly to prevent any faking of readings and the collusion of consumers and the meter readers.

Some utilities have customer-self-meter-reading programs (Carlson, Feb. 1977) especially to those consumers willing to adopt the method. The self-reading interval and the time that utility's man should do a check reading is agreed upon. The reading could be sent by mail or dropped into the utility's premises. The purpose of self-meter-reading is:-

(i) to reduce meter reading costs
(ii) to eliminate estimated bills as much as possible, and,
(iii) assist house owners.

This of course encourages the home owners to take special care of the meters. Whether it is self-reading or otherwise, some utilities have some meters read monthly, quarterly, or after a longer period depending on the revenue that they generate.

2.3.3 The Case of Nairobi

Manual meter reading is practised in Nairobi. The metered area is divided into four zones that are called Billing Groups. The present computer system for billing is such that all the meters falling within a Billing Group have to be read before the customers are billed. The average interval between any two meter readings for a Billing Group is called a billing cycle.

Whereas most water utilities in the developed countries like U.S.A. and Britain operate as independent organizations administratively, most of their counterparts in Africa do not act the same. The water utility is normally a department in a local authority. A few countries however have water supply being managed by independent bodies. A good example is the General Organization for Greater Cairo Water Supply established in 1968 under the jurisdiction of the Egyptian Ministry of Housing and Utilities for financial and technical matters and under the Ministry of Local Government for administrative matters (Hegab, July 1986).

One would therefore expect water utilities in Africa to experience more problems than their counterparts in the developed world. The area of meter reading is definitely one area that is quite problematic. Lack of adequate staff and reliable transport has been the major cause of meter reading backlogs experienced in the case of Nairobi.

No studies have been carried out in the past that have addressed themselves directly to the issue of improving meter reading at W.S.D. Wagura and Gupta (1981) did carry out studies on the improvement of operations at W.S.D. Wagura's study focused on the location of additional Water depots in the City based on the pipe leakage data from various areas. His conclusion was that location of additional depots would improve the activities of the Operations and Maintenance section of W.S.D. and centralized at the Kampala Road depot. Gupta's study was related to that one by Wagura and concerned itself with the scheduling and control of transport labour force and materials from the Kampala Road depot. The findings of the above studies were not implemented but Gupta's findings on scheduling of transportation and labour force might be useful to the meter reading section.

Another study that would be said to be somehow related to meter reading problem is the leakage study carried out by Mikip Limited Consulting Engineers in 1984. The aim of the study was to find out the amount of water consumed and the amount that is wasted mainly through leaking mains. A comparison was to be made of the amount of water billed and the amount produced from the sources. One finding of the study was that there was no regular inspection and replacement of the meters and consequently the accuracy of the meters read was not known. This meant that the study could not accurately determine the amount of 'unaccounted for' water.

As mentioned in Chapter 1 there have been suggestions to reduce the meter reading frequency especially for most of the numerous residential domestic water consumers but bill them monthly on reliable estimates. (Mulder, 1982; Severn Trent Water Authority, 1986). These are suggestions that W.S.D. should consider implementing perhaps after studies. This study is therefore an attempt to investigate whether average water consumption in some residential areas can follow a predictable pattern that could be used to obtain water consumption estimates.

2.4 FORECASTING WATER CONSUMPTION

2.4.1 Forecasting in General

Management makes many important decisions that require forecasting of the future. The various departments of an enterprise require some type of forecasts in order to carry out their functions. There is however no single forecasting method that can meet the needs of all decision making situations. (Wheelwright and Makridakis, 1973). These authors have further distinguished planning and forecasting. Forecasting is generally used to describe what will happen under a set of circumstances if the manager makes no changes. Planning, on the other hand, involves use of forecasts to help make decisions about the circumstances that are likely to be most attractive to the company.

The various forecasting techniques that have been developed to cater for various circumstances can be divided into two broad categories; qualitative techniques and quantitative techniques. In quantitative techniques historical data is used together with a certain set of rules to develop a prediction of future values. Where such data is not readily available or applicable the judgement of the management is very essential and qualitative forecasting then becomes very appropriate. Mathematical models are not appropriate in this case and the situations involved are normally highly uncertain. The techniques are still largely intuitive and address themselves to issues like technological breakthroughs, changing societal attitudes and political developments among others. There are however, some forecasting techniques like subjective probabilistic forecasting that do not fall within the quantitative or the qualitative categories.

Selection of the forecasting technique depends on the characteristics of the various forecasting methods. Time horizon is the span of time into the future for which different forecasting methods are best suited. Qualitative techniques are used for longer time horizons than quantitative techniques. Included in this is also the number of periods concerned.

Some techniques are suitable only for single period forecasts while others can be used to forecast for several periods.

The pattern of data is another characteristic. Some data will display seasonal variation, trend or an average value with random fluctuations surrounding it. The underlying data pattern will also determine the appropriate model. Models, which are the basis of quantitative techniques can be classified as either time series or causal.

Other characteristics of forecasting techniques that govern their selection are cost, accuracy and ease of application. The costs involved in a forecasting technique are for development, storage, actual operation and opportunity cost. The accuracy in the forecast of some variable might be a very important factor in some situations and this implies a rigorous model. Managers will normally use that forecasting technique that they understand and have confidence in.

2.4.2 The Underlying Pattern of the Data

All forecasting methods assume that some pattern or relationship exists that can be identified and used as the basis for preparing a forecast. In quantitative techniques however, the technique has to match the data pattern. Four types of pattern usually discussed are horizontal, trend, seasonal and cyclical.

When there is no trend in the data, the result is a horizontal pattern, and the series is generally referred to as stationary; that is, it does not tend to increase or decrease in any systematic way. It is equally likely, therefore that the next value of the series will be above, on or below the stationary value.

When a series fluctuates according to some seasonal factor, the result is a seasonal pattern. The season may be monthly or some time period of the year, but they could also be weekly or daily variations during the month. Sale of items conditional on the weather like soft drinks follow a seasonal pattern.

A cyclical pattern is similar to a seasonal pattern except that the length of a single cycle is generally longer than a year. An example of a cyclical pattern is the price of agricultural products.

When there is a general increase or decrease in the value of a variable over time, a trend pattern results. Stock prices, GNP, and many other business and economic indicators follow a trend pattern. The trend could be linear or curvilinear.

It is important to note that a number of other patterns can be found in specific series of data but the four discussed above are the most important. Some series do combine a trend, seasonal and cyclical pattern.

This study involves quantitative methods of forecasting. These methods can be divided into two categories:

(i) time series, and,

(ii) causal models

Whereas all time series methods are quantitative, causal methods include both quantitative and qualitative techniques. Only causal models that involve qualitative techniques will be mentioned briefly.

2.4.3 Causal Models

Causal methods tend to be richer in their descriptive power than time series methods, the reason being that the latter operate only off part values of the forecasted variable. These models consider factors which impact or are related to that which is being forecasted. There may not be a direct cause-and-effect relationship but there is always a logical connection between the independent and the dependent variable (the one being forecasted). The factors considered in causal analysis can be either internal or external to the organization. In a typical firm factors like GNP and competitors' prices are external while selling prices and marketing expenditures are internal and all can affect the sales of the firm. Important models that are causal in nature are:-

(i) regression analysis, and,

(ii) econometric modelling.

The objective in regression analysis is to identify a functional relationship between one or more independent (predictor) variables and the dependent (forecast) variable. Those predictor variables with good predictive power are identified and the mathematical equation is developed. Statistical tests can be performed to determine the reliability of the coefficients of the equation.

Econometric models are used to forecast the effect of different economic policies and conditions. These models contain many equations which describe an economic system. Only large business organizations operate econometric models where a firm could be interested in the effect of its sales from given economic conditions and the actions of other firms. The sales of a given firm could be a function of the price, advertising expenditure, GNP, research and development expenditures, and the price of the firm's leading competitor. Regression analysis is commonly used in the development of econometric models but an organization requires financial and personnel resources to devote to the development of these sophisticated forecasting models (Gallagher and Watson, 1985, pp. 129). Time series analysis which will be involved in this study deserves separate treatment.

2.5 TIME SERIES ANALYSIS

In time series analysis methods, past data for the forecasted variable is used to generate projections of the future. Past values of the variable being forecasted are analysed in order to make forecasts for the future with the assumption that which has happened in the past will provide information as to what will happen in the future.

Simple time series does not address itself to causation and the analyst is unaware of the basic mechanism which is generating the series but he assumes that there is sufficient momentum in the series to ensure that the future behaviour will be like the past. When the analysis deepens, however, the analyst has more insight into the underlying causation and there are several predictor variables involved. This study will consider simple time series analysis.

An important notion in time analysis is time which determines the length of the series. The length is defined as the time between the recorded start and finish. It could also be defined as the number of observations. In the latter case it will depend on whether the observations are yearly, quarterly, monthly or daily. Wheelwright and Makridakis give an example of how rainfall over a 10 year period can be regarded as 10 observations for annual observations, 40 for quarterly values, 120 for monthly values, and 3652 for daily observations.

Another important aspect of time is the time horizon over which forecasts should be made. The definition of time horizons will vary but the following division is generally used:-

(i) immediate term (less than one month);
(ii) short term (one to three months);
(iii) medium term (three months to two years), and,
(iv) long term (more than two years).

Most quantitative methods are said to be appropriate for medium term forecasting (Gallagher and Watson, 1985).

Decomposition of time series is the breaking down of the series down into the individual components that were mentioned earlier. This is particularly necessary if it is realised that from the resulting pattern one of the components is dominant. The components are trend component which reflects a long-range general movement up or down over time. The seasonal component reflecting changes up or down at fixed points in time, usually a year or less. Changes at fixed points in time that cover periods greater than a year are due to a cyclical component. Random variation is what is left after all the other components have been accounted for i.e. the unexplained noise which remains. It is highly unlikely that cyclical component will emerge from the pattern of average water consumption.

There are a variety of time series analysis methods some of which are quite sophisticated. An example of the sophisticated ones is the Box Jenkins method. After the foregoing general ideas about time series analysis some of the common methods will be mentioned briefly. These are; the graphical method, moving averages, exponential smoothing, and trend analysis.

2.5.1 The Graphical Method

This does not require a mathematical model. Past data is graphed and forecasting done from the graph. The methods depends on the forecaster's ability and experience in identifying patterns in the data and making projections. Although it is simple, it is subjective. Another limitation is the fact that it is only possible when there is only one source of variation. The graphical method, however, is useful as a first stage before using more sophisticated methods to help identify the trend, seasonal, cyclical and random components. This helps in selecting an appropriate forecasting method.

2.5.2 Moving Average

A moving average is a useful and simple forecasting model for short to medium term forecasts. It uses the average of what has occurred in the past to forecast the future. In equation form:

$F_{t+1} = \bar{x}_t$ where

F_{t+1} = forecasted value of x in time t+1.

$\bar{x}_t$ = moving average computed up to and including value of x at time t.

Only the last N observations are used. Every time a new observation becomes available, the average shifts to include the newest observation and drops the oldest observation previously used. Hence the value of $\bar{x}_t$ is computed as:-

$$\bar{x}_t = \frac{x_t + x_{t-1} + \ldots + x_{t-N+1}}{N}$$

The number of terms included in the above computation will depend on prevailing circumstances. A dynamic situation will require more number of terms while a relatively stable situation will require less number of terms. The use of a moving average has limitations in that it does not capture a trend properly and fails to account for any seasonality. In addition, a number of terms is lost at the beginning and at the end of the period of analysis.

2.5.3 Exponential Smoothing

Exponential smoothing is an alternative to a moving average. Like a moving average it is used for short- to medium-term forecasts. An exponentially smoothed average is computed as follows:

$$\bar{x}_t = x_t + (1-\alpha)F_t$$

where $\bar{x}_t$, x_t and F_t take values as defined above and α is a smoothing constant between 0 and 1. The average computed through time period t is used as the forecast for time period t+1 and results in the model shown below:

$$F_{t+1} = x_t + (1-\alpha)F_t$$

Apart from the task of determining the values of the smoothing constant, exponential smoothing fails to capture cyclic and seasonal sources of variation.

2.5.4 Trend Analysis

Fitting a curve to a set of data is the objective of trend analysis. The trend analysis could be linear or curvilinear. In curvilinear trend analysis, quadratic and logarithmic curves, among others, are fitted to the data. In trend analysis time is the independent variable while the forecasted value is the dependent variable. A plotting of the data is normally recommended as a first step.

A linear curve or equation that best describes the demand data is selected using methods like ordinary least squares. Linear, quadratic and logarithmic equations can be handled using ordinary least squares.

A need frequently arises where seasonal variation is considered. Gallagher and Watson (1985) say that this extension to trend analysis model can be made without adding much complexity. An approach to this extension is to find out how much should be added to or subtracted from the trend forecast depending on the season as demonstrated by the above authors.

2.6 FOCUS OF THE STUDY

Water demand forecasting is done in an aggregative manner for capacity development. What is normally done for domestic water demand is to get future population projections and multiply this with per capita water consumption to get the expected demand. Non-domestic demand is estimated from the expected activity level.

It has been found that the above method of forecasting is rather simplistic and that the population figure alone is not adequate in estimating future demand. The Water and Sewerage Department did develop a model some time ago to estimate future domestic water demand (Report by W.S.D., June 1976). The regression model requires inputs for GDP, population growth, income distribution, house occupancy, non-domestic demand and a measure of water accessibility for squatters.

After capacity development, a great concern for a water utility as it has been emphasised all along in this chapter is the tracking down of the consumption through units of the user sectors in order to generate revenue.

In trend analysis, factors of causation are not considered. One can therefore investigate the trend of consumption for a given user sector. For a residential area, trend analysis for average water consumption can be done. In fact attempts have been made to assess the amount of water used by a 'typical' family in housing of different standards (La Touche, 1983). The major reason that one would expect the emergence of a trend in the average water consumption in households is that per capita consumption does increase in some cases. La Touche points out that even in areas of established supply, average per capita consumption may increase as some consumers in an area install modern plumbing and water consuming facilities. For high class housing, figures for per capita consumption may indicate the limit to which average per capita consumption will tend. Water price increases may lead to a declining trend in households' water consumption. This however might not be very significant as price elasticity of demand for water is normally low in urban areas.

Trend analysis has been used by some water utilities in the development of what is called Equivalent Residential Units (ERU) to determine water rates for all types of consumers (Woodcock, Journal AWWA, Sept. 1984). The historical average daily usage based on meter readings, is used to develop the factors with which an ERU schedule is established. The customer's historical or projected use of water can be used to determine the daily average demand that the consumer's connection will place on the water system. The single family home, or its equivalent, represents one unit.

It cannot be overemphasized that the data pattern is the best guide as to what further analysis is necessary. The data may not portray any trend at all or even any form that can be modelled. When monthly variations are random, the average figure over time might be the simplest predictor of what is expected.

CHAPTER 3

RESEARCH DESIGN

3.1 POPULATION

This exploratory study covered three residential areas of Nairobi where the households have individual water connections. The water meter accounts within a given residential area constituted the population.

It is assumed that the population chosen is reasonably homogeneous as far as factors that affect domestic water consumption are concerned. Residential areas in Nairobi generally reflect the income of the residents (though it does not always follow so). Residential homogeneity can therefore be assumed to be reflected by the type of house and fixtures as described below.

The housing classification adopted is as shown in Table 3.1 in Appendix B as used by the Water and Sewerage Department. Categories 1, 2 and 3 households are taken to correspond to high, middle and low income residential areas. Category 4 designated as very low income housing and unauthorised shanty areas was not relevant to the study as the people in this category are served through communal water points and licensed water kiosks.

In Category 1 lies substantial detached houses and modern houses with medium to large gardens in areas like Muthaiga, Lavington and Karen-Langata areas. Houses in this category would have full internal plumbing, with high water consumption for normal domestic purposes plus additional amounts of water for 'luxury' purposes like car washing and garden watering.

Category 2 applies to housing estates and flats whose occupants are in the middle income bracket. Households in this category would have full internal plumbing and use water for car washing, but generally little is used for garden watering.

The majority of the population with low income have households in Category 3. These people live in small houses and flats in the older parts of the city and the new site and service areas in the Eastern Extension. This type of accommodation is generally partially plumbed, often with a yard tap and one or two internal taps. Others are served by communal water points as in Shauri Moyo and Bahati estates. Houses in this category may or may not have flushing toilets.

It was originally decided to consider Lavington for Category 1 residential area, Buruburu for Category 2 and Jericho for Category 3. These areas were chosen after considering the information in Appendix B contained in Table 3.1 for household categorization and Table 1.1 for sections covered by the Billing Groups in, conjunction with Figure 1.3 of Appendix A, showing meter section boundaries. These tables were consulted before doing any sampling. The data required for the chosen households or meter accounts is contained in the meter reading books which are arranged according to the sections of a Billing Group. It was found convenient to select an area that dominates a section to avoid the situation where the data is scattered among many records.

The study covered the period January 1982 to December 1987, the latter date being determined by the availability of meter readings. Only those meter accounts that had been in operation throughout that period were considered. As from 1982 the supplies to the chosen areas were fully developed. Among other factors that influence the demand for domestic water consumption is its availability as reported by Tenier-Buchot (1980).

3.2 SAMPLING PROCEDURE

A pilot survey was conducted to determine the appropriate sample size to be taken in the chosen residential areas. The following formula was used to determine the number of households or meter accounts to consider:

$$n = \frac{z^2 s^2}{E^2} \quad \text{...............} \quad (1)$$

where n = number of households

z = reliability

s = sample standard deviation

E = maximum tolerable error.

The reliability factor in the study was set at 95% and hence z = 1.96. The population standard deviation being unknown was estimated from sample standard deviation in the pilot study. The maximum tolerable error is normally taken as half the reliability factor i.e. z/2 (Parson, 1978, pp. 312-315).

A random sample of 50 households from the meter books for each residential area were randomly selected. The chosen sample size was at least 30 in order to conform to the central limit theorem (Parson, 1978). A residential area normally lies within a section of a Billing Group and contains several meter books. There was stratification in the sampling since each meter book was to yield a given number of accounts (approximately fifty divided by the number of meter books in the section). Systematic random sampling was done from each meter book and the sampling interval was determined by the number of accounts in the book. The first account was randomly chosen so as to lie within the first ten pages of the meter book. It was ensured that all the meter accounts chosen had been operating during the whole period covered by the analysis. If an account failed to meet this criterion, the next account was considered.

The water consumption for the month of January 1982 was determined for the households chosen. The meter accounts in Lavington area were discarded because the consumption within the households varied very much necessitating a very big sample to be taken (n>200) when the formula for the sample size was used. Loresho and Kyuna residential areas were chosen to replace Lavington. Table 3.2 is a summary of the results of the pilot survey. The table shows the average water consumption for January 1982 for the 50 households used in the pilot survey, the standard deviation and the sample size arrived at after using equation 1. The adopted sample size is also shown for each of the residential areas. The sample sizes used in the study were 150 for Loresho and Kyuna, and 50 each for Buruburu and Jericho.

The adopted sample sizes are bigger than the calculated ones just to enhance the accuracy of the results. The households used in the pilot survey were used in the study. Daniel and Terrel (1975) have said that observations used in the pilot survey may be included in the final sample. It was only for Loresho and Kyuna areas that more households had to be sampled to increase the number to 150.

3.3 DATA COLLECTION

The data used in the study was secondary data obtained from the meter books in the meter reading section of W.S.D. The meter reading section is responsible for reading the consumer meters and to avail the meter books to the computer section for

Table 3.2: Summary of the Pilot Survey

Residential Area	Average Consumption	Standard Deviation	Calculated Sample size	Adopted Sample size
Loresho & Kyuna	44.02	5.52	122	150
Buruburu	19.4	2.75	35	50
Jericho	2.62*	1.65	11	50

*The figures for Jericho are in thousands of gallons while those of the other areas are in thousands of litres. Most of the water meters in Jericho register Imperial volumetric units. The few values that were in metric had to be converted to Imperial units.

punching and subsequent billing before being returned to the meter section again.

The meter accounts in a section of a Billing Group are recorded in a meter book. A section can have several books depending on the number of meter accounts in the section. A book can hold up to 300 meter accounts. Every page of the meter book which is called a meter card contains the information about the account. This information includes the stand pipe number (S.P. No.), the account number, name and address of the account holder. Also included is the plot number and the name of the estate where the meter is located.

Corresponding to the S.P. number is a file which is opened for every new water connection that is introduced. This is permanent for the property served and does not change when occupants change. The water meters are not changed unless they are defective. When residences change occupants the S.P. number is not changed. The name and address are changed together with the last digit of the meter account number. An account number contains eight digits the last of which may be zero to nine and designates the status of the meter account holder. A zero designates the first meter account holder, a one the second and so on.

Figure 3.2 shows a specimen of a water meter card. The three columns shown are used for recording data by

Figure 3.2: Specimen of a Water Meter Card

NAIROBI CITY COMMISSION
WATER METER READING CARD

S.P. No.	METER No.	ACCOUNT No.
62153	01C70657	3582981

NEW ACCOUNT No.

JOHN KIGONI
P.O. BOX 50828,
NAIROBI.

PLOT NO. 76/833

BURU BURU ESTATE

DATE	METER READING	REMARKS	DATE	METER READING	REMARKS

the meter readers in the field. The date when the meter is read is recorded in the first column. The meter reading figure is recorded in the second column. Most of the meters in current use have metric volumetric units in which case the meter reading figure is recorded in thousands of litres to the nearest thousand. In parts of the older areas of the City where old meters exist which have Imperial volumetric units, the meter reading figure is recorded in thousands of gallons and is expressed to the nearest 500 gallons. Both types of meters can exist within an area and to differentiate the units, the meter readers record the consumption in gallons with a decimal point.

The remarks column is used for recording any additional information about the meter. This might include the need for repair or the reason why a meter cannot be read for example if it is covered by mud or water, or if the gate is locked. Most meter readers prefer to record this information at the back of the meter card if more space is required. Another important use for the remarks column is the re-recording of the consumption figure if the reader feels that the first figure is illegible. A cross sign is marked on the column if the consumer is billed on the basis of an estimated reading.

Several sets of meter reading books were used because they have been changed three times since 1980.

Once the meter cards get filled the binding covers are removed from the books but the section number and the book number is written on top before storing them away.

The first task was to get the books containing the meter accounts for the chosen residential areas. The first and second lots of meter books contained meter readings for period 1980 to 1982 and 1982 to 1984 respectively. The former were very difficult to get because they had been damped at Water Stores, a store away from WSD offices. A heap of old unworthy stationery had to be removed before the books could be reached.

The third lot of meter books contained meter readings for the period 1984 to 1987. These were obtained from the meter reading section but were not arranged in any order. They were however in a better condition and were not as dusty as the first and second lot.

The fourth and last lot of the meter books were in active use and covered the period from May 1987. These were in good condition and were obtained from a room in the meter reading section where meter readers report for duty. Some difficulty was experienced in tracing a few books which had been taken to other sections like the billing section to sort out consumer complaints.

Data collection sheets were used to record the information obtained from the meter cards. The first data item to be recorded in the sheets was the meter account number followed by the date when the meter was read and the meter reading figure. It was found convenient to work through one set of the meter books at a time.

The meter reading dates did not fall within the beginning or end of a given month and adjustments had to be made in order to determine the monthly water consumption. The number of days between the meter reading dates and the corresponding water consumption were determined. The latter figure was obtained as a difference between the consecutive meter reading figures while the former was arrived at after considering the number of days in the months concerned. The amount of water consumed during the days falling within a given month was used to compute the monthly consumption using proportions. Except for the first and last months of the study period, all the other months had two monthly consumption figures taken and their average recorded as the adjusted consumption for the given month for the chosen meter accounts. The average number of days in a month was taken to be 30.

The adjusted monthly consumption figures were added for all the meter accounts in a given month and the sum divided by the total number of accounts to obtain the average monthly household consumption. This was done for all the months covering the period of analysis. This average monthly consumption figures were what was required for analysis.

3.4 AN OVERVIEW OF DATA ANALYSIS

For data analysis, the study period wad divided into two. The first duration covering 1982 to 1986 was used to develop the average water consumption trend curve. The second duration covering 1987 was used for validation. It was required to test whether the trend curve developed would be useful for predicting individual water consumptions in 1987.

The first step in the data analysis was to obtain a scatterplot to display the underlying data pattern. This is recommended as was mentioned in Chapter 2. The statgraphics package in the COMPAQ micro-computer was used to draw the scatter plot for each of the residential areas. Along the x-axis was displayed months from 1982 to 1986. The number of months was cumulative and a total of sixty months was therefore involved. The average monthly water consumption was shown along the y-axis in thousands of litres or gallons.

Anderson (1971, pp. 31) has stressed the fact that there is advantage in representing the trend curve by a polynomial of low degree because the curve is smoother and the function more economical. He however adds that where the underlying data pattern does not approximate a polynomial of low degree the investigator can opt for a polynomial of higher degree. He continues:

> "When there is no theory to specify the trend as a certain function of time, it may be possible to approximate it by a polynomial in time of low degree. In the simplest nontrivial case of a uniform movement up or down a first degree polynomial, that is, a straight line may give adequate representation. The polynomial trend is simply a descriptive device; it summarizes succinctly the overall characteristics. To do this usefully it must be fairly of low degree...the polynomial is a substitute for a more sophisticated and complicated (but unknown) function of time..."

The same computer package was used to develop the trend curves for the average water consumption for the given residential areas. The common trend curves are linear, quadratic and growth curves. From the inspection of the scatterplot and the fitting of the curves using the micro-computer the linear trend was found most appropriate for the data pattern displayed.

The trend line developed for the first portion of the study period was used to generate forecasts of average monthly water consumption during 1987 which covered the validation period. These values were tested against the individual water consumptions to see whether there was any significant difference between the two sets of values. A two sample t-test of the difference between the means was conducted at 95% confidence level. The first sample contained the individual water consumption values during a given month. The second sample contained the forecast value. If there were 50 individual consumption values taken, there were also 50 values which were made up of the forecast value.

If the difference between the two samples was not significant, then the average trend line could be used for billing purposes. The implication is that from W.S.D.'s point of view, the average water consumption curve can be used for prediction purposes. About the same number of water consumers will be above or below the predicted consumption value. If there was significant difference between the samples the implication is that the average water consumption curve cannot be used for billing purposes. If consistently low water consumption values were predicted, this is unfair to W.S.D because of underbilling. Any corrective activities taken (occasional meter reading) would be dealing with large deviations. If consistently high values are predicted this is unfair to the consumer who would be now overbilled. The detailed data analysis and findings are presented in Chapter 4.

CHAPTER 4

DATA ANALYSIS AND FINDINGS

4.1 INTRODUCTION

The average monthly water consumption data was analysed for each of the residential areas. The analysis was done in the following steps:-

1. Identification of the underlying data pattern from the average monthly water consumption values.

2. Fitting a suitable trend curve to the data pattern and generation of average water consumption values for the months of validation period.

3. Testing the suitability of the curve in predicting household monthly water consumption for the validation period.

The following sections describe how each of the above steps was carried out and the results that emerged from each of the residential areas.

4.2 IDENTIFICATION OF THE UNDERLYING DATA PATTERN

To identify the underlying data pattern for the average monthly water consumption values, a connected scatterplot (data points connected) was prepared for each of the residential areas. The data required for Jericho is contained in Table 4.1 of Appendix B. Tables 4.2 and 4.3 of the same Appendix contains the data for Buruburu, and Loresho and Kyuna respectively. The Stratgraphics package of the COMPAQ micro-computers was used to to prepare the scatterplots. It was required to assign variables to what was to be plotted on the vertical and horizontal axes. The vertical axis showed the average water consumption in the appropriate units. The horizontal axis showed cumulative time in months covering the period 1982 to 1986. The scale along the vertical axis depended on the magnitude and variation of the consumption values. Small values with little variation were plotted on a bigger scale than big values with a bigger variation. This is evident from the scatterplots obtained for Jericho and Loresho and Kyuna.

The scatterplots obtained for each of the residential areas are shown below. The scatterplot for Jericho residential areas is shown in Figure 4.1. It shows oscillations about a mean value and can be described as generally horizontal. Except for a few outliers, most values seem to be within the 2.4 to 2.7 thousand gallons consumption band. The oscillations are somehow exaggerated due to the big vertical scale. It is difficult to identify seasonality attributable to any months of the year from the oscillations.

In Figure 4.2 is shown the scatterplot for Buruburu

Figure 4.1: Scatterplot for Jericho

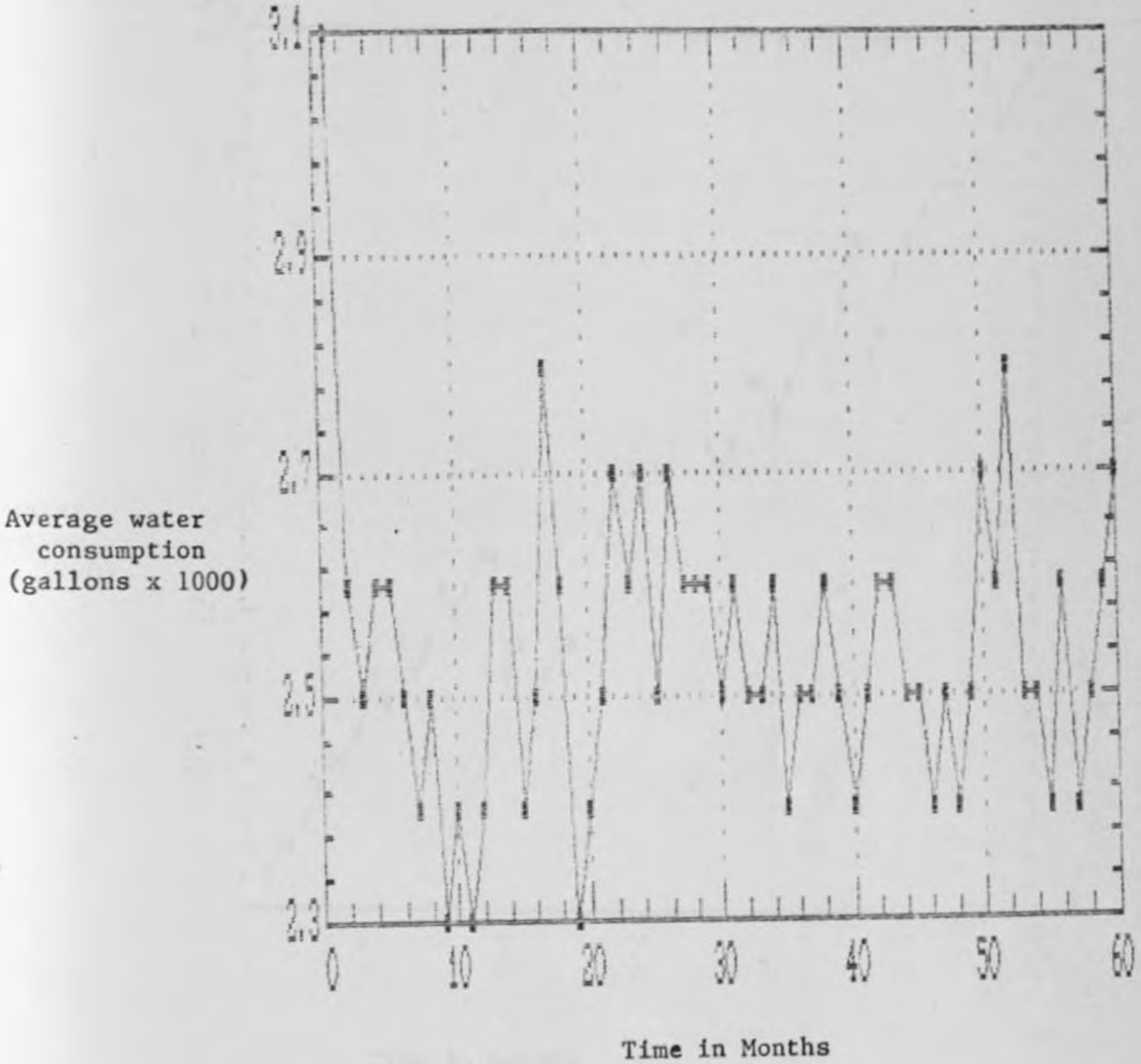


Figure 4.2 : Scatterplot for Buruburu

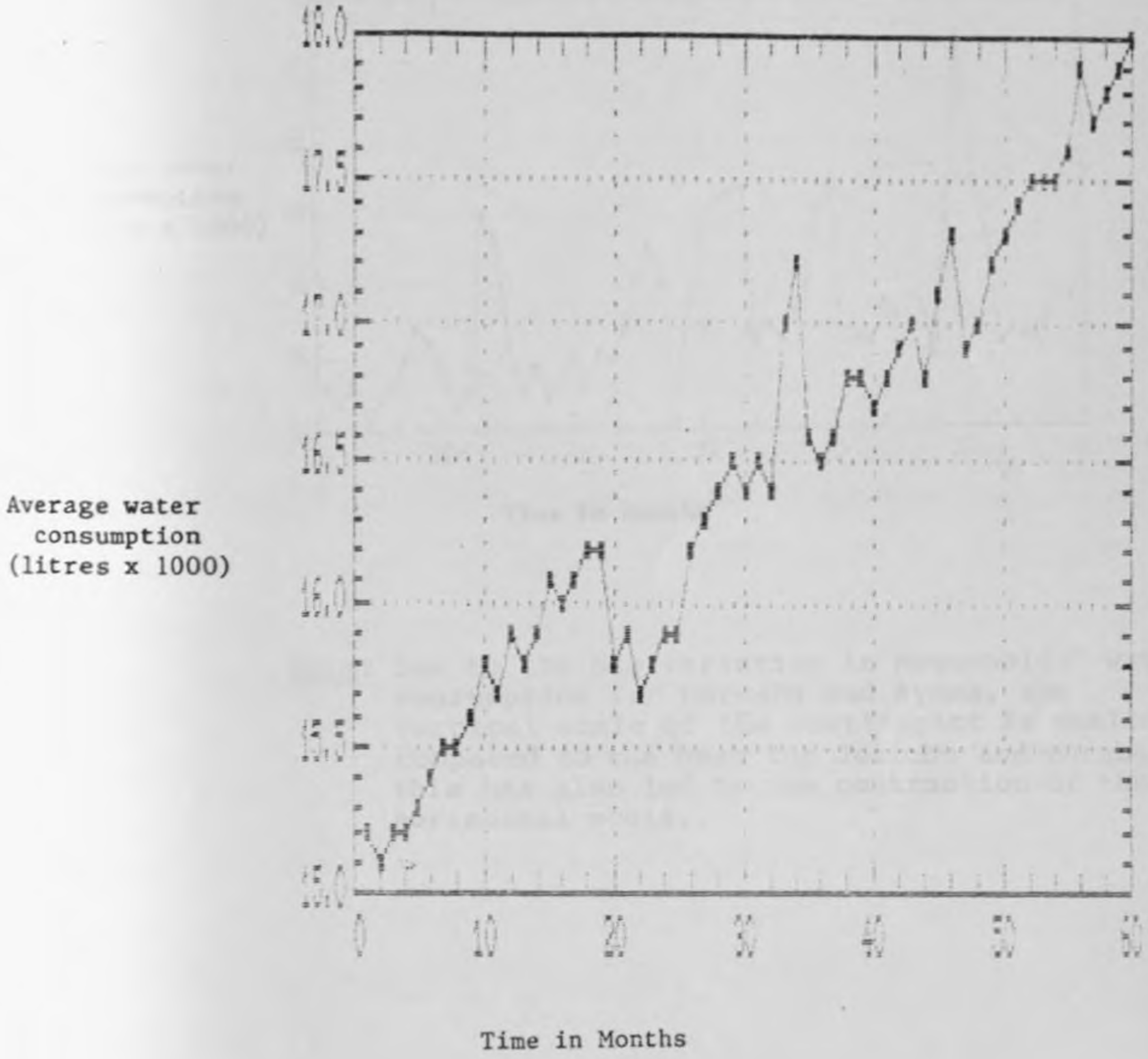
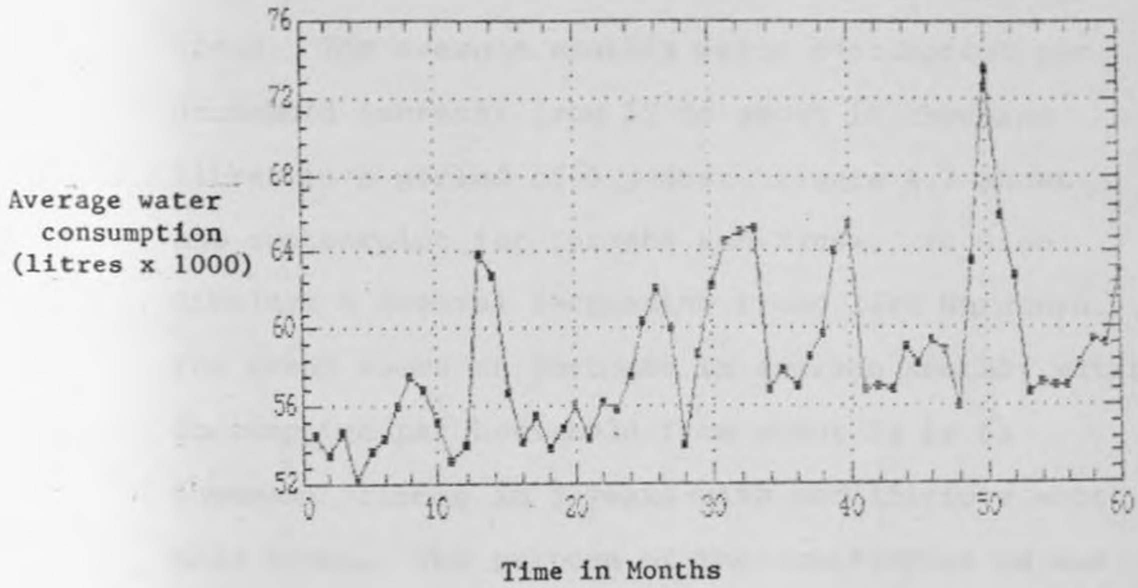


Figure 4.3: Scatterplot for Loresho and Kyuna



Note: Due to the big variation in households' water consumption for Loresho and Kyuna, the vertical scale of the scatterplot is smaller compared to the ones for Jericho and Buruburu. This has also led to the contraction of the horizontal scale.

residential area. It shows a general increasing trend. The average monthly water consumption per household increase from 15 to about 18 thousand litres in a period of 5 years. Figure 4.3 shows the scatterplot for Loresho and Kyuna. It also displays a general increasing trend like Buruburu. The trend shows an increase in average monthly water consumption per household from about 53 to 63 thousand litres in 5 years with oscillations about this trend. The purpose of the scatterplot as was mentioned earlier was to help in choosing a suitable trend curve to fit to the pattern. The choice of the trend curve also depends on the fact that a simple curve or a polynomial of low degree should be opted for, unless the underlying data pattern dictates otherwise as was mentioned in Chapter 3.

4.3 FITTING THE TREND CURVE AND GENERATING FORECASTS

From the connected scatterplot obtained for each of the residential areas, the data pattern showed a general linear trend. It was therefore decided to carry out simple trend analysis using the micro-computer. The available higher degree curves and polynomials gave higher mean errors than the trend line. The choice of a low degree polynomial after inspection of the underlying data pattern is appropriate as recommended by Anderson (1971).

When trend analysis was carried out, the trend line was plotted and the estimated function given. In addition a summary table was displayed containing information about the trend line as shown in Figure 4.4, 4.5 and 4.6. The average or mean error (ME) should be close to zero if the procedure has done well. The mean squared error (MSE) and the mean absolute error (MAE) can be used to compare different smoothing constants (simple trend analysis is a smoothing method which fits a linear trend on data using least squares) or different forecasting procedures. In general, the smaller the values of the MSE and MAE, the better the procedure has been in describing past performance.

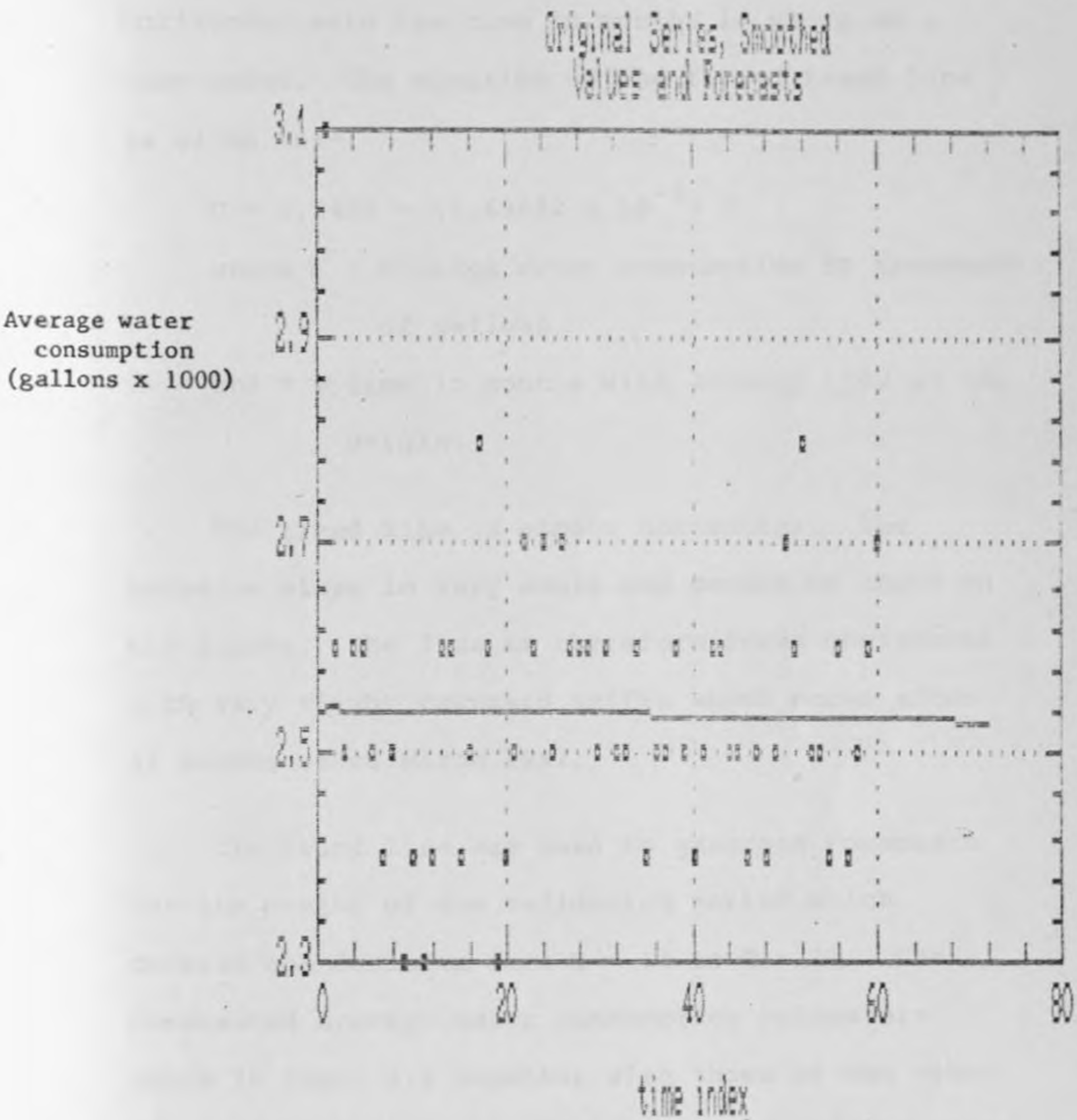
The mean percentage error (MPE) and mean absolute percentage error (MAPE) are calculated from the one-ahead forecast errors divided by the actual observation. They are displayed only if all non-missing data values are greater than zero. An inspection of Figures 4.4 and 4.5 and 4.6 show that the mean error (ME), the mean squared error (MSE) and the mean absolute error (MAE) are quite small meaning that the trend analysis lines did quite well in describing past performance.

The results of the simple trend analysis for each of the residential areas is given in the sections below

4.3.1 Results of Simple Trend Analysis for Jericho

The results of the analysis for Jericho are shown in Figure 4.4. The vertical axis shows the average

Figure 4.4: Results of the Trend Analysis for Jericho



ESTIMATED FUNCTION IS (2.5435+-1.69492E-4T)
Residual summary
AVERAGE ERROR (ME) = -3.25665E-16
MEAN SQUARED ERROR (MSE) = 0.0176886
MEAN ABSOLUTE ERROR (MAE) = 0.0999755
MEAN ABSOLUTE PERCENTAGE ERROR (MAPE) = 3.90542
MEAN PERCENTAGE ERROR (MPE) OR BIAS = -0.261982

SMOOTHED VALUES PLACED IN SMOOTHES FOR PERIODS 1-60
FORECASTS PLACED IN FORECASTS FOR PERIODS 61-72

water consumption in thousands of gallons. On the horizontal axis the time in months is shown as a time index. The equation of the fitted trend line is given as:-

$$C = 2.5435 - (1.69492 \times 10^{-4})\ T$$

where C = average water consumption in thousands of gallons

and T = time in months with January 1982 as the origin.

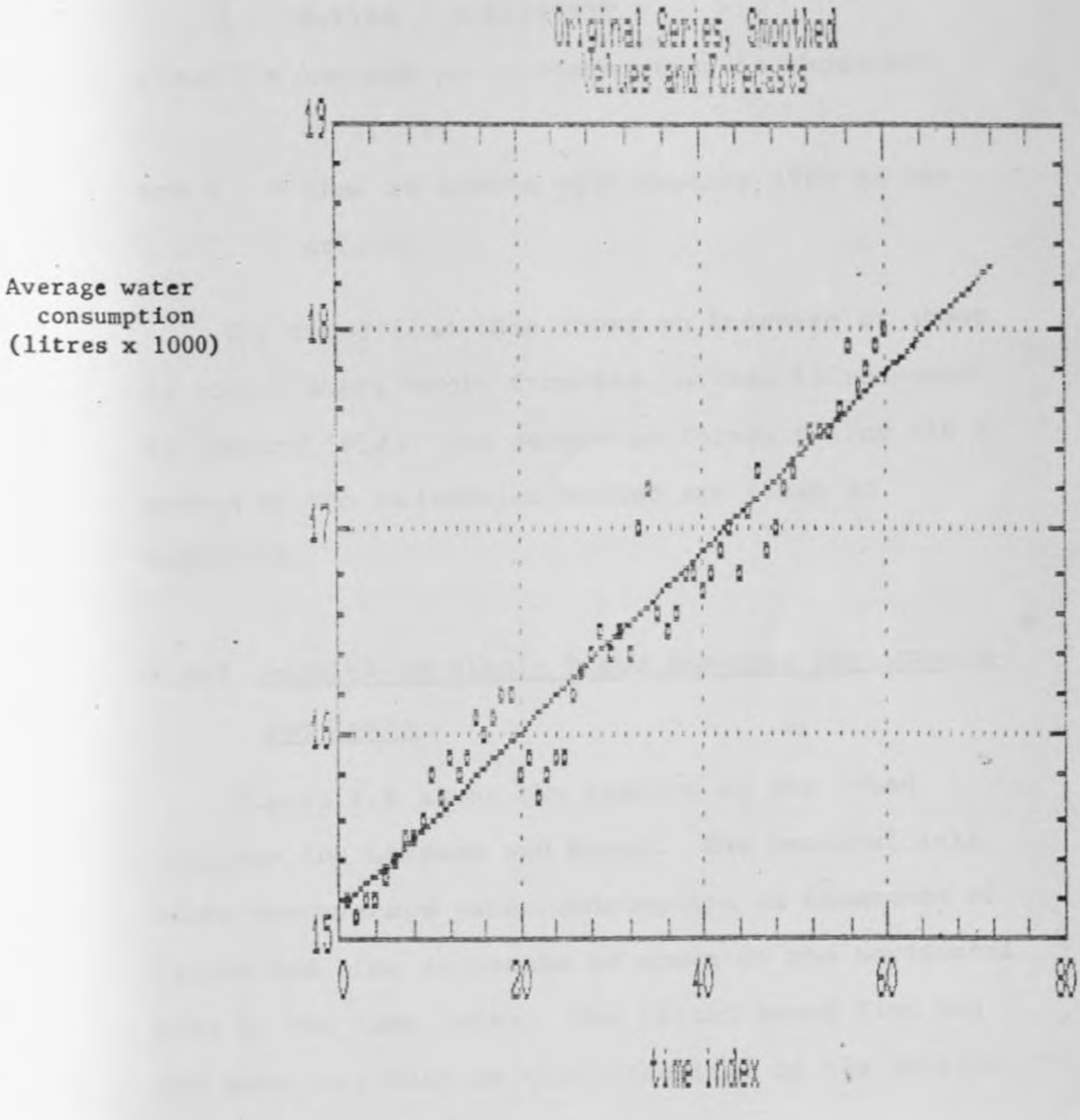
The trend line is almost horizontal. The negative slope is very small and cannot be shown on the figure. The line is therefore drawn horizontal with very slight downward shifts which occur after 32 months since March 1982.

The trend line was used to generate forecasts for the months of the validation period which covered the duration from T = 61 to T = 72. The forecasted average water consumption values are shown in Table 4.4 together with those of the other two residential areas. The forecasted average water consumption is constant during the months of the validation period.

4.3.2 Results of Simple Trend Analysis for Buruburu

The results of the trend analysis for Buruburu are shown in figure 4.5. The vertical axis for the plot of the trend shows the average water consumption

Figure 4.5: Results of the Trend Analysis for Buruburu



ESTIMATED FUNCTION IS (15.1394+0.0438983T)
Residual summary
AVERAGE ERROR (ME) = -5.92119E-17
MEAN SQUARED ERROR (MSE) = 0.0360728
MEAN ABSOLUTE ERROR (MAE) = 0.145911
MEAN ABSOLUTE PERCENTAGE ERROR (MAPE) = 0.886697
MEAN PERCENTAGE ERROR (MPE) OR BIAS = -0.0128598

SMOOTHED VALUES PLACED IN SMOOTHES FOR PERIODS 1-60
FORECASTS PLACED IN FORECASTS FOR PERIODS 61-72

in thousands of litres. The time in months is shown as a time index on the horizontal axis. The fitted trend line given as:-

$$C = 15.1394 + 0.0438983T$$

where C = average water consumption in thousands of litres

and T = time in months with January 1982 as the origin.

The trend line thus shows an increase of about 44 litres every month from the initial 15 thousand in January 1982. The generated forecasts for the months of the validation period are shown in Table 4.4.

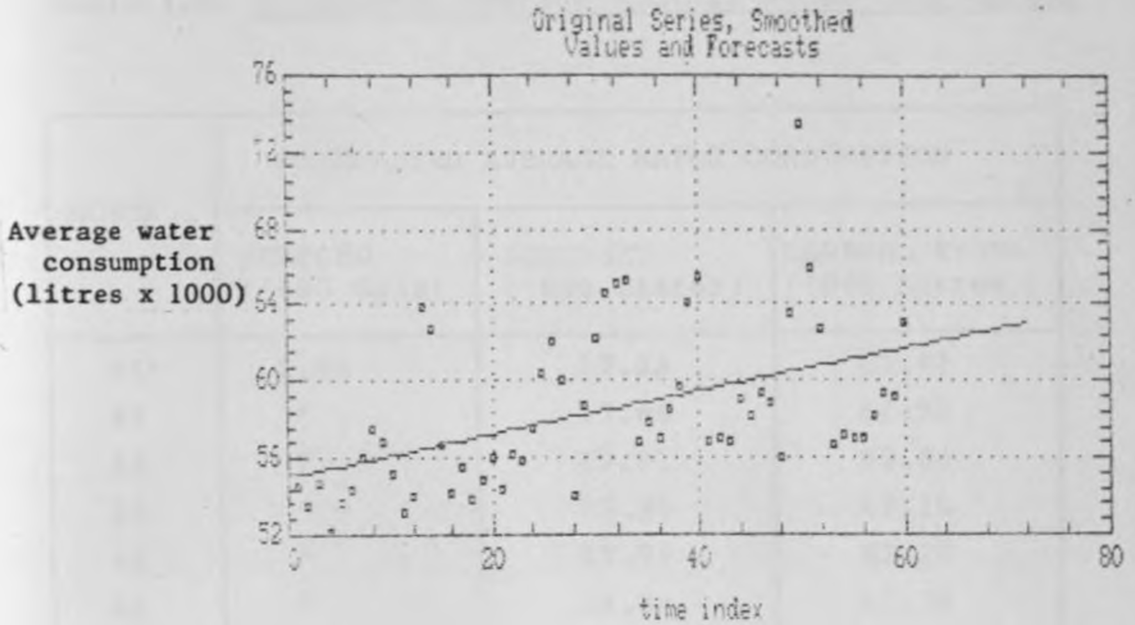
4.3.3 Results of Simple Trend Analysis for Loresho and Kyuna

Figure 4.6 shows the results of the trend analysis for Loresho and Kyuna. The vertical axis shows the average water consumption in thousands of litres and time in months is shown on the horizontal axis as the time index. The fitted trend line has the same variables as the trend line in the section 4.3.2 and is given as:-

$$C = 55.0128 + 0.111603T$$

There is thus an increase of about 1000 litres every month from the initial 55 thousand in January 1982. The generated forecasts for water consumption for the months of the validation period are shown

Figure 4.6: Results of the Trend Analysis for Loresho and Kyuna



ESTIMATED FUNCTION IS (55.0128+0.111603T)
Residual summary
AVERAGE ERROR (ME) = 1.30266E-15
MEAN SQUARED ERROR (MSE) = 12.6622
MEAN ABSOLUTE ERROR (MAE) = 2.79507
MEAN ABSOLUTE PERCENTAGE ERROR (MAPE) = 4.65555
MEAN PERCENTAGE ERROR (MPE) OR BIAS = -0.342834

SMOOTHED VALUES PLACED IN SMOOTHES FOR PERIODS 1-60
FORECASTS PLACED IN FORECASTS FOR PERIODS 61-72

in Table 4.4.

Table 4.4: Forecasted Average Monthly Water Consumption

MONTH	FORECASTED AVERAGE WATER CONSUMPTION		
	JERICHO ('000 Gals)	BURUBURU ('000 Litres)	LORESHO/KYUNA ('000 Litres)
61*	2.53	17.82	61.82
62	"	17.86	61.93
63	"	17.91	62.04
64	"	17.95	62.16
65	"	17.99	62.27
66	"	18.04	62.38
67	"	18.08	62.49
68	"	18.12	-
69	"	18.17	-
70	"	18.21	-
71	"	18.26	-
72*	2.53	18.30	-

*Corresponds to January and December, 1987 respectively.

4.4 TESTING THE SUITABILITY OF THE TREND LINE FOR PREDICTION

The trend line developed for each residential area was to be tested for its suitability in predicting monthly household water consumption. To do this the average monthly water consumption shown in Table 4.4 was used together with monthly consumption of all sampled households during 1987 which was the validation period. This period was not used in the development of the trend line.

A two-sample-analysis to test for the difference between sample means was carried out using the micro-computer. The null hypothesis (H_o) tested was that there was no significant difference between the actual household monthly water consumption and those obtained from the trend line in the given residential area during the validation period. The analysis compared the means and variances from two independent samples. The first sample contained the actual monthly water consumption for the chosen households. The second sample, same size as the first, contained values (all same) of the predicted water consumption for the given month. A two tailed t-test was carried out at 95% level of confidence.

Any significant difference between the sample means would imply that the curve developed would not be suitable for the prediction of the individual household water consumption in the given residential area. Acceptance of the null hypothesis on the other hand would imply that the curve would be suitable for prediction purposes.

The results of the analysis are shown in Table 4.5. The results show that the null hypothesis should be accepted for all the months of the validation period for both Jericho and Buruburu. There is therefore no significant difference between the actual household consumptions and those obtained from the trend line. The trend line therefore is appropriate to predict

Table 4.5: Results of the Two-sample-Analysis for Testing the Difference Between the Sample Means

MONTH	JERICHO		BURUBURU		LORESHO & KYUNA	
	COMPUTED t-value	DECISION on H_o	COMPUTED t-value	DECISION on H_o	COMPUTED t-value	DECISION on H_o
61*	-0.74673	Accept	0.33966	Accept	-3.6592	Reject
62	-0.44097	"	0.35977	"	-2.8984	"
63	0.34934	"	0.442167	"	-1.4153	Accept
64	0.69812	"	0.67247	"	-2.2154	Reject
65	-0.25730	"	0.43144	"	-3.1075	"
66	-0.58525	"	-0.42453	"	-3.1075	"
67	-0.58523	"	-1.6568	"	-3.1764	Reject
68	0.75432	"	-0.52643	"	-	-
69	0.84070	"	-0.01313	"	-	-
70	1.99160	"	-0.5380	"	-	-
71	0.43260	"	-1.48145	"	-	-
72*	-0.17297	Accept	-1.59207	Accept	-	-

*Corresponds to January and December, 1987 respectively.

the individual household water consumption. The analysis for Loresho and Kyuna was done up to the July consumption values. It was felt that this was adequate as almost all the tests carried out had led to the decision of rejecting the null hypothesis. The implication is that it is not appropriate to use the trend line to predict individual water consumption in Loresho and Kyuna due to the variation within individual household water consumption. The conclusion of the study is given in the next chapter.

CHAPTER 5

SUMMARY AND CONCLUSIONS

5.1 INTRODUCTION

This chapter mainly summarises the findings of the study in relation to the objectives put forward in Chapter 1. Recommendations, the limitations of the study, and suggestions for further research are also discussed.

The first objective of the study was to identify the water consumption pattern for households in the selected residential areas. The second objective was to test whether the pattern could be described by a trend curve. The third objective of the study was to investigate whether the trend curve developed could be used to predict household monthly water consumption and therefore be useful for billing purposes. These objectives were satisfactorily achieved as will be shown in the next section.

5.2 SUMMARY OF THE RESULTS OF THE STUDY

The results of the study will be summarised in relation to the objectives mentioned above.

5.2.1 Residential Water Consumption Pattern

The average household water consumption pattern was obtained after the data analysis in Chapter 4. The pattern was presented in the form of a scatterplot for each of the residential areas.

Category 1 residential area which was represented by Loresho and Kyuna estates, showed an increase in the average monthly water consumption. The rise in consumption showed very marked monthly variations. Buruburu Estate represented Category 2 residential area. The water consumption pattern showed a marked rise and the monthly variations were not as much as in the case of Loresho and Kyuna. The pattern displayed a distinct linear trend.

Category 3 residential area was represented by Jericho Estate. The pattern was more or less horizontal with generally small monthly variations. Most of the average values were within 2.4 to 2.7 thousands of gallons consumption band.

5.2.2 Fitting of a Trend Curve to the Consumption Pattern

It was found that the average water consumption values could be described by trend lines. The low values that were obtained after the data analysis for the mean error (ME), the mean squared error (MSE), and the mean absolute error (MAE) showed that the trend lines did well in describing the past consumption . The trend lines obtained for each residential category were presented in Chapter 4.

The trend for Jericho showed a very slight (almost negligible) decrease in average water consumption from an average value of about 2.54 thousand gallons in a month. In the case of Buruburu the trend showed an increase of about 44 litres every month from an initial value of about 15 thousand in January 1982. For Loresho and Kyuna the trend showed an increase of about 1000 litres from an initial value of 55 thousands in January 1982. It is evident that residents in Category 1 households consume more water than those of the other categories.

5.2.3 Testing the Suitability of the Trend Line for Prediction

The two-sample-analysis conducted showed that the trend line obtained for Jericho and Buruburu could be suitable for predicting individual household water consumption. From the analysis the trend line obtained for Loresho and Kyuna would not be suitable for predicting water consumption for individual households.

The implication therefore was that water consumers in Jericho and Buruburu could be billed from the water consumption values generated by their respective trend lines. The use of the trend line for Loresho and Kyuna could lead to a situation where some consumers are either grossly overbilled or underbilled, due to the large deviations from the predicted average consumption values.

5.3 CONCLUSIONS AND RECOMMENDATIONS

The major aim of the study was to find out if residential water consumption follows a predictable pattern that can be used to bill the consumers without having to read the water meter every month.

The first two chapters of this report dwelt at length about the problems that occur due to backlogs in meter readings. It was said that this is a challenging area for water utilities especially in urban areas both in developed and developing countries. While some water utilities in the developed countries are counteracting this meter reading problem with the automation of the meter reading excercise, developing countries do not have the kind of resources required to do this and have to find other appropriate ways of improving the exercise.

The prediction models obtained for categories 2 and 3 households can therefore form a basis for billing the water consumers in these households. There was little variation in the water consumption between households as the results of the test on suitability of the models for prediction indicated.

In addition to improvement in revenue receipts, there are other advantages of using the models developed to bill the consumers in the above residential categories. A big proportion of the residential areas in Nairobi belongs to these categories. These areas are very populous and the implication is that a big proportion of the available meter reading time is spent here. The individual monthly water consumption is generally low and hence the amount of revenue per meter reading is also low.

The reduction in the number of meter readings for a given interval of time could reduce some problems experienced by W.S.D. There would be less transport required to get the meter readers to these areas. The reduced number of meter readings required from a single man would lead to more accurate readings since the men would experience less physical exhaustion. There would be more time available for the meter readers to attend to other tasks like reporting of any repair and maintenance requirements.

The W.S.D. management can choose an appropriate time interval over which to bill consumers monthly before reading the meters and doing any necessary adjustments. After reading the meter, the actual consumption can be checked against what the consumer has been billed. Where a consumer has consumed more, the additional charge can be spread over some time and be reflected in the subsequent bills based on the future consumption estimates. If a consumer has paid for more water than has actually been consumed, the account can be credited and adjustments made to the future water bills. The effect of the above adjustments would be to refine the predicted average water consumption to suit an individual household.

5.4 LIMITATIONS OF THE STUDY AND SUGGESTIONS FOR FURTHER RESEARCH

The limitations of the study hinged around the fact that the data required depended on meter readings. The accuracy of these figures depended on the meter readers. Potential problems are when a meter reader records the wrong figures or wrong volumetric units.

Another limitation of the study was the fact that some of the meter readings for some accounts were widely spaced and the effect of averaging the consumption over a long period smothened the actual consumption pattern.

As was mentioned earlier in the study the accuracy of the reading will also depend on the accuracy of the meter recording the consumption. If some meters were faulty the consumption patterns arrived at after the analysis are not the true ones. A few meter cards were found to have constant meter readings over some time.

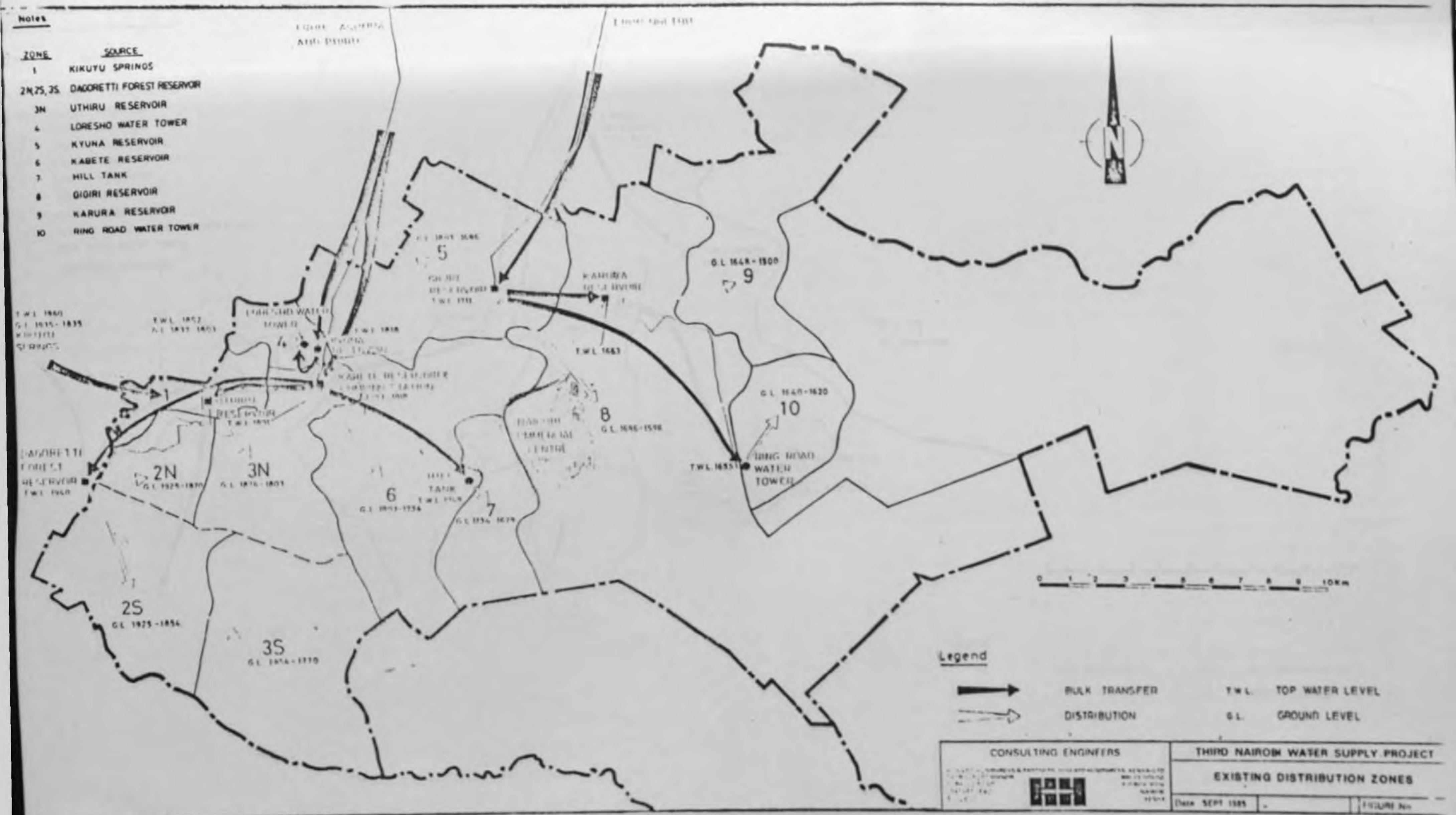
Numerous arithmetic calculations was involved to determine the average monthly consumption data. Although great care was exercised when doing so, errors are likely to have occurred.

Although meter reading has been identified as the major constraint in the prompt billing of the consumers, there are other activities involved before the bills can be dispatched. It would be useful therefore to find out the extent of delay that these activities contribute before the dispatching of the bills.

To help generalize the results it should be investigated whether the prediction models developed give similar results over the validation period in the other estates falling within the studied residential categories. The models for categories 1 and 2 households is appropriate for short term forecasting Studies should be carried out in the future to find out whether the same models are still applicable or other models are required altogether.

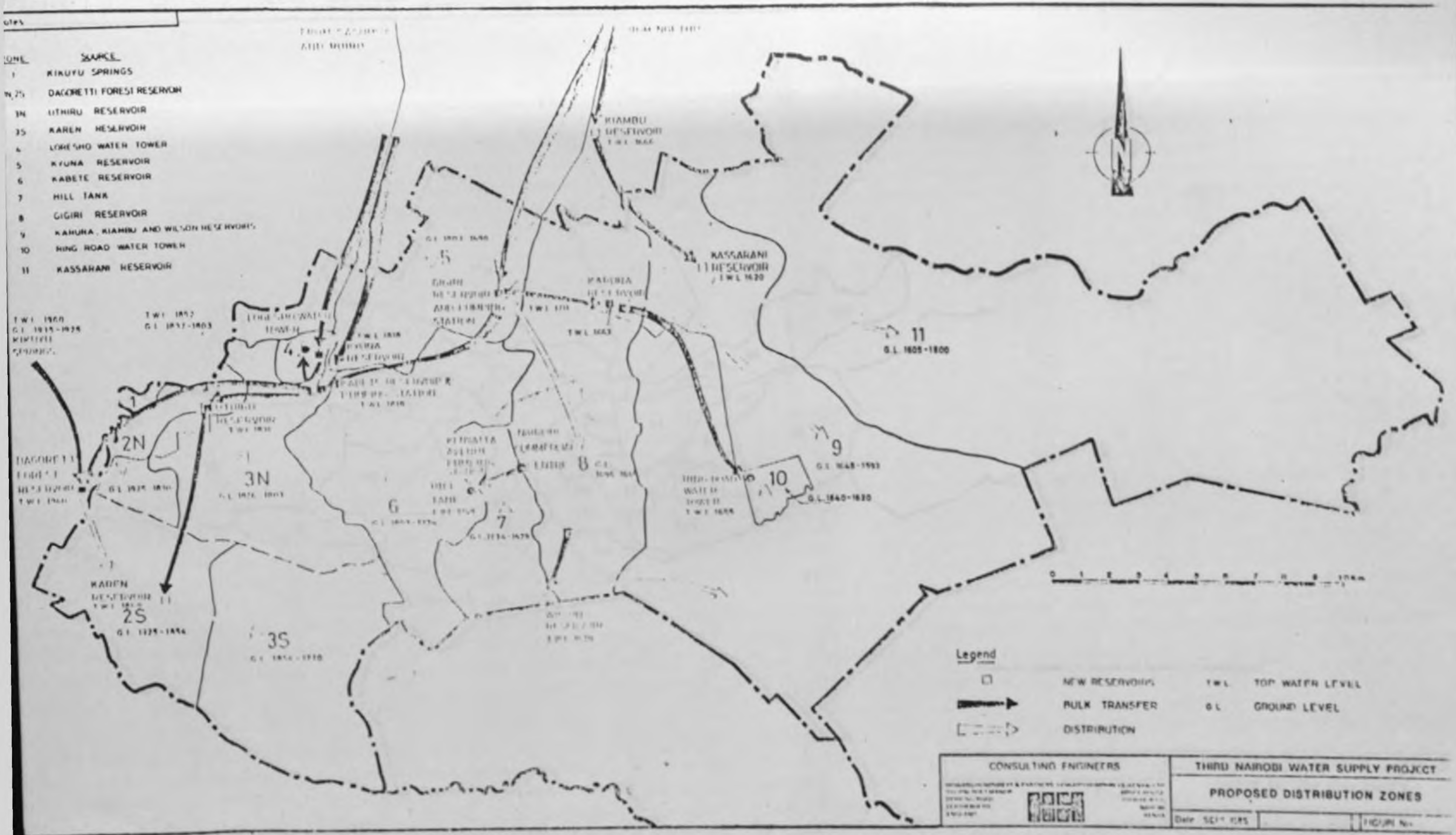
APPENDIX A

Figure 1.1: Existing Water Distribution Zones



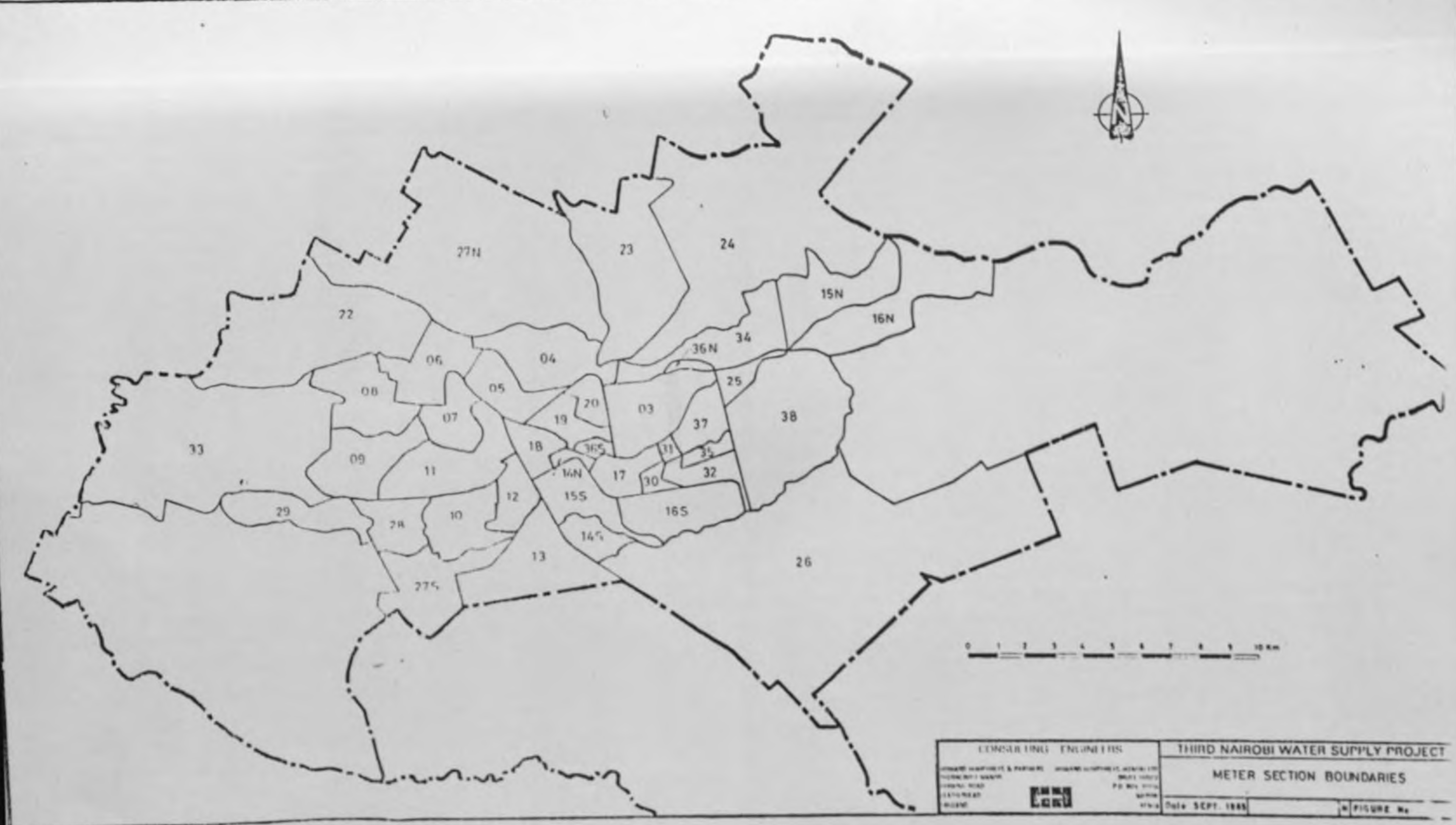
Source: Third Nairobi Water Project; Distribution Systems, Vol. 1 Report.

Figure 1.2: Proposed Distribution Zones



Source: Third Nairobi Water Project; Distribution Systems, VOl 1 Report.

Figure 1.3: Existing Meter Section Boundaries.



Source: Third Nairobi Water Project; Distribution Systems, Vol. 1 Report.

APPENDIX B

APPENDIX B

Table 1.1: SECTIONS WITHIN BILLING GROUPS

BILLING GROUP 1

SECTION	PLACE
01-02	Government Institutions
03	Eastleigh
04	Muthaiga and part of Parklands (mixed up)
05	Parklands
06	Westlands
07	Kileleshwa
08	Lavington

BILLING GROUP 2

SECTION	PLACE
09	Lavington
10	Ngong Road, Woodley, Joseph Kangethe Estate, Jamhuri, Highview, Ngummo, Magiwa, Golf Course
11	Kilimani
12	Madaraka, Upper Hill, Kenyatta N. Hospital
13	Nairobi West, South C, South B (parts),
14	South C, South B, Plainsview, Realty, Golden Gate, Railway Quarters (behind Kenya Polytechnic)
15	Industrial Area, Dandora
16	" " "
17	Kaloleni, Shauri Moyo, Kariakor, Race Course Rd., Bahati, Pumwani, Gikomba, Maringo.

Table 1.1 (contd.) BILLING GROUP 3

SECTION	PLACE
18	City Centre
19	Ngara Rd., Muranga Rd., Park Rd.
20	Pangani
21	-
22	Kyuna, Loresho
23	Ridgeways
24	Kasarani, Roysambu, Zimmermann, Kahawa West, Ruaraka, Kahawa Barracks
25	Kariobangi South, Kariobangi North, Korogocho, Civil Servant Quarters
26	Embakasi, Donholm, Industrial Area Ngei, Moi, Rubia, Onyonka Estates, Civil Servant Quarters
28	Kibera
29	Karen, Ngong Rd., Langata
	BILLING GROUP 4
30	Maringo, Mathare North
31	Jerusalem and part of Uhuru
32	Jericho
33	Kangemi, Kawangware, Riruta, Mountain View
34	Kariobangi North, Mathare Valley Korogocho, Roundabout Estate
35	Buruburu
36	New Pumwani (California) Huruma Flat
37	Uhuru, part of Buruburu, Kimathi Estate, Harambee
38	Gorofani, Umoja

TABLE 1.2: METER ACCOUNTS WITHIN SECTIONS OF BILLING GROUP

SECTION	NO OF ACCOUNTS	PERCENTAGE
	BILLING GROUP 1	OF TOTAL
01	977	00.7
02	389	00.3
03	8341	06.4
04	5427	04.1
05	2557	02.0
06	5009	03.8
07	2325	01.8
08	1714	01.3
	BILLING GROUP 2	
09	1914	01.5
10	4097	03.1
11	7951	06.1
12	3003	02.3
13	5868	04.5
14	3725	02.8
15	4935	03.8
16	3957	03.0
17	4216	03.2
	BILLING GROUP 3	
18	4498	03.4
19	5361	04.1
20	3046	02.3
21	1160	00.9
22	2467	01.9
23	3343	01.7

Table 1.2 (contd.)

SECTION	NO OF ACCOUNTS BILLING GROUP 3 (contd)	PERCENTAGE OF TOTAL
25	2261	01.7
26	1033	00.8
27	3281	02.5
28	2490	01.9
29	1427	01.1
	BILLING GROUP 4	
30	2408	01.8
31	1942	01.5
32	3971	03.0
33	5498	04.2
34	4120	03.1
35	5229	04.0
36	4300	03.3
38	4325	03.3
39	-	00.0

TABLE 3.1: HOUSEHOLD CLASSIFICATION

Category 1	-	Substantial detached houses and modern houses with medium to large gardens. Full internal plumbing with high water consumption for normal domestic purposes plus additional amounts for garden watering and car washing.
Category 2	-	Housing estates and flats occupied by those in the middle income bracket. Full internal plumbing and use of water for car washing but generally little for garden watering.
Category 3	-	Majority of the population in the low income category living in small houses and flats in the older parts of the City and the new sites and service areas. Partially plumbed, often with a yard tap and one or two internal taps. Others are served by communal water points. Houses may or may not have flushing toilets.
Category 4	-	Very low income housing and unauthorised shanty areas. Almost entirely dependent on licensed kiosks or wells.

Table 4.1: Average Monthly Water Consumption Values for Jericho, over the Period 1982 to 1986

Month	Consumption ('000 gallons)	Month	Consumption ('000 gallons)
1(Jan,'82)	3.1	31	2.6
2	2.6	32	2.5
3	2.5	33	2.5
4	2.6	34	2.6
5	2.6	35	2.4
6	2.5	36	2.5
7	2.4	37	2.5
8	2.5	38	2.6
9	2.3	39	2.5
10	2.4	40	2.4
11	2.3	41	2.5
12	2.4	42	2.6
13	2.6	43	2.6
14	2.6	44	2.5
15	2.4	45	2.5
16	2.5	46	2.4
17	2.8	47	2.5
18	2.6	48	2.4
19	2.3	49	2.5
20	2.4	50	2.4
21	2.4	51	2.6
22	2.7	52	2.8
23	2.6	53	2.5
24	2.7	54	2.5

Table 4.1 (contd.)

Month	Consumption ('000 gallons)	Month	Consumption ('000 gallons)
25	2.5	55	2.4
26	2.7	56	2.6
27	2.7	57	2.4
28	2.6	58	2.5
29	2.6	59	2.6
30	2.5	60(Dec '86)	2.7

Table 4.2: Average Monthly Water Consumption Values for Buruburu over the Period 1982 to 1986

Month	Consumption ('000 litres)	Month	Consumption ('000 litres)
1(Jan'82)	15.2	31	16.5
2	15.1	32	16.4
3	15.2	33	17.0
4	15.3	34	17.2
5	15.4	35	16.6
6	15.5	36	16.5
7	15.5	37	16.6
8	15.6	38	16.8
9	15.8	39	16.8
10	15.7	40	16.7
11	15.9	41	16.8
12	15.8	92	10.9
13	15.9	93	17.0
14	16.7	94	16.8
15	16.0	95	17.1
16	16.1	96	17.3

Table 4.2: Average Monthly Water Consumption Values for Buruburu over the Period 1982 to 1986 (contd.)

Month	Consumption ('000 litres)	Month	Consumption ('000 litres)
17	16.2	47	16.9
18	16.2	48	17.0
19	15.8	49	17.2
20	15.9	50	17.3
21	15.8	51	17.4
22	15.8	52	17.5
23	15.9	53	17.5
24	15.9	54	17.5
25	15.9	55	17.6
26	16.2	56	17.9
27	16.3	57	17.7
28	16.4	58	17.8
29	16.5	59	17.9
30	16.4	60(Dec'86)	18.0

Table 4.3: Average Monthly Water Consumption Values for Loresho and Kyuna over the Period 1982 to 1986

Month	Consumption ('000 litres)	Month	Consumption ('000 litres)
1(Jan, '82)	53.5	31	64.5
2	54.5	32	65.1
3	54.6	33	65.2
4	52.1	34	56.9
5	53.6	35	57.9
6	54.4	36	57.1
7	56.1	37	58.5
8	57.6	38	59.7
9	56.8	39	64.0
10	55.2	40	65.4
11	53.2	41	56.8
12	54.0	42	57.1
13	63.9	43	56.9
14	62.7	44	59.1
15	56.7	45	58.2
16	54.1	46	59.4
17	55.6	47	55.8
18	53.8	48	56.1
19	54.9	49	63.6
20	56.1	50	73.4
21	54.3	51	65.9
22	56.2	52	62.8
23	55.9	53	56.7
24	57.5	54	57.2

Table 4.3: Average Monthly Water Consumption Values for Loresho and Kyuna over the Period 1982 to 1986 (Contd.)

Month	Consumption	Month	Consumption
25	60.3	55	57.1
26	62.0	56	55.8
27	60.0	57	58.2
28	54.0	58	59.4
29	58.7	59	59.2
30	62.3	60(Dec' '86)	63.1

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