WATER RESOURCES RESEARCH INSTITUTE
University of Puerto Rico
Research Center
Mayagüez, Puerto Rico 00708

DETERMINATION OF DOMESTIC WATER CONSUMPTION RATES UNDER VARYING WATER PRESSURES

BY

LUIS A. NUNEZ

RESEARCH PROJECT

A-008-PR

TECHNICAL COMPLETION REPORT

"THE WORK UPON WHICH THIS PUBLICATION IS BASED WAS SUPPORTED IN PART BY FUNDS PROVIDED BY THE UNITED STATES DEPARTMENT OF THE INTERIOR AS AUTHORIZED UNDER THE WATER RESOURCES RESEARCH ACT OF 1964, PUBLIC LAW 88-379"

A-008-PR

DECEMBER 1969

This report prepared on December 1969 was out of print and has been re-printed on this date of April 26, 1972.

DETERMINATION OF DOMESTIC WATER CONSUMPTION RATES UNDER VARYING WATER PRESSURES

by

Luis Alberto Núñez
Visiting Professor

in cooperation with

Manuel F. de Vera

José Manuel Fidalgo

1. SYNOPSIS

The research project, as the title briefly describes, attempts to discover the possible influence of pressure on domestic (residential, or private) water consumption in the city of Mayaguez.

As a result of experimental research carried out on the houses selected in the city mentioned above, exclusively with residential consumption, it can be concluded that variations in water consumption rates in the houses studied are not due to variations in pressure in the water distribution system. Variations in consumption rates are due to causes un-related to pressure.

2. INTRODUCTION

The present investigation, "Determination of Domestic Water Consumption Rates Under Varying Water Pressures", has as its principal objective,

CONTENTS

the experimental determination of the influence of pressure in the water distribution system on domestic water consumption rates, (residential or private)

Frequently, in works on water sypply, it is found as given, that total consumption increases as the pressure in the water distribution system increases and vice-versa.

It is customary, in the practice of Hydraulic Engineering to divide the total water consumption or volume supplied into the following classifications:

1. Domestic consumption (residential or private)
2. Commercial and industrial consumption
3. Public consumption
4. Water not measured or recorded

Domestic consumption includes water used or assigned to:

1. Toilet and urinal flushing
2. Personal washing and bathing
3. Kitchen use
4. Drinking
5. Clothes washing
6. General house cleaning
7. Watering gardens and lawns
8. Automobile washing

Commercial and industrial consumption includes water used by:

1. Hotels
2. Office buildings

3. Breweries
4. Canneries
5. Laundries
6. Private hospitals
7. Paper, steel, and other factories

Public consumption, or supply, includes water used or assigned to:

1. Street cleaning
2. Sewer cleaning
3. Public fountains
4. Public sanitation
5. Public hospitals

Water not measured or recorded includes used or assigned water which has been sent into the water distribution network, but has not been sold, measured, or recorded. This item includes losses and leakages in the distribution system, but does not include loss in the interior of buildings.

3. REVIEW OF PERTINENT LITERATURE

In Appendix I, which appears at the end of this report, are cited the opinions of various authors of works dealing with water supply.

We would like to make clear the fact that instantaneously increasing the discharge of different sanitary fixtures does not always imply an increase in specific daily consumption.

In Appendix I, appear the opinions of professors Babbitt, Doland, Cleasby, as well as of other professors. These professors do not make clear whether the values they furnish are the result of experimentation or not.

These values coincide approximately with those obtained from a mathematical formula, considering that the discharge of a faucet or outlet is given by the following equation:

$$Q = Kp^{1/2}$$

where

Q = Discharge of the faucet or outlet

K = a constant

p = The prevailing pressure

Applying this formula for those cases where pressure varies from 25 lbs/in^2 to 45 lbs/in^2,

we have

$$Q_{25} = K\,25^{1/2} \quad \text{and} \quad Q_{40} = K\,45^{1/2}$$

from which

$$\frac{Q_{45}}{Q_{25}} = \frac{45^{1/2}}{25^{1/2}} = 1.34$$

Therefore

$$Q_{45} = Q_{25} + 0.34 \quad Q_{25}$$

In view of the opinions in Appendix I, and of many others on water consumption which could be cited, there is no alternative but to turn to further experimentation in order to decide the influence of pressure on domestic consumption rates.

4. THEORETICAL CONSIDERATION OF THE RELATION BETWEEN RESIDENTIAL CONSUMPTION RATES AND PRESSURE PREVAILING IN THE DISTRIBUTION NETWORK

This report designates the term sanitary fixture to mean any fixture used in residences which is designed for the convenience of, and in accordance with, the sanitary life of the house's inhabitants, and which uses a certain quantity of water.

Considered as sanitary fixture are: the toilet, the washbasin, the bathtub, the shower, the sink, the washing machine, the dishwasher, etc.

Sanitary fixtures may be classified into three groups:

a- Those consuming a fixed volume of water, such as tanks toilets, dishwashers, and washing machines.

b- Those consuming a variable amount of water, the amount depending on the way the fixture is used, such as washbasins, sinks, etc.

c- Those consuming a variable amount of water, the amount depending on the time during which the fixture is used, for example, showers.

Having made this classification, consider the hypothetical situation of three types of residences:

1- A residence equipped with sanitary fixtures consuming fixed volumes of water, or a residence in which the sanitary fixtures always used fixed volumes of water. For example, a residence with tank toilets, a washing machine, a dishwashing machine and washbasins, and bathtubs which are always used with the water deposited in them.

We have observed, especially in the United States, that many people, when using the washbasin to wash their face or hands, or the sink to wash the dishes, are accustomed to fill the washbasin or sink, using a determined volume of water. This is especially true in the United States.

2. A residence equipped exlusively with sanitary fixtures which do not use a determined volume of water, that is they are always used with the faucets open and running. For example, in Cuba, the general practice is to use sinks, washbasins, and showers with water running constantly during use.

3. A residence equipped with both kinds of sanitary fixtures, or using its fixtures both ways. In practice, this is probably the most frequent case.

In the first case, water consumption during one day will be

$$C_1 = V_I + V_L + V_F + V'_L + V_B$$

where

C_I = Volume of water used during one day

V_I = Volume of water used by the toilet during one day

V_L = Volume of water used by the washing machine during one day

V_F = Volume of water used by the dishwasher during one day

V'_L = Volume of water used by the washbasin during one day

V_B = Volume of water used by the tub during one day

The preceding formula may be expressed

$$\sum C_I = V \qquad \text{(Formula I)}$$

It is evident in this case that the pressure prevailing in the water distribution system exercises no influence on daily consumption. The only effect is that the fixture will fill, in less time, when pressure is greater. In this case, water consumption is independent of the pressure prevailing in the water distribution dystem.

In the second case water consumption during one day will be

$$C_2 = Q_F T_F + Q_D T_D + Q_L T_L$$

where:

C_2 = Volume of water used during one day

Q_F = Discharge of sink faucet

T_F = Time sink is used

Q_D = Shower discharge

T_D = Time shower is used

Q_L = Discharge of washbasin faucet

T_L = Time washbasin is used

Expressing consumption in general form, we derive that:

$$C_2 = \Sigma \quad QT$$

but each discharge may be expressed as a function of pressure:

$$Q = Kp^n$$

and that

$$C_2 = \Sigma \; KTp^n \quad \text{(Formula 2)}$$

In this case also, water consumption depends on pressure prevailing in the water distribution system, if we take into account hydraulic considerations only, even though the pressure has less effect in this case.

In the third case, water consumption during one day may be expressed as

$$C_3 = \Sigma \; V + \Sigma \; KTp^n \quad \text{(Formula 3)}$$

In this case, water consumption depends on the pressure prevailing in the water distribution, although somewhat less than in the second case. Only hydraulic considerations are taken into account, in the cases (a), (b) and (c).

In order to arrive at a practical result, it is well to include phychological factors, as well as those of convenience and comfort. For example: if a person washes his hands with the faucet running, and there is excessive pressure, the discharge will produce splashing due to the increased velocity produced by the pressure. The tendency is then to turn down the faucet and reduce the amount of water. If the margin of pressure producing excessive discharge is quite small, there is no doubt that the pressure has no practical influence on consumption.

In the same way when a person is taking a shower he instinctively opens the faucet so that water is discharged is not bothersome. Here as well, if the margin of pressure is quite small, the pressure will have no practical influence on consumption.

In addition, water escaping with greater velocity under greater pressure will wash off soap more quickly, and the faucet will run for less time. In Formula 2 and 3, the decrease in time T may compensate for the increase in pressure.

In the second and third case in order for the increase in pressure to compensate for the decrease in time, the following would have to occur: the valve of n, in practice is around 1/2, therefore, according to our formula for one sanitary fixture we have:

$$T_1 P_1^n = T_2 P_2^n$$

Let us assume that the pressure increase from 20#/ in 2 to 40#/ in 2, or another words, the pressure has been doubled.

from which

$$T_{20} P^{1/2}_{20} = T_{40} P^{1/2}_{40}$$

$$T_{40} = (20/40)^{1/2} T_{20}$$

$$T_{40} = 0.71 T_{20}$$

Consequently, in the case in which the pressure is 20 lbs/in^2, the sanitary fixture is used for 4 minutes, on the other hand if the pressure was 40 lbs/in^2, one would only have to use the faucet for 2.84 minutes, so that the increase in discharge due to increased pressure has been compensated for by a decrease in time used.

Innumerable examples could be cited to support this method of considering the problem. In order to decide whether or not pressure in the water distribution system influences domestic consumption rates, we are left with the choice of experimentation to confirm our conclusions.

It is well to note that in the foregoing theoretical analysis when we speak about residential consumption, we are refering to just that, without taking into consideration loss of wate in the distribution system of the house due to lack of maintenance. There is no doubt that leakage increases with pressure. The formula to figure this for one day is:

$$V = KTp^n$$

where

V = Water volume of the leak,

K = A constant,

T = A day, or the number of time units equivalent to one day,

p = pressure at the leak,

n = a number approximately equal to 1/2.,

Attention should be drawn to the difference between discharge and consumption or volume supplied.

Discharge, is the volume per unit of time, while consumption, is the volume used or assigned during a given time period. (one day)

There is no doubt that discharge always depends on the pressure, while consumption or volume supplied depends on the volume assigned or used. Consumption or volume supplied may be obtained from the product of discharge for the time considered. For example, if discharge is variable during a day, as happens in reality, consumption during the day will be

$$\text{consumption} = \int Q\, dt$$

where

Q = instantaneous discharge

t = time

If a person takes a shower using 5 gpm. for 10 minutes, with the faucet open, he consumes not 5 gpm, but 5 gpm for 10 minutes, or 50 gallons of water.

5. EQUIPMENT, APPARATUS, AND INSTRUMENTS USED IN THE INVESTIGATION AND THEIR INSTALLATION.

The equipment, apparatus and instruments used in each house studies were the following:

a. One centrifugal pump

b. One water meter

c. One meter-master

d. Valves

e. Metal pressure gauges

The centrifugal pump used in all cases was an Ingersol-Rand motorpump, 1-MRVH-7 1/2 two stage with 30 gpm against 250 feet of total dynamic load; 3, 450 rpm, curves characteristic of No. 7512-A, with an open 7 1/2 Hp, 220/440 volt, 3 phase and 60 cycle electric motor.

The water-meter was a six pointer Badger, with a circular dial and reading in liters.

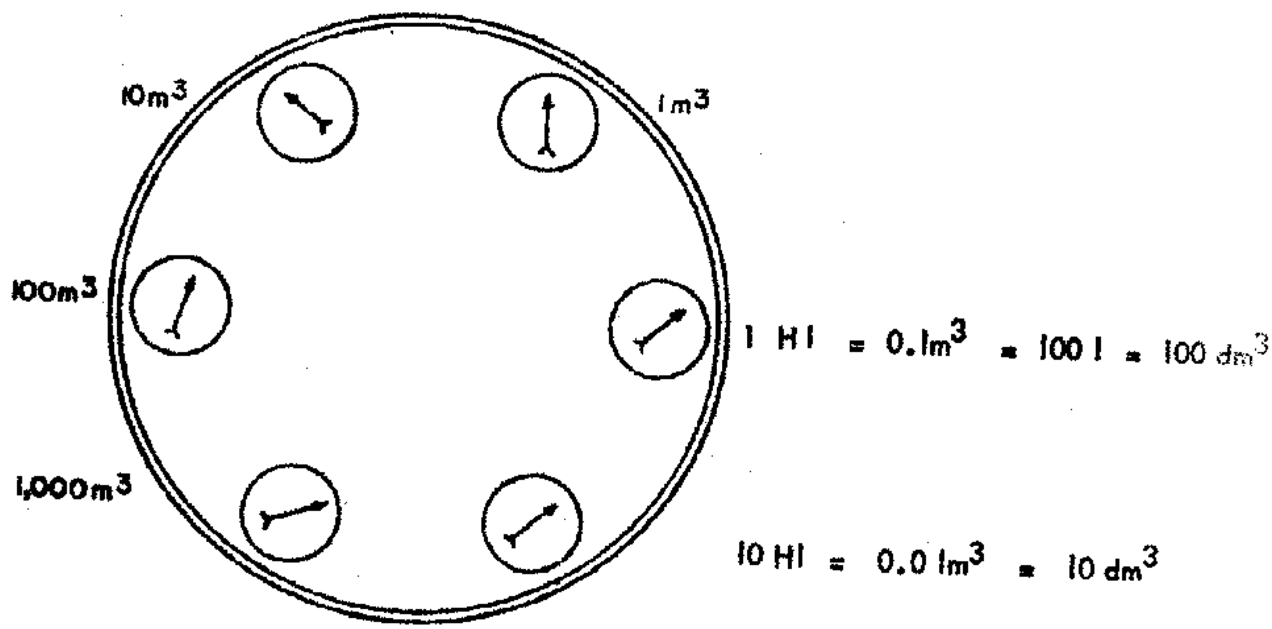

FIG. 1 - DIAL OF THE WATER METER

The meter-master was model No. 60P2P, manufactured by F. S. Brainard and Co.; the valves used were of the gate valve type, and the metal pressure gauges of the Bourdon type.

The meter-master, is a registering instrument that, when attached to a circular dial water-meter, registers the discharge or volume of water, and also shows the pressure of water entering during the 24 hours of a day.

The meter-master model used in this investigation is the 60P2P. It was installed on top of the box containing the water meter. It has a flexible hose connection designed to measure pressure and uses a double graph, one which measures pressure, and the other discharge.

One double graph lasts 24 hours and is divided into 15 minute intervals.

When the 24 hour graph is used, a pointer revolving not more than once every 3 minutes should be selected.

A complete oscillation of the pen's arm from one extreme to the other and back again registers one revolution of the indicator needle. If the meter-master installed is above the 10 hectoliter indicator needle, a complete oscillation of the needle arm would indicate 10 hectoliters, that is, its departure and its return.

Since the dial of its departure and return is divided into 5 equal parts, each of the dial's sub-divisions represent one hectoliter. The graph shows the same units as the meter.

Figure 1 represents the dial of the water meter used in the observations. The water meter's 6 indicator pointer are represented on the dial. The unit of volume corresponding to one complete revolution is shown next to each needle.

Keeping in mind that one liter is equivalent to the volume of 1 dm^3 and that 1 Hl = 100 liters, we have that:

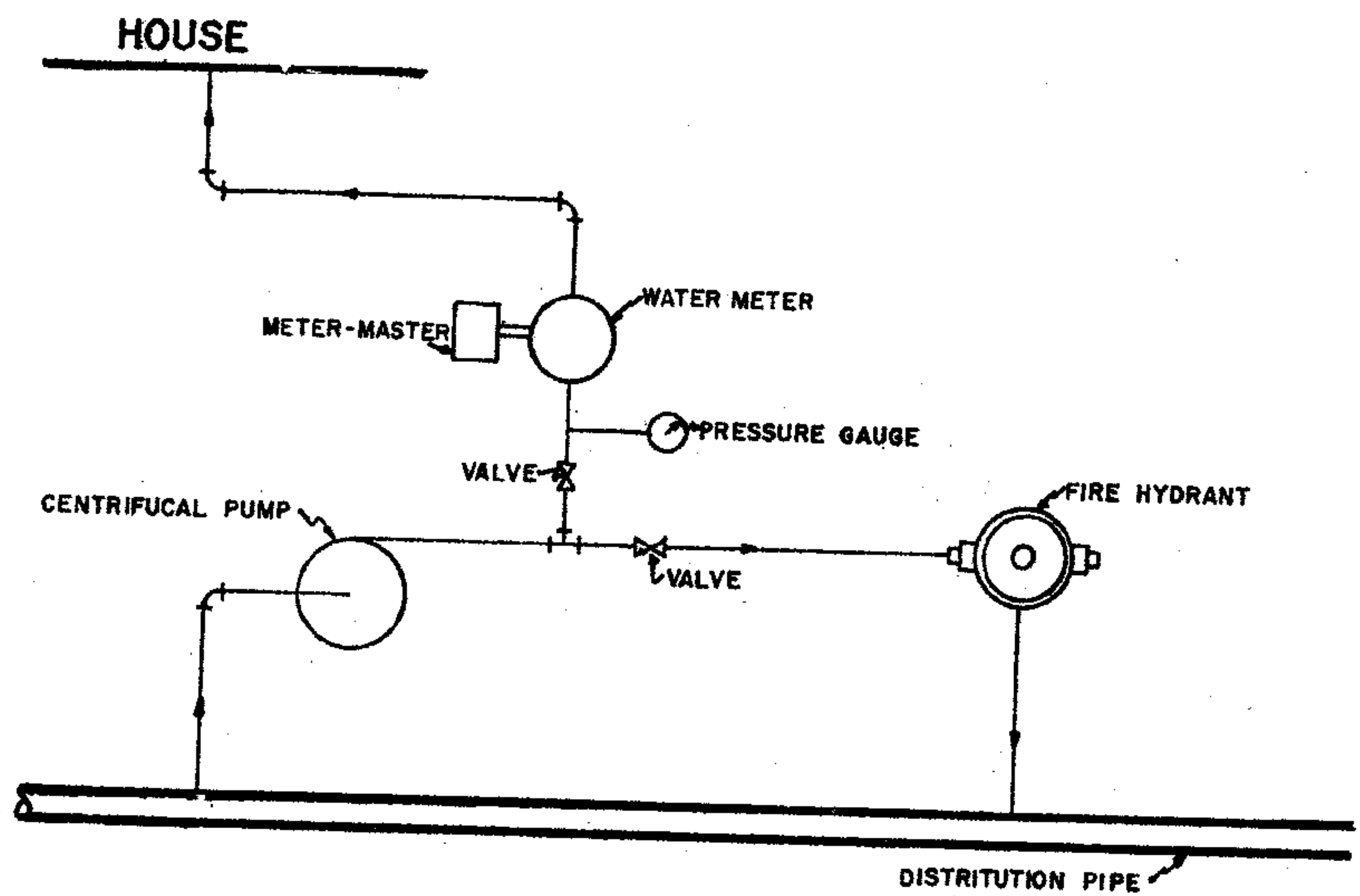

FIG. 2 - INSTALLATION OF THE EQUIPMENT AND APPARATUS

$$1\ HI = 100 \text{ liters} = 100\ dm^3 = 0.1 m^3$$

and

$$10 \text{ liters} = 10\ dm^3 = 0.01\ m^3$$

For example, if we obtain 457689 upon reading the six needles in descending order, this number indicates liters, or dm^3. Now, if the master-meter is attached to the needle for HI one complete oscillation of the needle shows 10 HI, and HI on the graph.

In order to conduct the research, the apparatus was installed in front of the selected houses.

Essentially, the installation consisted of mounting a centrifugal pump in series proceeding to the water meter, with by-pass at a fire hydrant if possible.

Figure 2 is a schematic diagram of the installation. The reason for this method of apparatus installation is due to the fact that the pump must work constantly to increase pressure available in the water system. Water temperature would reach undesirable levels without the by-pass, which returns water to the water system if the hydrant is open.

Leaks in the houses to be investigated can be located by the following:

1. The water-meter
2. The meter-master

If the test shows that there are leaks in the interior water distribution system of the house selected which are difficult to repair, then this house should not be used in the experiment.

If the leak is visible and easy to repair, then if should be repaired, so that the house can be used in the experiment.

To determine leaks with the water meter procced as follows:

Close all the faucets and water outlets that exist in the house and observe the water meter for a period of time. If the water meter indicates some consumption of water, then leaks exist. If the water meter does not indicate any consumption, then the house's distribution system is in good condition.

To determine leaks with the meter-master proceed as follows: observe the graph corresponding to the supply and assume that during the night and early morning no water is consumed.

If the graph indicates some consumption of water, then leaks exist in the water distribution system.

5. REQUISITES OF SELECTED HOUSES

If we examine carefully the schematic drawing of the installation of figure 2, we will realize some of the requisitions which the houses selected should have. Some are due to the type of investigation, others are measures of security.

The requisites are as follows:

1. They should be representative of the investigation to be realized.
2. They should have a water meter to which a meter-master can attached.
3. The water meter should be close to a water hydrant.
4. The houses should be near a post that has a three-phase current.
5. The traffic of pedistrians and vehicles, as well as the width of the sidewalk, should be considered, so to enable easy installation of the necessary equipment and the avoidance of accidents.
6. There should exist below normal pressure, so that the investigator can carry out increases of pressure.
7. The location of the house should be such that the possibility of damage to the equipment installed is at a minimum.

8. There should not be any leaks in the house's water distribution system.

9. The interior pipeline installations should be in good condition from the point of view of resistence of the pipes to increases in pressure.

10. The owner or tenant should give his authorization for the installation of the equipment and the carrying out of the investigation.

Complying with these requisitions resulted more difficult that it seems as was proven by the effort exerted in the selection of the houses used.

Beside the difficulties inherent in the investigation and the requisites to comply with, others of another nature developed.

For example, in the present case the following took place: after having selected a house that fulfilled the abovementioned requisites, and getting the owner's authorization and installing the necessary equipment and working months with this house, the owners withdrew their authorization because some of the pipes installed for the study broke.

There were many cases of damaged equipment due to traffic accidents and pedestrians passing nearby.

In one case, we were informed that there was a three-phase current that could be put at our disposal in a given house and after including this property in the Insurance Policy of the Institute, in case of damages, we had to withdraw this house on order of the Insurance Company due to a misunderstanding whereby they had been told that there was no three-phase current available there.

6. THE SELECTED HOUSES

After over-coming the various difficulties encounted in selection of the houses, that complied with the established requisites, the following houses were selected -:

A. Bosque Street No. 59, between Nereida and Orquideas Streets (Mayaguez)

B. Padre Aguilera Street No. 119, between Washington and Kofresi Street (Mayaguez)

C. José De Diego Street No. 51, corner of Peral Street (Mayaguez)

Description of Each House

A. Bosque Street No. 59 - This house had of 5 inhabitants, and had installed the following sanitary fixtures:

One bathroom, with

1 tank toilet

1 tub with shower

1 washbasin

1 bidet

One kitchen, with

1 sink with two faucets

One laundry room, with

1 faucet

1 electric washing machine

Yard, or garden, with

3 faucets

The house's service pipe is 3/4 inch. According to the map of the Mayaguez water system, a 6 inch diameter distribution main pipe serves this house. The map was drawn up by The Pitometer Engineer Associates.

Maximum estimated consumption for this house, using the Hunter method, is 10 gpm.

B. Padre Aguilera Street No. 119 – This house is occupied by [redacted] with the following sanitary fixtures installed:

<u>One bathroom, with</u>

1 toilet

1 shower

1 washbasin

<u>One kitchen, with</u>

1 sink with one faucet

<u>One laundry room, with</u>

1 clothes washing machine

<u>Yard, or garden, with</u>

1 faucet

The house's service pipe is 3/4 inch. According to the same map of the Mayaguez water system a 4 inch diameter distribution main pipe serves the house.

Maximum estimated consumption for this house, using the Hunter method, is 9 gpm

C. José De Diego Street No. 51 – This house had 2 residents, and the following sanitary fixtures installed:

<u>One bathroom, with</u>

1 tank toilet

1 tub with shower

1 washbasin

1 bidet

<u>One kitchen, with</u>

1 sink

1 slop sink

1 diswashing machine

<u>One laundry room, with</u>

1 clothes washer

<u>Yard, or garden, with</u>

1 faucet

This house has a 3/4 inch service pipe. According to the Pitometer map, a 4-inch diameter distribution main pipe serves the house. Maximum estimated consumption for this house, according to the Hunter method, is 10 gpm.

Generally, urban water distribution system pipelines are of a diameter such that the velocity of water flowing through them is between 3 and 5 feet per second. (Babbitt, Doland, and Cleasby, Water Supply Engineering, 6th. edition, McGraw Hill).

Among the three houses, the most unfavorable situation with respect to the system's distribution main was that of the house at Padre Aguilera Street No. 119, which consumes a maximum probable volume of 9 gallons per minute from a 4-inch diameter pipe. It should be noted that the house at José De Diego No. 51, if it does consume a maximum probable volume of 10 gpm from a 4-inch diameter pipe, is situated very near to a 14-inch pipe.

The average volume of flow through a 4-inch distribution main whose velocity is 5 feet per second is 196 gpm.

With a 4-inch pipe carrying 196 gpm there is a loss of pressure of 43 feet in every 1000 feet. When a pipe conducts 196 + 9 = 205 gpm, it loses pressure of 45 feet in every 1000 feet. That is, withdrawl of 9 gpm, maximum probable volume used by the house, from the 4-inch main, causes the hydraulic slope to decrease 2 feet in 1000 feet, which is to 0.087 lbs/in^2 in 1000 feet. This means that the withdrawl of 9 gpm has no appreciable effect on pressure in the service main serving Padre Aguilera Street No. 119. Influence on pressure will be still smaller when volume entering the house is less than the maximum, as will be in most cases.

Influence of the withdrawl is still smaller in the two other houses. Therefore, volume withdrawn in either of the three houses has no appreciable effect on pressure prevailing in the water distribution system supplying the house.

7. DATA OBTAINED FROM OBSERVATIONS MADE OF THE SELECTED HOUSES

In Appendix III, Table I, there is a summary of the data collected from observations for each of the houses used in the study. This information was taken from the Meter-Master Graphs of the corresponding houses.

Column 1: Number of the graph corresponding to the data that appears in Column 2, 3, 4 and 7.

Column 2: Date of installation and removal of the meter-masters, and the date they were read.

Column 3: Time that the graphs of the master-meter were installed and removed and that water-meter was read.

Column 4: Water-meter readings in liters.

Column 7: Pressure in the water distribution network in lbs/in^2.

8. ANALYSIS OF THE OBSERVATIONS ACCOMPLISHED

The analysis of the data obtained procceded as follows:

The differences between consecutive readings of the water meter is the volume consumed in liters in the interval of time between the two consecutive times corresponding to the previous readings. The volume of water consumed appears in Column 5 and the interval of time in Column 6, in Tables I corresponding to the selected houses.

Knowing the volume consumed in the interval of time and the number of inhabitants of the houses selected, we can find the volume consumed or used during 24 hours per person. This value appears in Column 8 of the tables mentioned.

The prevailing pressure of the urban distribution network was obatined in the following manner. During the hours of the day when water is used, which is generally from 7:00 am to 10:00 am., the pressure is read when no one is using the water. This is easy to find our by observing the graph of the meter master. This pressure is the pressure existing in the distribution network when the water is consumed. The reason for this will be better understood by reading Appendix 4, which appears in the back of this report. From these values are obtained the value of the pressure during the interval of time between two consecutive readings of the water meter.

By obtaining the daily consumption by day and by person and knowing the pressure existing in the urban distribution network we are able to relate these two magnitudes.

In Tables II, corresponding to the houses selected appear resume's of the values obtained.

In Tables II Appear:

Column I: The number of the graph corresponding to the degree of pressure and daily consumption per person which appear in the other columns of the table.

Other Columns. - Pressures existent in the urban distribution network in lb/in^2. and the consumption which corresponds to these pressures, in gallons per day and by person, both values are placed in the same column.

9. CONCLUSIONS AND RECOMMENDATIONS

Below is a table summarizing the final results obtained from the observations made.

AVERAGE CONSUMPTION RATES FOR DIFFERENT PRESSURED

Pressures	Consumption in GPCPD of Selected Houses		
lbs/in^2	Padre Aguilera 119	Bosque 59	José De Diego 51
50	12		
55	28		117
60	21		108
65	25	97	112
70	24	70	92
75		67	70
80	24	80	114
85			108
90			111
95			
100	21	63	
105	17		
110	39	72	
115			
120	17	83	
125		90	
130		131	

In the house at De Diego Street No. 51, consumption tends to diminish as pressure increases. Upon reaching a minimum value, consumption increases again.

In these three cases, if we represent the values for pressure on the abscissa and for consumption on the ordinate, arithmetic, logarithmic, and semi-logarithmic graphs do not show defined curves, since distribution of the various points is very irregular. For this reason it is logical to suppose that the variations in consumption are due to an unknown cause, foreign to pressure.

3. Average consumption in gallons per day for each of the houses studied is as follows:

Padre Aguilera No. 119 .... 25 GPCPD

Bosque Street No. 59 .... 74 GPCPD

De Diego Street No. 51 .... 93 GPCPD

The average values for each house have been obtained by assigning to each average, corresponding to each pressure, a weight equal to the number of times that pressure appears.

4. The average for the three houses is 64 GPCPD. This average is not significance because the it represent three cases only..

10. ACKNOWLEDGEMENTS

We have received extremely valuable and efficient cooperation from the different government agencies, offices, and departments, from officials of the University of Puerto Rico, Mayaguez, and , in general, from the people of the City.

We want to make especially clear our thanks to:

The Puerto Rico Water and Sewage Authority, especially to Mr. Manuel Sánchez [illegible], engineer of that agency.

To the Puerto Rico Water Resources Authority, particularly to Pelegrín Bousquet and Teodosio González, engineers of that agency.

To Mr. Justo Varela, engineer, Secretary of Public Works.

To the Municipaliy of Mayaguez, and in particular to Mr. Carlos A. Santiago, of the Municipality.

To Mr. Luis Irizarry, engineer, and to Mrs. Gladys Rodríguez, employees of the Finance Department, University of Puerto Rico, Mayaguez.

To the employees of the University Buildings and Grounds, to Mr. Héctor Quintero, Engineer, and to Mr. Juan B. Castro, electrician.

And finally, to the secretaries and typists of the Water Resources Research Institute, University of Puetto Rico, Mayaguez, who have aided these investigations by copying reports and other documents, and to the residents of the houses selected in this inquiry.

12. Bibliography

1. Babbitt, H. E.; Doland, J. J.; and Cleasby, J. L., Water Supply Engineering, 6th. ed, McGraw Hill, Page 15.

2. Clark, J. W., and Viessman W., Water Supply and Pollution Control, International Textbook Company. Page 30.

3. Fair, G. M., and Geyer, J. H., Elements of Water Supply and Waste Disposal. John Wiley and Sons. Pages 23 and 24.

4. Hardenburgh, W. A., Water Supply and Purification, 3rd. ed, International Textbook Company, Page 16.

5. Hunter, R. B., Method of Estimating Loads on Plumbing Systems, Report BMS, National Bureau of Standards, 1940.

6. Linaweaver, F. P., Residential Water Use, Baltimore, Md.: The Johns Hopkins University, Page 49.

7. Turneare, F. E., and Russell, H. L., Public Water Supplies. 4th. ed, John Wiley and Sons, Page 14.

Appendix I

Authorative Opinions on Water Consumption

Below is cited various authoratative opinions on water consumption.

1. Babbitt, Doland, and Cleasby in the 6th. edition of Water Supply Engineering, McGraw Hill Company, States: -

> "1-13. Pressure and Quality. The rate of use of water increases when the pressure is increased in the distribution system. The increased use is due, in part, to the greater loss of water through leaks and the greater amount runs to waste through open faucets. Increases in the rate of use of water with pressure have been known to reach 30% for a change from 25 to 45 psi. This fact should lead the designer to provide the lowest pressure that will give satisfactory service".

2. Fair and Geyer, in their work Elements of Water Supply and Waste Water Disposal, John Wiley and Sons, States: -

> "2-6. Uses and Averages .... The quantities delivered in North American communities approximate the values shown in Table 2-3, with wide variations to be expected because of differences in (1) climate, (2) standard of living, (3) extent of sewerage, (4) type of mercantile, commercial, and industrial activity, (5) cost of water, (6) availability of private water supplies, (7) quality of water for domestic, industrial, and other uses, (8) pressure in the distribution system, (9) completeness of meterage, and (10) management of the system... The flow of water through faucets and

similar outlets, as well as through leaks in mains and faulty plumbing, is akin to flow through an orifice and so varies around the square root of the pressure head. In distribution systems, therefore, high pressures result (1) in rapid discharge of fixtures and increased waste of water, and (2) in increased leakage. Operating pressures in excess of about 60 psi are no longer as important for fire fighting as they were before the advent of the motor pumper."

3. Professors Clark and Viessman, in their work Water Supply and Pollution Control, edited by International Textbook Company, states: -

"Water Pressure. Rates of water used increase with increasing pressure. This result is due partly to leakage and partly to the increased volumes of flow through fixture units per unit of time. For example, the water-use rate has been known to increase by as much as 30% for 20-psi change in line pressure. Pressures in excess of those required for satisfactory service should be avoided whenever possible."

4. Professors Turneare and Russell, in their classic work Public Water Supplies, 4th. ed. John Wiley and Sons, state

"Influence Affecting the Consumption Per Capita.... Good quality, flat rates, and high pressure tend to increase the consumption by encouraging a more liberal use and also, it may be said, greater wastefulness". (Page

5. Hardenbergh, in Water Supply and Purification, 3rd. edition, International Textbook Company, states: -

"24. Effect of Pressure. - Higher pressures in the mains and distribution pipes are conducive to increased loss from leaks and to greater wastage within homes because of faulty plumbing fixtures". (Page 14)

6. Linaweaver, of the Department of Sanitary Engineering and Water Resources, Johns Hopkins University, Baltimore, Md. on page 49, Report II, Phase 2, of Residential Water Use states: -

"Other Factors

Many other factors influence residential water use.. Some factors often thought to have considerable influence, such as pressure, should have no influence on actual domestic or sprinkling use. Under high pressure, the rate of use, q, may increase, but the time on t would be decreased to compensate and the resulting Q would be the same. Low a longer $\bar{t}$, with a large number of consumers, Q would again be about the same......"

Appendix II

Determination of Maximum Probable Water Volumes for the Selected Houses

In every case, the fixtures units have been taken from the table for that purpose appearing in publication BMS 79, National Bureau of Standards, United States Department of Commerce. The maximum probable discharge are from the accompanying graph in the same publication.

A. 59 Bosque Street   Fixture units for sanitary fixtures installed in this house are:

Bathroom

1 toilet tank

1 tub and shower

1 washbasin

1 bidet

bathroom total ......6 fixture units

Kitchen

1 sink

kitchen total ..... 2 fixture units

Laundry

1 electric washine machine

1 faucet

laundry total ..... 3 fixture units

Garden

3 faucets

garden total ..... 3 fixtures units

HOUSE TOTAL ..... 14 fixtures units

B. 119 Padre Aguilera Street Fixture units for sanitary fixtures installed in this house are:

Bathroom

1 tank toilet

1 tub

1 washbasin

bathroom total ...... 6 fixture units

Kitchen

1 sink

kitchen total ...... 2 fixture units

Laundry

1 electric washing machine

laundry total ...... 3 fixture units

Garden

1 faucet

garden total ...... 1 fixture units

HOUSE TOTAL ...... 12 fixture units

The maximum probable volume for these sanitary unit is 12 gpm.

C. <u>51 José de Diego Street</u> Fixture units for sanitary fixtures in this house are:

Bathroom

1 toilet tank

1 tub and shower

1 washbasin

1 bidet

bathroom total ...... 6 fixture units

Kitchen

1 sink

1 slop sink

1 electric dishwasher

kitchen total ...... 4 fixture units

Laundry

1 electric washing machine

laundry total ...... 3 fixture units

Outside faucets

1 faucet

total outside faucets .. 1 fixture units

HOUSE TOTAL ...... 14 fixture units

The maximum probable volume for these sanitary units is 10 gpm.

Appendix 3

TABLE I – RESUME OF DATA OBTAINED AND THE CALCULATIONS REALIZED

TABLE I

House Address : Padre Aguilera No. 119 Street, Buena Vista

No. of residents : 6

No. of Graph	Date	Time	Meter Reading	Total Consumption	No. of Hours	Pressure	GPCPD
			Liters	Liters	Hours	lb/in.^{2}	
1	2	3	4	5	6	7	8
	1967 Sept. 22	2:30pm	277263				
1				199	20.50	65	10.3
	Sept. 23	11:00 am	277462				
2				600	24.50	65	26.0
	Sept. 24	11:30 am	278062				
3				504	28.17	65	19.0
	Sept. 25	3:40 pm	278566				
4				505	24.58	65	21.8
	Sept. 26	4:15 pm	279071				
5				500	24.75	70	21.4
	Sept. 27	5:00 pm	279571				
6				551	22.75	70	25.7
	Sept. 28	3:45 pm	280122				
7				496	25.25	65	20.8
	Sept. 29	5:00 pm	280618				
8				388	18.50	65	22.2
	Sept. 30	11:30 am	281006				
9				–	–	65	–
	Oct. 1	–	–				
–				1061	52.25	–	21.5
				–	–	–	–
	Oct. 2	3:45 pm	282067				
10							
	Oct. 3	4:20 pm	282587				
11				520	24.58	65	22.4
	Oct. 4	4:20 pm	283213				
12				626	24.00	65	27.4
	Oct. 5	5:00 pm	283664				
13				451	24.67	65	19.3
	Oct. 6	4:00 pm	284220				
				556	23.00	65	25.7

No. of Graph	Date	Time	Meter Reading	Total Consumption	No. of Hours	Pressure	GPCPD
			Liters	Liters	Hours	l/b in.^{2}	
1	2	3	4	5	6	7	8
14				299	18,25	65	17.4
	Oct. 7	10:15 am	284519				
15				-	-	65	-
	Oct. 8	-	-				
-				507	49.75	-	10.8
				-	-	-	-
	Oct. 9	12:00 m	285026				
16				971	26,25	65	39.4
	Oct. 10	2:15 pm	285997				
17				-	-	65	-
	Oct. 11	-	-				
-				-	-	-	-
	Oct. 12	-	-	1,592	93,25		18.1
-				-	-	-	-
	Oct. 13	-	-				
-				-	-	-	-
	Oct. 14	11:30 am	287589				
18				295	22.00	70	14.2
	Oct. 15	9:30 am	287884				
19				444	26.50	70	17.8
	Oct. 16	12:00 m	288328				
20				404	23.50	70	18.2
	Oct. 17	11:30 am	288732				
21				627	24.25	65	27.4
	Oct. 18	11:45 am	289359				
22				1,425	24.00	70	63.0
	Oct. 19	11:45 am	290784				
23				245	23.75	70	11.0
	Oct. 20	11:30 am	291029				
24				-	26,58	70	-
	Oct. 21	2:05 pm	290741				
25				536	21.42	70	26.5
	Oct. 22	11:30 am	291277				
26				520	24.33	75	22.7
	Oct. 23	11:50 am	291797				
27				485	24.09	70	21.4
	Oct. 24	11:55 am	292282				
28				617	23.75	70	27 27.6
	Oct. 25	11:40 am	292899				
29				366	24.16	70	16.1
	Oct. 26	11:50 am	293265				
30				520	24.00	70	23.0
	Oct. 27	11:50 am	293785				
31				798	-	70	-
2	Oct. 28	-	294583	-	72.00	70	-
	Oct. 29	-	-	383			

No. of Graph	Date.	Time	Meter Reading	Total Consumption	No. of Hours	Pressure	GPCPD
			Liters	Liters	Hours	l/b in.^{2}	
1	2	3	4	5	6	7	8
	Oct. 30	11:50 am	294966				
33				644	27.42	65	24.9
	Oct. 31	3:15 pm	295610				
34				481	21.83	65	23.4
	Nov. 1	1:05 pm	296091				
35				1,534	23.92	65	68.0
	Nov. 2	1:00 pm	297625				
36				–	–	65	–
	Nov. 3	11:45 am	–				
–				412	47.50		9.2
				–	–	–	–
	Nov. 4	12:30 pm	298037				
37				2,111	118.00	–	18.9
	Nov. 9	10:30 am	300148				
38				539	26.50	60	21.6
	Nov. 10	1:00 pm	300687				
39				408	24.00	60	18.0
	Nov. 11	1:00 pm	301095				
40				192	21.25	60	9.6
	Nov. 12	10:15 am	301287				
41				454	25.58	60	18.8
	Nov. 13	11:50 am	301741				
42				570	24.17	60	25.0
	Nov. 14	12:00 m	302311				
43				404	23.83	55	18.0
	Nov. 15	11:50 am	302715				
44				998	23.92	55	44.2
	Nov. 16	11:45 am	303713				
45				0	24.00	65	–
	Nov. 17	11:45 am	303713				
46				857	27.25	60	33.4
	Nov. 18	3:00 pm	304570				
47				0	23.50	60	–
	Nov. 19	2:00 pm	304570				
48				–	–	60	–
	Nov. 20	–	–				
–				998	47.50		22.2
				–	–	–	–
	Nov. 21	2:00 pm	305568				
49				934	24.50	60	40.4
	Nov. 22	2:30 pm	306502				
50				213	27.50	60	8.8
	Nov. 23	6:00 pm	306715				
51				341	20.33	55	17.8
	Nov. 24	2:20 pm	307056				
52				380	23.67	65	17.0
	Nov. 25	2:00 pm	307436				
53				831	22.00	65	40.0

No. of Graph	Date	Time	Meter Reading	Total Consumption	No. of Hours	Pressure	GPCPD
			Liters	Liters	Hours	l/b in.^{2}	
1	2	3	4	5	6	7	8
	Nov. 26	12:00 m	308267				
54				0	23.75	60	–
	Nov. 27	11:45 am	308267				
55				–	–	60	–
–	Nov. 28	–	–	1,158	47.92		25.6
				–	–	–	–
	Nov. 29	11:40 am	309425				
56				629	23.83	60	28.0
	Nov. 30	11:30 am	310054				
57				1,541	24.33	55	67.3
	Dec. 1	11:50 am	311595				
58				393	24.17	55	17.3
	Dec. 2	12:00 m	311988				
59				104	24.00	60	4.6
	Dec. 3	12:00 m	312092				
60				142	23.75	–	–
	Dec. 4	11:45 am	312234				
61				298	23.58	55	13.4
	Dec. 5	11:20 am	312532				
62				624	24.42	55	27.2
	Dec. 6	11:45 am	313156				
63				581	28.75	55	21.4
	Dec. 7	4:30 pm	313737				
64				831	18.75	55	47.0
	Dec. 8	11:15 am	314568				
65				1,422	26.75	55	56.3
	Dec. 9	2:00 pm	315990				
66				–	–	55	–
	Dec. 20	11:30 am	319963				
67				394	–	55	–
	Dec. 21	–	320357		48.08		16.4
68				346	–	60	–
	Dec. 22	11:35 am	320703				
69				361	26.92	55	14.2
	Dec. 23	2:30 pm	321064				
70				492	22.00	60	23.9
	Dec. 24	12:30 pm	321560				
71				–	–	55	–
	Dec. 25	–	–				
72				931	47.50	–	20.8
				–	–	–	–
	Dec. 26	12:00 m	322491				
73				323	26.00	55	13.3
	Dec. 27	2:00 pm	322814				
74				444	21.33	55	22.1
	Dec. 28	11:20 am	323258				
75				469	23.17	55	22.2

No. of Graph	Date	Time	Meter Reading	Total Consumption	No. of Hours	Pressure	GPCPD
			Liters	Liters	Hours	lb in.^{2}	
1	2	3	4	5	6	7	8
	Dec. 29	9:30 am	323727				
76				–	–	55	–
	Dec. 30	–	–				
77				837	49.75		17.8
				–	–	–	–
	Dec. 31	11:15 am	324564				
78				409	23.75	55	18.3
	1968 Jan. 1	11:00 am	324973				
79				457	24.17	60	20.0
	Jan. 2	11:10 am	325430				
80				451	24.41	60	19.6
	Jan. 3	11:35 am	325881				
81				997	23.59	55	45.0
	Jan. 4	11:10 am	326878				
82				157	27.00	60	6.2
	Jan. 5	2:10 pm	327035				
83				395	20.33	60	20.6
	Jan. 6	10:30 am	327430				
84				418	24.17	65	18.4
	Jan. 7	10:40 am	327848				
85				548	23.83	60	24.4
	Jan. 8	10:30 am	328396				
86				419	23.17	55	19.2
	Jan. 9	9:40 am	328815				
–				–	–	–	–
	Jan. 10	–	–				
87				834	49.83	55	17.7
				–	–	–	–
	Jan. 11	11:30 am	329649				
–				545	23.75	–	24.4
	Jan. 12	11:15 am	330194				
88				309	26.50	50	12.4
	Jan. 13	1:45 pm	330503				
89				342	20.75	60	17.5
	Jan. 14	10:30 am	330845				
90				825	25.00	60	35.0
	Jan. 15	11:30 am	331670				
91				–	–	50	–
	Jan. 16	–	–				
–				1,029	45.00		24.2
				–	–	–	–
	Jan. 17	8:30 am	332699				
92				561	26.50	60	22.5
	Jan. 18	11:00 am	333226				
93				476	24.25	100	20.8
	Jan. 19	11:15 am	333736				

No. of Graph	Date	Time	Meter Reading	Total Consumption	No. of Hours	Pressure	GPCPD
			Liters	Liters	Hours	l/b in.^{2}	
1	2	3	4	5	6	7	8
	Jan. 31	11:15 am	340460				
93 a				371	27.75	105	14.2
	Feb. 1	3:00 pm	340831				
93 b				485	27.50	105	18.7
	Feb. 2	2:30 pm	341316				
93 c				392	21.50	105	19.3
	Feb. 3	12:00 m	341708				
93 d				522	22.75	-	-
	Feb. 4	10:45 am	322230				
93 e				420	24.50	120	18.2
	Feb. 5	11:15 am	342650				
93 f				2,221	23.42	-	-
	Feb. 6	10:40 am	344871				
93 g				340	24.08	120	15.0
	Feb. 7	2:45 pm	345211				
93 h				-	-	-	-
	Feb. 8	-	-	-	48.00		
93 i				-	-	-	-
	Feb. 9	2:45 pm	345211				
93 j				552	21.50	110	27.2
	Feb. 10	12:15 pm	345763				
93 k				472	27.17	110	18.2
	Feb. 11	3:25 pm	346235				
93 l				1,626	24.08	110	71.5
	Feb. 12	3:30 pm	347861				
93 m				423	-	-	-
	Feb. 13	-	348284				
93 n				-	-	-	-

No. of Graph	Date	Time	Meter Reading	Total Consumption	No. of Hours	Pressure	GPCPD
			Liters	Liters	Hours	l/b in.^{2}	
1	2	3	4	5	6	7	8
	Feb. 20	9:30 am	345343				
94				1,045	31.75	80	34.9
	Feb. 21	5:15 pm	346388				
–				–	–	–	–
	Feb. 22	–	–	631		80	
95							
	Feb. 23	11:40 am	347019		42.42		
				–	–	–	–
	Feb. 24	–	–	912			
–				–	–	–	–
	Feb. 25		347931		75.33		
96				662	–	80	–
	Feb. 26	3:00 pm	348593				
97				626	24.75	80	26.9
	Feb. 27	3:45 pm	349219				
–				554	25.92	–	22.7
	Feb. 28	5:40 pm	349773				
98				306	23.00	80	14.2
	Feb. 29	4:40 pm	350079				
99				424	22.66	80	19.8
	Mar. 1	3:20 pm	350503				
100				531	25.17	60	22.4
	Mar. 2	4:30 pm	351034				
101				380	21.00	70	19.2
	Mar. 3	1:30 pm	351414				
102				515	27.33	70	20.0
	Mar. 4	4:50 pm	351929				
103				808	23.67	70	36.1
	Mar. 5	4:30 pm	352737				
104				505	–	–	–
	Mar. 6	–	353242				

APPENDIX 3

TABLE I - RESUME OF DATA OBTAINED AND CALCULATIONS REALIZED

House Address : 59 Bosque Street, Ensanche Martínez

No. of residents : 5

No. of Graph	Date	Time	Meter Reading	Total Consumption	No. of Hours	Pressure	GPCPD
			Liters	Liters	Hours	l/b in²	
1	2	3	4	5	6	7	8
	Sept. 11	7:30 pm	821979				
1				-	-	70	-
	Sept. 12	4:00 pm	-				
				-	-	80	-
3				5,060	90.5		70.5
	Sept. 13	12:26 pm	-				
				-	-	70	-
	Sept. 14	3:45 pm	-				
				-	-	70	-
	Sept. 15	2:00 pm	827039				
5				-	-	70	-
	Sept.16	-	-	2,486	.o.25		67.5
				-	-	-	
	Sept. 17	12:15 pm	829525				
6				302	25.75	-	14.8
	Sept. 18	2:00 pm	829827				
7				2,604	23.50	65	140.0
	Sept. 19	1:30 pm	832431				
8				1,046	24.00	65	55.0
	Sept. 20	1:30 pm	833477				
9				1, 111	25.50	70	55.0
	Sept. 21	3:00 pm	834588				
10				1,677	24.00	80	88.8
	Sept. 22	3:00 pm	836265				
11				897	20.50	70	55.3
	Sept. 23	11:30 am	837162				
					-	-	-

No. of Graph	Date	Time	Meter Reading	Total Consumption	No. of Hours	Pressure	GPCPD
			Liters	Liters	Hours	1/b in^2	
1	2	3	4	5	6	7	8
–	Sept. 24	–	–				
				–	–	–	–
–	Sept. 25	–	–				
				–	–	–	–
12	Sept. 26	1:30 pm	–				
				–	–	65	–
13	Sept. 27	1:30 pm	840767				
				2,231	26.50	70	106.0
14	Sept. 28	4:00 pm	842998				
				–	–	63	–
–	Sept. 29	–	–	1,019	42.25		30.4
				–	–	–	–
15	Sept. 30	10:15 am	844017				
				1,479	24.25	70	76.6
16	Oct. 1	10:30 am	845496				
				913	22.50	75	51.0
17	Oct. 2	9:00	846409				
				–	–	70	–
–	Oct. 3	–	–				
				3,122	73.67	–	53.5
–	Oct. 4	–	–				
				–	–	–	–
18	Oct. 5	10:40 am	849531				
				–	–	80	–
19	Oct. 6	3:40 pm	–				
				5,520	73.33	80	95.0
–	Oct. 7	–	–				
				–	–	–	–
–	Oct. 8	12:00 m	855051				
				–	–	–	–
20	Oct. 9	2:00 pm	853821				
				–	–	70	–
–	Oct. 10	–	–				
				–	–	–	–
–	Oct. 11	–	–				
				–	–	–	–
21	Oct. 12	12:00 m	857730				
				–	–	–	–
–	Oct. 13	–	–	2,904	45.75	70	80.0
					–	–	–
22	Oct. 14	9:45 am	860634				
				1,097	26.50	75	52.2
23	Oct. 15	12:15 pm	861731				
				–	–	75	–

[illegible]	Date	Time	Meter Reading	Total Consumption	No. of Hours	Pressure	GPCD
			Liters	Liters	Hours	lb/in^2	
	2	3	4	5	6	7	8
	Oct. 16	-	-	200	47.75		
	Oct. 17	12:00 m	861931	-	-	-	
24	Oct. 18	11:30 am	864334	2,403	23.50	70	129.00
25	Oct. 19	12:05 pm	865314	900	24.58	70	50.2
26	Oct. 20	11:35 am	867344	2,030	23.50	70	109.0
27	Oct. 21	1:50 pm	867487	143	26.25	-	6.9
28	Oct. 22	11:45 am	869146	1,659	21.92	70	95.6
29	Oct. 23	11:45 am	870165	1,019	24.00	80	53.5
30	Oct. 24	11:45 am	871013	848	24.00	-	44.5
31	Oct. 25	11:30 am	873646	2,633	23.75	70	140.0
32	Oct. 26	11:50 am	874797	1,151	24.33	70	59.6
33	Oct. 27	11:40 am	875445	648	23.84	70	34.2
34	Oct. 28	12:00 m	876087	642	24.33	75	33.3
35	Oct. 29	12:00 m	876797	710	24.00	75	37.2
36	Oct. 30	11:45 am	878181	1,384	23.75	75	73.5
37	Oct. 31	3:00 pm	879225	1,044	27.25	70	48.5
38	Nov. 1	1:15 pm	880336	1,111	22.25	70	63.0
39	Nov. 22	1:10 pm	881449	1,113	23.91	70	58.5
40	Nov. 3	11:30 am	882459	1,010	22.34	70	57.0
41	Nov. 4	11:30 am	[illegible]	870	24.00	70	45.5
42	Nov. 5	12:45 pm	884525	1,196	25.25	70	59.8
				-	-	70	-

No. of Graph	Date	Time	Meter Reading	Total Consumption	No. of Hours	Pressure	G[illegible]
			Liters	Liters	Hours	l/b in.^{2}	
1	2	3	4	5	6	7	8
	Nov. 6			3,301	47.25		88.0
				-	-	-	
	Nov. 7	12:00 m	887826				
43				624	23.25	75	33.8
	Nov. 8	11:15 am	888450				
44				899	24.25	75	46.[illegible]
	Nov. 9	11:30 am	889349				
45				3,265	25.25	70	163.0
	Nov. 10	12:45 pm	892614				
[illegible]				2,439	24.92	70	123.0
	Nov. 11	1:40 pm	895053				
[illegible]7				1,943	20.33	80	121.0
	Nov. 12	10:00 am	896996				
48				511	25.50	80	25.[illegible]
	Nov. 13	11:30 am	897507				
[illegible]				1,108	24.25	70	57.[illegible]
	Nov. 14	11:45 am	898615				
[illegible]				2,010	24.00	70	106.[illegible]
	Nov. 15	11:45 am	900625				
51				2,204	23.75	70	117.[illegible]
	Nov. 16	11:30 am	902829				
52				1,586	24.08	80	85.[illegible]
	Nov. 17	11:35 am	904415				
53				1,274	26.17	70	61.6
	Nov. 18	1:45 pm	905689				
54				579	-	70	-

No. of Graph	Date	Time	Meter Reading	Total Consumption	No. of Hours	Pressure	GPCPD
			Liters	Liters	Hours	1/b in^2	
1	2	3	4	5	6	7	8
	Nov. 19	–	906268		48.75		
55				1,075	–	70	–
	Nov. 20	2:30 pm	907343				
56				1,313	23.25	70	71.0
	Nov. 21	1:45 pm	908656				
57				1,155	24.75	70	59.0
	Nov. 22	2:30 pm	909811				
58				–	–	70	–
–	Nov. 23	–	–	336	46.75		9.1
				–	–	–	–
	Nov. 24	1:15 pm	910147				
59				3,386	25.25	75	169.0
	Nov. 25	2:30 pm	913533				
60				2,186	21.50	80	128.5
	Nov. 26	12:00 m	915719				
61				1,774	23.33	80	96.0
	Nov. 27	11:20 am	917493				
62				1,189	28.75	70	52.1
	Nov. 28	4:05 pm	918682				
63				961	23.92	80	50.4
	Nov. 29	4:00 pm	919633				
64				881	20.00	80	55.5
	Nov. 30	12:00 m	920514				
65				–	–	70	–
–	Dec. 1	–	–	2,233	46.75		60.2
				–	–	–	–
	Dec. 2	10:45 am	922747				
66				1,054	25.00	120	53.5
	Dec. 3	11:45 am	923801				
67				1,306	23.75	130	69.3
	Dec. 4	11:30 am	925107				
68				1,105	24.25	120	57.3
	Dec. 5	11:45 am	926212				
69				944	23.75	120	50.3
	Dec. 6	11:30 am	927156				
70				1,421	28.75	120	62.4
	Dec. 7	4:15 pm	928577				
71				2,141	19.00	130	141.0
	Dec. 8	11:15 am	930718				
72				1,849	25.25	110	92.0
	Dec. 9	12:30 pm	932567				
73				2,697	–	100	–
	Dec. 20	11:30 am	945264				
74				1,866	24.00	100	98.0

No. of Graph	Date	Hours	Meter Reading	Total Consumption	No. of Hours	Pressure	GPCPD
			Liters	Liters	Hours	l/b in.^{2}	
1	2	3	4	5	6	7	8
	Dec. 21	11:30 am	947130				
75				1,156	24.00	100	98.0
	Dec. 22	11:30 am	948286				
76				1,238	27.00	110	57.8
	Dec. 23	2:30 pm	949524				
77				1,940	22.25	110	110.0
	Dec. 24	12:45 pm	951464				
78				-	-	105	-
	Dec. 25	-	-				
-				570	47.25		15.2
	Dec. 26	12:00 m	952034				
79				694	-	105	-
	Dec. 27	-	952728		47.16		
80				773	-	110	
	Dec. 28	11:10 am	953501				
81				517	21.83	100	29.9
	Dec. 29	9:00 am	954018				
82				958	32.00	105	37.8
	Dec. 30	5:00 pm	954876				
83				943	18.50	110	64.4
	Dec. 31	11:30 am	955919				
84				1,673	24.00	110	87.0
	1968 Jan. 1	11:30 am	957592				
85				936	24.00	110	49.3
	Jan. 2	11:30 am	958528				
86				1,251	27.50	110	57.3
	Jan. 3	3:00 pm	959779				
87				1,679	20.67	-	102.0
	Jan. 4	11:40 am	961458				
88				1,057	26.33	110	51.0
	Jan. 5	2:00 pm	962515				
89				1,334	21.00	110	80.0
	Jan. 6	11:00 am	963849				
90				1,319	23.50	120	70.6
	Jan. 7	10:30 am	965168				
91				1,000	23.67	120	53.2
	Jan. 8	10:10 am	966168				
92				1,678	23.33	120	90.8
	Jan. 9	9:30 am	967846				
93				2,301	28.50	120	102.0
	Jan. 10	2:00 pm	970147				
94				3,579	21.75	120	206.0
	Jan. 11	11:45 am	973726				
95				3,245	22.25	130	184.0

No. of Graph	Date	Time	Meter Reading	Total Consumption	No. of Hours	Pressure	GPCPD
			Liters	Liters	Hours	l/b/in.^{2}	
1	2	3	4	5	6	7	8
96	Jan. 12	10:00 am	973726				
	Jan. 13	1:30 pm	978976	1,965	27.50	125	90.0
97	Mar.19	2:30 pm	018360				
98	Mar.20	3:30 pm	019414	1,045	25.00	70	52.6
99	Mar.21	4:40 pm	020219	805	25.17	70	40.4
-	Mar.22			-	-	-	-
				1,898	42.83	70	56.7
-	Mar.23	11:30 am	022117	-	-	-	-
-	Mar.24	-	-	-	-	-	-
-	Mar.25	-	-	2,496	77.33	-	40.7
100	Mar.26	4:50 pm	024613	-	-	-	-
101	Mar.27	3:15 pm	025827	1,214	22.42	70	68.5
102	Mar.28	3:15 pm	026613	786	24.00	70	41.3
103	Mar.29	5:50 pm	087821	1,208	26.68	70	57.0
104	Mar.30	5:35 pm	028921	1,100	23.75	70	58.4
-	Mar.31	-	-	-	-	80	-
				1,122	46.92		30.2
105	Apr. 1	4:30 pm	030043	-	-		-
106	Apr. 2	3:00 pm	032271	2,228	22.50	70	125.0
	Apr. 3	10:10 am	033579	1,308	19.16	70	86.0

No. of Graph	Date	Time	Meter Reading	Total Consumption	No. of Hours	Pressure	GPCPD
			Liters	Liters	Hours	l/b in.^{2}	
1	2	3	4	5	6	7	8
	Apr. 4	11:35 am	033811				
107				1,261	23.92	70	66.7
	Apr. 5	11:30 am	035072				
-				5,228	99.50	-	67.0
	Apr. 9	3:00 pm	040300				
108				1,337	24.16	70	69.7
	Apr. 10	3:10 pm	041637				
109				1,032	30.51	70	42.7
	Apr. 11	9:40 pm	04669				
110				1,803	17.66	70	129.0
	Apr. 12	3:20 pm	044472				
-				1,020	23.42	-	55.0
	Apr. 13	2:45 pm	045492				
111				479	23.08	75	26.2
	Apr. 14	1:50 pm	045971				
112				1,516	26.75	70	71.5
	Apr. 15	4:35 pm	047487				
113				726	19.25	70	47.5
	Apr. 16	11:50 am	048213				
114				2,469	30.17	70	103.0
	Apr. 17	6:00 pm	050682				
115				290	21.50	70	17.0
	Apr. 18	3:30 pm	050972				
116				699	19.00	70	46.3
	Apr. 19	10:30 am	051671				

APPENDIX # 3

TABLE I - RESUME OF DATA OBTAINED AND CALCULATIONS REALIZED

House Address : 51 José de Diego Street, Peral corner

No. of residents : 2

No. of Graph	Date	Time	Meter Reading	Total Consumption	No. of Hours	Pressure	GPCPD
			Liters	Liters	Hours	l/b in.^{2}	
1	2	3	4	5	6	7	8
	1967 Dec. 28	2:10 pm	068260				
1				-	-	60	-
	Dec. 29	-	-	1,092	51.00		
-				-	-	-	-
	Dec. 30	5:10 pm	069352				
2				367	18.32	60	63.5
	Dec. 31	11:30 am	069719				
3				770	23.75	60	103.0
	1968 Jan. 1	11:15 am	074890				
4				-	-	60	-
	Jan 2	-	-	1,998	48.25		131.0
-				-	-	-	-
	Jan 3	11:30 am	072487				
5				736	24.00	55	97.5
	Jan 4	11;30 am	073223				
6				642	26.00	60	78.2
	Jan 5	1:30 pm	073865				
7				3,597	265.50	-	43.0
	Jan 16	3:00 pm	077462				
8				1,107	24.00	65	146.0
	Jan 17	3:00 pm	078569				
9				795	24.16	65	104.0
	Jan 18	3:10 pm	079364				
10				553	19.00	70	92.3

No. of the Graph	Date	Hour	Reading Water-Meter Liters	Total Consumption Liters	Time Hours	Pressure lb/in.^{2}	GPCPD
1	2	3	4	5	6	7	8
11	Jan. 19	10:10 am	079917				
12	Jan. 24	11:00 am	083541	3,624	120.84	-	95.5
13	Jan. 25	9:30 am	084199	658	22.50	70	92.5
14	Jan. 26	9:45 am	084757	558	24.25	65	73.0
15	Jan. 27	11:30 am	085574	817	25.75	65	101.0
16	Jan. 28	10:50 am	086026	452	23.33	70	61.5
	Jan. 29	10:00 am		-	-	70	-
				1,432	47.17		96.0
17	Jan. 30	10:00 am	087458	-	-	-	-
18	Jan. 31	11:24 am	088543	1,085	25.40	65	135.0
19	Feb. 1	2:45 pm	090198	1,655	27.35	60	192.0
20	Feb. 2	2:15 pm	091564	1,366	23.50	60	184.0
21	Feb. 3	12:00 m	092396	832	21.75	60	121.5
22	Feb. 4	11:40 am	093143	747	23.67	65	100.0
23	Feb. 5	11:10 am	094090	947	23.35	65	128.0
24	Feb. 6	11:12 am	095997	1,907	24.18	65	250.0
25	Feb. 7	11:30 am	096858	861	24.30	60	112.5
	Feb. 8	10:30 am	-	-	-	60	-
26	Feb. 9	10:15 am	097694		23.75		
27	Feb. 10	11:40 am	098317	623	25.42	60	77.5
28	Feb. 11	3:15 pm	099224	907	27.58	65	104.0
	Feb. 12	3:30 pm	100289	1,065	24.25	60	139.0
29	Feb. 13	-	-	1,047	42.67	60	77.5
	Feb. 14	10:10 am	101336	-	-	-	-
				-	-	-	-

No. of the Graph	Date	Hour	Reading Water Meter Liters	Total Consumption Liters	Time Hours	Pressure lb/in.²	GPCPD
1	2	3	4	5	6	7	8
30	Feb. 15	-	-	1,337	48.17	60	88.0
	Feb. 16	10:20 am	102673	-	-	-	
31				671	25.67	60	82.7
	Feb. 17	12:00 am	103344				
32				923	25.25	65	115.0
	Feb. 18	1:30 pm	104267				
33				928	25.75	60	114.0
	Feb. 19	3:15 pm	105195				
34				492	22.75	65	68.7
	Feb. 20	2:00 pm	105687				
35				1,010	27.17	60	118.0
	Feb. 21	5:10 pm	106697				
36				-	-	65	-
	Feb. 22	-	-				
-	Feb. 23	11:30 am	108871	-	-	-	-
37				528	22.25	65	75.2
	Feb. 24	9:45 am	109399				
-				-	-	-	-
38	Feb. 25	-	-	1,400	55.25	65	80.2
-				-	-	-	
	Feb. 26	5:00 pm	110799				
39				1,055	24.50	65	137.0
	Feb. 27	5:30 pm	111854				
40				631	24.00	60	83.6
	Feb. 28	5:30 pm	112486				
41				679	23.08	65	93.0
	Feb. 20	4:35 pm	113164				
42				1,341	22.59	65	188.0
	Mar. 1	3:10 pm	114505				
43				352	25.50	65	43.8
	Mar. 2	4:40 pm	114857				
44				397	21.00	65	60.0
	Mar. 3	1:40 pm	115254				
45				1,112	27.00	60	130.1
	Mar. 4	4:40 pm	116366				
46				761	24.00	60	100.1
	Mar. 5	4:40 pm	117127				
47				647	25.00	60	82.2
	Mar. 6	5:40 pm	117774				
48				630	21.33	60	93.5
	Mar. 7	3:00 pm	118404				
49				1,172	29.25	60	126.5

No. of the Graph	Date	Hour	Reading Water Meter Liters	Total Consumption Liters	Time Hours	Pressure lb/in.^{2}	GPCPD
1	2	3	4	5	6	7	8
	Mar. 8	8:15 pm	119576				
-					258.00	-	-
	Mar. 19	2:15 pm	137532				
50				611	27.33	65	71.0
	Mar. 20	5:35 pm	138143				
51				1,481	23.17	65	203.0
	Mar. 21	4:45 pm	139624				
52				807	18.75	65	136.5
	Mar. 22	11:30 am	140431				
-				-	-	-	-
	Mar. 23	-	-	-			
-				-	-	-	-
	Mar. 24	-	-	2,998	101.16		93.5
-				-	-	-	-
	Mar.25	-	-	-			
-				-	-	-	-
	Mar. 26	4:40 pm	143429				
53				698	24.52	60	90.0
	Mar. 27	5:10 pm	144127				
54				805	24.00	60	106.3
	Mar. 28	5:10 pm	144932				
55				899	24.57	60	116.0
	Mar. 29	5:45 pm	145831				
56				686	23.75	60	91.5
	Mar. 30	5:30 pm	146517				
57				-	-	-	-
	Mar. 31	-	-	1,615	47.16	65	109.0
				-	-	-	-
58	Apr. 1	4:40 pm	148132				
				685	23.92	65	91.0
	Apr. 2	4:35 pm	148817				
59				1,122	29.42	60	121.0
	Apr. 3	10:00 pm	149939				

No. of the Graph	Date	Hour	Reading Water-Meter Liters	Total Consumption Liters	Time Hours	Pressure lb/in. 2	GPCPD
1	2	3	4	5	6	7	8
	Apr. 4	11:30 am	150343				
60				1,094	23.00	55	150.1
	Apr. 5	10:30 am	151437				
-				3,203	48.00	-	-
	Apr. 7	10:30 am	154639				
61				1,398	25.00	70	177.0
	Apr. 8	11:30 am	156037				
62				1,036	28.00	60	117.0
	Apr. 9	3:30 pm	157073				
-				-	-	-	-
	Apr. 10	-	157073				
63				488	41.50	70	
	Apr. 11	9:00 am	157561				
64				1,593	30.25	65	166.0
	Apr. 12	3:15 pm	159154				
65				519	23.25	65	70.8
	Apr. 13	2:30 pm	159673				
66				824	23.25	65	112.0
	Apr. 14	1:45 pm	160497				
67				1,074	27.00	65	126.0
	Apr. 15	4:45 pm	161571				
68				540	18.92	55	90.7
	Apr. 16	11:40 am	162111				
69				1,086	29.83	55	115.0
	Apr. 17	5:30 pm	163197				
70				877	21.50	55	129.0
	Apr. 18	3:00 pm	164074				

No. of the Graph	Date	Hour	Reading Water-Meter Liters	Total Consumption Liters	Time Hours	Pressure lb/in. 2	GPCP
1	2	3	4	5	6	7	8
	Apr. 29	3:00 pm	171656				
71				688	25.67	70	85.0
	Apr. 30	4:40 pm	172344				
72				1,198	25.08	70	151.0
	May. 1	5:45 pm	173542				
73				170	24. 25	65	22.1
	May. 2	6:00 pm	173712				
-				-	-	-	-
	May 3	-	-				
74				-	-	50	-
	May. 4	9:30 am	174755				
75				1,032	27.50	50	
	May. 5	1:00 pm	175787				
	May. 25	9:30 am	192500				
76				678	24.50	70	87.6
	May. 26	10:00 am	193178				
77				592	23.50	75	80.0
	May 27	9:30 am	193770				
				-	-	-	-
	May 27	9:00 am	193708				
78				873	25.00	90	111.0
	May 28	10:00 am	194581				
79				997	25.50	80	124.0
	May 29	11:30 am	195578				
80				404	21.50	75	59.6
	May 30	9:00 am	195982				
81				1,330	28.50	80	148.0
	May 31	1:30 pm	197313				
82				441	19.75	80	70.8
	Jun . 1	9:15 am	197753				

No. of Graph	Date	Time	Meter Reading	Total Consumption	No. of Hours	Pressure	GPCPD
			Liters	Liters	Hours	$l/b\ in^2$	
1	2	3	4	5	6	7	8
83				944	23.25	85	128.0
	Jun. 2	8:30 am	198697				
	Jun. 6	11:00 am	201632				
84				859	24.00	85	113.5
	Jun. 7	11:00 am	202491				
85				827	26.50	85	99.0
	Jun. 8	1:30 pm	203318				
86				957	19.50	85	156.5
	Jun. 9	9:00 am	204275				
87				864	30.75	85	89.2
	Jun. 10	3:45 pm	205139				
88				643	24.25	85	84.0
	Jun. 11	4:00 pm	205782				
89				489	24.00	85	64.5
	Jun. 12	4:00 pm	206271				
90				1,011	24.25	85	132.00
	Jun. 13	4:15 pm	207282				

APPENDIX No. 4- DAILY CONSUMPTION PER PERSON AT DIFFERENT PRESSURES

Table No. 2

Home Address: Padre Aguilera St. No. 119, Buena Vista

No. of the Graph	Pressures: lb/in.^{2}									
	55	60	65	70	75	80	85	90	100	110
	Daily Consumption Per Person: GPCPD									
1	2	3	4	5	6	7	8	9	10	11
1			10.3							
2			26.0							
3			19.0							
4			21.8							
5				21.4						
6				25.7						
7			20.8							
8			22.2							
9			21.5							
10			22.4							
11			27.4							
12			19.3							
13			25.7							
14			17.4							
15			10.8							
16			39.4							
17										
18				14.2						
19				17.8						
20				18.2						
21			27.4							

No. of the Graph	Pressure: lb/in.^{2}									
	55	60	65	70	75	80	85	90	100	
	Daily Consumption Per Person: GPCPD									
1	2	3	4	5	6	7	8	9	10	11
22				63.0						
23				11.0						
24										
25				26.5						
26					22.7					
27				21.4						
28				27.6						
29				16.1						
30				23.0						
31										
32										
33			24.9							
34			23.4							
35			68.0							
36										
37										
38		21.6								
39		18.0								
40		9.6								
41		18.8								
42		25.0								
43	18.0									
44	44.2									
45										
46		33.4								
47										
48		22.2								
49		40.4								
50		8.3								
51	17.8									

No. of the Graph	Pressure: lb/in.^{2}									
	55	60	65	70	75	80	85	90	100	
	Daily Consumption Per Person: GPCPD									
1	2	3	4	5	6	7	8	9	10	11
52			17.0							
53			40.00							
54										
55		25.6								
56		28.0								
57	67.3									
58	17.3									
59		4.6								
60										
61	13.4									
62	27.2									
63	21.4									
64	47.0									
65	56.3									
66										
67										
68										
69	14.2									
70		23.9								
71										
72										
73	13.3									
74	22.1									
75	22.2									
76										
77										
78	18.3									
79		20.0								
80		19.6								
81	45.0									

No. of the Graph	Pressure : lb/in.^{2}									
	50	55	60	65	70	80	100	105	110	120
	Daily Consumption Per Person: GPCPD									
1	2	3	4	5	6	7	8	9	10	11
82			6.2							
83			20.6							
84				18.4						
85			24.4							
86		19.2								
87		17.7								
88	12.4									
89			17.5							
90			35.0							
91										
92			22.5							
93 a								14.2		
93 b								18.7		
93 c								19.3		
93 d										
93 e										18.2
93 f										
93 g										15.0
93 h										
93 i										
93 j									27.2	
93 k									18.2	
93-l									71.5	
93 m										
93 n										
94						34.9				
95										
96										
97						26.9				
98						14.2				

No. of the Graph	Pressure: lb/in.^{2}									
	55	60	65	70	75	80	85	100	110	120
	Daily Consumption Per Person: GPCPD									
1	2	3	4	5	6	7	8	9	10	11
99						19.8				
100		22.4								
101				19.2						
102				20.0						
103				36.2						
104										

APPENDIX No. 4.- DAILY CONSUMPTION PER PERSON AT DIFFERENT PRESSURES

Table No. 2

Home Address: Bosque St. No. 59, Ensanche Martínez										
No. of the Graph	Pressures: lb/in.²									
	65	70	75	80	100	110	120	125	130	135
	Daily Consumption Per Person GPCPD									
1	2	3	4	5	6	7	8	9	10	11
1										
2										
3										
4										
5										
6										
7	140.0									
8	55.0									
9		55.0								
10				88.0						
11		55.3								
12										
13		106								
14										
15		76.6								
16			51.0							
17										
18				95.0						
20										

No. of the Graph	Pressures: lb/in.^{2}									
	65	70	75	80	100	110	120	125	130	135
	Daily Consumption Per Person: GPCPD									
1	2	3	4	5	6	7	8	9	10	11
21		80.0								
22			52.0							
23										
24		129.0								
25		50.2								
26		109.0								
27		95.6								
28				53.5						
29										
30		140.0								
31		59.6								
32		34.2								
33			33.3							
34			37.2							
35			73.5							
36		48.5								
37		63.0								
38		58.5								
39		57.0								
40		45.3								
41		59.8								
42										
43			33.8							
44			46.7							
45		163.0								
46		123.0								
47				121.0						
48				25.3						
49			57.5							

No. of the Graph	Pressures: lb/in.^{2}									
	65	70	75	80	100	110	120	125	130	135
	Daily Consumption Per Person: GPCPD									
1	2	3	4	5	6	7	8	9	10	11
50			106.0							
51			117.0							
52				83.0						
53			61.5							
54										
55										
56		71.0								
57		59.0								
58										
59			169.0							
60				128.5						
61				96.0						
62		52.1								
63				50.4						
64				55.5						
65										
66							53.5			
67									69.3	
68							57.3			
69							50.3			
70							62.4		141.0	
71									141.0	
72						92.0				
73										
74					98.0					
75					60.8					
76						57.8				
77						110.0				
78										
79										

No. of The Graph	Pressures: lb/in.^{2}								
	70	75	80	100	105	110	120	125	130
	Daily Consumption Per Person : GPCPD								
1	2	3	4	5	6	7	8	9	10
80									
81				29.9					
82					37.8				
83						64.4			
84						87.0			
85						49.3			
86						57.3			
87									
88						51.0			
89						80.0			
90							70.6		
91							53.2		
92							90.8		
93							102.0		
94							206.0		
95									184.0
96								90.0	
97	52.6								
98	40.4								
99	56.7								
100	68.5								
101	41.3								
102	57.0								
103	58.4								
104									
105	125.0								
106	86.0								

No. of the Graph	Pressures: lb./in.^{2}							
	65	70	75	80	100	110	120	130
	Daily Consumption Per Person: GPCPD							
1	2	3	4	5	6	7	8	9
107		66.5						
108		69.7						
109		42.7						
110		129.0						
111			26.2					
112		71.5						
113		47.5						
114		103.0						
115		17.0						
116		46.3						
117		53.0						
118		60.0						
119		34.6						
120		37.2						
121		43.3						
122		101.0						

APPENDIX No. 4.- DAILY CONSUMPTION PER PERSON AT DIFFERENT PRESSURES

Table No. 2

Home Address: José de Diego St. No. 51

No. of the Graph	Pressures: lb/in.^{2}							
	55	60	65	70	80	100	110	120
	Daily Consumption Per Person: GPCPD							
1	2	3	4	5	6	7	8	9
1								
2		63.5						
3		103.5						
4								
5	97.5							
6		78 .2						
7								
8			146.0					
9			104.0					
10				92.3				
11								
12				92.5				
13			73.0					
14			101 .0					
15				61.5				
16				96.0				
17			135.5					
18		197.0						
19		184.0						
20		121.2						

No. of the Graph	Pressures: lb/in.^{2}							
	55	60	65	70	80	100	110	120
	Daily Consumption Per Person: GPCPD							
1	2	3	4	5	6	7	8	9
21			100.0					
22			128.0					
23			250.0					
24		112.5						
25								
26		77.5						
27			104.0					
28		139.0						
29		77.5						
30		88.0						
31		82.7						
32			115.0					
33		114.0						
34			68.7					
35		118.0						
36								
37			75.2					
38			80.2					
39			137.0					
40		83.6						
41			93.0					
42			183.0					
43			43.8					
44			60.0					
45		130.1						
46		100.1						
47		82.2						
48		93.5						
49		126.5						
50			71.0					

No. of the Graph	Pressures: lb/in.^{2}							
	55	60	65	70	80	100	110	120
	Daily Consumption Per Person: GPCPD							
1	2	3	4	5	6	7	8	9
51			203.0					
52			136.5					
53		90.0						
54		106.3						
55		116.0						
56		91.5						
57			109.0					
58								
59								
60	150.1							
61				171.0				
62		117.0						
63								
64			166.0					
65			70.8					
66			112.0					
67			126.0					
68	90.7							
69	115.0							
70	129.0							

No. of the Graph	Pressures: lb/in.^{2}							
	65	70	75	80	85	90	100	110
	Daily Consumption Per Person: GPCPD							
1	2	3	4	5	6	7	8	9
71		85.5						
72		151.0						
73	22.1							
74								
75								
76		87.6						
77			80.0					
78						111.0		
79				124.0				
80			59.6					
81				148.0				
82				70.8				
83					128.0			
84					113.5			
85					99.0			
86					156.5			
87					89.2			
88					84.0			
89					64.5			
90					132.0			

APPENDIX IV

EFFECT OF VOLUME WITHDRAWN FROM A DISTRIBUTION PIPE ON THE PRESSURE AT THE POINT OF WITHDRAWAL

A and B (Fig. 3) are two supply mains of a water distribution system, and a distribution main connects them. There is a closed outlet at point (e) of the distribution main. Let

Q = discharge flowing through the distribution main when the outlet is closed

L = Length of the distribution main

D = diameter of the distribution main

L_1 = Length of the distribution main between supply main B and point of the outlet

L_2 = Length of the distribution main between supply main A and the point of the outlet

H = Loss of pressure between supply main A. and B

Q_1 = discharge flowing between main B and point of the outlet at the time of withdrawal

Q_2 = discharge flowing between main A and point of the outlet at the time of withdrawal

q = discharge withdrawn at point of the outlet

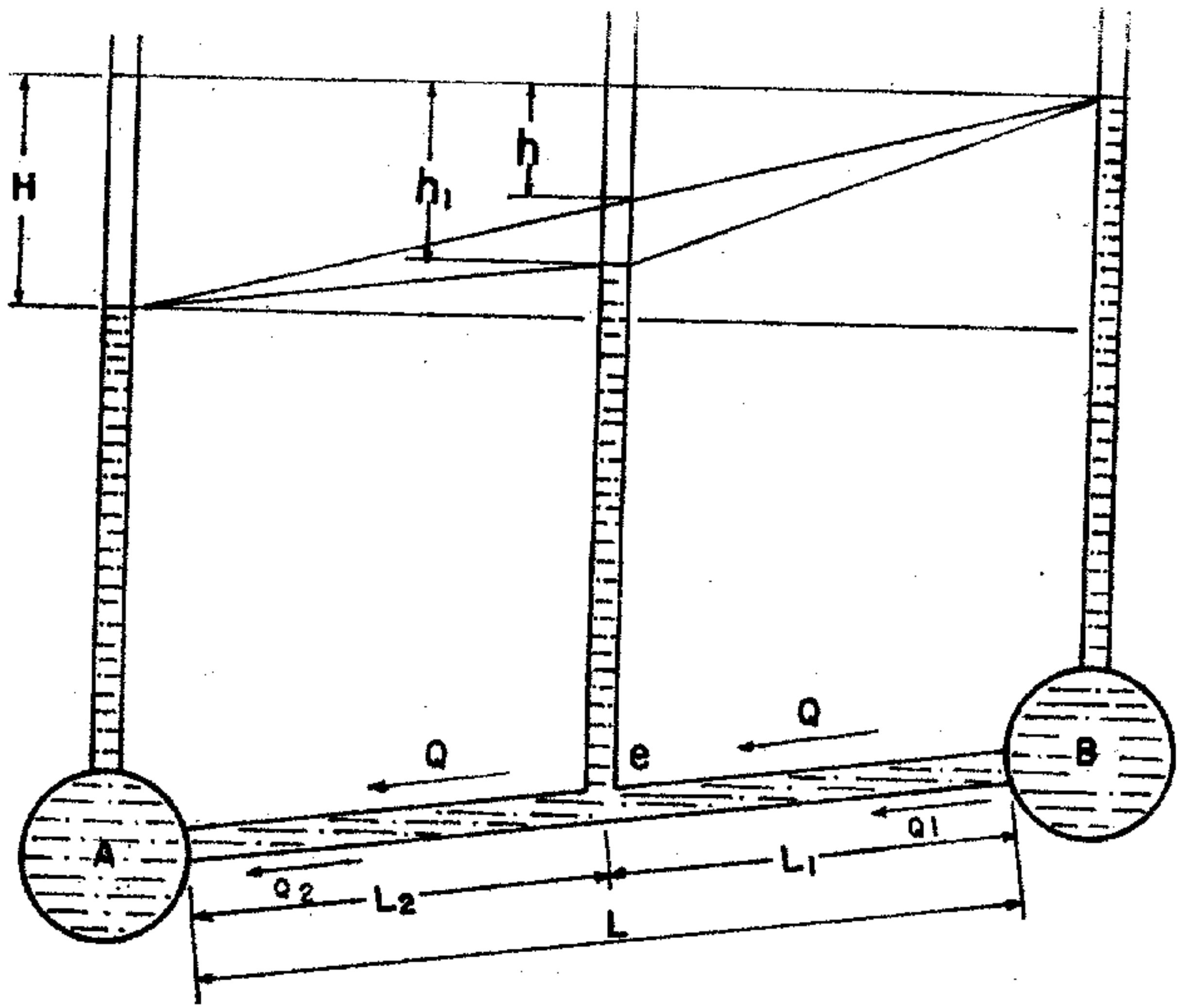

FIG. 3 - EFFECT OF THE VOLUME WITHDRAWN ON PRESSURE AT THE POINT OF WITHDRAWL.

When the volume withdrawn is zero, that is, when the outlet is closed, we have

$$H = K \frac{L}{d^5} Q^2$$

When q volume is withdrawn, that is, when the outlet is open

$$H = K \frac{L_1}{d^5} Q_1^2 + K \frac{L_2}{d^5} Q_2^2$$

pressures in mains A. and B remain constant.

From the two foregoing equations, we get

$$K \frac{L}{d^5} Q^2 = K \frac{L_1}{d^5} + K \frac{L_2}{d^5} Q_2^2$$

simplifying we get

$$L Q^2 = L_1 Q_1^2 + L_2 Q_2^2$$

but:

$L = L_1 + L_2$, therefore

$$L_1 Q^2 + L_2 Q^2 = L_1 Q_1^2 + L_2 Q_2^2$$

from which

$$L_1 (Q_1^2 - Q^2) = L_2 (Q^2 - Q_2^2) \qquad \text{Formula (A4-1)}$$

However, if we let $L_1 / L_2 = r$ and we know that $Q_2 = Q_1 - q$, we get

$$r (Q_1^2 - Q^2) = Q^2 - (Q_1 - q)^2$$

Carrying out operations and ordering with respect to Q_1, we get the equation

$$Q_1^2 - \frac{2q}{1+r} Q_1 - (Q^2 - \frac{q^2}{1+r}) = 0$$

The roots of this equation are:

$$Q_1 = \frac{q}{1+r} \pm \sqrt{Q^2 - \frac{r}{(1+r)^2} q^2}$$

If we now substitute the value of $Q_1 = Q_2 + q$ in the equation A4-1, we get

$$r\ (Q_2 + q)^2 - Q^2 = Q^2 - Q_2^2$$

Carrying out operations and ordering with respect to Q_2, we get

$$Q_2^2 + \frac{2\ q\ r}{1 + r}\ Q_2 - \left(Q^2 - \frac{r}{1 + r}\ q^2\right) = 0$$

The roots of this equation are:

$$Q_2 = - \frac{q\ r}{1 + r} \pm \sqrt{Q^2 - \frac{r}{(1 + r)^2}\ q^2}$$

Since Q_2 cannot be negative, its value will be

$$Q_2 = - \frac{q\ r}{1 + r} + \sqrt{Q^2 - \frac{r}{(1+r)^2}\ q^2}$$

Of the two values for Q_1, we take only

$$Q_1 = \frac{q}{1 + r} + \sqrt{Q^2 - \frac{r}{(\ 1 + r\ )^2}\ q^2}$$

Recall that it is necessary to have

$$Q_1 - Q_2 = q$$

In effect:

$$Q_1 - Q_2 = \frac{q}{1 + r} + \frac{q\ r}{1 + r}$$

$$Q_1 - Q_2 = q$$

If in the formulas that give the final values taken for Q_1 and Q_2, we suppose that the volume withdrawn is null, ie., $q = 0$, we will have:

$$Q_1 = Q = Q_2$$

which is correct

The following conclusion may be drawn from the foregoing. When a given volume, q, is withdrawn from a point on a distribution main, the volume flowing in the main above the point of withdrawal, Q_1, increases with respect the original volume, Q, in the main. Volume flowing below the point of withdrawal, Q_2, decreases with respect to the original, volume, Q. That is

$$Q_1 > Q$$
$$Q_2 < Q$$

Therefore, the hydraulic slope of the water above the point of withdrawal is greater than the hydraulic slope below the point of withdrawal. The first slope has a greater inclination than the original one; the second has less inclination than the original slope. See Fig. 3.

If h is the fall in the original slope in the section of withdrawal, we have according to the Weisbach-Darcy formula that:

$$h = K \frac{L_1}{d^5} Q^2$$

If h_1 is the fall in the slope above the section of withdrawal, when it is effected, we have, according to the Weisbach-Darcy formula:

$$h_1 = K \frac{L_1}{d^5} Q_1^2$$

The difference between pressure heads in the section of withdrawal will be:

$$\Delta h = h_1 - h$$

$$h = K \frac{L_1}{d^5} (Q_1^2 - Q^2)$$

That is, there is a difference in pressure in the section of withdrawal between the pressure prevailing before the withdrawal and that prevailing after the withdrawal However, if the volume withdrawn is small relative to the original volume in the distribution main, then the fall in pressure caused by the withdrawal is negligible.

Suppose a 4 inch distribution main 1000 feet long, through which an originally a volume of 196 gpm is flowing, and at a given point 9 gpm is withdrawn (situation at 119 Padre Aguilera St., the most unfavorable of the three selected cases in this study).

Applying the foregoing procedure to three separate points on the section of the withdrawal:

1. 10 feet from the inlet of the distribution main
2. 500 feet from the inlet of the distribution main
3. 990 feet from the inlet of the distribution main

The following table summarizes the results obtained in the three cases:

Table: Effect of Volume Withdrawn on Pressure in the Section of Withdrawal

Withdrawal	r	$\frac{1}{1+r}$	$\frac{1}{(1+r)^2}$	$\frac{r}{(1+r)^2}$	$0.0021 \frac{r}{(1+r)^2}$	Q_1
1	2	3	4	5	6	7
						gpm
10 ft.	0.0101	0.99	0.98	0.0099	0.00021	204.9
500 ft.	1.00	0.50		0.25	0.00053	200.5
990 ft.	99	0.01	0.0001	0.0099	0.00021	196.1

Withdrawal 10 ft. from inlet = 0.015 lbs/in.^{2}

Withdrawal 500 ft. from inlet = 0.0065 lbs/in.^{2}

Withdrawal 990 ft. from inlet = 0.0000 lbs/in.^{2}

The difference in pressure of .0015 lbs/in.^{2} is negligible confirming what has been already established. The other differences in pressure are even smaller.

Therefore, pressure prevailing in the distribution main before and after the withdrawal, is effectively the same.

Pressure in the distribution main is that registered by the meter-master when no withdrawal takes place.