

WATER LEAKAGE AND DETECTION IN MUNICIPAL WATER DISTRIBUTION NETWORKS

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Abstract

A methodology to estimate, to determine and to locate water losses from water distribution networks is presented. Various techniques are used to reduce the losses by employing limited manpower and simple instruments. Alternatives requiring sophisticated equipments are also introduced. Related case studies from Ankara Municipal Water Distribution Network are presented.

Keywords

Water distribution networks; Water leakage; Leakage Reduction Techniques; SCADA

1 Introduction

A water distribution system should supply necessary amount of potable water at demand points, for domestic, commercial, industrial, and fire fighting purposes; the system should be capable of meeting the demands almost any time at required pressures. However, sometimes considerable water leakages from the system may cause problems related to the pressures at

the consumers tap and significant water losses. Leakages might occur from the main feeder, distribution pipes, service pipes, or storage tank; the sizes of the leakages might change from small cracks to large breaks.

Excessive water losses can limit forming of further extensions of a water distribution network unless new sources are found and new transmission lines are constructed. Most important form of water losses is leakage. Leakage rates may change from very small values of 5-10% to values higher than 50%. In Turkey, leakage values are reported by the water utilities, in the big cities around 35%. The reasons of leaks are related to various factors such as the age of the network, the quality of the maintenance work, pipe material used, soil type, types of hydraulic operations, and high pressures.

2 Reduction of Water Leakages

There are various methods to reduce leakages in water distribution networks to a feasible rate (Smith et al., 2000); they are classified roughly in two groups: (1) direct methods, (2) indirect methods. Direct methods include all techniques which locate the leakage for an immediate repair. On the other hand, indirect methods comprise all the efforts to form a constant and homogeneous pressure field over the related pressure zone; indirect methods do not permit pressures above required pressures by adjusting pressure regulating valves and/or isolation valves of the network. Avoiding of excessive pressures will not allow formation of extreme leakages.

This study deals with direct methods. Application of direct methods especially in metropolitan areas is difficult because the determination of the weakest portions of the system in order to start to work is a tedious job. Most of the time, this kind of studies are conducted in areas where there is no excessive leakage. However, there are mainly two alternatives as a remedy. First possibility is to compare the supplied water and consumed water in the system. SCADA measurements and/or field measurements taken during night will indicate jerry-built networks. Second possibility is to compare the supplied water and the billings of the water utility.

If there are leaks from the system, the engineer should start his work from the weakest part. Basically, there are two kinds of leak detection methods: (i) Water Audit, (ii) Hydrostatic Testing.

In this study, Water Audit is employed. Water Audit follows the continuity principle. It can be applied to systems of various sizes such as pressure zone alone or even consumers of a bloc. If Water audit is applied to a system for the whole day, the daily demand curve of the system can be obtained. Order of the leakage can be estimated from night period of the daily demand curve. In order to conduct a water audit study, a flowmeter is required. However, the leak detection necessitates the exact location of the leak. One possible practice is listening for leaks. There are roughly two ways for water to leak from the pipe: first one is flowing out under orifice conditions, causing vibrations in the 500-800 Hz, the second one is striking the ground after escaping from the pipe, causing vibrations in the 20-250 Hz (Walski, 1985). It can be determined using different instrumentation. An acoustic leak detector as well as a more developed instrument, a correlation device is used for this purpose.

3 Case Study

3.1 Study Area

A case study has been conducted to determine the weakest pressure zone at which most of the leakage occurs; the study area is N8.1 zone of the water distribution network of the city of Ankara. N8.1 zone supplies water approximately to 25 000 people with lower incomes; this zone consists of one pumping station, one storage tank, 465 links, 373 junction nodes. SCADA (Supervisory Control and Data Acquisition System) and CIS (Customer Information System) of the water utility of Ankara (ASKI) provided the raw data for obtaining daily demand curves of various pressure zones and subzones of N8.1 pressure zone. Studies have indicated that losses around 100-200 m³/hr occur in various pressure zones of the North line. After having determined N8.1 as one of the weakest zones (considering leakage per customer), systematic valving operations have been conducted to locate areally the weakest subzone in N8.1. Finally, a list of weak subzones was presented to the water utility to carry on studies for locating exactly the leaks using electronic leak detectors.

Successful demonstrations had already been conducted for this purpose concerning mainly the determination of the point leaks.

3.2 SCADA

ASKI (Ankara Water Utility) / SCADA (Supervisory Control and Data Acquisition) is responsible for collecting, transmitting and storing data from various control points of the network (mainly pump stations and storage tanks) and then making decisions regarding the operations based on these data. SCADA program provides remote operation and control of pumps and control valves; 37 pump stations, 73 storage tanks and 15 further measuring stations making in total 124 stations are monitored and controlled on screens, including data in digital format.

3.3 Field Measurements

The aim of the field measurements is essentially to determine the areal locations of the water leakages of the study area (N8.1). The field program basically consisted of various valve operations at the field in order to investigate the study area as a whole (Figure 1) and in six different subzones. The purpose of the valve operations is the isolation of the related subzone in connection with the pump station (P23) and the storage tank (T53). This configuration allows acquiring the demand curve of the related zone (or the whole study area) using standard data recorded by the SCADA system employing the continuity equation.

Daily Demand Curves

Daily demand curves were derived using the continuity equation (Equation 1):

$$I - Q = dS / dt \quad (1)$$

where,

I = the average flowrate entering to the system for a period of dt, m³/hr

Q = the average flowrate going out from the system for a period of dt, m³/hr

dS= the storage in the tank T53 during the period dt, m³

The inputs to the system are the flowrate supplied by the pump, P23, and the outputs from the system can be accepted as the water consumed by the consumers and leakage from the network. Three daily demand curves for the whole system are presented for illustrative purposes on Figure 2, 3, and 4.

Leakage determination at the Areal Basis

Before applying any point leak detection method (for example, acoustic leak detection), it is necessary to estimate the amount of water leaking from the defined system and to determine the weakest part of the network. The leakage can be estimated from night period of daily demand curves; the period between 0:00 and 5:00 was used for this purpose. It was believed that the night consumption at these hours would be minimum since there aren't any industrial or manufacturing facilities; therefore, the estimated value would be very close to the water leaking from that section of the network. The demand values at night hours, between 0:00 and 5:00 were averaged and leakages from the whole system and every subzone (six subzones in total) were obtained this way. Note that the continuity equation was applied to each subzone for obtaining their daily demand curves under appropriate valving operations; in other words, in order to accomplish this task related isolation valves are closed so that the rest of the network is isolated from the the subzone considered except the storage tank and the pumping station. After having evaluated the data, leakages from individual zones are estimated. The total leakage is around 60 m³/hr (Table 1). First column of of Table 1 presents percentage of leakages and second column shows the distribution of average leakage estimated for whole N8.1 pressure zone to subzones.

According to the results, Şehit Kubilay district was indicated as the weakest portion of the N8.1 pressure zone including 25.75% of the total leakage and East of Çiğdemtepe district with 3.76% of leakage was in the best condition among other suzones. Therefore, the priority for conducting further study regarding water leakages should be given to Şehit Kubilay, then to South of Sancaktepe, West of Çiğdemtepe and North of Sancaktepe districts respectively. All these informations were transmitted to the water utility (ASKİ) for conducting further study to determine point leaks.

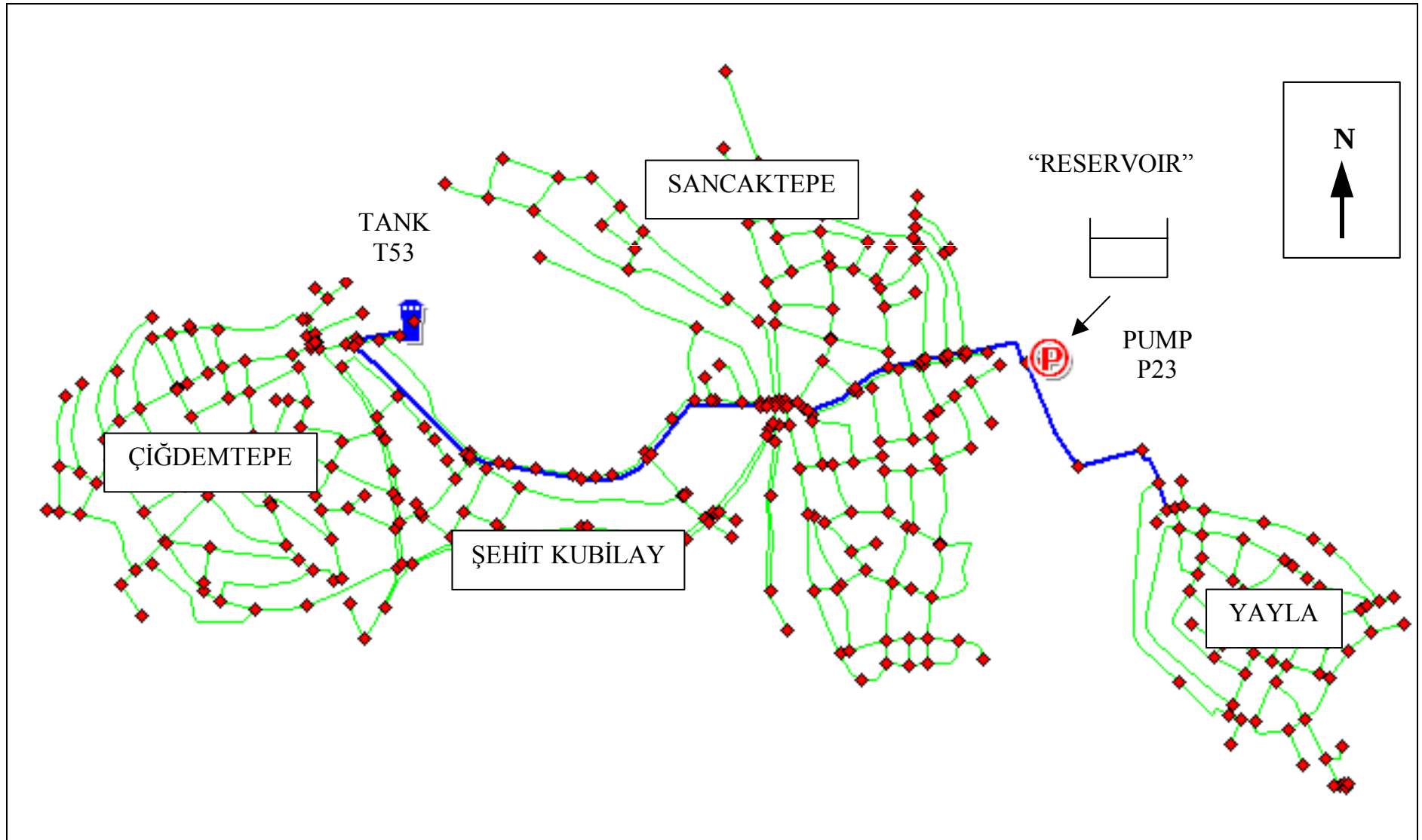


Figure 1. Water distribution network of N8.1 pressure zone

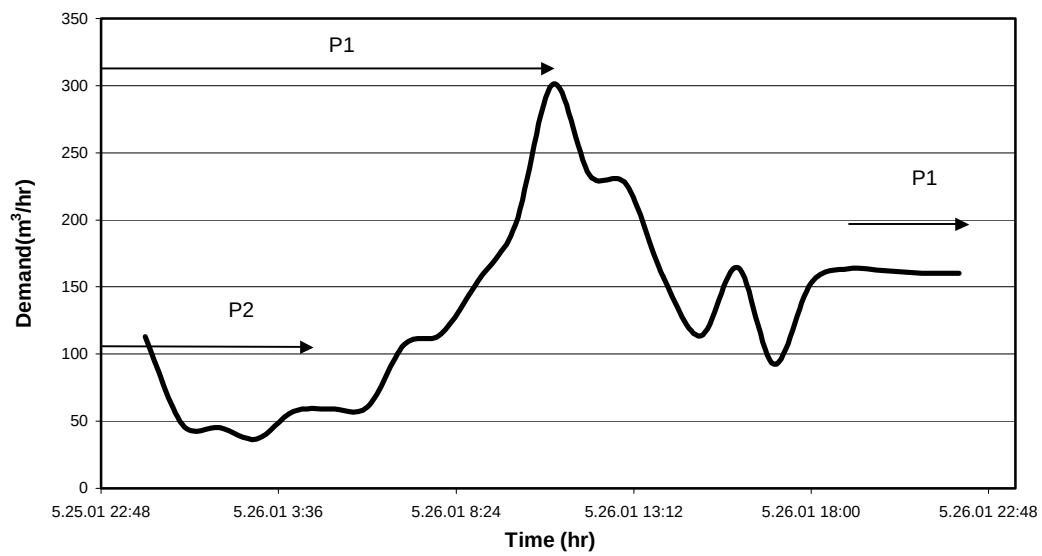


Figure 2. Daily demand curve for 26.5.2001

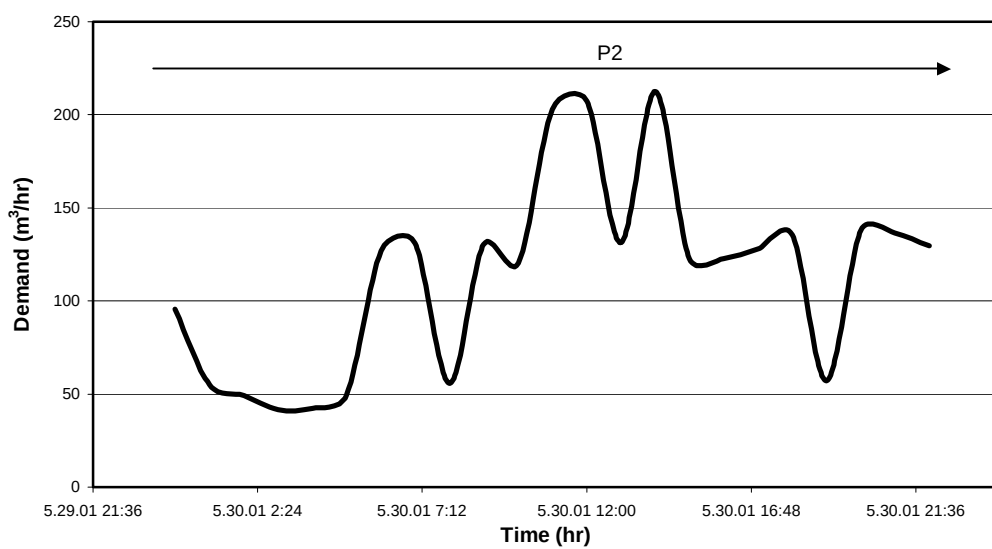


Figure 3. Daily demand curve for 30.5.2001

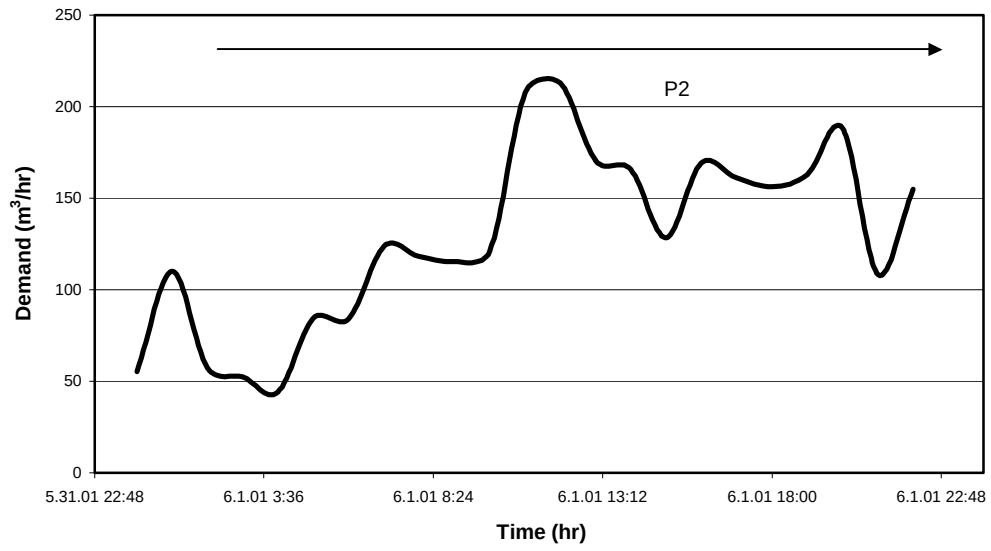


Figure 4. Daily demand curve for 01.06.2001

Table 1. Water Leakages of the Pressure Zone N8.1

ZONE	Percentage Leakage (%)	Leakage (m³/hr)
Main-Line	5.43	3.25
Yayla	8.11	4.86
South of Sancaktepe	19.47	11.66
Şehit Kubilay	25.75	15.42
West of Çiğdemtepe	19.29	11.55
East of Çiğdemtepe	3.76	2.25
North of Sancaktepe	18.18	10.89
N8.1	100.00	60.00

4 Conclusions

This study concerns mainly the development of a methodology for the determination and locating areally the water leakages regarding distribution networks. In order to accomplish this work, a case study was conducted in the water distribution system of a Greater City, Ankara. North pressure zone was choosen for the main study area because this zone is much more under control with respect to other zones. Preliminary studies and personal communications in the water utility have indicated that N8.1 pressure zone was leaking considerably; as a result of this fact, it was decided to conduct this study in this pressure zone.

There are two basic definitions in connection with the water losses; one is unaccounted-for water, the other is water leakage. Unaccounted-for water can be estimated by comparing annual water production and annual water bills concerning water consumption; unaccounted-for water can occur due to the water leaks, the utilization of fire hydrants, flushing works, main breaks, cleaning of storage tanks, inaccurate meters, and illegal use. Water leakage, generally, forms the largest percentage among all the already mentioned items. The percentage of water losses due to leakage may vary from 5% to 50% and even larger of the total supply. Water leakage can be defined as the difference between delivered water by the water utility and consumed water by the consumers. In this study, water leakage was studied.

Water leakage involves unnecessary expenses in pumping and water treatment costs; it should be added that costs necessary for repairing broken pipes of any size should be added to this list; of course, maintaining a system regularly at an acceptable level is prefereable to apply extensive rehabilitation programs to problematic systems (Walski et al., 2001). Leakage may also cause an excessive investment for developing new sources and/or expanding the system capacity to keep pace with increasing demands. In addition to these items, the amount of water itself, may be the most important factor concerning water leakage for cities located at geographical regions which might be affected by drought periods. Generally, cities with leaking systems get informed by the drought earlier than cities with strong sytems.

Furthermore, excessive amount of water may be a limiting factor for the development of a water distribution network; hugh amount of losses will result in low pressures throughout the

network. In this case – even there is sufficient amount of water - without conducting a water leakage study, a rehabilitation program will recommend only the construction of parallel supply lines and more storage tanks, and incorporating more pumps into the system; it is obvious that these solutions will be very uneconomical.

The main point for conducting this study - among others - was to show that it is possible to determine weak pressure zones of a water distribution network of a Greater City with the available manpower, tools, and technology of the water utility. No further demand was asked to the water utility for the realization of this study. Not only the weak pressure zones but also weak subzones were determined in this study. Of course, the degree of accuracy of the results are not very high; however, the factors affecting the study were determined and ways were indicated for overcoming these difficulties.

SCADA system was very important for detecting the weak pressure zones; furthermore, it was used also for detecting the weak subzones by employing only the continuity equation.

The crews of the water utility especially teams of the Department of Operations of ASKI are formed of skillful and capable people; however, this is not sufficient for operating a water distribution system. The water utility should have a complete control of the system regarding its elements (concerning all the defined pressure zones) including the characteristics, the locations and the status of the pipes, valves, hydrants, pumps, and tanks. Especially, valves need to be mentioned/discussed much more than others, because a better performance of this study was hindered by the nonexistent or existing valves at appropriate locations; malfunctioning valves should be added to this list. If there were not big problems concerning valves, further zoning would be possible for locating the leaks more precisely.

The duty of controlling the whole infrastructure of the water distribution network should not be given only to the Operations Department; it is a task to be fulfilled also by the SCADA Department and Computer Department. Geographical Information Systems (GIS) and SCADA services should be integrated together for giving services to the Department of Operations. Anyhow, a certain exploration study at an acceptable scale should be conducted to investigate the buried part of the network

4 References

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5 Presentation of Authors

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