HASAN KALYONCU UNIVERSITY
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LOSSES AND LEAKAGES IN DRINKING WATER DISTRIBUTION SYSTEMS

M. Sc. THESIS
IN
CIVIL ENGINEERING

BY
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Losses and Leakages in Drinking Water Distribution Systems

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Yahya KIZMAZ

ABSTRACT

LOSSES AND LEAKAGES IN DRINKING WATER DISTRIBUTION SYSTEMS

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Water, which first enters our lives as a living fluid in a mother's womb, is the first element of the people's basic needs throughout their lifetimes. It is a source of life. In recent years, water resources are diminishing day by day in our country and in the world as result of decrease in rainfall and change in climate due to global warming, and population growth and industrialization, and they are even insufficient in some regions. It is clear that it will become more difficult to deal with water problems in the near future if existing water resources are not used efficiently.

The fact that available water consists only 1% of the world's water resources, makes the management of water resources very important. In addition to limited drinking water resources, very-high costs of producing and distributing water in conformity with potable water standards increase the importance of the economical consumption of water and of the studies aiming at reducing water losses in the supply, storage, transmission, distribution and consumption of water. In the current situation, a part of water supplied to municipal water system after its collection, treatment and the completion of its controls, is recorded as loss and leakage. Expenditures made for a considerable amount of water treated to potable water standards go to waste because of the losses and leakages in drinking water networks. Water losses and leakages are a huge loss of cost and workforce. In today's conditions, the mitigation of loss and leakage rates of water supply and sewerage administrations and other related institutions, which is a major threat in terms of water supply and operational financing, is at the top of the issues that need to be addressed for the success of these institutions. On average 36% water loss occurs in drinking water networks and distribution systems in our country. This is a significant rate and it is necessary to focus on it and conduct studies for preventing losses and leakages.

Keywords: Water Distribution Systems, Water Losses and Leakages

ÖZET

İÇME SUYU DAĞITIM SİSTEMLERİNDEKİ KAYIP VE KAÇAKLAR

KIZMAZ, Yahya
İnşaat Mühendisliği Yüksek Lisans
Danışman: Prof. Dr. Mehmet KARPUZCU
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İlk olarak anne karnında bir yaşam sıvısı olarak hayatımıza giren su, insanların yaşam süreleri boyunca temel gereksinimlerinin en başında gelen öğesidir, su yaşam kaynağıdır. Son yıllarda ülkemizde ve dünyada küresel ısınmaya da bağlı olarak yağışların azalması, iklim değişiklikleri, nüfus artışları ve sanayileşme sonucu su kaynakları her geçen gün azalmakta ve bazı bölgelerde yetersiz kalmaktadır. Mevcut su kaynakları verimli bir şekilde kullanılmadığı takdirde yakın gelecekte su sorunları ile mücadelenin da ha da güçleşeceği açıktır.

Dünyadaki su kaynaklarının yalnızca %1'inin kullanılabilir olması su kaynaklarının yönetimi konusunu oldukça önemli hale getirmektedir. İçme suyu kaynaklarının sınırlı olmasının yanında, içme ve kullanma standartlarına uygun suyun üretilmesi ve dağıtılmasının maliyetinin oldukça yüksek olması, suyun ekonomik kullanımını ve su temininde, depolanmasında, iletiminde, dağıtımında ve tüketiminde su kayıplarının azaltılmasına yönelik çalışmaların önemini arttırmaktadır. Toplanması, arıtılması ve kontrolleri tamamlanarak şehre verilen suyun mevcut durumda, bir kısmı kayıp ve kaçak olarak kayıtlara geçmektedir. İçme suyu şebekelerinde oluşan kayıp ve kaçaklardan dolayı, içme ve kullanma standartlarına getirilmiş suyun önemli bir miktarı için yapılan harcamalar israf olmaktadır. Su kayıp ve kaçakları, büyük bir maliyet ve iş gücü kaybıdır. Su ve kanalizasyon idarelerinin ve diğer ilgili kurumların, su temini ve işletme finansmanı açısından büyük bir tehdit anlamına gelen kayıp ve kaçak oranının azaltılması günümüz şartlarında ilgili kurumların başarıya ulaşması için üzerinde durulması gereken konuların en başında gelmektedir. Ülkemizdeki içme suyu şebeke ve dağıtım sistemlerinde, ortalama %36 su kaybı oluşmaktadır. Bu oran çok ciddi olup üzerinde durulması ve kayıp ve kaçakları önleyici çalışmalar yapılması zorunluluk arz etmektedir.

Anahtar kelimeler: Su Dağıtım Sistemleri, Su Kayıp ve Kaçakları

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LIST OF SYMBOLS/ABBREVIATIONS

AWWA	American Water Works Association
GIS	Geographic Information System
GRP	Glass Fiber Reinforced Polyester
HDPE	High-Density Polyethylene
IWA	International Water Association
IBNET	International Benchmarking Network for Water and Sanitation
ISKI	Istanbul Water and Sewerage Administration
SCADA	Supervisory Control and Data Acquisition
SHW	State Hydraulic Works
SPO	State Planning Organization
PCP	Prestressed Concrete Pipes
TSE	Turkish Standart Institute
TURKSTAT	Turkish Statistical Institute
ASKI	Ankara Water and Sewerage Administration
GASKI	Gaziantep Water and Sewerage Administration
İZSU	İzmir Water and Sewerage Administration
KASKİ	Kahramanmaraş Water and Sewerage Administration
MASKİ	Malatya Water and Sewerage Administration

CHAPTER 1

INTRODUCTION

1.1. Definition of the Problem

Water is one of the most important elements of human life. The need for water is growing rapidly along with the growing population and developing economy. Despite the increasing needs, the water resources in the world are gradually diminishing for a variety of reasons. Exploring new resources and putting them at the disposal of people by bringing up them to available standards require huge costs. Therefore, the provision of water resources, which are on the top of basic life elements, made available to humans by bearing various costs, in an efficient manner without wasting them is one of the most important elements in terms of the management of water resources.

One of the most important problems encountered in the management of water resources in our country and in other countries is the loss and leakage of water in the grid. Water loss is by definition the amount of water that does not yield a return, or cannot be billed. In other words, it is defined as the difference between the amount of water supplied to the network and the amount of water used by the subscribers.

Unbilled water losses consist of physical water leaks in pipes, unauthorized meter connections, meter recording errors and free consumption. Water losses cause tremendous economic losses, and the quality of water in the network deteriorates along with physical losses. Studies conducted in various countries indicate that 25-50% of water is lost (physical loss) in water supply networks. The importance of the issue is also acknowledged in our country, and legal arrangements have been made and studies have started for preventing water losses and leakages in municipal networks and for Water Supply and Sewerage Administrations and various organizations to take measures in this regard. There is a need for detailed studies in our country to determine the various factors causing water losses using experimental methods, to group them according to their effectiveness with statistical methods and to spread these studies throughout the country. The results to be obtained from such studies will help to effectively develop water loss mitigation strategies.

1.2. Purpose and Scope of the Study

The aim of this study is to identify the causes of water losses throughout our country and of unbilled water losses, and to reveal the effectiveness of these causes and the activities for preventing water losses. Water is one of the natural resources for all man-kinds and living-beings. From smallest organism to till biggest creature, all the biological life system and human system is all up to water. 70% of our planet is covered with water but just %0.03 of this water have special of usable and potable (drinkable). Day by day water needs are increasing because world's population is increasing quite fast after all water source is been same.

1.3. Outline of the Thesis

In Chapter 1, main problems those led to this study are tried to be explained. Purpose and scope of the study are tried to be identified.

In Chapter 2, a brief survey on water resources, some of the most popular water supply related agencies and components of water losses in Turkey.

In Chapter 3, the methods to determine losses and leakages in distribution systems in our country are given.

In Chapter 4, detailed analysis of studies on water losses in our country especially example of Gaziantep.

In Chapter 5, conclusion of the study and recommendations for losses management studies can be done in the future are given.

CHAPTER 2

GENERAL APPROACH

2.1 Fresh Water Resources on the World

Water resources are natural resources of water that are potentially useful. 97% of the water on the Earth is salt water and only three percent is fresh water; slightly over two thirds of this is frozen in glaciers and polar ice caps. The remaining unfrozen freshwater is found mainly as groundwater, with only a small fraction present above ground or in the air. Fresh water is a renewable resource, yet the world's supply of groundwater is steadily decreasing, with depletion occurring most prominently in Asia, South America and North America, although it is still unclear how much natural renewal balances this usage, and whether ecosystems are threatened.The framework for allocating water resources to water users (where such a framework exists) is known as water rights (Gleick,1993).

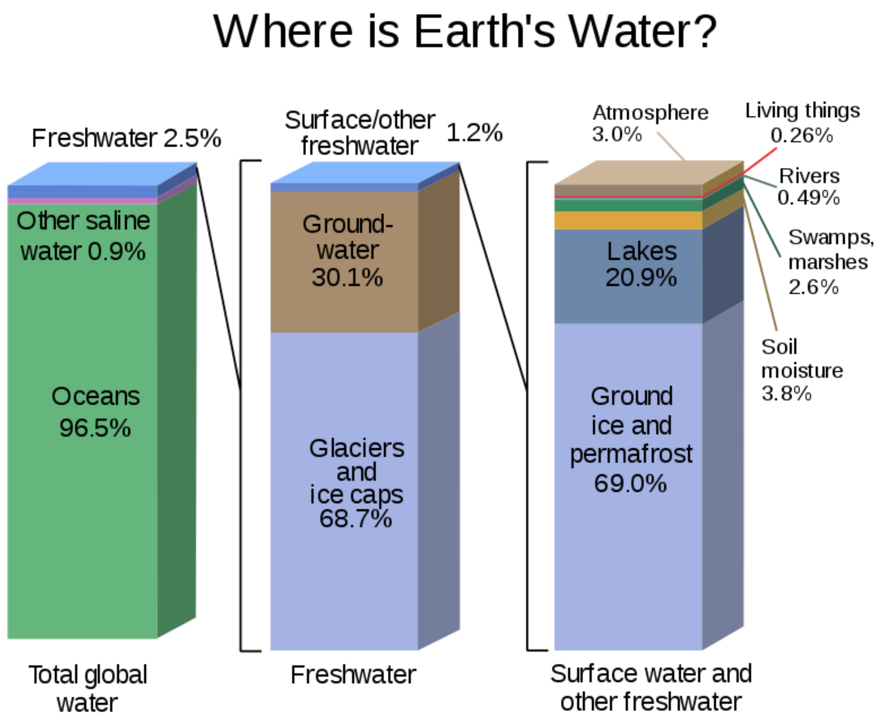

Figure 2.1 Distribution of Water on the World (Gleick,1993)

2.1.1. Surface Water

Surface water is water in a river, lake or fresh water wetland. Surface water is naturally replenished by precipitation and naturally lost through discharge to the oceans, evaporation, evapotranspiration and groundwater recharge.

Although the only natural input to any surface water system is precipitation within its watershed, the total quantity of water in that system at any given time is also dependent on many other factors. These factors include storage capacity in lakes, wetlands and artificial reservoirs, the permeability of the soil beneath these storage bodies, the runoff characteristics of the land in the watershed, the timing of the precipitation and local evaporation rates. All of these factors also affect the proportions of water loss (Radwan et al., 2010)

Human activities can have a large and sometimes devastating impact on these factors. Humans often increase storage capacity by constructing reservoirs and decrease it by draining wetlands. Humans often increase runoff quantities and velocities by paving areas and channelizing the stream flow.

The total quantity of water available at any given time is an important consideration. Some human water users have an intermittent need for water. For example, many farms require large quantities of water in the spring, and no water at all in the winter. To supply such a farm with water, a surface water system may require a large storage capacity to collect water throughout the year and release it in a short period of time. Other users have a continuous need for water, such as a power plant that requires water for cooling. To supply such a power plant with water, a surface water system only needs enough storage capacity to fill in when average stream flow is below the power plant's need (Gleick,1993).

Nevertheless, over the long term the average rate of precipitation within a watershed is the upper bound for average consumption of natural surface water from that watershed. Natural surface water can be augmented by importing surface water from another watershed through a canal or pipeline. It can also be artificially augmented from any of the other sources listed here, however in practice the quantities are negligible. Humans can also cause surface water to be "lost" (i.e. become unusable) through pollution.

2.1.2. Under River Flow

Throughout the course of a river, the total volume of water transported downstream will often be a combination of the visible free water flow together with a substantial contribution flowing through rocks and sediments that underlie the river and its floodplain called the hyporheic zone. For many rivers in large valleys, this unseen component of flow may greatly exceed the visible flow. The hyporheic zone often forms a dynamic interface between surface water and groundwater from aquifers, exchanging flow between rivers and aquifers that may be fully charged or depleted. This is especially significant in karst areas where pot-holes and underground rivers are common (Gleick, 1993).

2.1.3. Ground Water

Groundwater is fresh water located in the subsurface pore space of soil and rocks. It is also water that is flowing within aquifers below the water table. Sometimes it is useful to make a distinction between groundwater that is closely associated with surface water and deep groundwater in an aquifer (sometimes called "fossil water").

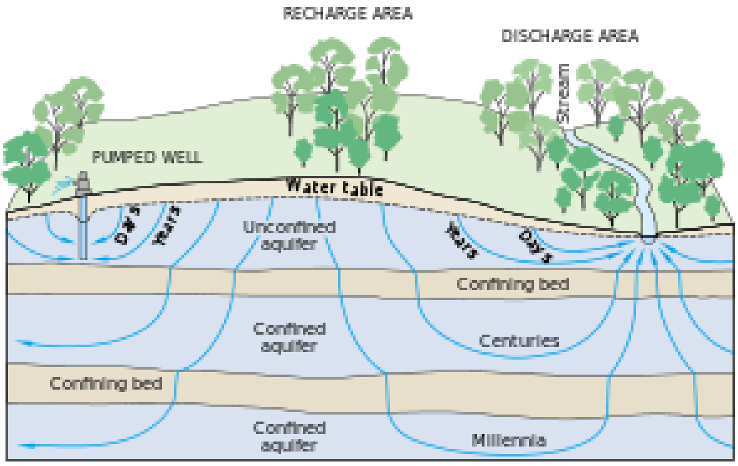

Figure 2.2 Relative groundwater travel times in the subsurface (Rasler et al.,2006)

Groundwater can be thought of in the same terms as surface water: inputs, outputs and storage. The critical difference is that due to its slow rate of turnover, groundwater storage is generally much larger (in volume) compared to inputs than it is for surface water. This difference makes it easy for humans to use groundwater unsustainably for a long time without severe consequences (Rasler et al., 2006).

Nevertheless, over the long term the average rate of seepage above a groundwater source is the upper bound for average consumption of water from that source.

Figure 2.3 A shipot (Gleick, 1993)

The natural input to groundwater is seepage from surface water. The natural outputs from groundwater are springs and seepage to the oceans.

If the surface water source is also subject to substantial evaporation, a groundwater source may become saline. This situation can occur naturally under endorheic bodies of water, or artificially under irrigated farmland. In coastal areas, human use of a groundwater source may cause the direction of seepage to ocean to reverse which can also cause soil salinization. Humans can also cause groundwater to be "lost" (i.e. become unusable) through pollution. Humans can increase the input to a groundwater source by building reservoirs or detention ponds (Gleick, 1993).

2.1.4 Frozen Water

Several schemes have been proposed to make use of icebergs as a water source, however to date this has only been done for research purposes. Glacier runoff is considered to be surface water (Rasler et al., 2006).

Figure 2.4. An Iceberg (Rasler et al.,2006)

The Himalayas, which are often called "The Roof of the World", contain some of the most extensive and rough high altitude areas on Earth as well as the greatest area of glaciers and permafrost outside of the poles. Ten of Asia's largest rivers flow from there, and more than a billion people's livelihoods depend on them. To complicate matters, temperatures there are rising more rapidly than the global average. In Nepal, the temperature has risen by 0.6 degrees Celsius over the last decade, whereas globally, the Earth has warmed approximately 0.7 degrees Celsius over the last hundred years.

2.1.5. Desalination

Desalination is an artificial process by which saline water (generally sea water) is converted to fresh water. The most common desalination processes are distillation and reverse osmosis. Desalination is currently expensive compared to most alternative sources of water, and only a very small fraction of total human use is satisfied by desalination. It is usually only economically practical for high-valued uses (such as household and industrial uses) in arid areas. However, there is growth in desalination for agricultural use, and highly populated areas such as Singapore or California. The most extensive use is in the Persian Gulf (Radwan et al., 2010).

2.2. Water Resources in Our Country

The total amount of Earth's water is 1.4 billion km^3. 97.5% of this water is contained in oceans and seas as salty water and the rest 2.5% is contained in rivers and lakes as fresh water. When considering that 90% of these little freshwater resources are found in the poles and underground, it is understood how little the amount of available fresh water that can be easily used by human beings is (Sagnak, 2013).

The average annual precipitation in Turkey is approximately 643 mm, which corresponds to an average of 501 billion m^3 of water per annum. 274 billion m^3 of this water return to the atmosphere through evaporation from the soil, water surfaces, and plants, whereas 69 billion m^3 of it feed the groundwater and 158 billion m^3 of it flow to seas and lakes in closed basins through rivers of various sizes. 28 billion m^3 of this 69 billion m^3 of water that feed the groundwater re-join the surface water through springs. There is also an average of 7 billion m^3 of water a year coming from neighbouring countries. These figures indicate that Turkey has a gross surface water potential of 193 billion m^3 (SHW Bulletin, 2018).

When 41 billion m^3 which feed underground water is also taken into consideration, the total renewable water potential of our country is estimated to be 234 billion m^3. However, within today's technical and economic conditions, the total surface water potential that can be consumed for various purposes is averagely 98 billion cubic meters per year, 95 billion m^3 of which is from the domestic rivers and 3 billion m3 of which is from the rivers originating from neighbouring countries (**Maritsa (**or **Evros) river** flows from Bulgaria to the Aegean Sea. **Orontes (**or **Asi) river** flows from Syria and crosses the provincial border of Hatay in Turkey and empties into the Mediterranean Sea). Together with the estimated potential of 14 billion m^3 of groundwater, our country has in total an average of 112 billion m^3 a year of consumable surface and groundwater potential, of which 44 billion m^3 is used.

Table 2.1 Potential Water Resources of Turkey (SHW Bulletin, 2018)

Water Resources' Potential	
Annual average precipitation	643 mm/year
Turkey's surface area	783,57 km^2
Annual precipitation	501 billion m^3
Evaporation	274 billion m^3
Seepage into underground	41 billion m^3
Surface Water	
Annual runoff	186 billion m^3
Available surface water	98 billion m^3
Groundwater	
Annual volume of water that can be drawn	14 billion m^3
Total Available Water (net)	112 billion m^3
Development Status	
Used in State Hydraulic Work's (SHW) Irrigation	32 billion m^3
Used in Drinking Water	7 billion m^3
Used in Industry	5 billion m^3
Total Water Used	44 billion m^3

Countries are classified as follows, according to their water assets:

Water Poverty: The quantity of water available per capita is less than 1,000 m^3 per annum.

Water Scarcity: The quantity of water available per capita is less than 2,000 m^3 per annum.

Abundance of Water: The quantity of water available per capita is more than 8,000-10,000 m^3 per annum (SHW Bulletin, 2015).

Turkey is not a country rich in water. According to annual amount of water per capita, our country is a country experiencing water scarcity. The quantity of water available per capita is around 1,519 m^3 per annum.

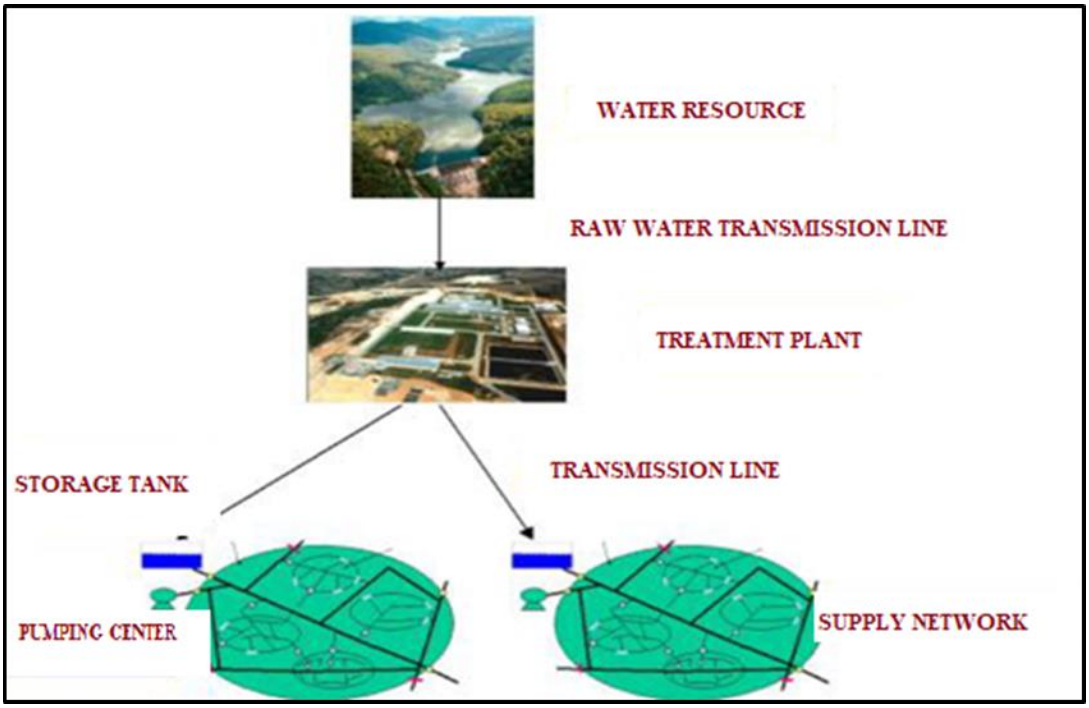

Figure 2.5.Drinking Water Supply and Distribution Systems (SHW Bulletin,2015)

The Turkish Statistical Institute (TURKSTAT) has predicted that in 2030 the population will be 100 million. In this case, it can be said that the quantity of water available per capita in 2030 will be around 1,120 m^3 per annum. Pressures on water resources can be predicted considering the impacts of the factors such as the current growth rate and changes in water consumption habits. In addition, all these predictions may be the case if the available resources are transferred after 20 years without destruction. Therefore, resources must be conserved very well and used rationally in order to deliver healthy and sufficient water for the future generations of Turkey (Arreguin-Cortes and Ochoa-Alejo, 1997).

2.3. Water Supply Related Agencies in Turkey

In our country, we can classify water supply-related agencies into three groups.

2.3.1. Decision Makers

- Ministry of İnterior
- Ministry of Agriculture and Forestry
- Ministry of Environment and Urbanisation
- Ministry of Industry and Technology
- Ministry of Foreign Affairs
- Ministry of Energy and Natural Resources
- Ministry of Treasury and Finance
- Ministry of Culture and Tourism

2.3.2. Administrators and Regulators

The specialized agencies affiliated to the ministries are contained in this group and they carry out planning and implementation work in accordance with the determined water policies.

The State Hydraulic Works (SHW) conducts observations, field surveys, feasibility studies, and project and construction studies about irrigation, hydroelectric energy, and water supply to residential areas with a population of over 100,000, and floods. The Bank of Provinces (Iller Bank) provides financial and technical support for water supply and sewerage projects of municipalities. Although no directly associated with water supply.The General Directorate of Local Administrations affiliated to the Ministry of Interior examines the performance of local authorities in various fields of activity (including water supply and wastewater issues) (SHW Bulletin, 2018).

2.3.3. Users

Municipalities are the main users of drinking water resources. In Turkey, there are 30 Metropolitan Municipalities, and the semi-autonomous water supply and sewerage administrations (such as İSKİ in İstanbul, ASKİ in Ankara, İZSU in İzmir, GASKİ in

Gaziantep, KASKİ in Kahramanmaraş) affiliated to these municipalities and waterworks departments of other municipalities are responsible for making the plan, project, construction and operation of water distribution systems. Municipalities may also transfer their rights on water distribution systems to private companies in accordance with the Law No. [3996] on the Realization of Certain Investments and Services in the Build-Operate-Transfer Model (e.g. İzmit and Bodrum municipalities) (ISKI Bulletin, 2017).

There are many agencies in our country that are competent in the field of water resources. There are several criteria for solving problems of drinking water, but the most important ones are;

1. Reducing water losses in the network to the lowest level as the most convenient way before starting to search for a new resource,

2. Efficient use of water resources can be achieved,

3. Through smooth collaboration between the agencies.

2.4. Components of Water Losses

Water losses can be examined in two main categories.

1) Physical losses

2) Non-Physical losses

2.4.1. Physical Losses

It is seepage water stemming from cracks in main water lines, service and valve connections, fire hydrants and service tanks. Due to the fact that water distribution pipes are generally buried in the ground, water leaks cannot be detected with the naked eye, therefore, it is difficult to detect the leaks and losses. Leakage controls are made in two ways, as passive and active methods. The passive method is acting with the occurrence of leak indications. For example, taking steps as result of pipe breaks in the form of water bursts that appear on the surface or upon customer complaints about low pressure and cuts in water supply. The active method is systematically detecting the leaks in the system by using various listening devices, sensors or by applying tests (for example, minimum night flow control test, hydraulic isolation test) (Toprak et al., 2007).

Figure 2.6. Example about Physical Water Losses

2.4.2. Non-physical (Administrative) Losses

Water that is not billed for various reasons, although it is consumed, enters this group. In-building installation leaks, quality of meter and its installation and service life, unbilled water due to faulty reading or meter failures, floods or discharges in water storage tanks, uncontrolled uses of fire hydrants, water transports by tankers and free consumption of various agencies (such as in parks, mosques, cemeteries, municipal facilities, public fountains) are examples of elements that comprise commercial losses.

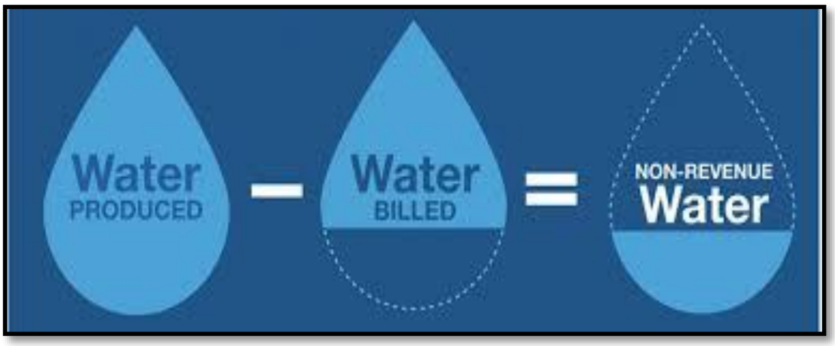

Figure 2.7 Example about Non-Physical Water Losses

2.5. Literature Review

Reducing the amount of water leaked, smart water networks can help reduce the money wasted on producing or purchasing water, and the related energy required to pump water and treat water for distribution. A UK demo site is presented focusing on leak management, integrating fixed flow and pressure instrumentation, advanced (smart) metering infrastructure and novel instruments (capable of high resolution monitoring). Example data analysis results for this site using the AURA-Alert anomaly detection system for Condition Monitoring are presented (Mounce et al., 2015).

High leakage levels in the water supply network of the city of Patras is one of the most important issues, which must be dealt by the Municipal Enterprise of Water Supply and Sewerage of Patras (DEYAP). The Non-Revenue Water is approximately 55% of the System Input Volume from which a significant proportion is estimated as being physical losses. Until now the approach to leakage control is a passive one, whereby leaks are repaired only when they become visible. Karathanasia and Papageorgakopoulosa (2016) developed a permanent Leakage Control System according to the International Water Association (IWA) methodology. Aggregation of various operational Databases through development of an intelligent reporting software with data warehouse techniques, Procurement of Leak detection equipment and training DEYAP’s personnel in the operation of Pressure Management systems.

One of the most challenging problems in the Chinese water sector is to fulfill water requests in urban areas with increasing population density and deteriorate water distribution infrastructures. Effective decision support systems (DSS) are required to manage energy consumption for pumping by simultaneously controlling leakage volumes. A recently approved joint project between Italy and China aims at transferring the latest advancements on water distribution network (WDN) analysis and management to Chinese water engineers to develop effective DSS by using the WDNetXL system (www.hydroinformatics.it). The preliminary DMAs design on a pilot WDN is reported to exemplify the WDNetXL decision support paradigm (Berardi et al., 2013).

Leakage detection and isolation in water distribution networks is addressed applying an optimal sensor placement methodology. The chosen technique is based on structural models and thus it is suitable to handle non-linear and large scale systems. A drawback of this technique arises when costs are assigned uniformly.The algorithm presented by Rosich (2016) is successfully applied to a District Metered Area (DMA) in the Barcelona water distribution network.

The architecture of the system is briefly presented and its most important modules are discussed in detail in Poland is presented. A pilot version of the system has been running since 2013 in this city, which still shows a high level of performance in leak detection, as well as reasonable efficiency for leak location (Moczulski et al., 2018).

CHAPTER 3

GENERAL REASONS OF WATER LOSSES

3.1. General Overview

Water loss usually refers to real physical losses in water distribution system. In fact, the total loss consists of various components. In order to standardize the subject of water losses and to enable researchers working on this topic to use the same terms, some international organizations have established methods identifying the components consisting water loss and specifying the performance indicators required for assessing a water distribution system in terms of water losses. The two of them which are most commonly used worldwide will be examined in detail.

3.1.1. IWA/AWWA Method

The American Water Works Association (AWWA) and the International Water Association (IWA) recommended the Water Balance Method in 2003 [2]. The components of the water balance are defined (see Table 3.1), how to construct the water balance is specified (see Table 3.2) and the indicators necessary for evaluating a water network in terms of water losses are defined (see Table 3.3), according to this method.

3.1.2. IBNET Method

The indicators related to water losses defined by the International Benchmarking Network for Water and Sanitation Utilities (IBNET) are given in Table 3.1 (Beper, 2007).

Table 3.1. Components of Water Balance According to IWA/AWWA Method (Iwa, 2007)

Water Balance Component	**Definition**
System Input Volume	The annual volume added to the water distribution system
Authorized Consumption	The annual water volume drawn by the registered consumers that is metered and/or un-metered
Water Losses	The difference between the System Input Volume and Authorized Consumption, which is the sum of Commercial and Physical Losses
Commercial Losses	The unbilled water as a result of unauthorized consumption, meter inaccuracies, and meter reading errors
Physical Losses	The leakage from the transmission and distribution mains, leakage and overflows from storage tanks, and leakage from service connections, shortly the volume of all losses up to the meter
Revenue Water	The billed and revenue-generating part of the System Input Volume
Non-revenue Water	The difference between the System Input Volume and Billed Consumption

Table 3.2. Water Balance Table According to IWA/AWWA Method (Iwa, 2007)

System Input Volume	Authorized Consumption	Billed Authorized Consumption	Billed Metered Consumption	Revenue Water
			Billed Un-metered Consumption	
		Unbilled Authorized Consumption	Unbilled Metered Consumption	Non-revenue Water
			Unbilled Un-metered Consumption	
	Water Losses	Administrative Losses (Commercial Losses)	Unauthorized Consumption	
			Meter Inaccuracies	
			Reading Errors	
		Real Losses (Physical Losses)	Leakage in Transmission and Distribution Mains	
			Storage Leaks and Overflows from Water Storage Tanks	
			Service Connections Leaks up to the Meter	

Table 3.3. Performance Indicators for Non-Revenue Water and Water Losses (Iwa, 2007)

Performance Indicator	**Remark**
Expression of the Non-revenue Water volume as the percentage of the System Input Volume	It can be calculated with a simple water balance; it is useful as a general financial indicator.
Expression of the Non-revenue Water cost as the percentage of annual costs of the water distribution system	It enables to express Non-revenue water components with different units.
Expression of the Apparent (Commercial) Losses as the percentage of the System Input Volume	It is a basic but a significant indicator; first, the volume of Commercial Losses should be calculated or estimated.
Expression of Real (Physical) Losses as the percentage of the System Input Volume	It is not suitable for evaluating the efficiency of the distribution system’s operation.

Normalized Real (Physical) Losses – Volume/Service Connection Number/Day	It serves as a useful operating performance indicator to reveal the targets for decreasing physical losses.
Unavoidable Real (Physical) Losses-UARL	It is a theoretical value indicating the limit to which the leakage can be decreased to if the latest technology is applied. It is a key value to calculate the Infrastructure Leakage Index (ILI). If water is not expensive, or not less, it not necessary for the system to be at this level.
Infrastructure Leakage Index-ILI	The ratio of Current Annual Real Losses (CARL) to Unavoidable Real Losses (UARL); it is a useful operating criterion to control physical losses.

Table 3.4. Indicators Recommended By IBNET for Non-Revenue Water (Toprak et al., 2007)

IBNET Indicator No.	Definition	Unit
6.1.	The difference between the supplied and sold water volumes (the volume of water loss) as the percentage of net-supplied water	%
6.2.	The amount of daily water loss volume per kilometer of the supply network	m^3/km/day
6.3.	The amount of daily water loss volume per connection	m^3/connection/day

3.2. Cause of Water Losses and Leakages

Today's technical opportunities and the technologies used do not give precise results at the point of detection of losses in water networks. Therefore, at this stage, bringing down the leakage-loss rates even to the level of %10 is considered as an acceptable value. Some studies previously done in various countries show that physical water losses constitute a significant part of the unbilled losses. Water losses were detected at the rates of %33 in the city Boston of the US, %24 in England and %12 in Germany (SHW Bulletin, 2018). This rate was %40 in Malaysia, %25 in both Brazil and Switzerland .The loss rate was found as %40 in the studies conducted in 15 different cities of Mexico. In Turkey, it is estimated that the leakage/loss rates in drinking water distribution networks is on average % 36 (GASKİ Bulletin, 2014).

The main reasons for physical losses that occur in drinking water networks are as follows. (GASKİ Bulletin, 2014).

3.2.1 High Water Pressure

Pressure resistance of the pipe used should be greater than the operating pressure resistance and the system should be supported with the necessary pressure-breaker valves etc. taking into consideration the pressure in the time intervals when water consumption is weak (Yüksel at el.,2004).

Figure 3.1.Example of High water pressure (Physical Water Losses)

3.2.2 Usage of Low-Quality Materials and Low Construction

All pipes used must be produced according to TSE standards (TSE: Turkish Standards Institution). They should not be exposed to direct sunlight during storage. PVC pipes whose colour has changed because of remaining uncovered for a long time, whose surface is whitened, and which have lost their elasticity and other properties, should not be used in the production of water supply network. Necessary measures should be taken to prevent the deformation of pipe insulations of steel pipes. There should be spiral-wound welding and film welding control should be done in their production. The raw material of polyethylene pipes must be 100% original. Attachment parts should be manufactured as much as possible with the injection method. It is not recommended to use the convection method because the parts manufactured by this method frequently break down. In ductile pipes, there must absolutely be no roughness on the inner surfaces, which are in contact with water, and no manufacturing faults on the concrete surfaces. When procuring pipes, their impact resistance should be taken into consideration. In all Pipe-Laying works, ground improvement, sand/gravel bedding and covering inside trenches should be done with care in accordance with the specifications. The point of drainage at the point of sand/gravel supply should be taken into consideration. An appropriate pipe diameter should be designed and an inappropriate pipe diameter should not be used.

3.2.3 Poor Workmanship in Fittings

Pipes, Valves, Suction Cups, Strainers, Fire Hydrants, Pressure Regulator Control Valves, Flow Meters and materials used in assembly are referred to as fittings. Valves with elastomeric bearing should be used for absolute sealing of the valves. Nodular cast iron (spheroidal graphite iron) body, elastomeric coating system produced with vulcanization system and F4/F5 class as sizing should be used. Figure as below shows some tree roots entering and growing through the pipe crack.

Figure 3.2.Example of Poor workmanship in fittings (Physical Water Losses)

3.2.4 Aging and Corrosion of the Pipe

After a certain period under the ground, pipes, and attachment get broken and destroyed due to contact with the soil and deformation of binding properties structural-wise as a result of chemical reactions. Water flows into underground and sewer through these fractures and cracks, which seriously increase the loss and leakage rates.

In Turkey, there were PVC, Steel, and Asbestos pipe productions, which are more than 40 years old, by agencies such as the General Directorate of Rural Services. These pipes need to be replaced by new pipes (Toprak et al.,2007).

Figure 3.3.Example of Aging and Corrosion of the Pipe (Physical Water Losses)

3.2.5 Soil Properties and Subsidence

Road embankment works in new settlement areas need to be compressed by watering in 20 cm layers with tonnage cylinder machines. Otherwise, with the passing of the winter-summer season, subsidence occurs and this constitutes a serious problem for the infrastructure (Yüksel et al., 2004)

Figure 3.4. Example of Soil Properties (Physical Water Losses)

3.2.6 Heavy Traffic Load on the Pipe:

It is important to determine the pipe's type, diameter, and manner of application, and the road covering's type on the routes where the traffic is busy and where heavy tonnage vehicles pass. In asphalt pavements, due to the damage to the pipelines, gallery spaces are formed in time, which also cause various accidents.

In the past, specific procedures and principles have not been determined in terms of the nature, type and location of infrastructure investments. In other words, while there is no regulation about which depth communication lines can go from drinking water, sewage, storm water, natural gas and electricity distribution from infrastructure facilities this uncertainty has been solved by authority today. Some laws of Metropolitan Municipalities give information about Geographical and Urban infrastructure systems. In Article 14 of the Municipal Law No 5393 is carried out, the locations of the infrastructure facilities are presented visually according to the road widths according to the provisions of the Regulation on Wastewater Collection and Removal Systems published in the Official Gazette dated 6/1/2017.

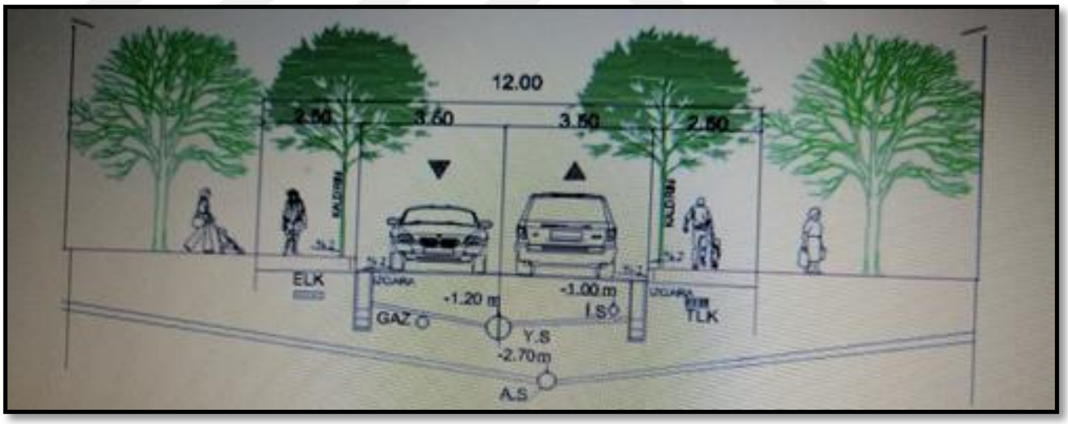

Figure 3.5. Regulation of location and depth of wastewater, drinking water electricity, gas, storm water pipe lines.

3.2.7 Water Quality and Chemical Properties

Poor-quality and unfiltered water drags along the solids contained in it, and these solids make abrasion effect and erode some points in the installation (such as pipe, jet, pump fan and body, and stuffing box). Solids combine with lime and increase calcification in the system, the limes clog the pipes and this causes an increase in pressure, which damages the attachments and leads to physical loss (Kabakcı and Karadoğan, 2003).

3.2.8 Fittings Made Incorrectly

Figure 3.6. Example of Incorrect Fitting (Physical Water Losses)

3.2.9 Pipe Types

Shorten the length of the transmission lines, save water, considerably reduce pollution risk by using pipes instead of aqueducts, open channels, tunnels or galleries, if appropriate, in transmission and network lines, which convey water from the source to the regions where it will be used, for the transportation of water. In drinking water transmission mains, mostly steel pipes, high-density polyethylene (HDPE) pipes or glass-fiber reinforced polyester (GRP) pipes are used. Steel pipes are preferred over other pipe types in situations where they must be operated at high operating pressures in water transmission mains. Resistance to high pressure, high transportation capacity, and long life are the reasons why steel pipes are preferred. The most important problem encountered in the use of steel pipes is the risk of corrosion. To avoid this, special protective coatings must be used. HDPE pipes, which are classified in polyethylene (PE) class of plastic pipes, are produced from HDPE raw material, which has high resistance to chemicals and crack propagation, and which is meltable at high temperature. HDPE pipes' ability to operate safely at very high and very low temperatures, high resistance to cracking and chemical substances, and a lifetime of minimum 50 years are among their important advantages. The risk of corrosion that occurs in metallic pipes, such as steel pipes, is not observed in HDPE pipes. It is not affected by earthquakes and earth movements due to its elastic structure. Since it is light, its installation and transportation are easy. However, low impact resistance and high cost at large scales make these pipes disadvantageous against alternative pipe types. GRP pipes are manufactured using polyester resin, glass fiber and silica sand raw materials. GRP pipes are much lighter than concrete and steel pipes. Therefore, its storage, loading, transportation, and installation is easier and more economical. Its advantages are high resistance to chemicals, non-requirement for cathodic protection and additional insulation material. The most important problem encountered in GRP pipes is the necessity of qualified workmanship in laying of pipes Pipeline burst occurs when pipe installation, trench digging and compression of filling material works are not made with due care. This is more common in GRP pipes than in other pipe types. The advantages and disadvantages of pipes intended to be used must be well known. In selecting the pipes to be used, besides the low cost, technical and operational aspects of the pipe should also be sufficient. Pipes must conform to the water pressure which they will be exposed to and to the characteristics of the water that will be conveyed and of the ground where the pipes will be installed (Toprak et al., 2007).

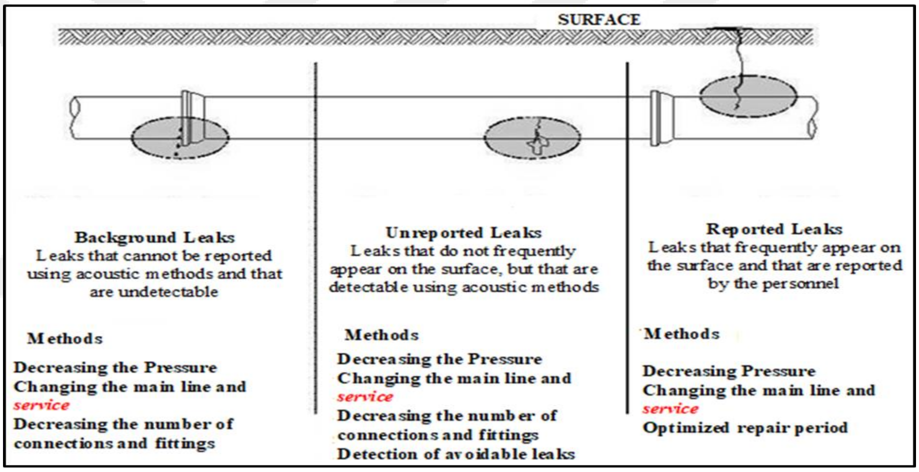

Figure 3.7. Components of Water Leak (Gaski Bulletin, 2014)

3.3. Control and Prevent Methods

Controls to prevent water losses in drinking water networks are usually done in two ways.

3.3.1 Active Control Method: is systematically detecting leakages in supply networks by using various listening devices, sensors or applying tests (step test, minimum night flow control test, hydraulic isolation tests, etc.) or conducting leak investigations with programmed walks on the supply network.

3.3.2 Passive Method: is intervening to breakdown by acting along with the occurrence of leak indications.

CHAPTER 4

REAL APPLICATION AND MITIGATION

4.1. Water Losses In Our Country And Mitigation Methods

Reasons of physical and non – physical water losses is a determining factor and vary from country to country (Table 4.1). It is accepted that the water loss in the network varies between 10-20%. In developing countries, these rates are observed to be much larger (Kingdom et al., 2006).

Table 4.1. Non-Revenue Water Amounts Development Levels of Countries (Kingdom et al., 2006)

Country Status	Water Supplied	System	Total Loss		Physical Loss		Non-Physical Loss	
	Population, 2002 (million)	Incoming Water Quantity (L/ day)	m^3/year (million)	%	m^3/year (million)	%	m^3/year (million)	%
Developed	744,8	300	12,2	15	9,8	80	2,4	20
Developing	837,2	250	26,7	35	16,1	60	10,6	40
Total			48,6		32,7		15,9	

According to World Bank data, approximately 45 million m3 of water per day (corresponding to the needs of approximately 200 million people) is lost in drinking water networks (World Bank, 2018). Looking at the 2010 non-revenue water rates of the International Benchmarking Network for Water and Sanitation Tools (IBNET); Values in Germany, the Netherlands and Australia are below 10%; In countries such as Bosnia and Herzegovina, Albania and Armenia, it is seen to be over 60% (Figure 4.1). In developed countries, the main cause of leaks is due to the high age of water networks. Although the problematic parts of the worn-out networks are renewed, problems arise again after a while due to the material and equipment life has been completed.

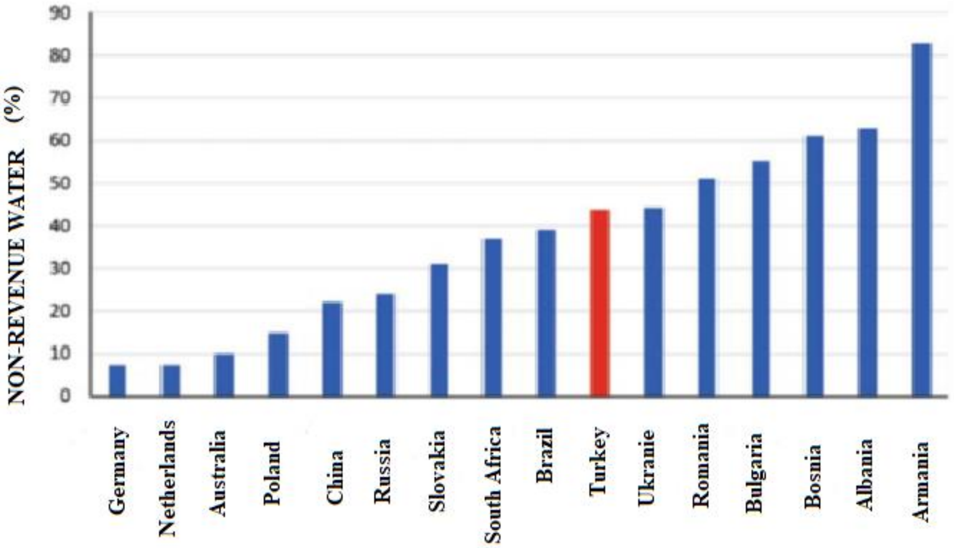

Figure 4.1.Non-Revenue Water Levels in 2010 for Some Countries (Gökdereli and Bahar, 2016)

According to 2010 data it is clear that Turkey has a very high proportion of water non-revenue ratio. In a study carried out by the International Water Service Association in 1991, water loss rates were determined according to the development level of the countries 8-24%, 15-24% in newly industrialized countries and 24-45% in developing countries are ideal, but this rate should be below 10% in any case (Gökdereli and Bahar, 2016).

The strategic importance of water resources has been well understood in recent years, and many developed and developing countries have been abolished earlier contracts on water, and municipalization activities have started (Akıllı et al.2017).For example, in the Netherlands, where water service has become public again, the rate of water loss has decreased to 3%, on the other hand this ratio has reported around 29% in the UK where water service was provided by the private sector.

The water loss rate in Turkey is quite far from the targets mentioned above it has been stated by the Minister of Water Affairs and Forestry in 2017. In a statement made by the Minister although it appears to be 35 percent in the statistics, it is emphasized that the leakage water is at least 50-55 percent according to our findings at the moment. The statistics of the administrations are given.

Table 4.2. Authorities Working on Water Losses in 2014 and 2015 (Gökdereli and Bahar, 2016)

	Total Municipality	Number Of Municipalities Sending Form		Number Of Municipalities Sending Form	
		2014	2015	2014	2015
Metropolis	30	19	18	63%	60%
City	51	31	19	61%	37%
District	919	206	189	22%	21%
Municipality	396	147	152	37%	18%
Total	1396	403	378	29%	27%

The number and proportion of the administrations which make the necessary measurements to prevent water losses. In other words, it can be seen from the table that almost two-thirds of the municipalities do not carry out activities in this respect.

Therefore, as mentioned in the statement of the Minister of Forestry and Water Affairs, water losses and management of this process a serious problem, the principles determined by the legislation does not reflect the truth.On the other hand, some administrations have made significant progress in this matter in Table 4.3 The loss-illegal rate, which was 72% in Kocaeli in 2004, was reduced to 23% as of April 2017 (Gökdereli and Bahar, 2016).

In addition, 12 water and sewerage authority made a determination in particular it is stated that 31% of the average water loss rate of these administrations (Turkey Water Institute, 2017). In a recent research, water loss rates were obtained as a result of examining the way of obtaining information from the water and sewer administrations and strategic documents and these ratios are given in the table below.

Table 4.3. Water Loss Indicators of Metropolitan Municipalities (SHW Bulletin,2018)

Metropolitan Municipality	**Water Loss Rate (%) [2014]**	**Water Loss Rate (%) [2015]**	**Water Loss Rate (%) [2016]]**
İstanbul	24,01	24,09	24,07
Bursa	23,86	22,67	22,87
İzmir	32,64	31,35	30,51
Samsun	35,28	38,51	37,47
Mersin	46,79	45,04	44,93
Konya	27,17	29,35	27,20
Tekirdağ	39,00	39,09	35,34
Sakarya	61,50	58,00	56,00
Şanlıurfa	55,00	43,00	37,00
Adana	40,34	39,97	38,44
Antalya	54,57	-	35,30
Gaziantep	35,28	-	-
Kayseri	-	-	18,80
Diyarbakır	56,00	55,00	49,43
Mardin	43,00	-	-
Kocaeli	45,00	42,00	38,00
Aydın	53,27	-	-
Denizli	45,00	-	-

The General Directorate of Local Administrations collects and publishes the statements of the municipalities. According to TURKSTAT data of 2012, the highest regional loss rates in drinking/potable water networks are observed in the South-eastern Anatolia region with 56.7 percent, followed by the Eastern Black Sea region with 56.1 percent, whereas the lowest losses were observed in the Eastern Marmara region with 33.3 percent. Water loss rates and water and wastewater revenue collection rates reported by metropolitan municipalities are given in Table 4.3.In the basin processing, the tools are used to see the delineation results, assess outcomes, and accept or deny the resulting delineation (SHW Bulletin, 2018).

4.2. Detection of Water Losses and Mitigation Methods

4.2.1. Methods of Detecting Water Losses

It is important to benefit from the developing technology in detecting water losses. The detection of unauthorized consumption, which is a non-metered consumption, is usually done by listening methods.

Water pipes near dwellings and workplaces which are non-subscribers should be checked with listening devices. Unauthorized excavations on the road should be checked on the road. Monthly consumption of subscribers should be monitored to detect meter and reading errors, and unexpected situations should be investigated.

The detection of physical losses is usually done with the appearance of leaking water on the road surface. If the water does not appear on the road surface, such leakage can be detected through listening devices. If the amount of water entering a particular area is checked periodically with flow meters, large flows, especially during night hours, can be detected. Flow meters can be remotely controlled with the SCADA (supervisory control and data acquisition) system continuously. For example, General Directorate of Malatya Water and Sewerage Administration (MASKI) selected two regions, drinking water lines were digitized in GIS environment and monitored by SCADA system. Sub-measurement zones were formed, and the water loss rates determined in this way. After this activity, the water loss rate in the first sub-measurement region was reduced from 78% to 13% and the water loss rate in the second region was reduced from 53% to 39% (Özdemir, 2017).

Istanbul İSKİ also acts with the same method, reduce the loss and leakage rate to 24% within the measurable areas. However, since the water loss rate in developed countries is below the 10% band, it is understood that closing the 14% difference is started with creating isolated areas managing and controlling the network (ISKI Bulletin, 2017).

4.2.2. Methods of Mitigating Water Losses

Separate measures need to be taken according to the loss type to reduce water losses.

Listening and controls should be increased to prevent unauthorized consumption, which is a non-metered consumption, and legal measures should be taken for the situations detected. The amount of water that will meet the basic needs of a family should be provided at a low price, and a gradual price increase should be made as the consumption increases. A certain amount of water can be supplied free of charge to low-income families. If a meter fault is detected, it should be replaced immediately.

Regular pipe renewal programs must be implemented to mitigate physical losses and worn pipes should be replaced. Pipes should be laid with care by bedding and covering the bottom and top of the pipes with thin material. Leaks should be prevented by checking the insulations of storage tanks. When the sluice channel of a storage tank is in operation, excess water should be transferred to other storage tanks, and water should be prevented from flowing for nothing. The pressure of the water distribution system should be reduced so that the pipes that are not resistant to pressure will not burst, the leaks in the pipe joints will be reduced and less water will be lost during the repair of a broken pipe. An important method for mitigating physical losses is separated zoning. In this method, the water distribution system is divided into independent, small and continuously monitored zones. Each zone's own water consumption is determined, and if an abnormal consumption is observed, a water leakage is suspected. But, the location of leakage is still found through the listening method (Yüksel et al., 2004)

When choosing the pipe type, flexible materials should be preferred, not fragile. Flexible materials suffer less damage from external forces such as earthquakes, ground subsidence and external loads. Long-lasting materials should be selected, metals should be protected against corrosion by cathodic protection.

Another measure for mitigating water losses is to increase the number of repair teams and shorten the intervention time. The components of leakage management to be applied to mitigate physical losses are shown in Figure 4.2.

Figure 4.2. Example of Leakage Management

Step by step way of mitigating water losses

a) Drinking-potable water supply and distribution system, design and construction at the lowest level of economic.
b) Establishment of Geographical Information Systems database by water administrations of Metropolitan and Provincial Municipalities, transferring existing data to the database by digitizing and updating continuously.
c) Drinking and potable water systems are designed as main pressure zone and sub-zones during the design phase.
d) Engineering inspections and controls during the construction of drinking water systems.
e) Pressure management in the system, continuous pressure measurement at critical points, reducing the highest static pressure from 80 mSS to 60 mSS where topographic structure is appropriate, and establishing pressure reducing / regulating valves and connection lines where necessary.
f) Selection, suitable materials to reduce water losses during the design.
g) To minimize water losses by performing controls in existing systems.
h) The water distribution network construction, maintenance and repair works related to other public infrastructure facilities such as electrical, gasses.
i) Continuous maintenance and repair works and active leak control.

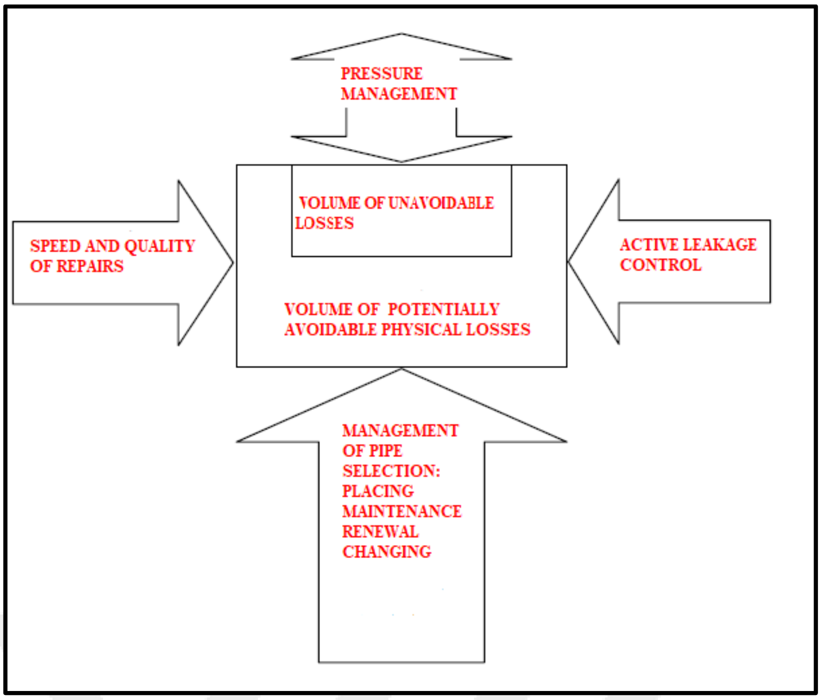

Figure 4.3.Four Main Components of Leakage Management (Iwa, 2007)

4.3. Benefits of Gained Losses

The benefits to be gained if the losses in drinking water networks are reduced to acceptable levels are summarized below.

4.3.1. Low Operating Costs

With low water pumping, the amount of electricity consumed diminishes, and accordingly, the operating costs decrease. It also decreases costs by reducing the costly treatments used in water-saving treatment plants.

4.3.2. Lowering of Investments

The amount of water saved will meet the increasing demand due to population growth, thus the investments which this demand would necessitate will be delayed.

4.3.3. Increased Income

With the reduction of water losses, costs will fall and corporate income will increase.

4.3.4. Developed Customer Service

The quality of service delivered to customers will increase and water quality will increase with loss control provided in the networks.

4.3.5. Lower Cost Burden for the Consumer

More efficient use of resources will reduce the cost burden on the consumer.

Figure 4.4 Effect of non-revenue water

CHAPTER 5

STUDIES ON GAZIANTEP

5.1. Studies Done in Some Provinces on Water Losses

In our country, the studies on the losses in drinking water distribution systems are not sufficient. The majority of existing studies done by the municipalities are aimed at determining the percentage of water losses. Whereas studies aiming to detect and prevent water losses are limited. Some studies done in our country on water losses and the findings obtained are given below.

ISKI (Istanbul Water and Sewerage Administration) initiated a comprehensive renewal work on water and wastewater systems in Istanbul. To this end, treatment plants, pumping stations, transmission and distribution lines, and water storage tanks have been brought up to international standards. Thus, about 60% of the water losses went down to 24.07%, and the wastewater treatment rate of 10% rose to 90% (Kavurmacıoğlu and Karadoğan, 1999). According to the report of the infrastructure working group gathered in Antalya in 2016 with the participation of the Water and Waste Water Administration (ASAT) and the State Hydraulic Works (SHW) officials to assess the city's drinking water problem, the water losses are at 35.34%. The report stated that the losses are caused by construction and operational errors (Lai, 1991). In a study conducted for Bursa, it was stated that the losses occurred in the water distribution network were 22.87% for 2016 (Öztürk et al., 2017).

Water losses are not only the problem of large cities but also of small and medium-sized settlements. The infrastructure report prepared by the Konya Municipality in 2016 stated that the rate of loss in the city's drinking water network is 27.2% (Konya, 2016). This value reaches 49, 43% in the city center of Diyarbakır province. In Turkey, water loss rates vary between 22.87% and 56% (Roberts, 1985). In a limited number of studies done in our countries, suggestions were made for reducing water losses. It was reported that water losses can be mitigated through separate zoning and pressure reduction in water distribution systems (Songur and Dabanlı, 2006). In a study carried out for the city center of Diyarbakir, a 15% decrease was achieved in water loss just in one month as a result of the imposition of a penalty for unauthorized consumptions (Yalılı and Solmaz, 2004).

Training studies on water losses have also started in our country. The project PROWAT (Planning and Implementing a Non-Revenue Water Reduction Strategy Improves the Performance of Water Supply and Distribution Systems), which has started within the Leonardo Da Vinci programme, which is one of the European Union's training programs, aims to prepare materials for the training of all persons involved in drinking water systems (Yüksel et al., 2004).

5.2. Studies Done in the Province of Gaziantep on Water Losses

5.2.1 Water Resources of Gaziantep

The Kartalkaya dam located in Pazarcik, a district of the province of Kahramanmaras, is the most important source that provides Gaziantep's drinking and potable water need. The water taken from there is delivered to the city via 3 elevation centers (pumping stations) and 53.7 kilometers of the transmission line and is elevated to 296 meters with pumps. The first transmission line consists of prestressed concrete pipes with a diameter of 1400 mm and the second one, which is located parallel to the first one, consists of steel pipes with a diameter of 1,800 mm. In this system, water flows from the Kartalkaya dam to treatment plants via the installed pumps at a flow rate of $4.5m^3/sec$ (Yüce et al., 2016).

The Mizmilli wells located in the province of Kahramanmaras are the second important source that supplies the city with water. Water is delivered to the city through 3 elevation centers and 44 kilometers of the transmission line and is elevated to 602 meters with pumps. The amount of water supplied to the city from 30 drilled wells is 85,000 m^3/day (Yüce et al., 2016).

As the third important water source, there are 14 deep wells located in different parts of the city that supply the grid with 35,000 m^3/day water.

As the fourth water sources of Gaziantep is Düzbağ Project. It carries water from Kahramanmaraş to Gaziantep without any energy consumption and any water interruption for many years. This project has implemented by General Directorate of State Hydraulic Works (Yüce et al., 2016).

Figure 5.1 Transmission pipeline of Düzbağ Dam

In the Düzbağ Project, first stage is construction of a regulator. Drinking water will be taken from the river and storaged. Gaziantep will have 75% more affordable water. Completion of construction of Düzbağ Dam, Gaziantep will have water any energy consumption with only gravity (GASKİ Bulletin, 2018).

Figure 5.2 Transmission line of Düzbağ Dam

With the commissioning of Düzbağ Dam which is planned to be completed in 2025, this amount will increase to 173, 60 million m³ annually. Project will be contain construction of regulator, power station, transmission line, distribution line and a tunnel (GASKİ Bulletin, 2018).

Figure 5.3 Transmission line of Düzbağ Dam

Project started on 07.02.2017 and transmission - distribution line have almost completed. Kartalkaya promotional renewal totally 102.970 m pipeline have been installed. The project of Düzbağ, 96.60 million cubic meters of water to be taken from Göksu River will be delivered to Gaziantep. Completion of the construction of Düzbağ Dam, this amount will increase to 173, 60 million m³ / year (GASKİ Bulletin, 2018).

There is a 2,045,000 m-long water distribution network in Gaziantep, whose population is 1,844,438 as of 31 December 2016 according to the address-based population registration system.

5.2.2. The Importance of Preventing Water Losses for Gaziantep

The Province of Gaziantep constantly receives migration due to its geographical location and because of being an industrial city. As the water resources of the city are inadequate, a large part of the drinking and potable water needs is provided from remote cities, which creates high energy costs. In order to meet the ever-growing demand for water in parallel with population growth and to reduce high energy costs, it is necessary that the loss and leakage rates in drinking water distribution networks a

5.2.3. Works Done Citywide by GASKİ

The General Directorate of GASKİ operating under the Gaziantep Metropolitan Municipality has carried out the following works to prevent losses in drinking water distribution systems.

Mapping of the drinking water network of Gaziantep and creation of the hydraulic model within the scope of the project it was aimed to:

- Map, with elevations and coordinates, the approximately 2,000 km-long drinking water networks, including all valves, fire hydrants, drains and suction cups, and record
- Transfer mapped network information to the existing Geographic Information System (GIS),
- Measure pressure zones regionally (determining the number, location, and type of zone meters required for regional measurement),
- Create ideal pressure zones,
- Create sub-measurement zones within pressure zones,
- Perform the hydraulic modeling of the drinking water distribution network.

As a result of the hydraulic modeling, it is aimed to prepare application projects for changing the pipes, valves, pressure breaker valves, flow meters, fire hydrants and similar fittings of around 300 km-long drinking water network lines that need to be renewed. With this project, the entire drinking water network was transferred to a digital medium; thus, the damages that other infrastructure organization might give to the drinking water network in conducting their works will be prevented. Furthermore, since measurements can be made in drinking water networks, loss and leakage rates in the network will be determined and finding remedies for them will become easier. Energy saving will be achieved through the establishment of new pressure zones. The data (flow rates etc.) required for the projects to be prepared for the new settlement units will also be easily obtainable from this system. The remote control of the supply network will be provided through hydraulic modeling that will work integrated with the SCADA system (Gaski Bulletin, 2014).

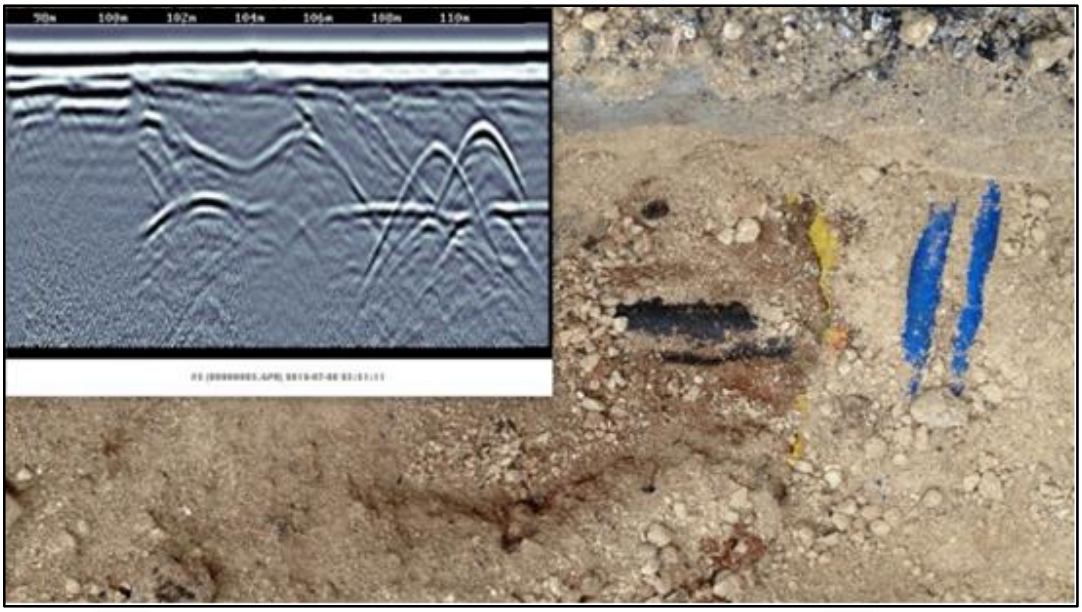

Figure 5.4.Digital Modelling Formation Studies

5.2.4. SCADA System

The term “SCADA” is an acronym which stands for “Supervisory Control And Data Acquisition”. In short, it can be translated as "Remote Monitoring and Control System". The water network management is controlled through the SCADA system that consists of computers, communication equipment, and sensors.

At the SCADA control center, the system is monitored and controlled for 24 hours by operating in 3 shifts. The SCADA system is used to measure the quantities of water supplied to the city and the regions, to perform pressure measurements, to open and close the valves remotely, to operate the pump stations in line with energy tariffs according to their storage levels, to prevent tank overflows, to measure the water quality of water resources, and to reduce high pressures with pressure-breaker valves.

In this system; 152 points are controlled in total, including Water Resources, the Kartalkaya Dam and Pump Stations, Wells, Inner-city Storage Tanks, and Pumping Stations, Drinking-Water Treatment Plant entrance and exit, inner-city measuring points.

Figure 5.5. A Water Loss Detected During Channel Imaging

5.2.5. Renewal of Old Distribution Networks and Water Storage Tanks

Throughout the province of Gaziantep, the network lines are renewed and losses and leakages are brought under control in the regions where the old network lines have completed their lifetime and continuously break down. Works on drinking water have been carried out in many neighbourhoods in different regions of the province within the scope of these studies and programs are prepared for the renewal of old lines in the coming years as well. Furthermore, a significant part of the transmission line consisting of old PCP pipes (Prestressed Concrete Pipes) in the city has been renewed within this scope (Tarımcı et al., 2002).

Figure 5.6. An Old Prestressed Concrete Pipe

In all these studies, it is aimed to decrease the loss and leakage rate, which was initially at the level of 50% in Gaziantep, to the level of 20% as targeted by the Ministry of Environment and Urban Planning (Toprak et al., 2007).

Figure 5.7.Renewal of Water Storage Tanks

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

From the smallest living organism to the greatest living being, it is water that keeps all biological life and human activities alive. Water, which has so much importance in our lives, is unfortunately not infinite. Our available drinking and potable water resources are declining day by day. The need for water is increasing from day to day as the water resources remain constant despite the rapid increase in population.

The supply of water in drinking and potable water standards, or the supply of existing resources to consumers by bringing them up to drinking and potable water standards, obliges administrations to make extremely laborious and costly investments. The loss of a considerable amount of water in supply lines that is collected from different regions with very-high-energy costs and brought to Treatment Plants and then supplied to municipal water networks after being brought in line with the standards by undergoing various processes and chemical treatments, means a serious loss of labour, money and time for the administrations.

This issue has still not received the necessary attention despite high water losses in our country. A significant water resource will be gained if the losses that are averagely 36% can be brought to European standards. Serious measures should be taken to mitigate water losses. With simple and inexpensive measures, a considerable amount of loss can be prevented. The results of the Municipal Performance Measurement (BEPER) and Local-Information projects that were carried out by the General Directorate of Local Administrations revealed that some of the municipalities did not even keep the water loss statistics.

Effective loss mitigation programs should be implemented by the relevant agencies to reduce water losses in drinking water distribution networks. Specialist personnel should be trained about the prevention of losses and leakages and units that will keep the system under constant control should be established. All drinking water distribution networks and water storage tanks in the city should be archived by establishing geographical information systems and the old drinking water lines that have completed their economic life should be replaced with durable pipes that conform to today's conditions. The new lines that will be newly built in consumption regions should be constructed in line with the technical requirements and more attention should be paid to technical controls in order to avoid labour and installation errors that may occur during construction. The causes of losses and leakages should be investigated starting from the regions where water losses and leakages are intense, and the program implemented should include the topics of correct determination of water production, measured and recorded water consumption, and the rapid detection and control of physical losses. In order to prevent illegal use of water, construction of pipe line should be suitable regulations about water delivery systems. The system should be checked frequently at end of construction. Administrative (non-physical) losses should be controlled and water meter tracking should be made. Pressure management must be performed. It is a very effective way to reduce actual water losses by checking the regions where the loss rates are high with the equipment developed for detecting losses and leakages, faulty manufacturing should be determined and necessary repairs should be done as quickly as possible. This program should propose effective and economical suggestions for reducing water losses to the acceptable limits depending on the type and quantity of the losses detected.

Moreover, the consumers' awareness of water losses should be raised, hotlines should be established to quickly detect the losses and leaks occurred in consumption regions and intervene to them.

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APPENDIX

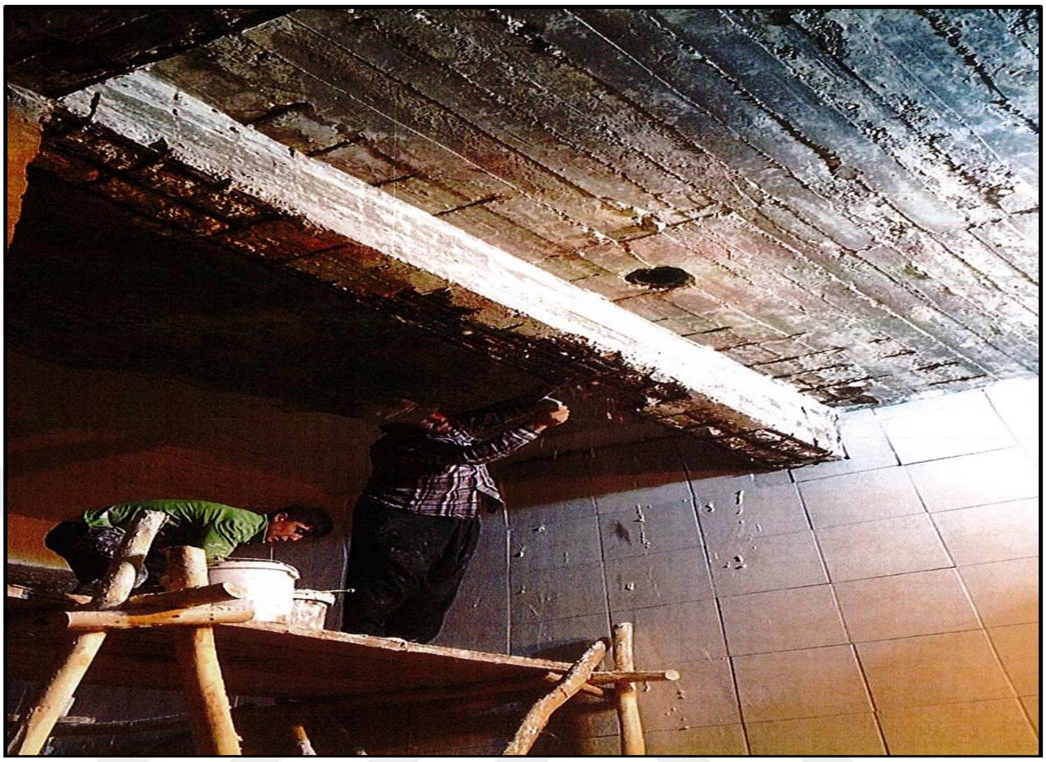

Figure A.1. Renewal of Water Storage Tanks

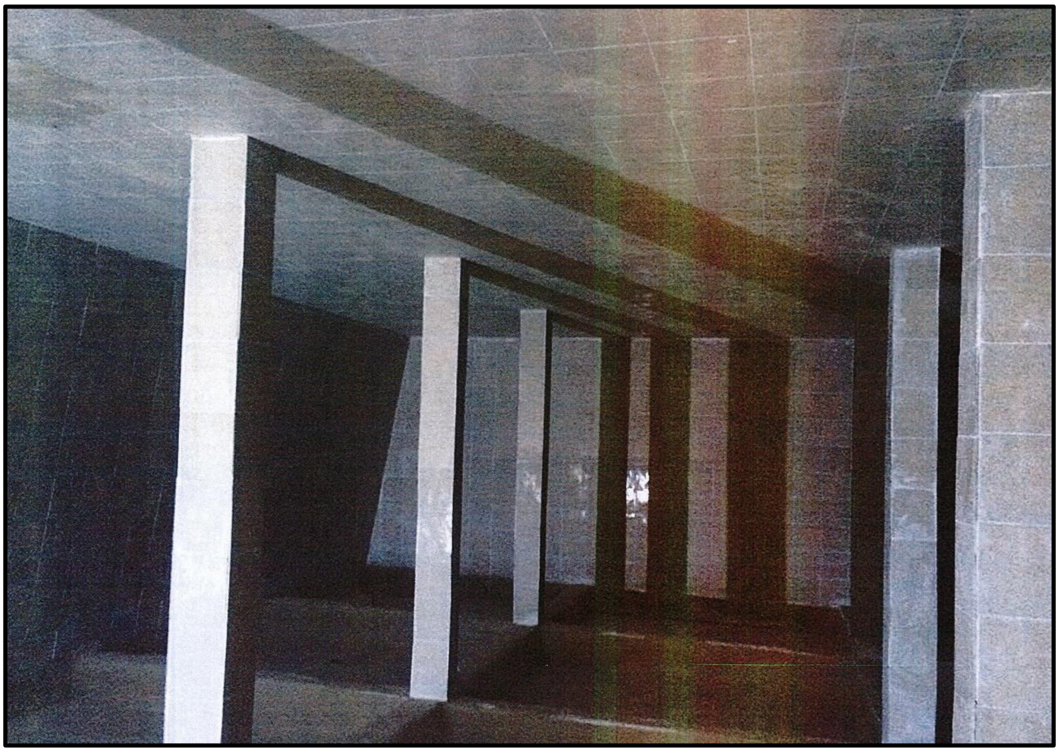

Figure A.2. Renewal of Water Storage Tanks

Figure A.3. Renewal of Water Storage Tanks

Figure A.4. Renewal of Water Storage Tanks

Figure A.5. Pipe bedding and covering in PE 100 pipe laying

Figure A.6. Pipe bedding and covering in PE 100 pipe laying