SUSTAINABLE MANAGEMENT OF DHAKA CITY WATER SUPPLY THROUGH DISTRICT METERING AREA APPROACH: A CASE STUDY

By

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A project work submitted to the Department of Industrial and Production Engineering, Bangladesh University of Engineering and Technology in partial fulfillment of the requirements for the degree of Master of Engineering in Advanced Engineering Management

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CANDIDATE'S DECLARATION

It is hereby declared that this thesis/project or any part of it has not been submitted elsewhere for the award of any degree or diploma.

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DEDICATION

To the Almighty

And

To my family

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ABSTRACT

One of the major issues affecting water utilities is the considerable difference between the amount of water put into the distribution system and the amount of water billed to consumers. Besides, water shortage and the future threat posed by changing climatic conditions has intensified the need for the development of appropriate water management approaches, which aim in keeping a balance between water supply and demand. District metering is a technique used to improve water distribution system. Dividing the open network into smaller, DMAs enables to manage the system more.

Data is collected from 10 DMAs situated in Banani, Gulshan, Mohakhali, Tejgaon, Tejkunipara, Kawranbazar, Shaheenbagh areas having 72 DTW, 41 DMC and 12500 service connections. The produced water volumes are determined through accurate measurement of monthly water production of DTW's, accurate measurement of monthly in and outflow through DMC's and main transmission Saidabad line. The consumed water volumes are measured from billing data using up-to-date service connection list. Using supplied volumes and consumed volumes, Non-revenue water (NRW) is calculated.

Operation and maintenance is a crucial element of sustainability of DMA system. Sustainability of DMA insists on mainly reduction of system losses in water distribution network. Besides, pressure management in distribution line, increase of surface water production, elimination of illegal connections and promoting legal connections in low income community areas help to keep resources in balance to sustain for next generation. DMA management helps to deliver quality water to customer with less system losses. The purpose is to describe the best means to smooth operation and maintenance, maximize DMA assets and equipment operational availability, while minimizing equipment downtime with optimum manpower. Prompt activities with continued focus on NRW are the basis for sustainable DMA management in the study area.

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LIST OF ABBREVIATION

ADB	Asian Development Bank
CBO	Community Based Organization
DMA	District Metered Area
DMC	DMA Meter Chamber
DTW	Deep Tube Well
DWASA	Dhaka Water Supply and Sewerage Authority
GoB	Government of Bangladesh
GIS	Geographic Information System
GPS	Global Positioning System
IWA	International Water Association
KPI	Key Performance Indicator
LIC	Low Income Areas
LGD	Local Government Division
LGED	Local Government Engineering Department
MIS	Management Information System
MODS	Maintenance Operation Distribution Service
MLGRD&C	Ministry of Local Government, Rural Development and Co-operatives
NGO	Non-Governmental Organization
NRW	Non-Revenue Water
O&M	Operation and Maintenance
POTW	Privately Owned Tube Well
PPP	Public-Private Partnership
RTU	Remote Terminal Unit
SCADA	System Control and Data Acquisition

CHAPTER 1
INTRODUCTION

1.1 Background

Water sustainability has got both local and global concern due to the loss of water in traditional system [1]. The increasing amount of water loss gives rise to amount of non-revenue water in conventional water distribution network system In order to maintain a balance between water supply and demand and to reduce the considerable amount of non-revenue water (NRW) in water distribution network the necessity for appropriate water management approaches has got intensified [2-3]. An estimate of in Asian cities by Asian Development Bank (ADB) finds that the average NRW rate of the total water produced in Asian cities is 30% [4-5]. Whereas in Dhaka city NRW rate is 23.40 %, while total demand of water is 2350 million litre per day (MLD) and total production is 2450 MLD [6]. In order to tackle NRW, District Metering Area (DMA) has got enormous potential as a water distribution network system.

District metering area (DMA) is a total turnaround program, which with limited resources achieve sustainability by tackling NRW and reduce as well as solving crisis related with water loss. A pilot program was carried out from March 2006 to December 2007 at Manikdi area (under Cantonment Thana), a densely populated narrow area of Dhaka which was a huge challenging area to distribute water because of substandard of household connections and leakage of water under very low pressure. Manikdi area was losing about 58% of its water to leakage and theft. Appropriate implementation of DMA brought down the physical losses from 53% in March 2006 to 14% in January 2007 and increased water pressure and improves meters and meter reading in the pilot area. Manikdi pilot project collected essential data for the design of the project and rate of NRW is founded as 8% [7].

Following successful pilot study, DMA is currently being applied as surveillance tool to make water supply system sustainable in Dhaka city by Dhaka Water Supply and Sewerage Authority (DWASA) which has been formulated funding jointly ADB and GoB. This study aims to demonstrate how sustainable management of water in a DMA can reduce system loss in Banani, Gulshan, Mohakhali, Tejgaon, Kawranbazar, Tejkunipara, Shaheenbagh areas.

1.2 Problem Identification

The main flaws of old pipeline networks for a consistently raising population of a mega city Dhaka are as follows:
Water losses were 40.38% of total supplied water in Dhaka WASA distribution network at 2008. This indicates large amount of financial impact as authority don't get any revenue for it. It was expressed as operational inefficiency. So reducing NRW and maintain it below 15% is the main challenge.

Number of illegal connections and leakages were so high in past that it could not be eliminated without total replacement of old pipe lines. Besides, it was a prime reason of entering dirty water in network and causing water borne diseases. Absence of legal connections in low income community was a source of hampering social life.
As water supply in mega city Dhaka is mostly depending on ground water and water level is falling down, sustainable management is required to supply water to all customers for a long period. So, new approach is much needed to manage limited resources in a way to benefit future generations.

1.3 Objectives of the study

The key objectives of the study are:

- To study performance after implementation of a DMA approach with focus on NRW
- To outline strategic approaches to improve DMA's operation and maintenance

1.4 Study Outline

Chapter 1 gives the background of the study and identification of the problems related to Dhaka city water supply. Basing on that, the study objectives and study area have been identified.
Chapter 2 presents the existing district metering area approach in various parts of world and their characteristics using secondary data. Alternative methods of DMA and reasons for choosing DMA is mentioned. Finally two parameters of DMA sustainability are pointed out.
Chapter 3 discusses the methodology of DMA implementation and data resources. Data acquisition and processing is figured out briefly.
Chapter 4 highlights DMA management and sustainability issue in case description.
Chapter 5 discusses NRW calculation process. Individual DMA's NRW trend and outcome is pointed out. Water production, consumption and energy efficiency performance is analysed and discussed in Chapter 5.
Chapter 6 concludes the study mentioning few limitations of the study. In study area how these studies benefit to achieve sustainable DMA is discussed in the contribution section. Based on the study, recommendations are made for future study on DMA.

1.5 Area of study

The jurisdiction area of Dhaka Water Supply and Sewerage Authority (DWASA) MODS Zone 5 is the study area. It consists of total 12847 square meters and includes Banani, Gulshan, Mohakhali, Tejgaon, Tejkunipara, Kawranbazar, Shaheenbagh areas. It's consisted of total ten (10) DMAs. These 10 DMAs cover both household and commercial connections altogether 15000 connections.

The prime reason behind choosing DWASA MODS zone 5 for this study as it's the only completed zone with full equipped DMA approach. Another fact is that this zone offer much needed diversity to analysis overall pattern. For example, DMA

501, 502, 503, 504, 505, 506, 510 is characterized by medium population density, wide and planned roads. There are a number of government establishment and educational institutions as well as commercial and industrial estates. People living in this area are mainly of high income group. Meanwhile DMA 507, 508 and partial of 509 is characterized by both household and industrial area. Tejkunipara, Bagunbari, Shahinbagh, Nakhalpara area of DMA 509 is densely crowded area and roads are not well planned and narrow. Two large slums of Dhaka, Koril and Satala are also situated respectively in DMA 502 and 507.

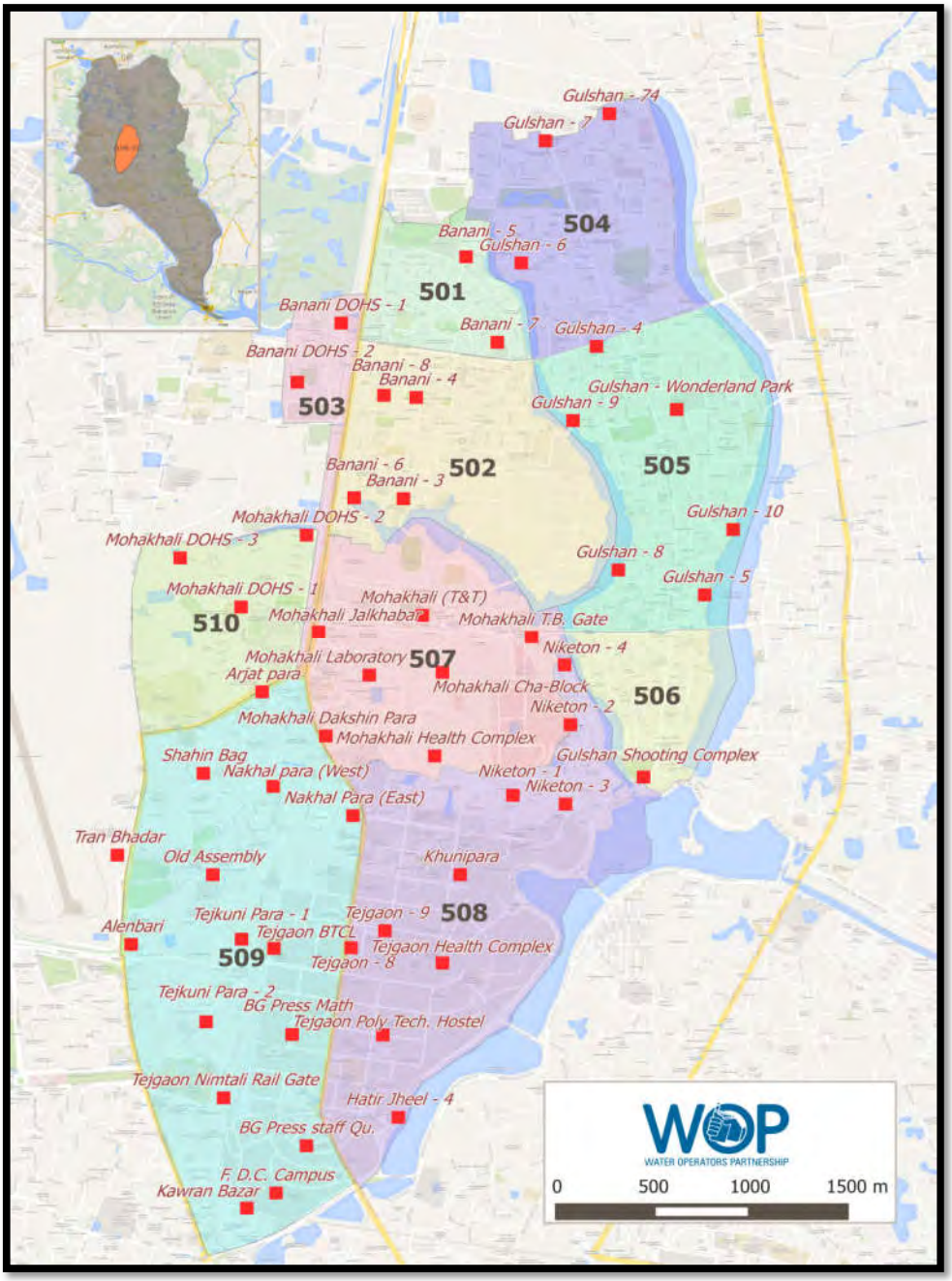

Figure 1.1: Map of study area (Source: Water operator partnership 1)

The boundary and size of a DMA depends on the topographic conditions and the number of water users. Typical number of water connection is varied from 336 to 3,751 per DMA. The boundary of a DMA is defined to include a standard number of water supply resources. So, study area provides a clear image of real consequences.

CHAPTER 2
LITERATURE REVIEW

2.1 Background

The concept of DMA management was first introduced to the UK water industry in the early 1980s by the then UK Water Authorities Association. UK water industry implemented it first in the City of Plymouth with the aim of reducing leakage [8]. DMAs are being introduced into the distribution networks of many countries of the world, with practitioners following the detailed guidelines produced for them by members of the Water Loss Specialist Group - of the International Water Association (IWA) [9]. Central and West Asian countries is pioneer to introduce DMA in Asian water network. In Southeast Asia, Vietnam, Thailand, Indonesia, Philippines implemented DMA in their respective water distribution network [10].

In Bangladesh, DWASA has started full phase implementation of DMA in MODS zone 5 under Dhaka Water Supply Sector Development Project (DWSSDP) in recent years. The objective of establishing DMA is to provide sustainable and reliable water supply in Dhaka city.

2.2 Various DMA related project

DMA is a very popular approach to deliver better service to consumers and improve water distribution network. In most cases, these successes are achieved through a long-term commitment by utility management and the government.

Managing water loss following DMA approach is regarded as the most critical function in Phnom Penh Water Supply Authority's (PPWSA) operation because a decrease in water loss results in an increase in billings and income. In 1993 the rate of water loss experienced by PPWSA was 72%. This rate decreased to approximately 7% in 2016. This achievement over a relatively short time frame resulted in PPWSA earning high praise from a number of international institutions and PPWSA being awarded a number of trophies and world awards [11]. Thailand is another example of successful implementation of DMA approach and it's in process of continuous improvement. In the past, the water loss rate in Thailand exceeded 50%. The Metropolitan Waterworks Authority (MWA) and Provincial Waterworks Authority (PWA) reduced this to less than 30% in 2012 [12]. Another biggest NRW reduction project anywhere in the world found at Maynilad Water Services in Philippines. In 2007 the NRW stood at about 66% of production and within Maynilad services area about one third of the nine million people were unserved with piped water. About this time Maynilad changed its ownership and management and entered into a DMA approach with Miya, a global NRW management group. Between 2008 and 2013 the NRW was lowered from 66% to 35% and this represented a saved volume of water of around 800,000 cubic meters per day or enough to serve a big city [13].

2.3 Justifications for choosing DMA

DMA approach offer competitive advantages compared to other alternatives due to technical, geographical and financial aspects. Main factors behind choosing DMA is mention below:

- Suitable to design considering geographical characteristics of Dhaka city
- Reduction of NRW
- Conjunctive use of surface Water and ground Water
- ADB giving backup financial aspects
- Diagnoses based on practical implementation of DMA in Manikdi
- Full implementation is possible in Dhaka city
- Illegal service connections are legalized
- Satisfaction of both DWASA and customers

2.4 Sustainable DMA parameters

Globally it is accepted that reduction of water losses is key indicator to achieve sustainability. Low NRW is the focal point to make DMA sustainable [14]. If NRW is higher, there is high probability of leakages in network, water contamination and wastage of both water resources and finance.

To achieve sustainable development, it's mandatory to have access of distributed network to all class of people in a society [15]. Previously water connections in low income communities (LIC) did not recognize and not integrated in network due to thousands of illegal connection and illegal water business. Again, sustainable development goal (SDG) number 6 highlight the need of ensures availability and sustainable management of water for all [16]. This social parameter is also considered in this study.

CHAPTER 3
CASE DESCRIPTION

3.1 DMA Management

DMA management is vital to ensure sustainability of DMA approach. It helps to deliver quality water to customer with less system losses. The purpose is to describe the best means to smooth operation and maintenance, maximize DMA assets and equipment operational availability, while minimizing equipment downtime with optimum manpower. Prompt activities with continued focus on NRW are the basis for sustainable DMA management in the study area.

3.1.1 Staffing policy

Staffing policy is concerned with selecting employees who have the skills required to perform particular jobs. Staffing policy can be a tool for developing and promoting a corporate culture. An ethnocentric approach to staffing policy is followed to manage DMA in study area.

Due to limitation of manpower, staffing policy is the key to maintain discipline at DMA areas. The Executive Engineers (EE) is responsible for executing all types of DMA management. DMA Manager is EE's main co-coordinator and responsible person to conduct smooth DMA O&M. As lots of work need to carried out in MODS zone, Sub-divisional Engineer (SDE) and Assistant Engineer (AE) work together with DMA manager to ensure proper DMA assets operation and maintenance.

According to work plan of DMA Manager, Deputy Manager(s) supervises and carried out relevant field work taking assistance from DMA caretakers like PLM, APLM. Sub-Assistant Engineer(s) help DMA Deputy Manager(s) in their respective DMA.

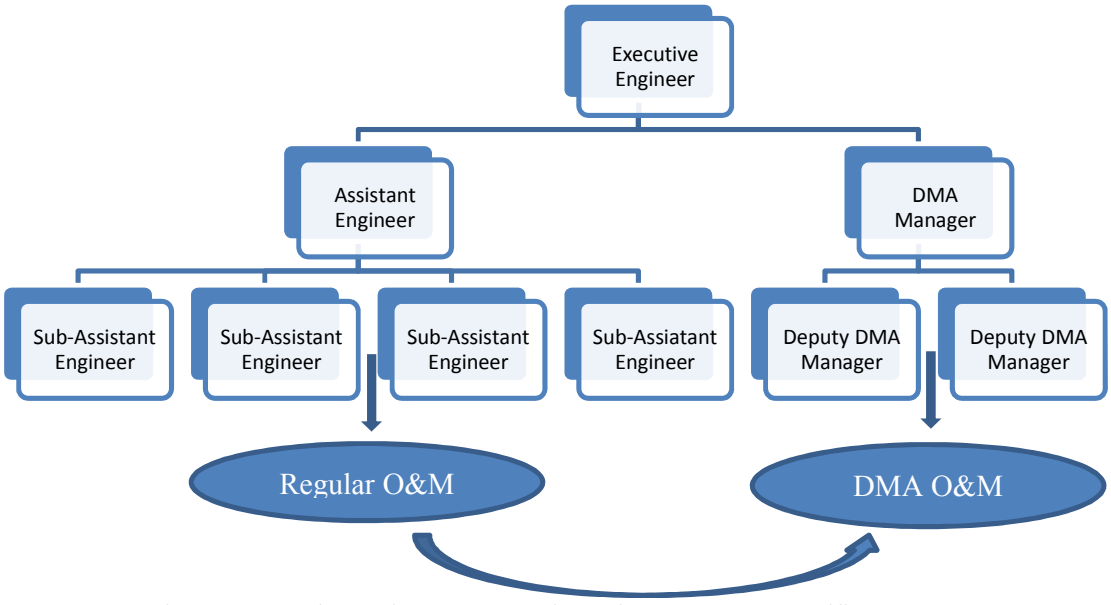

Figure 3.1: Schematic representation of MODS zone staffing.

Each DMA has minimum single caretaker. DMA caretaker takes care of every asset of a DMA i.e. pipe line, sluice valve, DMC, washout, ARV, house connections following monthly maintenance plan.

DMA Management Team would work as a parallel unit at the MODS zone offices side-by-side the existing unit responsible for operation and maintenance of the DMA's.

3.1.2 DMA Operation & Maintenance

DMA Operation and maintenance (O&M) is a crucial element of sustainability of DMA system. O&M activities, which encompass not only technical issues, but also managerial, financial and institutional issues, must be directed towards the elimination or reduction of the major constraints which prevent the achievement of sustainability.
Operation and Maintenance refers to all the activities needed to run a water supply system, except for the construction of new facilities. The overall aim of operation and maintenance is to ensure efficiency, effectiveness and sustainability of water supply facilities.

3.1.2.1 DMA Operations

DMA operations follow Standard Operating Procedures (SOP) for normal operations for pipelines and other assets, including service connections. Emergency operations have been considered for special situation such as chlorine leakage in a PTW or failure of a PTW.
Normal operation consists of periodic patrolling, inspection, servicing and surveys in order to prevent pipeline accidents and leakage. In order to minimize damages when a leak occur an on-duty system organized into maintenance team that can respond in the event of an emergency. Water lorry and portable vehicles are kept ready to provide emergency supplies to areas where shortage or cut off from water.

3.1.2.2 DMA Maintenance

A series of maintenance work is carried out in weekly, monthly and yearly plan, both in schedule and unscheduled maintenance activities. Network inspection, flushing of the well, cleaning and greasing of mechanical parts and replacement of items with a limited lifespan is done as a part of DMA preventive maintenance. It sometimes also includes minor repairs and replacement as dictated by the DMA caretakers. Regular inspections and surveying of DMA assets is essential for management of the services in the service area of the DMA.
Inspections of assets are done by walking, looking and touching principle by the DMA caretakers. Work plan is planned and supervised by DMA Manager while DMA Deputy Manager is completed surveillance tasks taking assistance from DMA Caretakers.

Pipeline patrols are implemented systematically based on a set of implementation program. Pipeline drawings, measuring tape and inspection report sheets are carried with safety equipment during patrols. Pipeline appurtenance inspection is categorized

in following job:

- Sluice valve, air valve and Non-return valve inspection and servicing
- Valve chamber inspection and servicing.

Pipe flushing is done to drain turbid water through wash out and systematically flushing sediment deposits and scale deposits in the distribution pipes. Particular importance is given in DMC's NRV, Bulk Water Meter, Pressure Gauge, and PRV/PSV during maintenance work. Sluice valve maintenance is done by recording status of valve Nr, valve size, stroke, valve visibility and reachability, valve lid functionality.

Corrective maintenance is also critical for the maintenance in the DMA of production sources. FM division has done the task as troubleshooting when defects occur at PTW or inflow/outflow bulk meter, pressure reducing stations and repairs of electromechanical parts i.e. pumps, switchboards, control, pressure valves.

3.1.3 Asset management

A Systematic process of effectively maintaining, upgrading and operating assets of study area. It simply do the right thinks at the right moment.

Table 3.1: Assets list of study area

DMA	Pipeline Length (m)	Hydraulic Assets	Breakdown of Assets
501	10476	121	Gate Valve: 90; Wash Out: 2; ARV: 13; PRV: 2; PSV: 6; NRV: 8; BWM: 0
502	24366	179	Gate Valve: 142; Wash Out: 4; ARV: 9; PRV: 6; PSV: 6; NRV: 12; BWM: 0
503	3753	40	Gate Valve: 20; Wash Out: 1; ARV: 1; PRV: 1; PSV: 5; NRV: 6; BWM: 6
504	23961	104	Gate Valve: 98; Wash Out: 5; ARV: 1; PRV: -; PSV: -; NRV: 12; BWM: 12
505	27751	143	Gate Valve: 135; Wash Out: 6; ARV: 2; PRV: -; PSV: -; NRV: 8; BWM: 8
506	7754	48	Gate Valve: 44; Wash Out: 2; ARV: 2; PRV: -; PSV: -; NRV: 10; BWM: 10
507	30288	190	Gate Valve: 179; Wash Out: 4; ARV: 7; PRV: -; PSV: -; NRV: 6; BWM: 6
508	36239	186	Gate Valve: 177; Wash Out: 5; ARV: 4; PRV: -; PSV: -; NRV: 7; BWM: 7
509	59458	357	Gate Valve: 340; Wash Out: 12; ARV: 5; PRV: -; PSV: -; NRV: 10; BWM: 10
510	10219	81	Gate Valve: 75; Wash Out: 3; ARV: 3; PRV: -; PSV: -; NRV: 4; BWM: 4

Factors are kept in mind to manage all asstes of study area are understanding performance of existing assests and collecting data and turning it into useful information. Based on it, priortising the list assets to rehabilitate or replace.

3.1.4 Automation

Data is being accumulated by shifting collection method manual to automatic by introducing Supervisory Control and Data Acquisition (SCADA) and data logger (software: XiLog) in some areas. Obtained data will be compared with manually collected data and find out the reliable ones. Mapping software i.e. ArcGIS and QGIS are used extensively for mapping and marking individual assets. SCADA, GIS and data loggers role are described below:

Synchronizing with SCADA

The operation of DTWs needs to be synchronized with the desired inter-DMA flows and pressures, rationing schemes, and energy saving requirements. In order to achieve the enhanced network operation, flows and pressures at study area 5 DMAs have SCADA at 16 DTWs and 5 DMCs.
SCADA works in 4 steps to measure and record Water flow, Pressure, ground water level of DTWs and status of chlorine. Working steps are data acquisition, network data communication, data presentation and control. Pump run/off and chlorine status of full or empty in cylinder are controlled in digital input or output segment. Pressure, flow, water level and power consumption are controlled in analogue input or output segment.

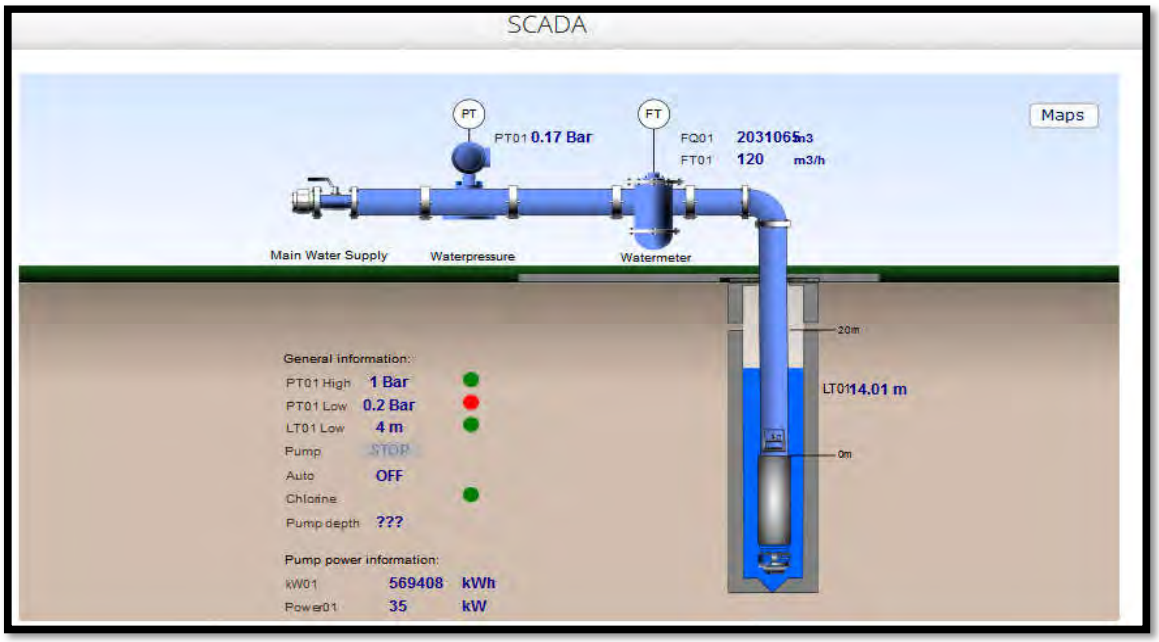

Figure 3.2: Individual DTWs status in SCADA

It can access quantitative measurements of important parameters both at real time and over time. It also can detect and correct problems as soon as they begin and measure trends over time to discover and eliminate bottlenecks and inefficiencies in the process.

GIS maps

GIS Map is very important to locate and describe the distribution network, district meter chambers and customer connections. GIS reading of house connection, leakage repairing is taken by DMA Manager in a prescribed sheet during the execution of works. This information is updated by the same DMA Manager to the Asbuilt Drawing.

ArcGIS and QGIS software is used in this study. QGIS is extensively used as it is free version and more easy to use. All details regarding HC, meter, DMA, Zone, owner name, account number, address, reference pipe, dia (mm), building ID, customer type, length (m), WGS_X, WGS_Y, elevation, street name, location etc. 24 information can collect any time from attribute table of QGIS. Required information can filter and estimation can be done prior to do the job. DMA 506 is represented in QGIS map in following section:

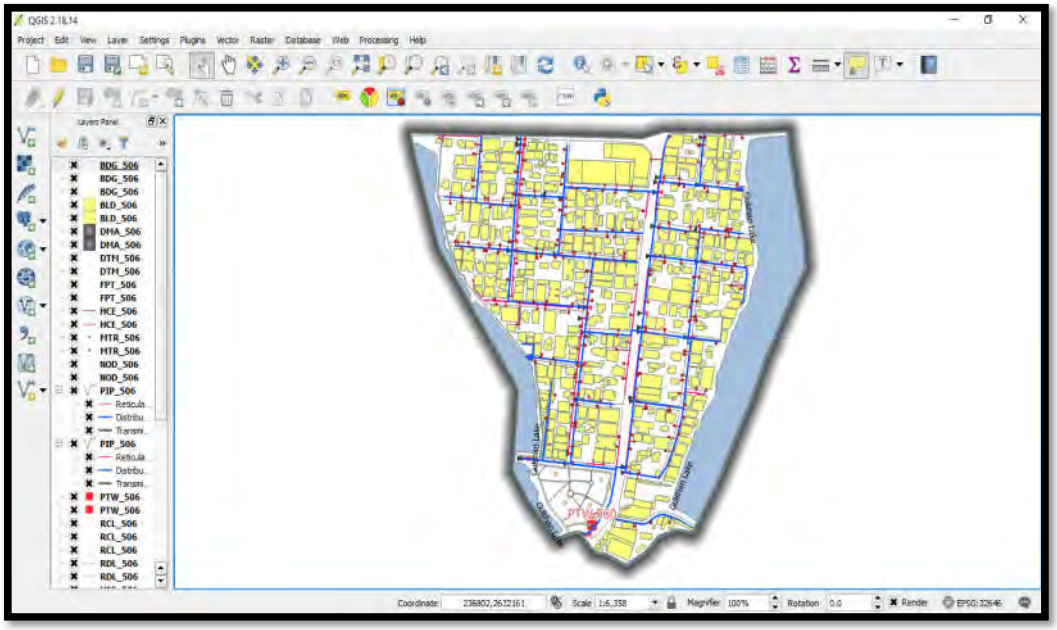

Figure 3.3: Map of DMA 506 from QGIS

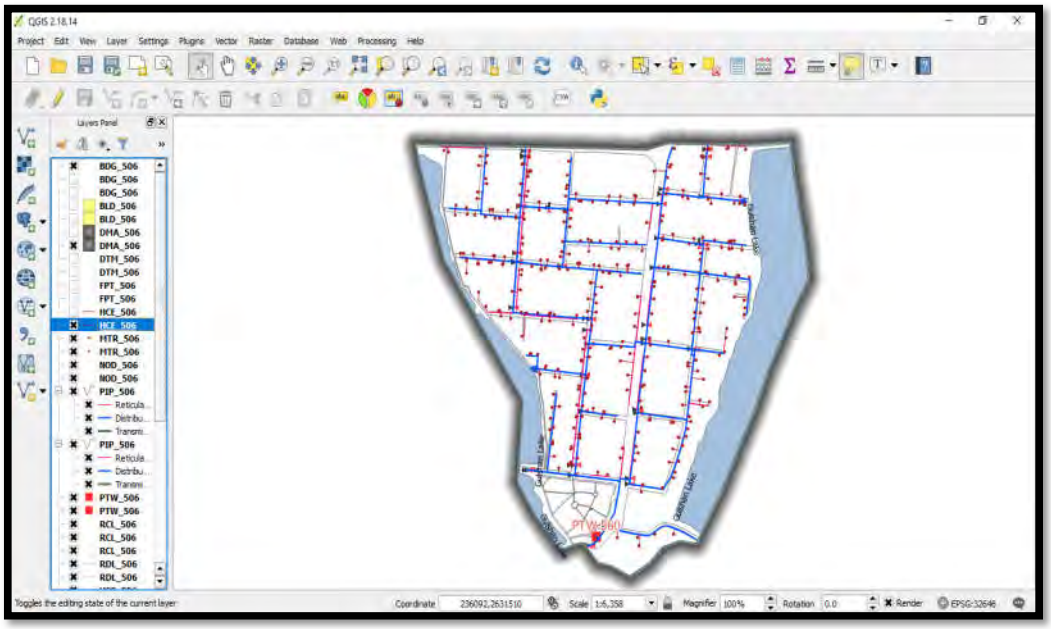

Figure 3.4: Service connections of DMA 506 from QGIS

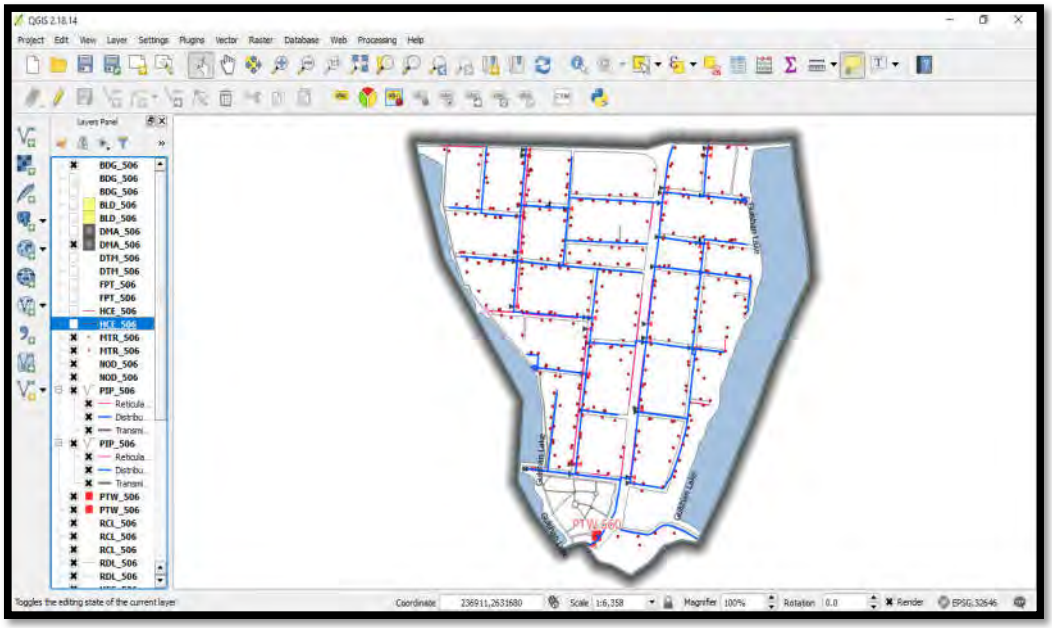

Figure 3.5: Meter of DMA 506 from QGIS

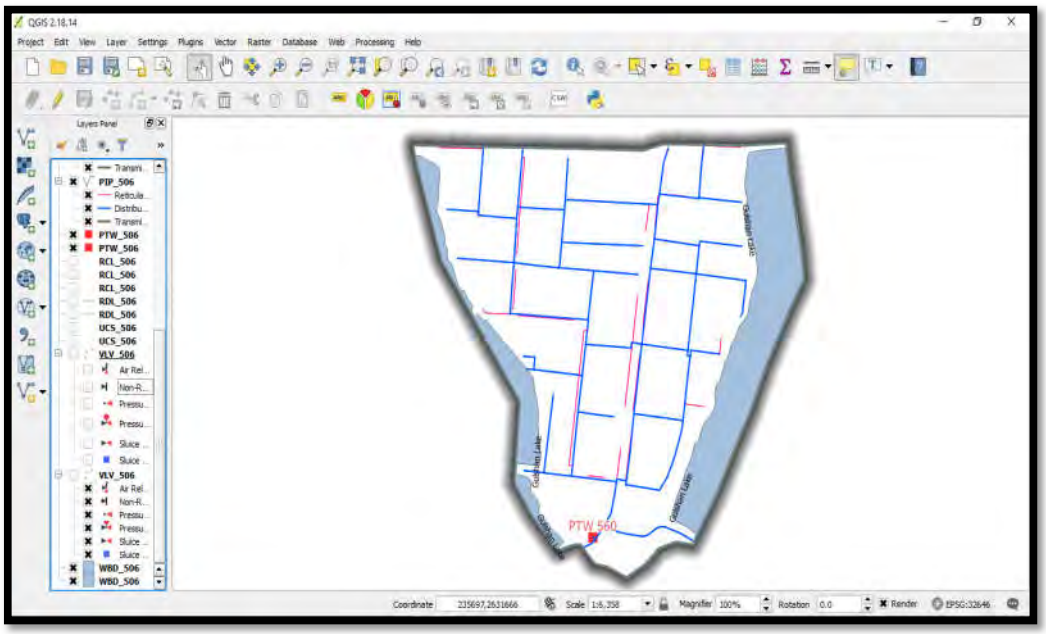

Figure 3.6: Pipe lines (reticulation=red, distribution= blue) of DMA 506 from QGIS

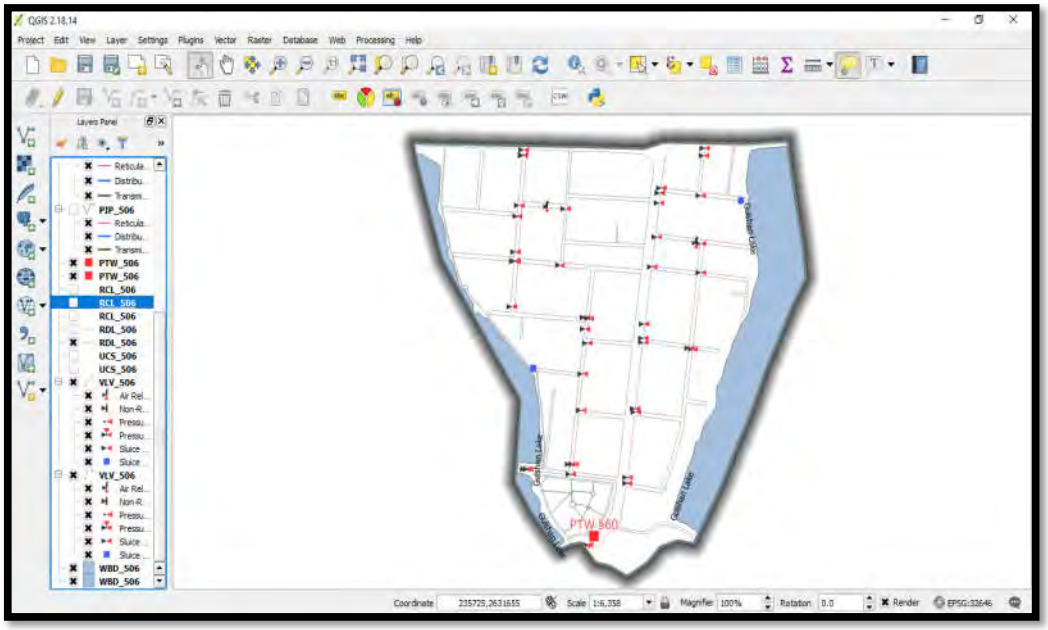

Figure 3.7: PTW and Valves location of DMA 506 from QGIS

DATA Logger

Data loggers are used to record the pressure and flows from DTW and DMC. It is an instrument which stores the raw data electronically so as to be able to transfer it to the computer with a data cable link. A simple push fit connection with the street main enables direct recording of pressure for future retrieval.

3.1.5 Water rationing

Water rationing is a legal and technical approach to combat water shortage with limited resources. The design and implementation of rationing schemes can greatly be enhanced in a network which is restructured into DMAs, as flows and pressures in a DMA can better be controlled and impact of rationing schemes is better understood. Secondly, flows between DMAs can be measured and therefore better be substantiated. From the perspective of the customer it is important that the rationing of water is known and predictable. This enables the customer to manage its water intake.
Unfortunately, at dry season water production falls short to the water demand in the selected areas of DMA 509. Nakhalpara and Tejkunipara areas of DMA 509 are forced to implement water rationing schemes from DMA 508.

3.1.6 Addressing customer complaints

Water complaints are addressed quickly in DMA approach as it's easy to isolate affected area by closing valves. In DMA system, hydraulic assets location is well-known in GIS map.

Common complaints are leakage, getting no water and dirty water. In piped network system, this problem was huge. At present this problem is reduced in great extant and customer is getting prompt feedback service. Statically, it is shown that how DMA approach help to increase customer satisfaction. In July 2016 to June 2017 period, 243 leakages found where only 90 leakages are found in July 2017 to June 2018. All of the leakages are rectified within short time.

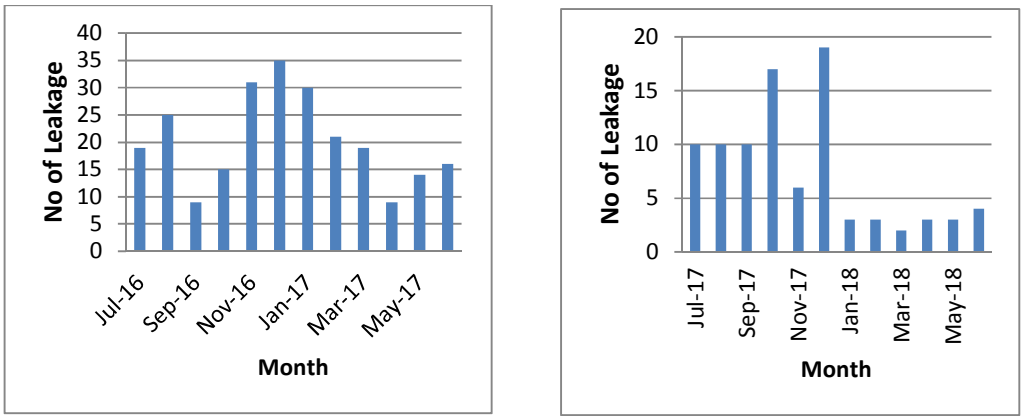

Figure 3.8: Comparison between numbers of leakage in study area over July 2016 to June 2017 with over July 2017 to June 2018

Anyone can lodge any water related problems by calling at 16162 from cellular device. WASA Link will forward this problem via SMS to respective technical personnel of respective DMA. Until the problem is rectified problem will be shown in central server. In case of any denial or negligence or delay action, this SMS will be forwarded to higher officials of DWASA. As a result of this process, general customer is getting positive feedback in term of service.

3.2 Sustainability of DMA

Sustainability of DMA insists on mainly reduction of system losses in water distribution network. Besides, pressure management in distribution line, increase of surface water production, elimination of illegal connections and promoting legal connections in low income community areas help to keep resources in balance to sustain for next generation.

3.2.1 Reduction of NRW

NRW is not a technical problem only. Commitment and good governance is the key to monitor NRW. Awareness and capacity building throughout the organization is needed to come forward to waste of money, customer complaints, inconvenience residence and water unviability.

Prioritising amoung the components of NRW is first step to monitor NRW performance. Immediate action is taken if NRW stands above 15% in any individual DMA of study area. As the DMA network is new, leakages are registered very few all over the study area. Thus physical losses of NRW are negligible. So address commercial losses more and more to reduce NRW in study area. Generally, there is a greater financial return on reducing commercial losses than for reducing the equivalent physical losses. Efficient use of scarce resources also helps to reduce NRW.

3.2.2 Pressure management

In DMA of study area, 1 bar pressure is maintained. But during commissioning this network is tested with 6 bar pressure. 1 bar pressure is maintained as an optimum value for whole network. To counteract this, high inlet pressures are required at peak times to ensure all customers receive a satisfactory supply.

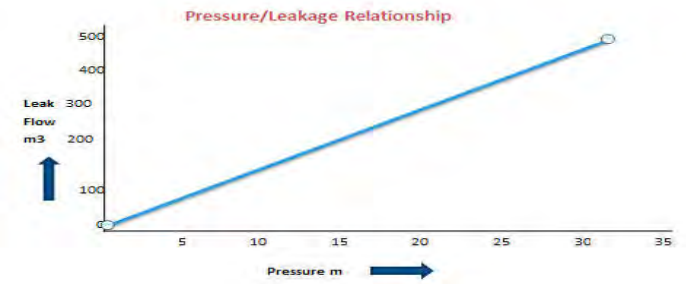

Figure 3.9: Pressure vs leakage graph

There is a direct link between the pressure in a distribution network, and the amount of leakage, bursts and consumption that occurs. High and fluctuating pressures cause burst mains and recurrence of leaks and higher household flows. Reducing pressures therefore has the following benefits:

- Reduce background leakage
- Reduce major leaks from bursts
- Extend lifetime of assets

- Encourage lower consumer water consumption

Reductions in pressure however, have an obvious impact on the levels of service to customers. DWASA authorities decide to maintain 1 bar pressure in whole network which can withstand 6 bar pressure.

3.2.3 Surface water production

To make DMA sustainable, surface water production is another important factor. Dhaka city has been experiencing a sharp declination in groundwater with more than 20 meters lower down during the last seven years at a rate of 2.81 meter per year. Present ratio of surface water and ground water production is 22% and 78% in DWASA. The groundwater supply inevitably and urgently needed to be augmented with treated surface water. However, treating surface water is much more technically complex and expensive than using groundwater. As there is no surface water production source within study area, surface water is importing from Saidabad water treatment water plant. Amount of surface water import in June 2018 is tabulated below:

Table 3.2: Surface water import in study area

DMA	DMC	Amount (m3)
506	Tejgaon-Gulshan Link Road	60208
507	IPH & Jalkhabar	22752
508	Savy Ice cream & Nabisco	131310
509	Mohakhali Bus Terminal & Holy Cross	116373

This figure is very low compared to ground water production. Being fully aware of the situation, DWASA chooses partially converting to surface water as a source for drinking water production, reducing its dependence on groundwater from 78% (2015) to about 30% (2021). For that purpose, DWASA has a number of surface water treatment plants under commission:

Table 3.3: Overview of DWASA's surface water treatment plants

Name of surface water plant	Status	Capacity
Chandirgath	In service	50000 m3/day
Goodnail	In service	75000 m3/day
Saidabad phase 2	In service	225000 m3/day
Saidabad phase 3	In process	450000 m3/day
Gandharbpur treatment plant	In process	500000 m3/day
Padma (Jashaldia) WTP	In process	450000 m3/day

Ground water is not a granted source as water level is decreasing day by day. To ensure security for future generation, surface water production is targeted to rise up to 70%.

3.2.4 Protect illegal connection

In piped water service, illegal connection was so high that it became almost impossible to distribute quality water due to thousands of leakage in main transmission line. Illegal connection is harmful for network as its prime reason for losing revenue. Besides, dirty water enters in network which cause health hazard like water borne diseases.

Figure 3.10: Illegal connections in DMA 507

DMA approach is rehabitated the old pipe lines completely with new HDPE pipe in study area to resolve this massive problem. Each and every service connection in DMA system is given legally following standard operating procedure.

To protect illegal connections, no connections are allowed from transmission mains lines (315 mm dia). This is designed to transfer water from one area to another. Distribution Pipes with having nominal diameter between 110mm and 315mm are designed to distribute water within DMA. Service connections from pipes above 200mm diameter are not allowed from these lines. Reticulation lines (Diameter between 75mm and 110 mm) are installed parallel to distribution mains or in tertiary roads to provide service connection.

After implementation of DMA in study area, only Mohakhali Health Institute Quarter is found to have 247 illegal connections at DMA 507. Prompt legal action is taken against the consumer to prevent reoccurrence of event. Illegal connections are disconnected by Mobile court with presence of Executive Magistrate.

3.2.5 Legal connections in LIC

A strong correlation no doubt exists between high NRW and high levels of unserved urban poor. The poor do use water, and often it is water illegally obtained from the formal piped systems of water utilities. Dhaka's low income communities (LIC) live predominantly in informal, often temporary, settlements on public or private land, with an average population density of 220.000 inhabitants per square km. Average

density of Dhaka city is 30000 per square km. So in a LIC area more than 7 times people are living compared to urban area.

Previously, the water demand in LIC areas has not been fully recognized and as a consequence LIC areas have not been systematically integrated in the design and construction network. Huge efforts are taken to integrate LICs in DMA networks in study area to abolish illegal connections, which highly contribute to NRW. DWASA, together with several donors, NGOs and CBOs, is undertaking a number of water and sanitation projects to tackle the inadequate service provision and total beneficiary about 0.4 million with improved water services. A comparative scenario of two biggest slums in Dhaka Korail and Sattala is presented below:

Table 3.4: Comparison between past and present status in LIC area

Past	Present
Korail had only 14 legal connections to DWASA	1775 legal connections in slums of study area, each one serving 15–25 households.
Controlled by “mustangs” (middlemen)	NGO runs Community Based Organization (CBO) to solve problem of middlemen.
Selling water from 65 illegal connections at 15–20 times the DWASA rate	Water is selling as regular tariff of DWASA
No contribution in monthly bill	Contributing evenly to the monthly bill

During the period of 30 April to 31 May 2018, total consumption in these accounts is 1096498.381 m3 and total bill is 38479686 BDT [17]. This figure out the astonishing success of connection to LIC areas because previously they, slum people consume bulk amount of water illegally and Government did not receive any revenue in return. Only successful implementation of DMA and legal connections to LIC made these possible.

3.2.6 Human resource development

Human resource development is an integral part for sustainable DMA management. It has a higher attrition rate as the employees feel stagnant and look for greener pasture elsewhere. Keeping up to date with the trends and the technology and occasional refresher courses add a new life to both the employee and the organization.

Training is the acquisition of knowledge, skills, and competencies as a result of the teaching of vocational or practical skills and knowledge that relate to specific useful competencies. Training has specific goals of improving one's capability, capacity, and performance. In addition to the basic training required for an occupation or profession, who recognize the need to continue training beyond initial qualifications to maintain, upgrade and update skills throughout working life. The types of training provided for DMA management as:

- Basic Training
- Field Training
- On Job Training

Field/Physical training concentrates on mechanistic goals, training-programs in this area develop specific skills, often with a view of peaking at a particular time. Some physical training programs focus on raising overall physical fitness. The field training exercises are usually practice which provides fairly realistic scenarios and situations based on actual situations. The field training is as installation of piping system, operation of the system, maintenance of the networks, repairing of the equipment, plants operating and adjusting. On-the-job training takes place in a normal working situation, using the actual tools, equipment, documents or materials that trainees will use when fully trained.

3.3 Kaizen philosophy in DMA approach

The philosophy of kaizen is applied to manage and to achieve high accuracy in DMA management. Kaizen is a system that involves every employee – from senior management to the DMA caretaker. Following kaizen philosophy, DMA approach encourages everyone to come up with proposals for a small improvement on a regular basis and work as a team.

As an action plan, Kaizen is about organizing events focused on improving specific areas. These events involve teams of employees at all levels, with an especially strong emphasis on involving DMA Deputy Manager and DMA caretaker team. As a philosophy, Kaizen is about building a culture where all employees are actively engaged in suggesting and implementing improvements.

Kaizen event in DMA management in study area is like this:

- Target NRW level below 15%
- Review the current state of NRW and develop a plan for improvements.
- Implement improvements
- Review and fix what doesn't work.
- Report results in KPI, monthly overview and DMA maintenance report.

Thus, consistent application of Kaizen as an action plan creates tremendous long-term value by developing the culture that is needed for truly effective continuous improvement.

CHAPTER 4
METHODOLOGY

4.1 DMA implementation

DMA is hydraulically isolated area which has inter-connectivity with adjacent DMAs. It can conjunctively use surface water or ground water and both. For example, DMA 501 has four water sources: groundwater, surface water, conjunctively managed water systems, and, if necessary, water from an adjacent DMA.
Scaling up the DMA approach involved breaking down large, sprawling network into DMAs, each one hydraulically isolated independent of the other areas in water pressure, quantity, and quality. Each area has intake and exit meters to measure supply within the area. Each consumer has a functional meter to determine consumption. It's easy to know exactly what amount of water is going into an area and what's going out. It's all measured. DMA has been rehabilitated by using HDPE pipes. For installing pipe, the HDD method has been applied first time in Bangladesh. DMA is established in study area by following steps:

- Surveyed and model DMA area design
- Used trenchless technology (TT) horizontal directional drill (HDD) method
- Rehabilitated the existing whole network by HDPE pipe
- Replaced all service connection (SC)
- All illegal SC were legalized
- DMA under full pressure & Flow control
- GIS database

4.2 Source of data

Data for this study is collected from two sources. Primary data is taken from 10 DMAs of study area. It's collected and processed over period of July 2017 to June 2018. Secondary data is collected from Dhaka WASA official website and scholarly contents.

4.2.1 Primary data

72 DTW and 41 DMC is the source of production data. On the other hand, consumption volume of water is collected from 12500 service connections of study area. Besides, DMA maintenance and addressing consumers problem have produced relevant data like number of leakage, no water complaint etc.

4.2.1.1 Creating DMA and isolating area

Total about 12847 square meters areas in Mohakhali, Banani, Gulshan, Tejgaon, Tejkunipara, Kawranbazar, Shaheenbagh are divided into total ten DMAs. These 10 DMAs cover both household and commercial connections altogether 12500 connections.

Table 4.1: Individual DMA's area and location

DMA	Area (sq. meter)	Location	Thana
501	517	Banani (North)	Gulshan
502	1388	Banani, T & T Colony	Gulshan
503	322	Banani (West)	Gulshan
504	1185	Gulshan-2	Gulshan
505	1468	Gulshan-1 (Partial), Gulshan-2	Gulshan
506	534	Gulshan-1	Gulshan
507	1494	Mohakhali, T & T Colony	Gulshan
508	2236	Tejgaon Industrial Area	Tejgaon
509	2870	Tejkunipara,Kawranbazar, Shaheenbagh, Railway Area	Tejgaon
510	833	Mohakhali DOHS	Cantonment

DMA boundary is created considering existing production deep tubewell and path to connect surface water deliver line. DMCs are put in strategic location so that it can export or import water with near-by DMAs. Another important factor is number of house connection. As per IWA, single DMA can serve upto 3000 service connections depending upon type of use. If consumption is high, service connection number is low in respective DMA. DMA boundaries are tabulated below:

Table 4.2: DMA boundaries

DMA	North	East	South	West
501	Banani Graveyard	Banani Lake (DMA 504)	Kamal Atatuk Avenue Road (DMA 502)	New Airport Road (DMA 503)
502	Kamal Atatuk Avenue (DMA 501)	Gulshan-Banani Lake (DMA 505)	TNT math (DMA 507)	New Airport Road (DMA 503)
503	Dhaka Cantonment Area	New Airport Road (DMA 501)	Mohakhali DOHS (DMA 510)	Dhaka Cantonment Area
504	Baridhara DOHS Graveyard	Gulshan Lake	Madani Avenue (DMA 505)	Banani Lake (DMA 501)
505	Madani Avenue (DMA 503)	Gulshan Lake	South Avenue Gulshan 1 (DMA 506)	Gulshan Lake (DMA 502)
506	South Avenue Gulshan 1 (DMA 504)	Gulshan Lake	Hatirjheel	Gulshan Lake (DMA 507)
507	Gulshan Lake-TNT math (DMA 502)	Gulshan Lake (DMA 506)	Niketon (DMA 508)	Shahid Tajuddin Ahammed Avenue (DMA 510)
508	Niketon (DMA 507)	Hatirjheel	Hatirjheel	Shahid Tajuddin Ahammed Avenue (DMA 509)
509	Shahinbagh (DMA 510)	Shahid Tajuddin Ahammed Avenue (DMA 508)	Panthapath Tejgaon link Road	Kazi Nazrul Islam Avenue - Bir Uttam Zaiur Rahman Road
510	Banani DOHS (DMA 503)	Rail Line (DMA 503)	New Airport Road (DMA 509)	Dhaka Cantonment Area

DMA wise production DTW and DMC chambers are tabulated below:

Table 4.3: Status of DMA's DTW and DMC

DMA	No of DTW	Monthly Production (m3)	No of DMC	Water Export/Import
501	4	115810	4	Both
502	9	594850	6	Both
503	2	63000	2	Both
504	5	213320	6	Both
505	6	433295	4	Both
506	1	63840	5	Both

DMA	No of DTW	Monthly Production (m3)	No of DMC	Water Export/Import
507	7	436650	3	Both
508	14	535770	4	Both
509	20	1193961	5	Both
510	4	208380	2	Both

Table 4.3: Status of DMA's DTW and DMC (continued)

4.2.1.2 Identifying all service connections

Each DMA has an up-to-date service connection and customer list. It's made by conducting an initial customer survey of the service connections and customers in the DMA during the creation of the DMA. Identifying all service connections and customers with details information, GIS system is updated with GPS co-ordinates so that it can be traced any time for any necessity. Updated customer database with new connections, temporarily disconnected customers; permanently disconnected etc. is kept in record. Private owned tubewell (POTW) connections are also identified and keep in record. But these accounts do not contribute to supply water in DMA network. Thus it's excluded during calculation of NRW.
DMA code is added to each customer account in the customer database to allow DMA-wise selection of customer and billing data. DMA wise service connection is listed below:

Table 4.4: DMA wise service connections

DMA	No of connections
501	448
502	963
503	194
504	722
505	1175
506	336
507	2362
508	1939
509	3751
510	591

4.2.2 Secondary data

To compare various parameters secondary data is used. Secondary data is accessed from Dhaka WASA website, DMA Operation and Maintenance Manuals and research on DMA articles.

4.3 Data acquisition and processing

For NRW management both operational and commercial data are equally important. Operational data is collected by respective engineering personnel. Production report is made from Individual data of DTW and updated at central database. DMA Deputy Manager is responsible to collect DMC reading of every month with assistance of DMA caretakers. Then total supplied volume of water is found combining DTW production and DMC reading. DMA Manager is responsible to do this job. Meanwhile, commercial data is collected by revenue inspector. Raw data is given entry and forwarded to MIS Dept. Consumed billing data is collected from MIS dept and summarized by DMA Manager to calculate NRW. Finally, DMA Manager, the responsible person calculates NRW by combining both data.

4.3.1 Supply volume of water

The produced water volumes are determined through accurate measurement of monthly water production of DTW's, accurate measurement of monthly in- and outflow through DMC's; water in- and outflow from other DMA's and main transmission Saidabad line. Accurate measurement of supplied water volumes requires accurately functioning bulk water meters at the DTW's and DMC's, monthly meter reading of bulk water meters and verification of the produced and supplied volumes.

Important steps in monthly produced and supplied volumes:

- Checking whether meter reading figure at the beginning of the new month is equal to the meter reading figure at the end of the previous month per DTW and DMC;
- Reporting of problems with the accuracy of the bulk water meter and of the meter reading taken of each DTW/DMC; Repairing/replacing non-functional bulk water meters;
- Reporting for fluctuations in produced volumes;
- Frequent verification of accuracy of the bulk meter by using an electro-magnetic clamp-on flow meter.

4.3.2 Consumed volume of water

The consumed (billed) water volumes are determined through using up-to-date service connection list per DMA, accurate measurement of monthly consumed water, calculation of the billed volume per DMA consumed by all customers via service

connections and analysis of customer and consumption data. Important steps in monthly consumed volume per DMA:

- Obtain monthly billing list per DMA per customer from MIS department.
- Verification of duplicated accounts entry and removal of duplicated billed volume;
- Verification of missing accounts in billing list;
- Verification of consumption period > 30 days;
- Only take billed volume for account type General in account for NRW calculation, water supplied through network. The account type Tubewell in the billing list is volume of water billed to customers that has been extracted from their own private tube well (POTW).

CHAPTER 5
RESULT AND DISCUSSION

5.1 Calibration of NRW

The NRW is calculated as difference between supplied volumes and consumed volumes, expressed in m^3 and in % of total supplied volume.

5.1.1 Measurement of supplied water volumes

Supplied water volume is the combination of individual water pump and respective DMC reading. The total produced water volume (Q_{total}) into the DMA is water produced at DTW in the DMA (Q_{DTW}) itself plus additional supply from other DMA's transmission lines or minus supply to other DMA's through DMC's (DMC_{in} – DMC_{out}). For water importing, it is considered as positive and water exporting, it is considered as minus.

5.1.1.1 Deep Tube Well production

Deep tube well production volume is calculated from flow meter's litre per minute water production and respective running hours. Both figure is multiplied and converted to monthly production in cubic meter unit. Another method is used if flow meter is not working. For monthly pump production, meter reading at the beginning and at the end of month is taken and subtracting value is given the monthly production of individual pump. Water production of study area for April 2018 is tabulated in appendix section.

Total production of April 2018 is 3858876 cubic meter. Banani 8, Banani DOHS-1, Mohakhali Laboratory, Mohakhali DOHS-4 pump's flow meter is not working and these 4 pumps production is estimated based on monthly running hours and production litre per minute.

5.1.1.2 DMA Meter Chamber (DMC) reading

At the beginning of month DMC reading is manually collected. Only 5 DMC's has SCADA facilities and data are collected automatically. For monthly DMC reading, DMC reading at the beginning and at the end of month is taken and subtracted to get the value. If the date of DMC reading doesn't match exactly following next month date, interpolation is done considering duration of month to find expected reading. DMC reading for April 2018 is listed in appendix section.

No change is found in some DMC chamber because of inlet/outlet line is put off as respective DMA is self-sufficient in water production and no water rationing is needed. Summary of DMA wise DMC reading is tabulated below:

Table 5.1: DMA wise DMC reading of study area for April 2018

DMA	DMC Reading
501	0
502	-151200
503	0
504	0
505	-14270
506	60460
507	11830
508	131570
509	18520
510	-35510

Here, minus sign means water is exporting and positive sign means water is importing.

5.1.2 Measurement of consumed water volume

Volume of water consumption is measured from customer billing. Generally Revenue inspectors physically collect the customer bill. Subtracting the meter reading at the end and the beginning of mouth, consumption of respective month is calculated. A sample billing of DMA 506 for month of April 2018 is shown in appendix section.

Total consumption from 336 service connection for April 2018 is 126805.46 cubic meter. Zero consumption is found in 21 service connections. Most of in these 21 connections have duplicate service connection and giving minimum bill to keep connections in active.

5.1.3 NRW

Following International Water Association's (IWA) formula, NRW is calibrated for respective DMA. It is defined as the relative difference between produced (Q_{total}) and consumed/billed volume (Q_{billed}) to customers.

Total water supplied volume is the combination of Deep Tubewell production, DMC export or import value and any other factors like water selling from water hydrant. Here, only one DTW at DMA 506 with production 63840 cubic meter. Water coming through DMC 1400 ltr/min, so monthly import figure is 60480. Other factors for DMA 506 are zero.

Q_{total} (cubic meter)			
DTW	DMC	Others	Total
63840	60480	0	124300

Total water billed value is found from April month consumption of 336 service connections. Among 336 connections, 12 connections have private owned tube wells (POTW) with gross production of 7279 cubic meter. This amount is deducted from total consumed valve as it's a private owned production and no relation with zonal production. Other factor is zero for DMA 506 as there is no water ATM or no complain of overbill is recorded.

Q_{billed} (cubic meter)			
Consumed	POTW	Others	Total
126805.46	-7279	0	119526.5

NRW of DMA 506 for April 2018 = $100* [(Q_{total} - Q_{billed})/ Q_{total}]$
= 100* [(124300-119526.5)/124300]
= 3.8

Following same procedure, NRW for other DMAs have been calculated and tabulated below:

Table 5.2: DMA wise NRW calculation

DMA	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17	Jan-18	Feb-18	Mar-18	Apr-18	May-18	Jun-18
501	6	4.2	5	7	2	6	3.4	1	1.3	5.2	3.6	6.7
502	16.6	15	8.9	12.7	8.8	17.3	17	8.7	9.8	8	11.6	7.9
503	3.9	13.7	1	6.7	15.3	12.1	10.6	15.9	9.4	8.8	12.7	13.3
504	16.9	16	17.5	15.2	16.6	11.1	12.7	8.1	3.5	2.2	0.8	4.5
505	14.7	10.9	14.5	11.5	8.7	9	1.6	1.4	8.9	1.3	4.5	0.95
506	7.5	3.4	5.4	9.6	7.8	0.3	8.5	3.2	8	3.8	3.4	3.6
507	14.7	17.2	16.3	16	15.7	16.1	18.6	11.9	11.1	6.5	13.7	8.7
508	18.2	14.4	12.9	17.8	14.3	13.8	12.1	13.9	13	16	14.5	13.3
509	13	6.7	13.6	8.7	10.6	14.2	8.2	5.2	10.4	14.1	13.6	13.2
510	4.9	16.8	9.8	8.7	3.3	9	0.7	4.2	0.5	3.1	9.8	3.9
Average NRW	11.64	11.83	10.49	11.39	10.31	10.89	9.34	7.35	7.59	6.9	8.82	7.61

5.2 NRW trend Study

The objective is to monitor NRW levels in 10 DMA's under target value 15%, keep losses in control and find out the reason of high NRW.

5.2.1 Trend and outcomes of NRW in DMA 501

NRW of DMA 501 for period July 2017 to June 2018 is listed below:

Table 5.3: NRW of DMA 501

Month	DMA 501
July, 2017	6
August, 2017	4.2
September, 2017	5
October, 2017	7
November, 2017	2
December, 2017	6
January, 2018	3.4
February, 2018	1
March, 2018	1.3
April, 2018	5.2
May, 2018	3.6
June, 2018	6.7

The average NRW for the period July 2017 to June 2018 is 4.28%. NRW trend for DMA 501 is very good.

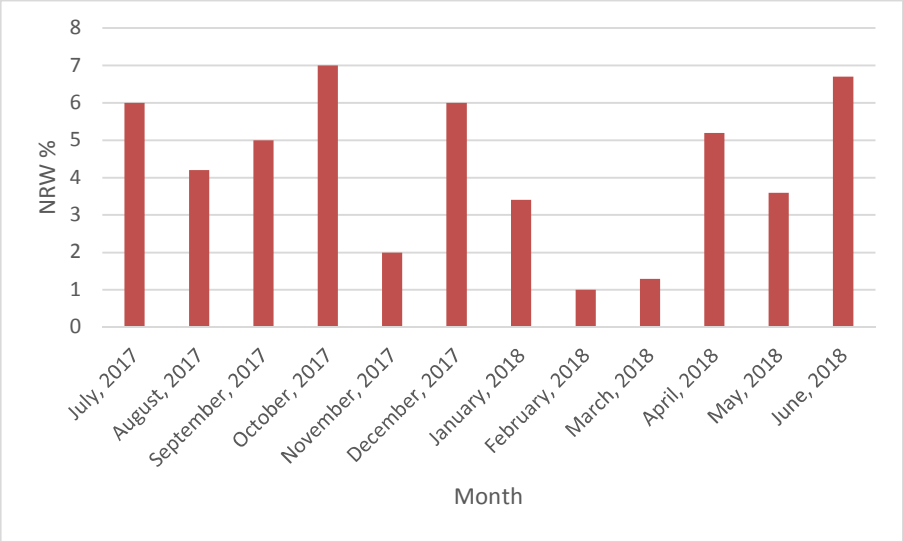

Figure 5.1: NRW trend of DMA 501

Field visit by Deputy Manager and Sub-Assistant Engineer with DMA care taker found overbill in 4 service connection. Banani 5 and 7 pump production was found respectively 1600 ltr/min and 1100 ltr/min. No export or import through 4 DMC was found due to in and outline valve is putted off due to sufficiency of water and good pressure.

5.2.2 Trend & outcomes of NRW in DMA 502

NRW of DMA 502 for period July 2017 to June 2018 is listed below:

Table 5.4: NRW of DMA 502

Month	DMA 502
July, 2017	16.6
August, 2017	15
September, 2017	8.9
October, 2017	12.7
November, 2017	8.8
December, 2017	17.3
January, 2018	17
February, 2018	8.7
March, 2018	9.8
April, 2018	8
May, 2018	11.6
June, 2018	7.9

The average NRW for the period July 2017 to June 2018 is 11.85%. But inconsistency in calculating NRW from July to December 2017 was found. After taking rectification action, average NRW from January to June 2018 is stood at 10.5%.

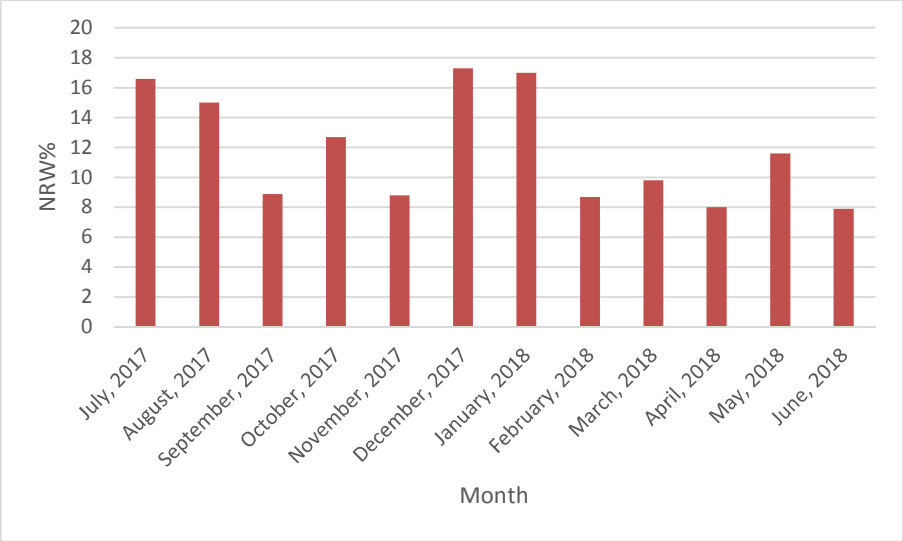

Figure 5.2: NRW trend of DMA 502

Two consecutives high NRW found at July and August 2017. The main reason of high NRW is not considering DMC reading of 6 chambers. Considering DMC reading, NRW is found 8.9% in September 2017.

Again two high NRW is found in between December 2017 to January 2018. After lots of study and field visit, reason is found that DMC 2C is reading not collecting

properly. It became full of water frequently for nearby car washing garage. DMC chamber and valve cover is arisen and reading is taken carefully at this DMC. Besides one Water ATM is open Banani 3 pump which reading is also considered and NRW continue to come in good range from April 2018.

5.2.3 Trend & outcomes of NRW in DMA 503

NRW of DMA 503 for period July 2017 to June 2018 is listed below:

Table 5.5: NRW of DMA 503

Month	DMA 503
July, 2017	3.9
August, 2017	13.7
September, 2017	1
October, 2017	6.7
November, 2017	15.3
December, 2017	12.1
January, 2018	10.6
February, 2018	15.9
March, 2018	9.4
April, 2018	8.8
May, 2018	12.7
June, 2018	13.3

The average NRW for the period July 2017 to June 2018 is 10.28%.

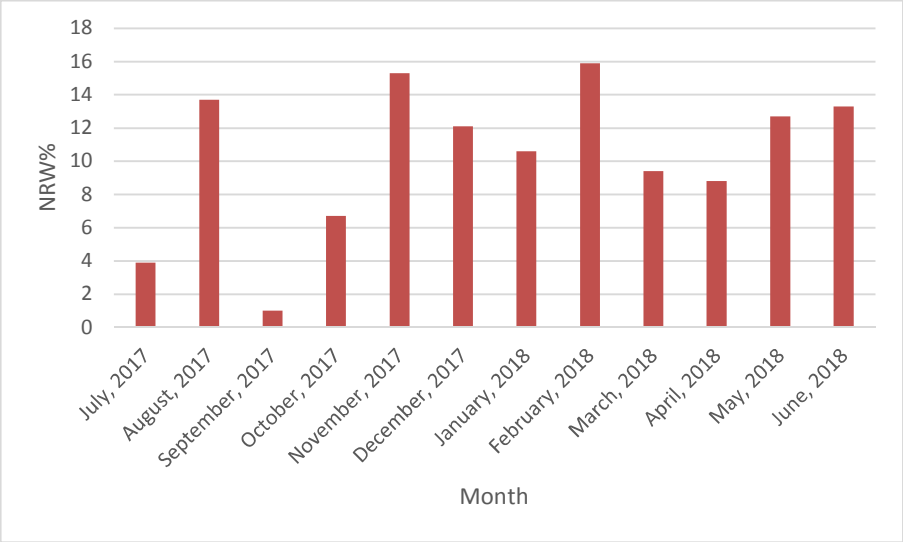

Figure 5.3: NRW trend of DMA 503

DMA 503 is the only DMA in study area which is not fully completed. Banani DOHS, locally is known as Old DOHS is not covered with DMA facilities. Reason behind that DOHS society did not permit to do construction work in DOHS Area.

But after seeing the advantages of DMA like no suction pump is needed and household reservoir automatically filled, they requested to do DMA in DOHS area.

NRW of November 2017 is calculated 15.3%. Then emphasis is given on field survey. Production report is rechecked with pump visit and whole areas house connection is visited and cross-matched with GIS and As-built data base. Some service connections are found which situated in DMA 503 but billed with DMA 507. After correction, NRW return to below 15%. In February 2018, total supplied water volume is increased due increase of production in two Banani DOHS pumps. As a result, gap between supplied and billed water is increased and NRW hit 15.9%. In following month consumption also increase 2703.89 m3 and gap is minimized and NRW continue to show good value.

5.2.4 Trend & outcomes of NRW in DMA 504

NRW of DMA 504 for period July 2017 to June 2018 is listed below:

Table 5.6: NRW of DMA 504

Month	DMA 504
July, 2017	16.9
August, 2017	16
September, 2017	17.5
October, 2017	15.2
November, 2017	16.6
December, 2017	11.1
January, 2018	12.7
February, 2018	8.1
March, 2018	3.5
April, 2018	2.2
May, 2018	0.8
June, 2018	4.5

The average NRW for the period July 2017 to June 2018 is 10.42%.

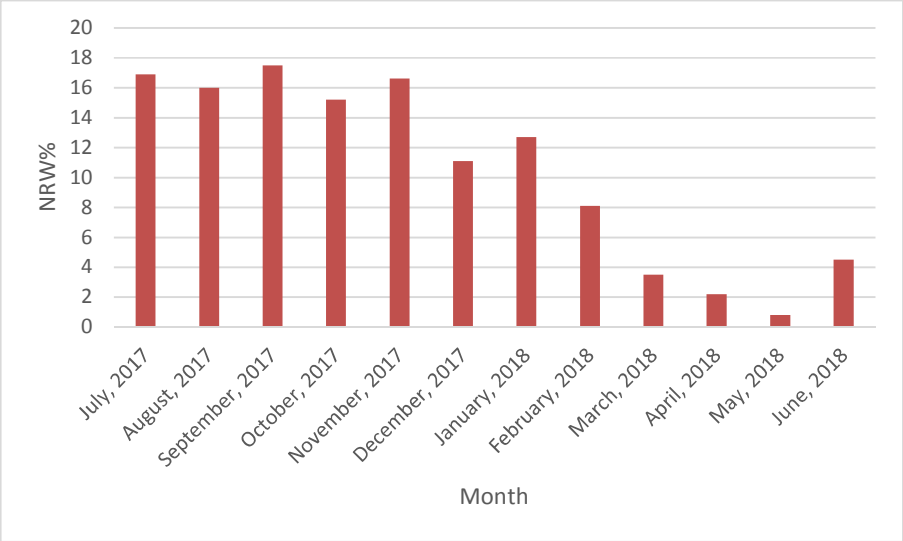

Figure 5.4: NRW trend of DMA 504

High NRW trend of DMA 504 is found in between period of July 2017 to November 2017. Lots of field survey is done to find out actual reason in period. All DMC reading is taken carefully and DTW production is cross-checked. Finally house connections consumption is checked at December 2017 in Road 63, Road 66 and Road 67 and found overbilled in customer accounts. Based on this field visit, the excess water volume is reduced from consumer and NRW is found good figure.

5.2.5 Trend & outcomes of NRW in DMA 505

NRW of DMA 505 for period July 2017 to June 2018 is listed below:

Table 5.7: NRW of DMA 505

Month	DMA 505
July, 2017	14.7
August, 2017	10.9
September, 2017	14.5
October, 2017	11.5
November, 2017	8.7
December, 2017	9
January, 2018	1.6
February, 2018	1.4
March, 2018	8.9
April, 2018	1.3
May, 2018	4.5
June, 2018	0.95

The average NRW for the period July 2017 to June 2018 is 7.33%.

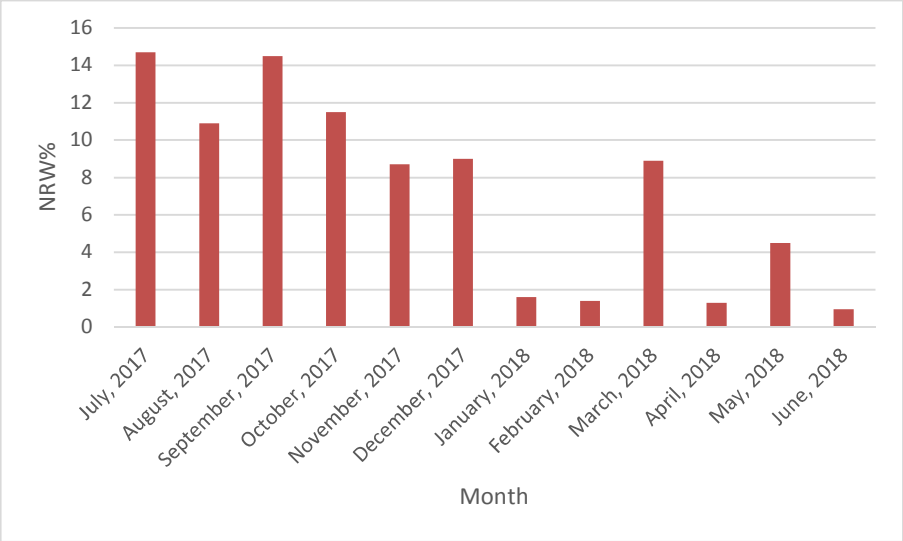

Figure 5.5: NRW trend of DMA 505

High NRW is found at July and September 2017. Probable cause is found that DMC 505A (Road-49/North Avenue) is exporting water to DMA 504. Besides, DMC 505-D (Gulshan to Baridhara Link Road) is also exported water in August 2017. From January 2018, public owned tubewell's (POTW) consumption is found enlisted in consumption report. POTW water does not come in DMA network. So, it can't be include in consumption report. Excluding 55 POTW 51233.2 m3 volume of from consumption report, total consumption stands 416962 m3 while production is recorded 424024 m3. NRW of January 2018 is stood at 1.6%. Same thing is done in consumption report fellow months of 2018 and NRW figure out in good range.

5.2.6 Trend & outcomes of NRW in DMA 506

NRW of DMA 506 for period July 2017 to June 2018 is listed below:

Table 5.8: NRW of DMA 506

Month	DMA 506
July, 2017	7.5
August, 2017	3.4
September, 2017	5.4
October, 2017	9.6
November, 2017	7.8
December, 2017	0.3
January, 2018	8.5
February, 2018	3.2
March, 2018	8
April, 2018	3.8
May, 2018	3.4
June, 2018	3.6

The average NRW for the period July 2017 to June 2018 is 5.37%.

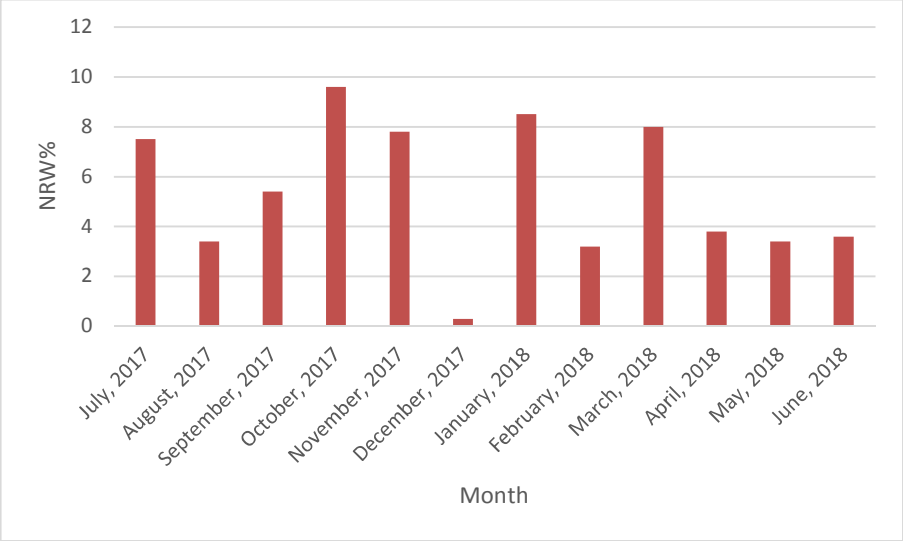

Figure 5.6: NRW trend of DMA 506

NRW trend in DMA 506 is started with very good percentage. DMA 506 has only one production pump at Gulshan shooting club complex and 5 DMC chambers. Good amount of water imported from Saidabadh at Shooting Club DMC 506-C. In October 2017, water consumption is recorded very high 135677.8 m3 but production is recorded low 44170 m3. After field visit reason is found that pump's water production is lower to 1704 liter per minute which was 1993 litre per minute in September 2017. At the same time water import in DMC 506-C (Gulshan shooting club) is metered 33460 m3 which was 63780 m3 in September 2017. DMC 506-C reading is cross-checked with clamp on meter and DMC import is recorded 1400 litre per minute. Then, DMC import figure in corrected and monthly figure stand at 60480 m3 and finally NRW stand at 5.4. In next month November 2017, water production is increase 54160 m3 with 2010 litre per minute and NRW is calculated 7.8%. In January 2018, 11 POTW's 6694 m3 consumption is deduced from consumption report following data handling error in DMA 505. Finally NRW stands at 8.5%. NRW trend in following month of 2018 is in very good range.

5.2.7 Trend & outcomes of NRW in DMA 507

NRW of DMA 507 for period July 2017 to June 2018 is listed below:

Table 5.9: NRW of DMA 507

Month	DMA 507
July, 2017	14.7
August, 2017	17.2
September, 2017	16.3
October, 2017	16
November, 2017	15.7
December, 2017	16.1
January, 2018	18.6
February, 2018	11.9
March, 2018	11.1
April, 2018	6.5
May, 2018	13.7
June, 2018	8.7

The average NRW for the period July 2017 to June 2018 is 13.87%.

Figure 5.7: NRW trend of DMA 507

NRW trend of DMA 507 is upward from July to December 2017. No DMC reading is found upto September 2017. Then maintenance work is done in all 3 DMC chambers. But not expected result is found considering DMC reading. Then again field visit is conducted in all DMA assets and find that huge amount of water selling from Mohakakhali pump hydrant and people are taking water from office compound for various purposes. Considering office hydrant and office meter reading, NRW is giving better result from January 2018. In February 2018, Mohakhali Jalkhabar DMC is repair as it goes under road divider of DNCC and it's possible to take DMC reading. After considering above observations, NRW is stood at 11.9%.

Overall trend of NRW is showing good performance compared to past period. It's suggested to keep this DMA under close monitor because 247 illegal connections are found at IPH Staff Quarter. Legal action is taken against consumers and illegal connections are removed in presence of Executive Magistrate. This is only incident of taking illegal connection is reported in whole study area.

5.2.8 Trend & outcomes of NRW in DMA 508

NRW of DMA 508 for period July 2017 to June 2018 is listed below:

Table 5.10: NRW of DMA 508

Month	DMA 508
July, 2017	18.2
August, 2017	14.4
September, 2017	12.9
October, 2017	17.8
November, 2017	14.3
December, 2017	13.8
January, 2018	12.1
February, 2018	13.9
March, 2018	13
April, 2018	16
May, 2018	14.5
June, 2018	13.3

The average NRW for the period July 2017 to June 2018 is 14.52%.

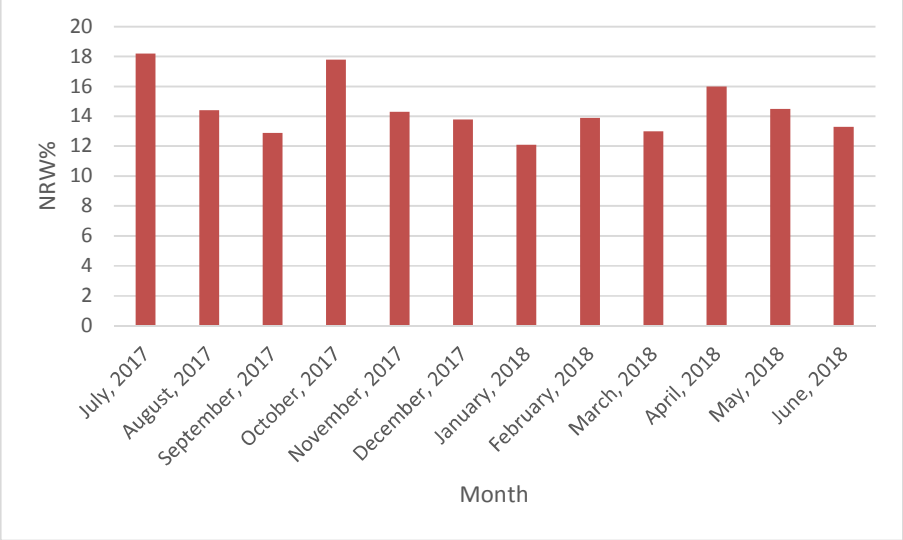

Figure 5.8: NRW trend of DMA 508

NRW trend shows that DMA 508 is inconsistent. It's third large DMA in study area with 1940 service connections. Main reason is DMC reading. Out of 4 DMC in

DMA 508, 508-D (Savy Icecream) DMC has high import volume. 508-C (B.G Press-Satrasta) DMC has moderate import. Little volume of water is imported from 508-A (Nabisco) DMC. This water is coming from Saidabadh surface water treatment plant.

Due to high value of NRW, several field visits are conducted throughout the DMA area. In February 2018, field visit found that Nikaton 4 pump has backflow of water. This pump is operated 12 hours per day and NRV is not functioning. Another reason is found that Tejgaon 8 pump hydrant is delivering water to DMA 509 by water browsers. Per day minimum 15 vehicle water is sold carrying 6000 litre water each. DMA 508 should be kept under watch-dog of management.

5.2.9 Trend & outcomes of NRW in DMA 509

NRW of DMA 509 for period July 2017 to June 2018 is listed below:

Table 5.11: NRW of DMA 509

Month	DMA 509
July, 2017	13
August, 2017	6.7
September, 2017	13.6
October, 2017	8.7
November, 2017	10.6
December, 2017	14.2
January, 2018	8.2
February, 2018	5.2
March, 2018	10.4
April, 2018	14.1
May, 2018	13.6
June, 2018	13.2

The average NRW for the period July 2017 to June 2018 is 10.96. NRW trend for DMA 509 is increasing which indicate that close supervision is needed.

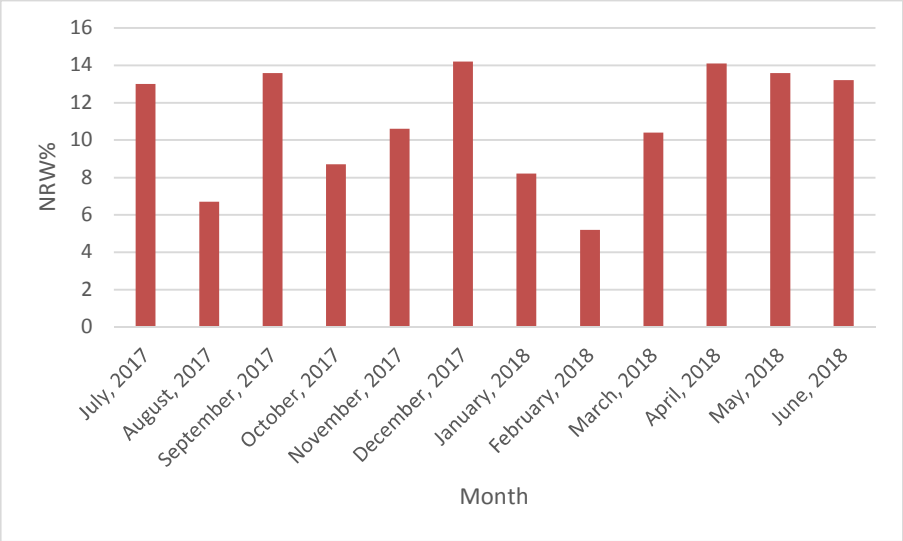

Figure 5.9: NRW trend of DMA 509

DMA 509 is the biggest DMA of study area. With 3750 plus service connection, this DMA areas have huge water demand. High NRW is recorded in December 2017. Mohakhali Bus terminal DMC is responsible for it. It's difficult to take reading due to huge traffic all the time and DMC was full of water. After proper maintenance, de-watering the DMC and timely reading from DMC chamber, this issue is solved March 2018. Another big factor is that this DMA is continuously delivering water to MODS zone 3 with four 4'' dia pipe at 0.5 bar pressure. ETV DMC is also exporting huge amount of water to adjacent areas which is out of study area. So, it's suggested to keep DMA 509 under close supervision all the time and keep maximum utilization of 20 DTW at best without any failure.

5.2.10 Trend & outcomes of NRW in DMA 510

NRW of DMA 510 for period July 2017 to June 2018 is listed below:

Table 5.12: NRW of DMA 510

Month	DMA 510
July, 2017	4.9
August, 2017	16.8
September, 2017	9.8
October, 2017	8.7
November, 2017	3.3
December, 2017	9
January, 2018	0.7
February, 2018	4.2
March, 2018	0.5
April, 2018	3.1
May, 2018	9.8
June, 2018	3.9

The average NRW for the period July 2017 to June 2018 is 6.22%. NRW trend for DMA 510 is very good.

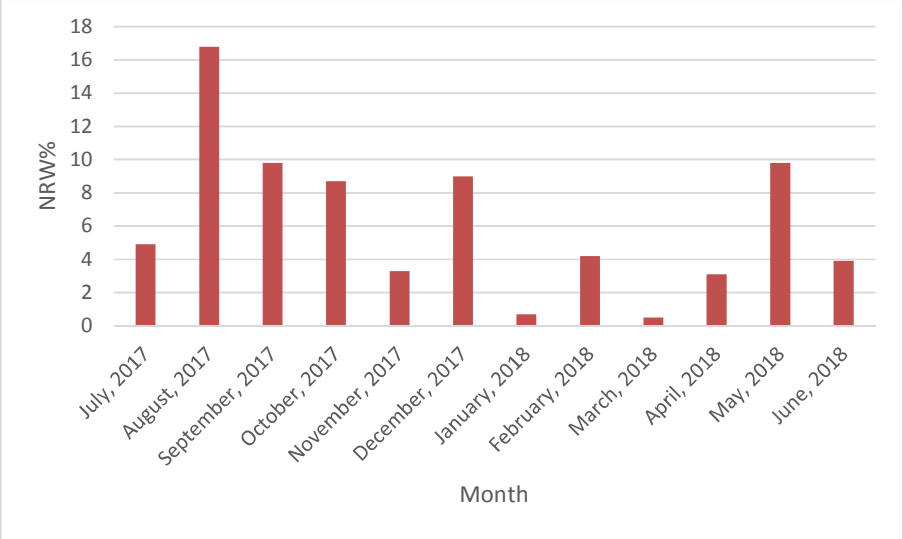

Figure 5.10: NRW trend of DMA 510

High NRW (16.8%) is shown at August 2017 due to increase in DTW production 30900m3 and import of water through Shahinbagh DMC. After one month, Shahinbagh DMC continues to export water to DMA 509 and it's still going on due to high demand of water at DMA 509. Overall NRW trend of DMA 510 is very good

5.2.11 Trend of NRW in whole study area

Since it is difficult to obtain supplied volumes and billed volumes for exact the same period (month), it is recommended by IWA to monitor the NRW for a longer period. Though study is started at July 2017, step by step a few important factors is considered in NRW calculation based on commissioning report and field survey to achieve accuracy. Average NRW of study area is calculated from table 5.2 and it's 9.51%.

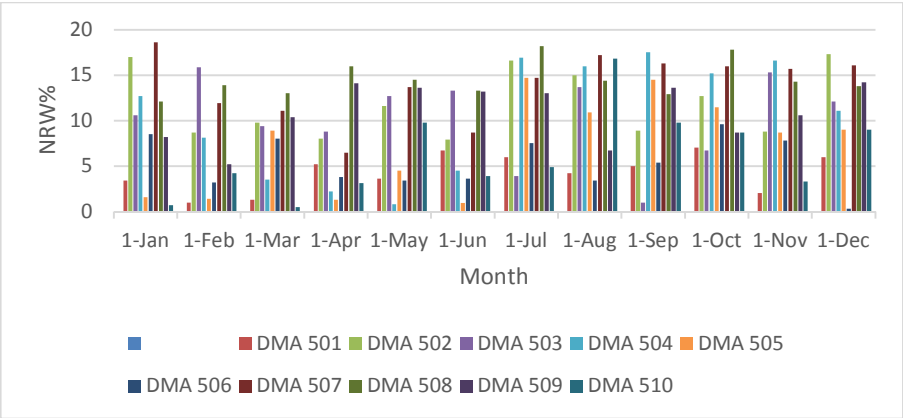

Figure 5.11: Overview of NRW (in %) on a monthly basis from July 2017 to June 2018.

5.3 Performance analysis

Water production, consumption and energy efficiency is highlighted in performance analysis.

5.3.1 Water production

Water production is increased to cope with raising demand from consumers and gradual decreasing underground water level. In one year interval, 14 production deep tubewells are increased in number.

Table 5.13: Monthly water production from July 2017 to June 2018 in study area

Year	Month	DTW No	Production (m3)
2017	July	59	3722421
	August	59	3963086
	September	61	3695719
	October	61	3922970
	November	72	3933855
	December	72	3940082
2018	January	72	3856976
	February	72	3568480
	March	72	4168384
	April	72	3858876
	May	72	4129410
	June	73	3883781

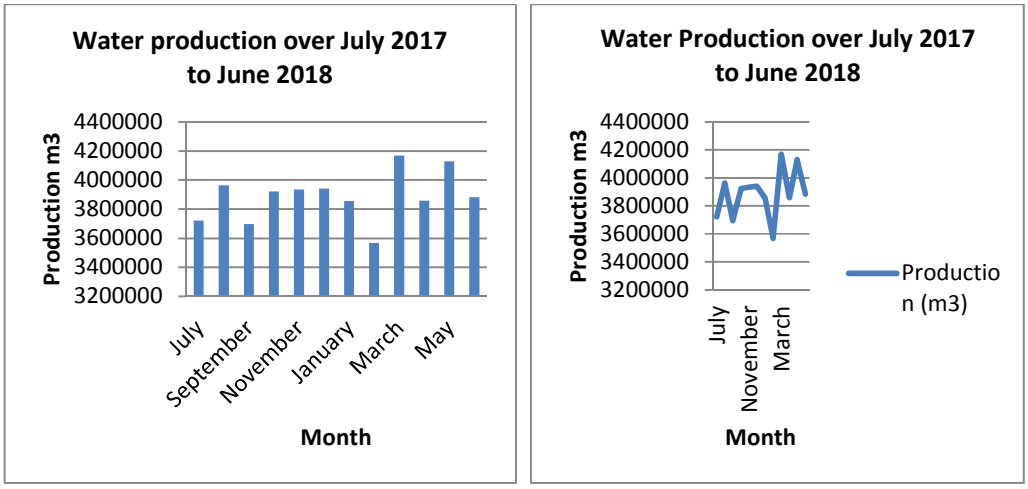

Figure 5.12: Monthly water production from July 2017 to June 2018 in study area

Highest water production is reported in March 2018, at the beginning of hot season. Lowest water production is found in February 2018. Average production is over last one year is 3887003 cubic meter.

5.3.2 Water consumption

Water consumption varies due to seasonal variance and type of living. Generally more water is needed in hot season. DMA 501, 503, 504, 505, 506 covers up high income people and their water demand is high irrespective of seasonal variance. Portion of DMA 507, 508, 509 are industrial area and their demand is always high.

Table 5.14: Monthly water consumption from August 2017 to June 2018 in study area

Year	Month	SC	Consumption (m3)
2017	August	12454	3626071
	September	12452	3684866
	October	12457	3761894
	November	12455	4502703
	December	12416	3640546
2018	January	12458	3580632
	February	12460	3536174
	March	12479	3605996
	April	12481	3667935
	May	12492	3611671
	June	12479	3685541

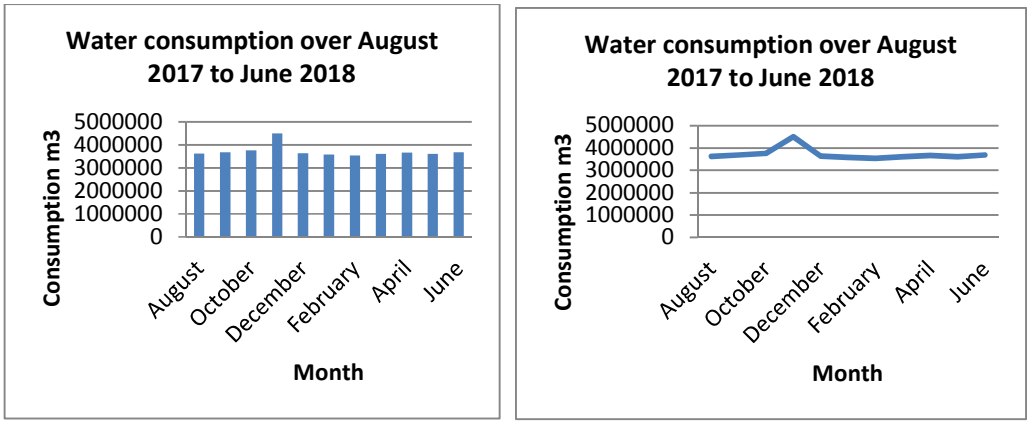

Figure 5.13: Monthly water consumption from August 2017 to June 2018 in study area

From July 2017 to June 2018, average consumption is 3718548 cubic meter from average 12462 service collections. Accept November 2017, a consistency is seen in consumption pattern.

5.3.3 Energy consumption

Energy efficiency is calibrated by comparing electric energy consumption of DTW to water production of respective production deep tubewell (DTW).
Energy efficiency= Energy (KWh)/ water production (cubic meter)

Individual value of energy efficiency is represented in graph which shows that respective pump is operating in good or bad range. Energy efficiency below 0.5 is considered good, above 0.5 is considered bad and equal to 0.5 is considered as bench-mark performance.

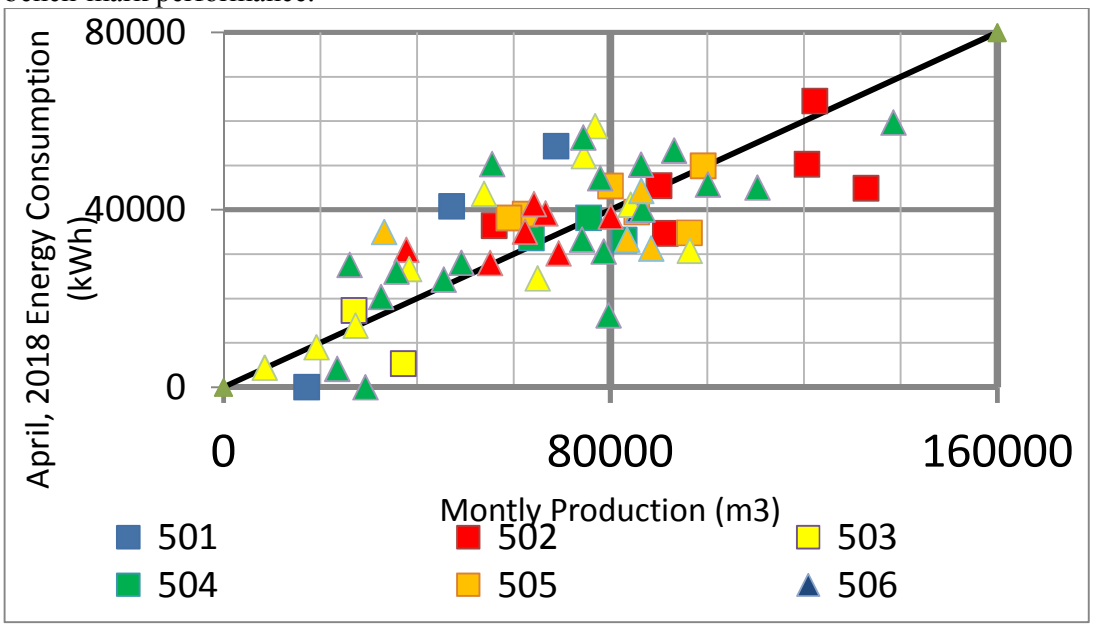

Figure 5.14: Individual pump's energy efficiency.

Considering individual DTW energy efficiency, total DMA's energy efficiency is calibrated following exactly the same procedure.

Table 5.15: Energy efficiency of April 2018 of study area

DMA	Production (m3)	Energy (kWh)	Energy efficiency (kWh/m3)
501	115810	101972	0.88
502	594850	260485	0.44
503	63000	50301	0.80
504	213320	118863	0.56
505	433295	232512	0.54
506	63840	30589	0.48
507	436650	216921	0.50
508	535770	305814	0.57
509	1193961	676745	0.57
510	208380	146828	0.70

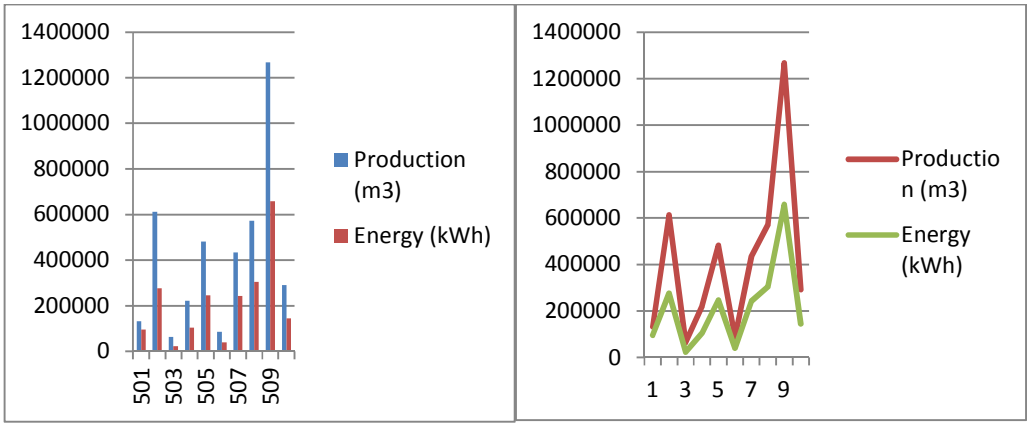

Figure 5.15: The production and energy consumption per DMA in study area

This value helps to create priority list for regeneration, change or replacement of DTWs. Besides it sorts out easily which machinery performance is degrading and consuming more power compare to production.

5.4 Discussion

Key points based on this study are discussed below:

- As per International Water Association (IWA), NRW below 15% is globally accepted very good performance. The World Bank recommends that NRW should be "less than 25%".

  Table 5.16: Performance analysis base on NRW (%) (Source: IWA)

Range of NRW	Description
<15%	Low level of NRW, very good performance
15-30%	Low level of NRW, good performance
30-40%	Average level of NRW, average performance
40-50%	High level of NRW, poor performance
>50%	Very high level of NRW, very poor performance

  World's average NRW is 36.6% [18] whereas NRW in developed and developing countries is 15% and 35% respectively [19]. Average NRW for Asian countries is 28.7 % [20]. At present, gross NRW of Dhaka city is 22% where average NRW of study area is found 9.51%.

- July to December 2017 period many problem is found. Among them lack of attention in collecting DMC reading is most important. Without accurate DMC reading, it's impossible to calculate NRW perfectly. DMC reading was collected by PLM, APLM and reading did not collect at same date of collection of consumption data from customer.
- Observations for negative NRW are:

I. Decrease in produced volumes by DTWs is directly reflected in a negative NRW
II. If actual meter reading is not taken on a monthly basis, there is a certain risk of inaccuracy in the billed volume of individual months and cause systematically over-billing of consumption to customers. Non-functional water meters reading are estimated and there is high probability of inaccuracy in reading.

- DMA system assists to eliminate 5% to 40% illegal service connections from implementation stage to today in various part of study area. Now water is distributed to all service connections through legal channel. 247 illegal connections are found in IPH Staff Quarter area of DMA 507 over duration of study and legal action is taken against the consumers. In presence of executive magistrate, all illegal connections are disconnected and public awareness is raised. Then, people apply for legal connections. As soon as they pay the due bill, they get legal connections.
- Consumers do not use suction pumps in DMA 501, 502, 503, 504, 505, 506, 510 areas due to 1 bar pressure and available water in network. Household reservoir is automatically filled with water having advantage of pressurized water supply in 24/7 hours which was imaginary in piped network system. This ultimately reduced electricity cost of customers. But, some areas of DMA 507, 508 and 509 need suction due to reduction of ground water level for seasonal variance.
- Water supply is given through legal service connections in slum areas of Korali and Satala within area of respectively DMA 502 and DMA 507. Present generation of children in slum's 1st experience clean water available just outside of doorstep. Besides social life standard is improved in LIC and decrease health related medical cost.
- DMA system in study area assist to increase water supply as system loss become minimum and management become easier compared to previous system. Even in emergency, water rationing helps to meet customer demand. All this results have gained the trust of customers and improve customer satisfaction.

CHAPTER 6
CONCLUSION AND RECOMMENDATIONS

6.1 Conclusions

Average production and consumption of water over July 2017 to June 2018 is 3887003 and 3718548 cubic meter respectively. Average NRW of study area is 7.62%. Tariff for 1 cubic meter water is BDT 11.02 and 35.28 respectively for domestic and commercial purposes (DWASA's latest tariff; 01 July 2018). It is notable that world's cheapest tariff is charged in Dhaka. With this low tariff DWASA is making profit in study area only because of low system loss.

The objective of the study is achieved by reducing NRW below 15% and maintained it over long period. Low NRW is an indicator for sustainable DMA management. From a financial point of view it is not appropriate to try to reduce NRW to the lowest possible level, because the marginal cost of reducing NRW increases once the cheaper options have been exploited. All illegal connections are eliminated and water supplies to slum areas through legal connections are the remarkable achievement of DMA approach.

6.2 Recommendations

The meter reading, billing and collection process to be outsourced by an external party. It may be done by students. This external party will receives a fee for their activities based on the collected revenues. It will be helpful to get consumption data on time and keep NRW in control. The focus of monitoring NRW levels in the coming years will be more on keeping commercial losses in control.

All consumption data cannot be collected at the same date by revenue staffs. Few and fixed numbers of revenue staff are working to collect consumption data from respective areas following household holding and road number. This should be done DMA wise by keeping 100% similarities with production data record. To cover whole DMA area in a single day (generally at the beginning and end of the month), more revenue inspector is needed. Presently interpolation is done to convert these data. As result, there is probability to get overbilling or under-billing in consumption data.

All DTW and DMC of study area need to be brought under full SCADA facilities. This automation will help to access data digitally and reliably at any time. Thus production data will be more accurate.

Increase surface water production for maintaining 1 bar pressure in network. As ground water treatment plant is costly and time consuming process, it would be addressed as a long term solution to ensure supply water security for future generations.

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APPENDICES

DMA terminologies

DMA

The District Meter Areas (DMA) design is an innovative methodology of water networks management, based on the pressure patterns control and on the water flows monitoring, in order to reduce water losses and to optimize the water systems management. So, district metering is a technique used to improve water distribution system (WDS) management and consists in partitioning a WDS into smaller portions called District Metered Areas.

A district is an area of a distribution system which is specifically defined, e.g. by the closure of valves, and in which the quantities of water entering and leaving the district are metered as shown in Figure.

These districts are obtained by placing and closing isolation valves along certain pipes connecting one DMA to another (closed links) and placing a flow meter in the remaining connecting pipes (open links). Based on the measured inflow and outflow of each DMA and taking into account storages, it is possible to determine the water balance of the DMA and monitor minimum night flows, thereby obtaining information that is useful for identifying the presence of leakage within the district. Data acquired at the DMA level can be effectively used in the context of real-time system management.

NRW

Non-revenue water (NRW) is defined as the volume of water supplied into the system that does not generate revenues. It consists of:

- Water that has been produced and is "lost" within the network before it reaches the customer, i.e. Physical Losses;
- Water that has been consumed by the customer but has not been billed to the customer or not billed correctly to the customer, i.e. Commercial losses.

Ideally, all treated water should be delivered to the consumer, the volume accurately measured and, together with the appropriate tariff, a bill sent to the customer for payment. In practice, water is lost within the network system (pipe bursts, leakage, overflows of reservoirs) and consumed water is not billed correctly to the customer (meter inaccuracies, data handling errors), not billed at all to customers (unauthorised use like meter tampering or illegal connections) or some consumers are not required to pay for their water (unbilled authorised consumption). The total of physical and commercial losses equals the NRW.

Supplied water volume is the combination of individual water pump and respective DMC reading.

$$Q_{total} = Q_{DTW} + DMC_{in} - DMC_{out}$$

Where the total produced water volume (Q_{total}) into the DMA is water produced at DTW in the DMA (Q_{DTW}) itself plus additional supply from other DMA's / transmission lines or minus supply to other DMA's through DMC's (DMC_{in} – DMC_{out}). For water importing, it is considered as positive and water exporting, it is considered as minus.

Water Balance

The International Water Association (IWA) Water Balance is the preferred format for presenting water losses. The IWA water balance is used to assess and estimate the various components of the commercial losses.

$$\text{NRW} = 100\% * \frac{\text{Q}_{\text{total}} - \text{Q}_{\text{billed}}}{\text{Q}_{\text{total}}}$$

NRW is defined the relative difference between produced (Q_{total}) and billed volume (Q_{billed}) to customers. This implies that NRW is a figure before collection of the billing.

<table>
<tr><td rowspan="4">Supplied water volume (Production)</td><td rowspan="2">Authorized consumption</td><td rowspan="2">Billed Authorised consumption</td><td>Billed Metered Consumption</td><td rowspan="2">Revenue Water</td></tr>
<tr><td>Billed Un-metered/Estimated Consumption</td></tr>
<tr><td rowspan="2">Water losses</td><td rowspan="2">Commercial losses</td><td>Unbilled Authorized consumption</td><td rowspan="3">Non-revenue water</td></tr>
<tr><td>Apparent losses</td></tr>
<tr><td colspan="2">Physical losses</td></tr>
</table>

Figure A1: The IWA balance shows the various components of Non-Revenue Water

Water balance component	Definition
Supplied water volume	The volumetric input to the treated water supply system
Authorized consumption	The volume of metered and/or unmetered water legitimately taken by registered customers, the water supplier and other authorized consumers.
Water loss	The difference between supplied water volume and authorized consumption, consisting of apparent losses plus physical losses.
Apparent losses	Unauthorized consumption and all types of metering, data handling and billing inaccuracies.
Physical losses	The water volume lost through all types of leaks, breaks and overflows on pipes, service reservoirs and service connections, up to the point of customer metering.
Revenue water	Those components of supplied water volume which are billed and produce revenue.
Non-revenue water	The difference between supplied water volume and billed authorized consumption

Figure A2: Definition of the IWA NRW components

Table A1: Maintenance plan for DMA 506

Monthly Work Plan of DMA 506			
Name: Mr ABC		**Designation: DMA Caretaker (PLM)**	
Jun-18	**Day**	**Name of Activity**	**Remarks**
01	Friday	Weekly Day off	
02	Saturday	DMC Reading	
03	Sunday	Valve visit: Valve No 1-7	
04	Monday	Valve visit: Valve No 8-14	
05	Tuesday	Valve visit: Valve No 15-21	
06	Wednesday	Valve visit: Valve No 22-28	
07	Thursday	Valve visit: Valve No 29-35	
08	Friday	Weekly Day off	
09	Saturday	Valve visit: Valve No 36-44	
10	Sunday	2 ARV open/close	
11	Monday	2 wash out open/close	
12	Tuesday	Valve maintenance (if required)	
13	Wednesday	Valve maintenance (if required)	
14	Thursday	Wash out & ARV maintenance (if required)	
15	Friday	Weekly Day off	
16	Saturday	Valve Rotate	
17	Sunday	Valve Rotate	
18	Monday	Valve Rotate	
19	Tuesday	Valve Rotate	
20	Wednesday	Field visit & survey or any other tasks specified	
21	Thursday	Field visit & survey or any other tasks specified	
22	Friday	Weekly Day off	
23	Saturday	Field visit & survey or any other tasks specified	
24	Sunday	Visit to DMC (Rd 134) & do required maintenance	
25	Monday	Visit to DMC (Rd 7) & do required maintenance	
26	Tuesday	Visit to DMC (Rd 1) & do required maintenance	
27	Wednesday	Visit to DMC (Shooting club) & do required maintenance	
28	Thursday	Visit to DMC (Police Plaza) & do required maintenance	
29	Friday	Weekly Day off	
30	Saturday	Field visit & survey or any other tasks specified	

Table A2: DTW production of study area for April 2018

SL	DMA	Name of Pump	Production (L/M)	Monthly Running Hours	Meter Reading at the start of the month (cubic meter)	Meter Reading at the end of the month (cubic meter)	Monthly Production (cubic meter)
1	501	Banani 5	1388	712	4,223,690	4,282,990	59,300
2	501	Banani-5 (Old pump)	700	700	618,880	634,540	15,660
3	501	a)Banani 7	959	710	4,908,660	4,949,510	40,850
5	502	Banani 3	1551	595	4,019,880	4,075,250	55,370
6	502	Banani 4	1849	720	3,173,460	3,253,340	79,880
7	502	a)Banani 6	2316	608	864,000	948,500	84,500
9	502	a)Banani 8	3500	710	0	0	149,100
11	502	Banani 9	2591	718	351,900	463,500	111,600
12	502	Korail Jamaibajar	2747	694	17,500	131,900	114,400
14	503	Banani DOHS-1	2000	300	0	0	36,000
15	503	Banani DOHS-2	1364	330	1,080,980	1,109,780	27,000
16	504	Gulshan 6	1565	706	4,577,350	4,643,650	66,300
18	504	Gulshan 7	1624	710	1,599,130	1,668,320	69,190
19	504	Gulshan 74	1822	712	3,377,270	3,455,100	77,830
21	505	Gulshan 10	1105	707	4,276,540	4,368,550	46,872
22	505	Gulshan 4	1699	719	4,622,370	4,695,660	73,290
23	505	Gulshan 5	1971	654	3,901,510	3,978,853	77,343
24	505	Gulshan 8	2024	600	984,730	1,057,610	72,880
25	505	Gulshan 9	1757	715	4,938,330	5,013,700	75,370
26	505	Wonderland Park	2049	712	3,900,530	3,988,070	87,540
27	506	Shooting complex	1970	540	831,600	895,440	63,840
28	507	Mohakhali 'Cha' Block	1358	709	1,071,380	1,129,170	57,790
29	507	M. Health Complex	1797	696	2,838,600	2,913,640	75,040
30	507	Mohakhali Jalkhabar	1144	691	1,403,220	1,450,630	47,410
31	507	Mohakhali Laboratory	1852	720	0	0	80,000
32	507	M Dakshin Para	1284	677	1,332,240	1,384,400	52,160
33	507	M T&T Colony	1571	694	2,722,940	2,788,370	65,430
34	507	Mohakhali TB Gate	1373	714	2,860,760	2,919,580	58,820
35	508	Hatir Jheel	1695	665	3,285,980	3,353,600	67,620
36	508	Khunipara	1422	687	3,220,800	3,279,400	58,600
37	508	Niketon 1	1667	180	1,663,000	1,681,000	18,000
38	508	Niketon 2	1222	360	1,352,590	1,378,990	26,400
39	508	Niketon 3	1956	72	1,628,180	1,636,630	8,450
40	508	Niketon 4	1626	360	1,892,380	1,927,510	35,130
41	508	Tejgaon 8	1195	709	2,833,860	2,884,700	50,840
42	508	Tejgaon 9	1892	704	2,511,100	2,591,030	79,930
44	508	T. Health Complex	2182	705	3,830,100	3,922,400	92,300

SL	DMA	Name of Pump	Production (L/M)	Monthly Running Hours	Meter Reading at the start of the month (cubic meter)	Meter Reading at the end of the month ((cubic meter))	Monthly Production ((cubic meter))
46	508	Tejgoan Polytechnic	1652	682	3,769,910	3,837,510	67,600
48	508	T. Lift station	1846	279	86,050	116,950	30,900
49	509	Tejgaon Police Station	1178	713	684,250	734,650	50,400
50	509	Alenbari	2509	715	3,087,500	3,195,150	107,650
51	509	Arjatpara	2091	696	3,223,530	3,310,860	87,330
52	509	BG Press Math	1717	701	3,575,200	3,647,400	72,200
53	509	BG Press Staff.Qtr	1629	574	2,246,300	2,302,400	56,100
54	509	East Nakhal Para-1	2012	682	2,141,109	2,223,450	82,341
55	509	East Nakhal Para-2	487	127	1,667,840	1,671,550	3,710
56	509	F.D.C Campus	2105	574	1,865,600	1,938,100	72,500
57	509	Kawran Bazar	1463	437	1,775,600	1,813,950	38,350
58	509	Old Assembly Baban1	1656	717	3,324,500	3,395,720	71,220
59	509	Old Assembly Baban2	2832	147	369,520	394,500	24,980
60	509	Shahenbag	1048	706	2,432,850	2,477,250	44,400
61	509	Tejgaon BTCL	1567	693	2,736,100	2,801,250	65,150
62	509	Nimtali Rail Gate	1758	711	3,610,250	3,685,250	75,000
63	509	a)Tejkuni Para-1	1801	715	2,963,490	3,040,770	77,280
65	509	Tejkuni Para-2	2970	642	3,918,300	4,032,700	114,400
66	509	Shiya mosjid pump	2082	668	480,540	563,980	83,440
67	509	Tran Bhandar	1001	708	2,475,640	2,518,150	42,510
69	510	Mohakhali DOHS-1	1343	669	1,833,900	1,887,800	53,900
70	510	Mohakhali DOHS-2	1781	685	2,199,300	2,272,500	73,200
71	510	Mohakhali DOHS-3	342	695	519,150	533,430	14,280
72	510	Mohakhali DOHS-4	1595	700	0	0	67,000

Table A2: DTW production of study area for April 2018 (Continued)

Table A3: DMC reading of study area for April 2018

Sr	DMC Name	Direction	Location	01-Apr-18	01-May-18	Remarks
1	501-A1	In	Road 27 - Garden	9318	9318	
	501-A1	Out		2	2	
2	501-A2	In	Road 23 - Next to garden	535	535	
	501-A2	Out		10670	10670	
3	501-B	In	Road 18 – University	274	274	
	501-B	Out		1	1	
4	501-C	In	Road 27 – Playground	999997	999997	
	501-C	Out		3915	3915	
5	502-A1	In	Road 4 (Kamal Ataturk Ave)	2	2	
	502-A1	Out		2	2	
6	502-B	In	Road 11	5584	5584	
	502-B	Out		7	7	
7	502-A2	In	Road 1-Chairman Bari	92	92	
	502-A2	Out		2	2	
8	502-C	In	Road ½	28939	28939	
	502-C	Out		117159	132279	
9	502-D	In	Road 5/6	39	39	
	502-D	Out		34	34	
10	502-E	In	Gulshan 2 – Lake	1	1	
	502-E	Out		2	2	
11	503-A	In	Kakoli Police Box (Banani DOHS)	0	0	
	503-A	Out		385	385	
12	503-B	In	Mohakhali Railgate	5	5	
	503-B	Out		5	5	
13	504-A	In	Road 62/63	999989	999989	
	504-A	Out		9399	9399	
14	504-B	In	Road 50- Gulshan 2			Not Visible for road carpeting
	504-B	Out				
15	504-C1	In	Gulshan Avenue	42	42	
	504-C1	Out		3	3	
16	504-C2	In	Road-92- Gulshan Baridhara link Bridge	9	9	
	504-C2	Out		1	1	
17	504-D	In	Road 72 -Baridhara DOSH	276	276	
	504-D	Out		3461	3461	
18	504-Z8	In	Gulshan-2 to Baridhara	8970	8970	
	504-Z8	Out		1	1	

19	505-A	In	Road-49-North Avenue (Banani Link)	922	922	
	505-A	Out		38757	40184	
20	505-B	In	Road-94-North Avenue (Banani Baridhara Link)	21	21	
	505-B	Out		0	0	
21	505-C	In	South Avenue, Near PARTEX Office	7	7	
	505-C	Out		237	237	
22	505-Z8	In	Gulshan-1 to Badda Link Road	134037	134037	
	505-Z8	Out		120546	120546	
23	506-A1	In	Road 134	8	8	
	506-A1	Out		1144	1144	
24	506-A2	In	Road 7	3438	3438	
	506-A2	Out		463	463	
25	506-B	In	Road 1	997029	997029	
	506-B	Out		999855	999855	
26	506-C	In	Tejgaan Gulshan link road (shooting club)	95663	95663	
	506-C	Out		8363	8363	
27	506-Z8	In	South Badda near Police Plaza	48938	109398	
	506-Z8	Out		999722	999724	
28	507-A	In	IPH Gate	90591	91774	
	507-A	Out		2	2	
29	507-B	In	Mohakhali South Area (ICDDRB)	1478	1478	
	507-B	Out		2	2	
30	507-C	In	Mohakhali (Jalkhabar)	59455	59455	
	507-C	Out		5	5	
31	508-A	In	Nabisco	17551	17607	
	508-A	Out		5204	5204	
32	508-B	In	Bijoy Shoroni	34	34	
	508-B	Out		102	102	
33	508-C	In	B.G press (Satrasta)	20839	20842	
	508-C	Out		10	10	
34	508-D	In	Savy-Icecream	667663	680764	only in line, no out line
	508-D	Out				
35	509-A	In	ETV	182	182	
	509-A	Out		208254	215226	
36	509-B	In	Tibbate			Not Visible for road carpeting
	509-B	Out				
37	509-C	In	Shatrasta	2035	2035	
	509-C	Out		7	7	
38	509-D	In	Holy Cross road	25287	26015	

	509-D	Out	Farmgate	1178	1178	
39	509-E	In	Mohakhali Bus Terminal	588819	596915	
	509-E	Out		32	32	
40	510-A	In	Shahinbag	996905	996901	
	510-A	Out		16766	20317	
41	510-B	In	British Tobaco (BAT)	16508	16508	
	510-B	Out		999729	999729	

Table A3: DMC reading of study area for April 2018 (continued)

Table A4: DMA 506 service connections consumption for April 2018

Sr.	Account	Customer Category	Reading at 31 March 2018	Reading at 30 April 2018	Consumption
1	0504000019	Domestic 100%	8,005,000	8,076,000	71,000
2	0504000020	Domestic 100%	61,180,000	62,181,000	1,001,000
3	0504000031	Commercial 100%	6,995,000	6,995,000	0
4	0504000042	Commercial 100%	3,891,000	3,980,000	89,000
5	0504000097	Domestic 100%	3,312,000	3,378,000	66,000
6	0504000199	Commercial 100%	7,618,000	7,692,000	74,000
7	0504000246	Commercial 100%	5,548,000	5,678,000	130,000
8	0504000257	Domestic 100%	1,782,000	1,813,000	31,000
9	0504000315	Commercial 100%	4,555,000	4,870,000	315,000
10	0504000371	Domestic 100%	11,250,000	11,277,000	27,000
11	0504000382	Commercial 100%	6,710,000	6,757,000	47,000
12	0504000439	Commercial 100%	35,681,000	35,950,000	269,000
13	0504000473	Commercial 100%	18,590,000	19,000,000	410,000
14	0504000484	Commercial 100%	26,566,000	27,032,000	466,000
15	0504000495	Domestic 100%	34,257,000	35,500,000	1,243,000
16	0504000508	Domestic 100%	34,853,000	35,393,000	540,000
17	0504000531	Domestic 100%	1,520,000	1,600,000	80,000
18	0504000746	Commercial 100%	6,695,000	6,782,000	87,000
19	0504000780	Domestic 100%	6,114,000	6,114,000	0
20	0504000804	Domestic 100%	15,975,000	16,238,000	263,000
21	0504000837	Domestic 100%	1,935,000	2,032,000	97,000
22	0504000848	D 50% C 50%	7,745,000	7,890,000	145,000
23	0504000917	Commercial 100%	11,670,000	11,846,000	176,000
24	0504000928	Commercial 100%	11,077,000	11,307,000	230,000
25	0504000939	Domestic 100%	48,032,000	49,135,000	1,103,000
26	0504000995	Domestic 100%	13,448,000	13,458,000	10,000
27	0504001009	Domestic 100%	22,970,000	23,755,000	785,000
28	0504001010	Commercial 100%	31,390,000	32,028,000	638,000
29	0504001065	Domestic 100%	36,912,000	37,540,000	628,000
30	0504001190	Domestic 100%	13,425,000	13,700,000	275,000

31	0504001225	Commercial 100%	2,750,000	2,956,000	206,000
32	0504001281	Commercial 100%	10,685,000	10,912,000	227,000
33	0504001350	Domestic 100%	5,751,000	5,918,000	167,000
34	0504001383	Commercial 100%	9,170,000	10,400,000	1,230,000
35	0504001452	Domestic 100%	10,360,000	10,630,000	270,000
36	0504001474	Domestic 100%	9,962,000	10,523,000	561,000
37	0504001587	Domestic 100%	33,682,000	34,307,000	625,000
38	0504001598	D 40% C 60%	17,752,000	18,402,000	650,000
39	0504001601	Domestic 100%	4,300,000	4,300,000	0
40	0504001703	Commercial 100%	12,904,000	13,135,000	231,000
41	0504001758	Commercial 100%	34,144,000	34,872,000	728,000
42	0504001781	Commercial 100%	22,702,000	22,788,000	86,000
43	0504001827	Domestic 100%	4,708,000	4,925,000	217,000
44	0504001861	Domestic 100%	6,867,000	7,000,000	133,000
45	0504001907	Commercial 100%	15,543,000	16,202,000	659,000
46	0504001974	Commercial 100%	19,119,000	19,440,000	321,000
47	0504002022	D 70% C 30%	2,043,000	2,290,000	247,000
48	0504002088	Domestic 100%	1,645,000	1,666,000	21,000
49	0504002113	D 40% C 60%	35,762,000	36,498,000	736,000
50	0504002191	D 65% C 35%	1,050,000	1,850,000	800,000
51	0504002204	Domestic 100%	41,608,000	42,348,000	740,000
52	0504002271	Domestic 100%	17,052,000	17,360,000	308,000
53	0504002339	Domestic 100%	40,928,000	41,608,000	680,000
54	0504002373	Domestic 100%	3,763,000	3,853,000	90,000
55	0504002486	Commercial 100%	15,612,000	15,780,000	168,000
56	0504002511	Domestic 100%	13,450,000	14,470,000	1,020,000
57	0504002522	Commercial 100%	8,228,000	8,375,000	147,000
58	0504002806	Commercial 100%	27,612,000	28,762,000	1,150,000
59	0504002851	D 93% C 7%	2,199,000	3,206,000	1,007,000
60	0504002908	Domestic 100%	2,705,000	2,753,000	48,000
61	0504002975	Domestic 100%	6,150,000	6,241,000	91,000
62	0504003216	Domestic 100%	11,743,000	12,200,000	457,000
63	0504003227	Domestic 100%	4,546,000	4,576,000	30,000
64	0504003238	Domestic 100%	17,233,228	17,420,218	186,990
65	0504003341	Commercial 100%	1,219,000	1,243,000	24,000
66	0504003432	Commercial 100%	24,960,000	25,395,000	435,000
67	0504003487	Commercial 100%	4,885,000	5,278,000	393,000
68	0504003501	Domestic 100%	3,003,000	3,300,000	297,000
69	0504003578	D 85% C 15%	71,357,000	72,245,000	888,000
70	0504003727	Domestic 100%	36,375,000	37,423,000	1,048,000
71	0504003761	Domestic 100%	18,069,216	18,387,336	318,120
72	0504003829	Commercial 100%	7,152,000	7,170,000	18,000
73	0504003874	D 50% C 50%	11,964,000	12,370,000	406,000
74	0504003987	Domestic 100%	17,162,000	17,602,000	440,000
75	0504004046	D 90% C 10%	5,600,000	5,704,000	104,000
76	0504004104	Commercial 100%	34,448,000	34,868,000	420,000

77	0504004160	Domestic 100%	17,960,000	18,180,000	220,000
78	0504004217	Commercial 100%	13,430,000	13,938,000	508,000
79	0504004319	Commercial 100%	23,794,000	24,201,000	407,000
80	0504004331	Commercial 100%	5,515,000	5,549,000	34,000
81	0504004375	Domestic 100%	6,224,000	6,735,000	511,000
82	0504004433	Domestic 100%	8,370,000	8,432,000	62,000
83	0504004546	Commercial 100%	1,104,000	1,510,000	406,000
84	0504004580	Commercial 100%	48,694,000	49,943,000	1,249,000
85	0504004591	Domestic 100%	12,695,000	12,903,000	208,000
86	0504004717	Domestic 100%	29,957,000	30,280,000	323,000
87	0504004784	Commercial 100%	147,000	365,000	218,000
88	0504004808	Domestic 100%	5,903,000	6,020,000	117,000
89	0504004819	Commercial 100%	12,442,000	12,548,000	106,000
90	0504004875	Commercial 100%	0	860,000	860,000
91	0504004900	Commercial 100%	4,656,000	4,673,000	17,000
92	0504004977	D 95% C 5%	23,657,000	23,826,000	169,000
93	0504004999	Domestic 100%	9,027,000	9,534,000	507,000
94	0504005116	Commercial 100%	26,540,000	27,120,000	580,000
95	0504005296	Commercial 100%	12,173,000	12,401,000	228,000
96	0504005310	D 60% C 40%	61,878,000	62,688,000	810,000
97	0504005321	Domestic 100%	9,015,000	9,155,000	140,000
98	0504005376	Domestic 100%	6,454,000	6,565,000	111,000
99	0504005401	Commercial 100%	32,310,000	33,004,000	694,000
100	0504005456	Domestic 100%	275,000	557,000	282,000
101	0504005478	Domestic 100%	11,970,000	12,320,000	350,000
102	0504005490	Commercial 100%	4,175,000	4,412,000	237,000
103	0504005514	Domestic 100%	3,951,948	4,028,388	76,440
104	0504005547	Domestic 100%	47,550,000	49,100,000	1,550,000
105	0504005569	Commercial 100%	9,135,000	9,159,000	24,000
106	0504005570	Domestic 100%	9,731,000	9,870,000	139,000
107	0504005649	Domestic 100%	18,321,000	18,600,000	279,000
108	0504005650	Commercial 100%	29,870,000	30,450,000	580,000
109	0504005694	D 20% C 80%	5,053,000	5,245,000	192,000
110	0504005752	Commercial 100%	42,916,875	43,798,125	881,250
111	0504005821	Commercial 100%	4,673,000	4,870,000	197,000
112	0504005887	D 95% C 5%	33,890,000	34,780,000	890,000
113	0504005934	D 85% C 15%	9,124,000	9,323,000	199,000
114	0504006060	Domestic 100%	15,970,000	17,202,000	1,232,000
115	0504006093	Commercial 100%	52,165,000	52,765,000	600,000
116	0504006106	Domestic 100%	7,640,000	7,742,000	102,000
117	0504006139	Domestic 100%	1,685,000	1,708,000	23,000
118	0504006219	Commercial 100%	9,434,000	9,517,000	83,000
119	0504006242	Domestic 100%	2,249,000	2,300,000	51,000
120	0504006264	Commercial 100%	11,070,000	11,268,000	198,000
121	0504006286	Commercial 100%	6,597,000	6,702,000	105,000
122	0504006311	Commercial 100%	7,006,000	7,230,000	224,000

123	0504006399	Commercial 100%	19,996,000	20,223,000	227,000
124	0504006402	Commercial 100%	26,220,000	27,027,000	807,000
125	0504006537	Commercial 100%	4,226,000	4,275,000	49,000
126	0504006628	Domestic 100%	22,565,000	22,990,000	425,000
127	0504006695	Commercial 100%	59,228,000	60,220,000	992,000
128	0504006946	Commercial 100%	41,940,000	43,108,000	1,168,000
129	0504007049	Domestic 100%	1,247,000	1,277,000	30,000
130	0504007152	Commercial 100%	1,823,000	1,841,000	18,000
131	0504007210	D 20% C 80%	5,945,000	6,475,000	530,000
132	0504007334	Domestic 100%	22,667,000	22,667,000	0
133	0504007345	Domestic 100%	18,595,000	19,270,000	675,000
134	0504007356	D 70% C 30%	17,868,585	18,344,235	475,650
135	0504007390	Domestic 100%	76,065,000	77,300,000	1,235,000
136	0504007594	Commercial 100%	8,160,000	8,296,000	136,000
137	0504007629	Commercial 100%	9,643,000	9,810,000	167,000
138	0504007685	Commercial 100%	201,000	520,000	319,000
139	0504007856	Domestic 100%	8,945,000	9,140,000	195,000
140	0504007936	Domestic 100%	20,714,000	21,300,000	586,000
141	0504007992	Domestic 100%	180,000	352,000	172,000
142	0504008153	Commercial 100%	25,110,000	25,290,000	180,000
143	0504008164	Commercial 100%	9,023,000	9,220,000	197,000
144	0504008200	Commercial 100%	1,250,000	1,520,000	270,000
145	0504008233	Domestic 100%	5,274,000	5,375,000	101,000
146	0504008415	Commercial 100%	2,560,000	2,635,000	75,000
147	0504008448	Domestic 100%	27,837,000	28,830,000	993,000
148	0504008459	Commercial 100%	9,098,000	9,265,000	167,000
149	0504008620	Commercial 100%	5,460,000	5,705,000	245,000
150	0504008653	Domestic 100%	9,404,000	9,530,000	126,000
151	0504008853	Commercial 100%	30,602,000	32,078,000	1,476,000
152	0504008926	Commercial 100%	233,000	979,000	746,000
153	0504008960	Commercial 100%	7,103,000	7,300,000	197,000
154	0504009030	Domestic 100%	53,775,000	54,367,000	592,000
155	0504009074	Domestic 100%	3,708,000	3,796,000	88,000
156	0504009314	Domestic 100%	83,626,000	84,998,000	1,372,000
157	0504009405	Domestic 100%	61,500,000	63,007,000	1,507,000
158	0504009494	Commercial 100%	5,962,000	6,030,000	68,000
159	0504009610	Commercial 100%	9,952,000	10,200,000	248,000
160	0504009654	D 50% C 50%	3,000	3,000	0
161	0504009665	D 70% C 30%	4,065,000	4,115,000	50,000
162	0504009756	Domestic 100%	44,340,000	44,990,000	650,000
163	0504009778	Commercial 100%	4,379,000	4,379,000	0
164	0504009858	Commercial 100%	5,966,000	5,966,000	0
165	0504009916	Domestic 100%	68,720,000	69,670,000	950,000
166	0504009949	Domestic 100%	10,917,000	10,947,000	30,000
167	0504010000	Domestic 100%	36,733,000	37,423,000	690,000
168	0504010055	Commercial 100%	4,993,000	5,117,000	124,000

169	0504010066	Domestic 100%	1,737,000	1,764,000	27,000
170	0504010226	Commercial 100%	4,484,000	4,936,000	452,000
171	0504010293	D 70% C 30%	5,126,000	5,206,000	80,000
172	0504010317	Domestic 100%	114,000	114,000	0
173	0504010351	Commercial 100%	13,178,000	13,370,000	192,000
174	0504010395	Domestic 100%	6,405,000	6,475,000	70,000
175	0504010453	Domestic 100%	10,555,000	11,255,000	700,000
176	0504010464	Domestic 100%	21,802,000	23,550,000	1,748,000
177	0504010624	D 80% C 20%	38,810,000	39,503,000	693,000
178	0504010657	D 67% C 33%	5,803,000	5,868,000	65,000
179	0504010975	Domestic 100%	20,720,000	21,125,000	405,000
180	0504010986	Commercial 100%	25,804,000	26,153,000	349,000
181	0504011034	Commercial 100%	7,936,000	8,072,000	136,000
182	0504011067	Commercial 100%	19,563,000	19,998,000	435,000
183	0504011501	Domestic 100%	15,885,000	17,031,000	1,146,000
184	0504011578	Commercial 100%	7,533,000	7,648,000	115,000
185	0504011658	Domestic 100%	13,789,000	14,669,000	880,000
186	0504011750	Commercial 100%	17,513,000	17,932,000	419,000
187	0504011885	Commercial 100%	1,250,000	1,500,000	250,000
188	0504012068	Domestic 100%	24,830,000	25,400,000	570,000
189	0504012193	Domestic 100%	1,100,000	2,100,000	1,000,000
190	0504012637	Domestic 100%	2,864,000	3,534,000	670,000
191	0504012693	Commercial 100%	3,300,000	3,350,000	50,000
192	0504012831	Domestic 100%	0	0	0
193	0504013296	Domestic 100%	4,134,000	4,227,000	93,000
194	0504013752	Domestic 100%	1,401,000	2,120,000	719,000
195	0504013785	Commercial 100%	1,583,000	2,349,000	766,000
196	0504013956	Domestic 100%	6,886,000	6,886,000	0
197	0504014026	Commercial 100%	2,210,000	2,210,000	0
198	0504014093	Domestic 100%	1,950,000	1,959,000	9,000
199	0504014117	Domestic 100%	3,892,000	4,320,000	428,000
200	0504014424	Commercial 100%	21,567,000	21,804,000	237,000
201	0504014446	Domestic 100%	5,008,000	5,065,000	57,000
202	0504014673	Domestic 100%	73,948,000	75,439,000	1,491,000
203	0504014968	Domestic 100%	11,574,000	11,675,000	101,000
204	0504015436	Commercial 100%	6,594,000	6,698,000	104,000
205	0504015709	Domestic 100%	1,892,000	1,892,000	0
206	0504016006	Domestic 100%	1,988,000	1,988,000	0
207	0504016153	D 30% C 70%	23,645,000	23,800,000	155,000
208	0504016777	Commercial 100%	1,587,000	1,587,000	0
209	0504017472	Commercial 100%	281,000	470,000	189,000
210	0504017654	Domestic 100%	5,143,000	5,245,000	102,000
211	0504018848	Commercial 100%	7,184,000	7,277,000	93,000
212	0504019656	Domestic 100%	3,200,000	3,274,000	74,000
213	0504020911	Domestic 100%	3,783,000	3,821,000	38,000
214	0504021810	Domestic 100%	9,783,000	10,321,000	538,000

215	0504022424	D 20% C 80%	4,569,000	4,686,000	117,000
216	0504028919	Commercial 100%	3,037,000	3,244,000	207,000
217	0504039003	Commercial 100%	12,130,000	12,330,000	200,000
218	0504046693	Commercial 100%	2,999,000	3,072,000	73,000
219	0504066864	Commercial 100%	24,460,000	25,050,000	590,000
220	0504090686	Domestic 100%	1,054,000	1,078,000	24,000
221	0504090722	Commercial 100%	5,977,000	6,600,000	623,000
222	0504092257	D 96% C 4%	5,879,000	7,200,000	1,321,000
223	0504093156	Domestic 100%	18,116,000	18,421,000	305,000
224	0504093225	Commercial 100%	6,124,000	6,163,000	39,000
225	0504093292	Domestic 100%	45,910,000	46,630,000	720,000
226	0504093510	Domestic 100%	8,224,000	8,304,000	80,000
227	0504099403	Commercial 100%	71,540,000	71,615,000	75,000
228	0504103319	Commercial 100%	28,901,000	29,468,000	567,000
229	0504106970	Domestic 100%	15,965,000	16,131,000	166,000
230	0504110421	D 70% C 30%	15,110,000	15,350,000	240,000
231	0504111024	D 40% C 60%	8,608,000	8,762,000	154,000
232	0504111375	Commercial 100%	3,134,000	3,177,000	43,000
233	0504111386	Domestic 100%	5,764,000	5,785,000	21,000
234	0504113059	Commercial 100%	5,330,000	5,724,000	394,000
235	0504127011	Domestic 100%	14,250,000	14,643,000	393,000
236	0504132665	D 95% C 5%	67,898,000	68,958,000	1,060,000
237	0504140665	D 85% C 15%	146947000	148300000	1,353,000
238	0504144238	Domestic 100%	2,680,000	2,711,000	31,000
239	0504147480	Domestic 100%	19,197,000	19,365,000	168,000
240	0504148834	Domestic 100%	10,180,000	10,525,000	345,000
241	0504151500	Domestic 100%	23,188,000	23,599,000	411,000
242	0504152658	D 90% C 10%	13,970,000	14,370,000	400,000
243	0504152705	Domestic 100%	21,515,000	21,941,000	426,000
244	0504155366	Commercial 100%	9,815,000	9,957,000	142,000
245	0504167995	Domestic 100%	5,768,000	6,348,000	580,000
246	0504172969	Commercial 100%	1,540,000	1,540,000	0
247	0504177556	D 50% C 50%	25,650,000	26,100,000	450,000
248	0504179488	Domestic 100%	1,090,000	1,125,000	35,000
249	0504180134	Domestic 100%	52,075,000	52,977,000	902,000
250	0504186578	Domestic 100%	22,382,000	22,900,000	518,000
251	0504186778	Domestic 100%	35,723,000	36,343,000	620,000
252	0504189231	Domestic 100%	18,429,560	18,769,010	339,450
253	0504189242	Domestic 100%	24,022,363	24,614,533	592,170
254	0504196261	Commercial 100%	4,610,000	4,693,000	83,000
255	0504197578	Commercial 100%	333,000	333,000	0
256	0504200267	D 50% C 50%	8,315,000	8,429,000	114,000
257	0504201356	Domestic 100%	21,379,000	21,780,000	401,000
258	0504208980	D 20% C 80%	64,140,000	65,389,000	1,249,000
259	0504211345	Domestic 100%	2,463,000	2,463,000	0
260	0504211511	Commercial 100%	3,206,000	3,410,000	204,000

261	0504223123	Domestic 100%	8,035,000	8,198,000	163,000
262	0504224941	Domestic 100%	23,629,000	24,245,000	616,000
263	0504226099	D 40% C 60%	8,683,000	9,000,000	317,000
264	0504231342	Domestic 100%	6,471,000	6,582,000	111,000
265	0504238123	Commercial 100%	4,056,000	4,800,000	744,000
266	0504239846	Domestic 100%	14,190,000	14,400,000	210,000
267	0504243364	Commercial 100%	2,055,000	2,278,000	223,000
268	0504253407	Domestic 100%	1,790,000	1,980,000	190,000
269	0504256769	Domestic 100%	35,536,000	36,180,000	644,000
270	0504259371	Commercial 100%	20,733,000	21,097,000	364,000
271	0504271976	Domestic 100%	19,416,000	19,836,000	420,000
272	0504275102	D 25% C 75%	19,101,000	19,355,000	254,000
273	0504277654	Domestic 100%	9,038,000	9,055,000	17,000
274	0504280825	D 50% C 50%	50,085,000	50,445,000	360,000
275	0504295151	Commercial 100%	0	0	0
276	0504317156	Domestic 100%	41,079,852	41,568,402	488,550
277	0504322887	D 70% C 30%	9,044,000	9,248,000	204,000
278	0504328812	Commercial 100%	17,358,000	17,570,000	212,000
279	0504334747	Domestic 100%	6,588,000	6,700,000	112,000
280	0504335790	Commercial 100%	308,000	308,000	0
281	0504338090	Domestic 100%	17,150,000	17,428,000	278,000
282	0504345010	Commercial 100%	14,774,000	15,006,000	232,000
283	0504353305	Commercial 100%	6,550,000	7,350,000	800,000
284	0504356276	Domestic 100%	25,650,000	25,900,000	250,000
285	0504366080	D 50% C 50%	16,688,000	16,941,000	253,000
286	0504373423	Domestic 100%	21,420,000	21,810,000	390,000
287	0504375272	Domestic 100%	48,704,000	49,009,000	305,000
288	0504375367	Commercial 100%	2,095,000	2,140,000	45,000
289	0504398316	Commercial 100%	1,101,000	1,123,000	22,000
290	0504409980	Domestic 100%	18,640,000	19,140,000	500,000
291	0504420929	Commercial 100%	28,835,000	30,200,000	1,365,000
292	0504423262	Domestic 100%	19,593,000	19,860,000	267,000
293	0504444800	Commercial 100%	12,604,000	13,050,000	446,000
294	0504475815	Domestic 100%	32,117,000	32,817,000	700,000
295	0504485896	Domestic 100%	15,412,000	15,951,000	539,000
296	0504491876	Domestic 100%	15,660,000	15,660,000	0
297	0504492233	D 30% C 70%	3,181,000	3,353,000	172,000
298	0504492493	Commercial 100%	13,890,000	14,170,000	280,000
299	0504492552	Domestic 100%	8,417,000	8,518,000	101,000
300	0504498101	Commercial 100%	19,940,000	20,336,000	396,000
301	0504504556	Domestic 100%	969,252	982,092	12,840
302	0504504777	Commercial 100%	5,990,000	6,328,000	338,000
303	0504534563	D 90% C 10%	10,661,000	10,964,000	303,000
304	0504534747	Commercial 100%	29,178,000	29,759,000	581,000
305	0504542945	Domestic 100%	7,210,000	7,218,000	8,000
306	0504551777	D 90% C 10%	24,826,000	25,510,000	684,000

307	0504562787	Commercial 100%	615,000	855,000	240,000
308	0504577847	Commercial 100%	10,958,000	11,292,000	334,000
309	0504588839	D 20% C 80%	2,671,000	2,715,000	44,000
310	0504610320	Commercial 100%	15,661,000	16,068,000	407,000
311	0504610519	Domestic 100%	15,485,000	15,830,000	345,000
312	0504610535	Commercial 100%	17,539,000	18,676,000	1,137,000
313	0504612319	Domestic 100%	13,171,000	13,171,000	0
314	0504612366	Domestic 100%	25,900,000	26,600,000	700,000
315	0504612390	Domestic 100%	44,682,000	45,283,000	601,000
316	0504612416	Domestic 100%	39,035,000	39,715,000	680,000
317	0504613080	Domestic 100%	31,554,000	32,361,000	807,000
318	0504619369	Commercial 100%	61,794,000	63,305,000	1,511,000
319	0504652128	Domestic 100%	12,898,000	13,170,000	272,000
320	0504665334	Domestic 100%	19,587,000	20,300,000	713,000
321	0504667882	Commercial 100%	59,399,000	61,900,000	2,501,000
322	0504671505	Domestic 100%	4,086,000	4,150,000	64,000
323	0504674885	Commercial 100%	18,350,000	19,205,000	855,000
324	0504679823	D 50% C 50%	1,611,000	1,643,000	32,000
325	0504683793	Commercial 100%	638,000	652,000	14,000
326	0504684525	Domestic 100%	2,015,000	2,021,000	6,000
327	0504713763	Domestic 100%	10,671,000	10,840,000	169,000
328	0504725129	Commercial 100%	6,941,000	7,370,000	429,000
329	0504738931	Commercial 100%	1,377,000	1,654,000	277,000
330	0504738949	Commercial 100%	4,221,000	4,311,000	90,000
331	0504744279	Commercial 100%	3,281,000	3,850,000	569,000
332	0504744407	Commercial 100%	295,000	709,000	414,000
333	0504748201	Commercial 100%	1,033,000	1,266,000	233,000
334	0504752553	Commercial 100%	11,165,000	12,400,000	1,235,000
335	0504752607	Commercial 100%	0	80,000	80,000
336	0504755331	Domestic 100%	110,000	164,000	54,000

Table A4: DMA 506 service connections consumption for April 2018 (continued)

Table A5: DMA wise total supplied and billed volume from January to June 2018

DMA	Jan-18		Feb-18		Mar-18		Apr-18		May-18		Jun-18	
	Total supplied vol (m3)	Total bill vol (m3)	Total supplied vol (m3)	Total bill vol (m3)	Total supplied vol (m3)	Total bill vol (m3)	Total supplied vol (m3)	Total bill vol (m3)	Total supplied vol (m3)	Total bill vol (m3)	Total supplied vol (m3)	Total bill vol (m3)
501	139330	144184	125580	124285.8	137251.6	135444.1	130873.2	123955.2	133977.4	129080	134600	125480
502	422940	308669	339340	309552	392766	314906.4	329250	302878.6	328071	289798.6	360592	331988.6
503	76979	68827	87398.57	73502.3	84128	76206.19	83043.22	75676.09	84603.3	73777.19	81866	70970.09
504	213020	240018	207838	224757.9	235460	227108.6	230827.6	225577.1	241834.8	239835.6	197490	188637.1
505	423844	416962	431284	425244.4	469285	427498.6	431592.4	433195.5	474909.2	453225.1	433726	429622.1
506	136040	124442.1	115148	111398.3	138708	127537.1	124300	119526.5	118416.9	114316.3	111538	107415.5
507	494779.6	402372	451986.1	397968.3	479776.6	426243.6	460458.4	430409.4	476395.6	411272.6	452602	413065.2
508	718380	561639.3	652130	560866.7	655790	569954.5	656771.1	551045.3	634142	542074.8	654365	567467.1
509	1079250	883198	914114	866002.7	990321	887326.5	1051330	902672	1021684	882173.6	1059433	919200.1
510	223601	221979.3	175835.7	183168.8	206202	205165.9	201760.3	195450.2	234233.35	211186.1	221090	212357.8

Table A6: Water production summary from August to December 2017.

	Aug-17		Sep-17		Oct-17		Nov-17		Dec-17	
DMA	Production	Pump	Production	Pump	Production	Pump	Production	Pump	Production	Pump
501	152680	3	145960	3	174200	3	156150	4	140546	4
502	464910	6	431440	6	448308	6	466120	9	520170	9
503	80080	2	76070	2	72730	2	60480	2	54864	2
504	217170	3	199010	3	217390	3	211100	5	204900	5
505	461040	6	413870	6	458842	6	449672	6	441352	6
506	44790	1	42680	1	44170	1	54160	1	56040	1
507	519336	7	501176	7	513514	7	477360	7	497766	7
508	603970	10	539420	11	634080	11	663222	15	575084	14
509	1170720	17	1134449	18	1135192	18	1167461	19	1212260	20
510	248390	4	211644	4	224544	4	228130	4	237100	4
Total	3963086	59	3695719	61	3922970	61	3933855	72	3940082	72

Table A7: Water production summary from January to June 2018.

DMA	Jan-18		Feb-18		Mar-18		Apr-18		May-18		Jun-18	
	Production (m3)	Pump	Production (m3)	Pump	Production (m3)	Pump	Production (m3)	Pump	Production (m3)	Pump	Production (m3)	Pump
501	139330	4	125580	4	133140	4	115810	4	114200	4	94020	4
502	504940	9	495910	9	613204	9	594850	9	580630	9	514728	9
503	57000	2	57000	2	64200	2	63000	2	68974	2	71450	2
504	192840	5	186660	5	221950	5	213320	5	217250	5	183240	5
505	402372	6	373592	6	482362	6	433295	6	434542	6	428650	6
506	56150	1	51990	1	85760	1	63840	1	65550	1	51330	1
507	492520	7	425590	7	435268	7	436650	7	490096	7	531400	8
508	578064	14	506720	14	573300	14	535770	14	582460	14	552510	14
509	1182250	20	1115270	20	1267747	20	1193961	20	1303750	20	1219845	20
510	251510	4	230168	4	291453	4	208380	4	271958	4	236608	4
Total	3856976	72	3568480	72	4168384	72	3858876	72	4129410	72	3883781	73

Table A8: Water consumption summary from August to December 2017.

DMA	August,2017		September,2017		October,2017		November,2017		December,2017	
	SC	Consumption (m3)	SC	Consumption (m3)	SC	Consumption (m3)	SC	Consumption (m3)	SC	Consumption (m3)
501	447	146126.753	447	145578.540	448	161182.302	448	156487.610	448	148464.274
502	959	281898.082	959	315095.130	961	314153.474	960	322509.240	966	327741.322
503	194	69085.816	194	76111.030	194	77581.179	194	76679.170	195	74594.809
504	723	385381.713	722	386743.690	723	370276.713	721	379093.020	726	390206.854
505	1172	483066.433	1170	486806.670	1171	492712.474	1171	493080.760	1172	492313.401
506	334	120552.811	335	116100.480	336	135677.810	335	124345.620	335	128145.374
507	2358	424517.495	2358	419493.64	2358	430028.251	2358	414927.050	2313	397539.181
508	1933	572172.235	1937	567876.550	1932	589638.566	1933	1387475.020	1930	555050.453
509	3743	936615.339	3739	980052.630	3743	986046.244	3744	943801.680	3740	910689.683
510	591	206655	591	191008.240	591	204597.293	591	204304.410	591	215801.408
Total	12454	3626071.677	12452	3684866.600	12457	3761894.306	12455	4502703.580	12416	3640546.759

Table A9: Water consumption summary from January to June 2018.

DMA	January,2018		February,2018		March, 2018		April, 2018		May, 2018		June, 2018	
	SC	Consumption (m3)	SC	Consumption (m3)	SC	Consumption (m3)	SC	Consumption (m3)	SC	Consumption (m3)	SC	Consumption (m3)
501	448	144184.493	446	139841.844	448	151000.111	448	147042.16	449	152167.04	449	147670
502	963	308669.071	962	309552.024	963	314825.924	963	310580.08	962	289786.605	961	340372.55
503	194	68827.975	193	73502.3	194	76206.193	194	75676.09	195	73777.193	194	70970.09
504	722	391310.562	719	394362.056	722	388456.562	722	391767.06	723	406025.562	718	388637.06
505	1172	468195.037	1171	479678.356	1173	484719.147	1175	504896.11	1175	524925.7	1169	488558.77
506	335	131136.056	335	111398.312	337	127537.142	336	126805.46	334	121595.319	336	115795.47
507	2360	401492.291	2358	397968.308	2363	400804.962	2362	430409.35	2365	409962.645	2361	436515.18
508	1930	561639.340	1937	560866.74	1938	569954.488	1939	550915.767	1940	540071.79	1940	565464.08
509	3744	883198.028	3749	866002.716	3750	887326.499	3751	902672.03	3757	882173.57	3760	919200.13
510	590	221979.316	590	203001.9	591	205165.875	591	227171.2	592	211186.13	591	212357.84
Total	12458	3580632.169	12460	3536174.56	12479	3605996.903	12481	3667935.307	12492	3611671.5	12479	3685541.2

Table A10: Individual pump's energy efficiency

DMA	Name of Pump	Production (cubic meter)	Energy(Kwh)	Energy efficiency (kWh/ cubic meter)
501	a) Banani 5	68352	61217	0.90
501	Banani 7	46860	40755	0.87
502	Banani 3	55370	32944	0.59
502	Banani 4	79880	31277	0.39
502	Banani 6	84500	45405	0.54
502	Banani 8	149100	41686	0.28
502	Banani 9	111600	45160	0.40
502	Korail Jamaibajar	114400	64013	0.56
503	Banani DOHS-1	36000	31108	0.86
503	Banani DOHS-2	27000	19193	0.71
504	Gulshan 6	66300	49553	0.75
504	Gulshan 7	72420	38448	0.53
504	Gulshan 74	79032	30862	0.39
505	Gulshan 10	97566	50440	0.52
505	Gulshan 4	73290	34948	0.48
505	Gulshan 5	77343	40080	0.52
505	Gulshan 8	72880	30758	0.42
505	Gulshan 9	75370	43200	0.57
505	Wonderland Park	87540	33086	0.38
506	G. Shooting complex	63840	30589	0.48
507	Mohakhali 'Cha' Block	57790	34894	0.60
507	M. Health Complex	75040	35080	0.47
507	Mohakhali Jalkhabar	47410	22810	0.48
507	Mohakhali Laboratory	80000	34938	0.44
507	M. Dakshin Para	52160	24786	0.48
507	M. T&T Colony	65430	26497	0.40
507	Mohakhali TB Gate	58820	37916	0.64
508	Hatir Jheel	67620	41111	0.61
508	Khunipara	58600	19843	0.34
508	Niketon 1	18000	8740	0.49
508	Niketon 2	26400	13189	0.50
508	Niketon 3	8450	4479	0.53
508	Niketon 4	35130	24549	0.70
508	Tejgaon 8	50840	43588	0.86
508	Tejgaon 9	79930	42501	0.53

508	T. Health Complex	88830	30773	0.35
508	Tejgoan Polytechnic	65472	62994	0.96
509	Alenbari	107650	45000	0.42
509	Arjatpara	87330	46385	0.53
509	BG Press Math	72200	31121	0.43
509	BG Press Staff.QR	56100	50309	0.90
509	East Nakhal Para	86051	50543	0.59
509	F.D.C Campus	72500	45000	0.62
509	Kawran Bazar	38350	20576	0.54
509	Old Assembly Bhaban	71220	44132	0.62
509	Old Assembly Bhaban 2	24980	3306	0.13
509	Shahenbag	44400	31382	0.71
509	Tejgaon BTCL	65150	39096	0.60
509	Nimtali Rail Gate	75000	38382	0.51
509	Tejkuni Para-1	77280	33829	0.44
509	Tejkuni Para-2	114400	61577	0.54
509	Tran Bhandar	42510	35699	0.84
508	Tejgaon Police Station	50400	43782	0.87
508	Tejgaon Lift Station	30132	14047	0.47
509	West N Shiya Mosjid	83440	29026	0.35
509	West Nakhal Para	25000	27600	1.10
510	Mohakhali DOHS-1	53900	43013	0.80
510	Mohakhali DOHS-2	78090	35296	0.45
510	Mohakhali DOHS-3	31275	31879	1.02
510	Mohakhali DOHS-4	84000	36640	0.44

Table A10: Individual pump's energy efficiency (continued)