CHAPTER 1

INTRODUCTION

Background of the Study

In the last few decades, international agencies have moved remarkably towards achieving sustainable water supplies for human well being. For instance, "Water for Thirsty Cities" (UNCHS, 1996), "International Drinking Water Supply and Sanitation Decade" (1981-1990), "Water for All Policy" (ADB, 2000), "Water for Life" (WWC, 2002), "World Water Forum" (1997, 2000, 2003, 2005), etc. are some of the projects undertaken by countries and communities in different parts of the world. Water is recognized as the basic ingredient of food production, a moderator of economic development, and an essential element for the healthy functioning of all the world's ecosystems. Indeed, having sufficient, safe, and clean water is one of the essentials of a human being's healthy life.

Growing population, urbanization, industrialization, and the whirlwind pace of globalization has led to change in today's world. They have produced a greater impact on people lives and the precious natural resources, particularly "water". Approximately 97% of the water on the earth is saline, located in the oceans and seas. Less than 3% of the water resources in the world are fresh water. Approximately 69% of fresh water is stored in glaciers and ice caps and cannot be readily used, 30 % is stored in ground water, and less than 1% is found in rivers and lakes, which is easily available for use as fresh water on earth (Shiklomanov, 1993).

Issues related to water sustainability are of major interest locally and globally. This has created an increasing international trend towards studying water sustainability. This is especially true in areas with increasing water shortage due to natural phenomena or rapid development, while water loss is unavoidable in every water utility. Locally, the Government, water authorities and consumers have become increasingly concerned over the state of national water loss and the slow progress of water utilities towards reducing or managing issues into water loss or non-revenue water (NRW) levels. Non-revenue water seriously affects the financial viability of water utilities and importantly threatens the water supply sustainability. Thus, we have to consider new approaches for water sustainability in urban water supply systems.

Traditionally, the local or municipal authorities (town, city) are responsible for providing public water needs, disposal of wastewaters, and the control of water pollution. However, many governments or city authorities have failed to fulfill people's needs due to the inability to cope with the increasing demand of water. Other agencies of government, businesses, and the general community need to be more involved and participate. They must actively participate in the solutions by modifying their behavior patterns in water supply management, particularly in reducing water loss or non-revenue water management in both water authorities and water users. Therefore, to meet urgent needs in the urban water sector and to manage water sustainability in the urban context more efficiently, countries are starting to reconsider and modify accordingly their current approaches to the formulation and implementation on water loss or non-revenue water reducing policies and action programs.

In the City of Yangon, water supply and any water supply related matter are the responsibility of the city government. City is highly urbanized and is the designated economic center of the Union of Myanmar. Population in the city is increasing very fast. However, the amount of water supply from city authority does not correspond to the increasing population and economic activities.

The City water supply network is very old. Established in 1842, water leakage from the system is very high. Unaccounted for water (UfW) in the city water supply has been estimated at 65% in 2002 (JICA study team on improvement of water supply system in Yangon City reported, 2002). Yangon City is encountering critical urban water supply shortages in recently. These are due to severe financial limitations, less developed infrastructure, lower level of skills and technology, political, cultural, and social influences (Tun, 2005). The objective of this study is to draw some policy implications for water loss or NRW control in urban water supply management at Yangon City.

By drawing from the experiences of other countries and using Yangon City as a case study, this paper hopes to provide better information and insight as to how better non-revenue water management can be applied to improve urban water supply. The paper hopes to achieve this by introducing better technologies, better water resources management practices and to enhance water loss management polices.

Significance of the Research

Non-Revenue Water (NRW) management is important for urban water supply systems in all countries. A high NRW level is the result of a poorly run water utility that lacks the governance, the autonomy, the accountability, the technical and managerial skill necessary to provide reliable service to their people. To illustrate this point, a comparison of Yangon City public waterworks system with other ASEAN countries public waterworks system are shown in Table 1.1, it shows the weak performance of water supply system management in Yangon City.

Only 37% of the water supply service area has piped water connection in Yangon, compared to 82% in the public waterworks at Bangkok and 100% in those of Kuala Lumpur and Singapore. In terms of number of house connections per capita, the gap between Yangon on the one hand and Bangkok, Manila, and Singapore on the other hand is even much wider.

Table 1.1: Comparison of Public Waterworks Systems in the Selected ASEAN Countries

Name of Countries	Area (km^3)	Service Coverage area (%)	House connection ('000)	Non-revenue water (%)	Water availability (hrs/day)	Staff per 1000 connections
Bangkok	893	82	917	38	24	4.60
Jakarta	212	27	312	53	18	5.90
Kuala Lumpur	243	100	126	36	24	1.12
Manila**	1274	69	719	58	17	9.80
Singapore	640	100	835	7	24	2.00
Yangon	238	37	92	60*	12	12.00

*****This is 1997 data. Lack of production metering and very little consumption metering make it difficult to determine realistic UFW.

** With significant private water vending; other cities do not have any significant water vending

Source: Asian Development Bank (1997), Second Water Utilities Data Book, Manila.

Jakarta has the lowest service coverage in terms of percentage of service area and house connections per capita. However, in terms of measures of inefficiency (i.e., ratio of non-revenue water, hours of water availability in the system, and number of personnel per 1000 connections), Yangon has the worst record of all. On the average, Yangon WSS provides water for only about 12 hours per day, whereas piped water service is available 18 hours a day in Jakarta, 17 hours a day in Manila and 24 hours in the other cities. Management of water supply efficiency and financial performance also greatly suffers from over-manning as indicated by the high ratio of staff personnel to the number of connections.

The most dramatic evidence of water supply management inefficiency is the high ratio of non-revenue water (NRW) or water that is not accounted for due to illegal connections, leakages, and other weaknesses in WSS management. For instance, NRW is only 7% in Singapore (one of the lowest worldwide) and about 38% in Bangkok, which is about the average among developing countries. In contrast, NRW comprises 60% of total water production in Yangon.

Increasing population, urbanization, and industrialization has contributed to a decrease in water supply capacity (high losses of water) and an increase of the water supply shortage in Yangon City. In the future, with new housing developments and the progress of economic activities, the water supply sector would be adversely affected by over extraction of surface water and ground water if there were no improvement in the management of water supply in the study area, Yangon City.

Reducing water losses in urban water supply are a fundamental requirement for improved water supply management and sustained water resources in urban areas. Most studies related to urban water issues have been feasibility studies undertaken in drawing a master plan for the improvement of city water supply system and preparation for water supply construction loans from multilateral/bilateral agencies such as JICA, and ADB. There have been a few household-level demand studies. These were done in relation to health, nutrition, poverty, and urban studies. All were descriptive and most of them simply documented the sources of water supply. Willingness to pay for water and sanitation studies was done in some rural areas. The city government began taking concrete steps to address the urban water issues. The appropriate water loss control action programs are being calculated. However, there is no clear sense of the causes of water loss in the city water supply management. Finding solutions are seriously hampered by limited empirical analysis. A comprehensive research needs to identify the causes of water losses or high non-revenue water in the urban water supply management and it is necessary to consider appropriate policy framework for ensuring long-term water sustainability in Yangon City.

Statement of Research Problem

Based on the research need, the importance of this study is achieving water sustainability by reducing non-revenue water in Yangon City water supply system. Thus, the research question raised is ***"Would non-revenue water management promote water sustainability in Yangon City?*** In answering this research question, supplementary questions will be asked throughout the case study on the current level of water supply management and its further potential for improvement of water supply in Yangon.

1. What is the non-revenue water situation in exiting water supply system of Yangon?
2. What strategies are being done by the water institution to reduce NRW in Yangon?
3. What is the people's perception on water supply system in Yangon?
4. Are the people willing to pay or willing to participate to improve water services?
5. What policies are promulgated to reduce NRW and are the existing water policies responsive to NRW reduction in Yangon?
6. What policies can be recommended to reduce NRW in Yangon?

These questions will seek to evaluate and analyze the water resource availability, water service quality, effectiveness and efficiency of water institution, accounting on non-revenue water for sustainability of water supply. This study will also try to explore the people's willingness to pay for getting water and to seek their opinion on current water price and services.

Objectives of the Study

The main objective of this research is to investigate NRW for sustainability of water to meet current and future water needs in the Yangon City. This research study also aims to provide data on the needs of vital water resources sustainability and the experiences of other countries in reducing NRW management for implementing water supply system management in Yangon City's future development .The specific objectives of the study are:

- Describe water resources availability and the NRW situation in the existing water supply system in Yangon.
- Analyze policies, laws, regulations and institutions for water supply services in Yangon.
- Describe strategies and experiences of Yangon and other Asian countries in reducing NRW management.
- Analyze the potential contribution of reducing NRW to water sustainability in Yangon.
- Determine people's perception of water supply system and the willingness for improvement of water services in Yangon
- Provide policy recommendations for NRW reduction in water supply management, which are concerned with water sustainability in Yangon city.

Assumptions

The assumptions in this study are:

1. There is a significant relationship between managing non-revenue water reduction and ensuring urban water sustainability.

2. Non-revenue water control is an integral component in the urban water supply system management to consider improved policy recommendation for effective water supply system management.
3. Effective NRW control in urban water supply management is essential for urban water supply sustainability.
4. People's willingness to pay and to participate in water supply management will definitely help the control of NRW, water authority as well as urban water sustainability.

Scope and Limitations of the Study

NRW management for sustainable water resources management in the urban area is a broad and complex issue. Given the limitations of time, it is impossible to go into details of all its aspects. There are some following scope and limitations:

Scope: Water resources sustainability issues can occur at different spatial scales, ranging from global to city, community and workplace scale. This research deals with the water sustainability issues that are of relevance to and are concerned with city community scales.

The urban water resources management issues links with various levels of management such as global, regional, national, local/city, district and community levels. Nonetheless, the current research will deal with urban water resources management at the city management issues and levels.

Reducing non-revenue water management is the broad concept. There are political, technical, economical and social points of view. In this paper, the socioeconomic point of view would be presented and the technical viewpoint would be discussed briefly.

Limitations: There is a lack of research within water resource areas in Myanmar. This research gap and fragmented availability of data for water resources is one of the major difficulties that the researcher encountered during this study. Myanmar academics have not yet paid attention to the water resources management and sustainability areas so there are very few, if any, Myanmar publications in this regard. There is very little data giving complete, accurate and systematic information about the evaluation and measurement of the water supply system improvement in Yangon city. There are some contradictions in the data and information from different sources. The fact is that multiple uncertainties will affect the accuracy of water demand and supply figures that the researcher should take care. Given time and financial limitations, the study will only concentrate on water resource within Yangon City municipal area for water resources development considered in the improvement of City water supply system.

This study relies on the responses from water resource professionals and water users. The nature, character and intensity of water problems, human resources, institutional capacities, the relative strengths and characteristics of the water sectors, the cultural setting, natural conditions and many other factors differ greatly between countries and regions, as well as in local situation. It is assumed that their responses will be fair representations of how their particular organization is structured and how is it performing. One hopes that for the benefit of research the respondents appreciate the need to portray accurate and unbiased accounts of their views on water supply management.

CHAPTER 2

LITERATURE REVIEW

This chapter reviews literature that addresses on managing water sustainability and about non-revenue water in water supply management based mainly on the theory of sustainability, control theory and participation theory.

Theoretical Background

Theory of Sustainability

The theory of sustainability suggests an initiative can be sustained, and it takes the sustainability issue head on during strategic analysis. *Evaluators can facilitate its development* (Heather, Coffman, and Marielle, 2002).

The theory of sustainability can help strengthen the ability to make choices that will increase the likelihood, that the work of an initiative can be sustained. These choices and the set of activities that stalk from them may otherwise be different if sustainability is not considered as one of the key factors guiding the creation of the strategy.

The theory of sustainability propels the dynamic concept for a long-term future as well as the present. Dynamic concept implies changes in societies and their environments, technologies and cultures, values and aspirations. Sustainability is a characteristic of a process or a state that can be maintained at a certain level indefinitely. A sustainable society must allow and sustain such change, i.e., it must allow continuous, viable and vigorous development, which is what we mean by sustainable development.

Sustainable development is defined as the development that meets the needs of the present without compromising the ability of future generations to meet their own needs

(WCED, 1987). In the real world, it is impossible to define sustainable development in an operational manner in the detail and with the level of control presumed in the logic of modernity. Thus, many of the academics with an interest in sustainable development in the late eighties and early nineties approached the subject from an economics background (for instance, Dasgupta, 1993; Pearce, 1989) attempting to price the environment through a framework of fiscal controls and incentives (see Dresner, 2002 for a comprehensive discussion of this). This argues that the best way to protect the natural environment is to assign it an economic value based on people's willingness to pay. The aim is to internalise all the external costs to the economy in terms of pollution, resource depletion and human health. That sustainable development is still chasing a divergent set of policy goals, at the international level at least is highly evident in the more recent academic literature (Ayre and Callway, 2005).

In the extensive discussion and use of the concept, three aspects of sustainable development have been recognized - economic, environmental, and social aspect. An economically sustainable system must be able to produce goods and services on a continuing basis, to maintain manageable levels of government and external debt, and to avoid extreme sectoral imbalances, which damage agricultural or industrial production.

An environmentally sustainable system must maintain a stable resource base, avoiding over-exploitation of renewable system or environmental sink functions and depleting non-renewable resources only to the extent that investment is made in adequate substitutes. A socially sustainable system must achieve distributional equity, adequate provision of social services including health and education, gender equity, political accountability and participation.

Control Theory

Control theory provides a procedure for the construction of a control law. The control law specifies which input value to use for every state of the system. In the present day, the motivation for control theory shifts with the development of technology and with the needs of society (Schuppen, 2000).

Control theory is an interdisciplinary branch of engineering and mathematics that deals with the behaviour of dynamical systems. The desired output of a system is called the reference. When one or more output variables of a system need to follow certain reference overtime, a controller manipulates the inputs to a system to obtain the desired effect on the output of the system.

Participation Theory

Participation theory forwarded the concepts of intimacy, consensuality, coordination, competence and pretension as important in understanding and establishing true and lasting participation. The theory defines intimacy as the closeness and camaraderie that is created when partners are able to satisfy each other's needs. According to the participation theory, consensuality and coordination are pillars of every successful partnership. Without the partner's consent, there is a risk of alienating them through coercion. Unless dissent is voiced, agreements are pretended. If one decides to do something but insists, it must be done his/her way, his/her partner(s) become irritated and frustrated. In order for development projects to satisfy the deepest needs of its beneficiaries, they must first come to an agreement regarding what to do. Participation theory helps us to appreciate the difficulty inherent in reaching a consensus (Raymond, 1996).

The scopes of the environmental resource management issues that are often addressed by public agency planners outweigh technical considerations. Most planners, however, are not formally trained to organize and manage the complex human and organizational problems associated with public participation programs. Nevertheless, environmental issues are the best handled with the participation of all citizens concerned as highlighted in international environmental treaties, Principle 10 of the declaration of the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro (Brazil, 1992). Agenda 21 adopted by UNCED recognized the important role of public participation in environmental impact assessment (EIA) in achieving sustainable development (Item 23.2 of Agenda 21). Paradoxically, Wright (1976) also stated that participation is valuable; it creates a community where people show more respect for one another. Thus, public participation is at the heart of development. They are not only the ultimate beneficiaries of development, but they are also the agents of development.

Management of Water Sustainability

Principles of Water Sustainability

Water is an important resource necessary for survival of human beings, economic development, and the functioning of the ecosystem. Organisms can live only where there is access to adequate supplies of water. Issues of water quality and quantity have forever troubled humans, characterized by the phenomena of floods and droughts. While several recent efforts have made progress in defining the issues (Golubev et al. 1988, Koudstaal et al. 1992, Plate 1993, Raskin et al. 1995), the sustainability issues of water resource management have not been clearly defined. Water resources are non-substitutable, very essential for the survival of human beings and their depletion may impose heavy economic costs (Pearce *et al*., 1994) and health consequences on future generations.

Since the late twentieth century, water use has been raised sharply by several major driving forces such as increasing population, economic development and climate change, etc,. Misuse of water resources and poor water resource management practices have often resulted in depletion of aquifers, falling water tables, shrinking inland lakes, and stream flows diminished to ecologically unsafe levels. However, the availability of water sets the environment in which we live: less than 1% of the world's fresh water resources are in rivers and lakes that easily available for use as fresh water on the earth. The allocation of water on earth is also set unfavorably with our population. We can see that the Amazon River accounts for 15% of the global runoff and 0.5% of the world population use, while China has 21% of the world population and 7% of the global runoff (WRR, 1994; PRB, 1998). Under these circumstances, the need for improved and more efficient management of water resources is obvious.

Within the concern over the global implications of water problems, sustainability of water has been advanced as an important objective to be realized in natural resources management and water management as well. This concept is not new. It has been used in scientific literature for many centuries in fishery, forestry, groundwater, and other areas indicating the rate of use of renewable natural resources to ensure the continuous supply of resources and their maximum use. In 1987, the World Commission of Environment and Development (WCED) reintroduced the sustainable development principle, which subsequently was turned into the UN action plan, Agenda 21, by UNCED (1992). The popular definition of sustainability in the Brundtland Commission Report entitled *Our Common Future* (WCED, 1987) is "*the ability to meet the needs of the present generation without compromising the ability of future generations to meet their needs*." One more virtue, the concept of sustainable development means the basic principle of harmonizing environment and development, but the issue of harmonizing development and the environment is so difficult and controversial. Because the definition of sustainable development consists of three conceptual components: needs, generations and equity, this implies that the development is necessary because of human needs but that intra-generational and inter-generational equity should hold. In recent times, the concept of sustainable development with intra-inter generational equity motivates various leading policy agencies to reconsider the environmental impacts of their projects and development activities. With these new policies, financial and other institutions, national and international, are now expressing support for the implementation of the sustainability principle.

In the context of freshwater resources, many discussions of sustainability require that we understand both the physical resource and the service or supply that those resources must provide. Those water resource systems can satisfy the changing demands that will inevitably be placed on them, without significant system degradation (Loucks, & Gladwell, 1999). However, their performance may vary at different times and under different socio-cultural conditions. Dixon and Fallon (1989) provided a useful way of sustainability for water resources management with respect to the social-physical-economic concept. They clearly defined at the "*sustainability of water resources management* is *a set of activities that ensures that the social value of the services provided by a given water resources system will satisfy present societal objectives without compromising the ability of the system to satisfy the objectives of future generations"*. This includes three considerations for water sustainability such as nature (river and their environment and ecosystem), current generation, and future generation needs. Thus, water resource systems must be considered integral parts with a changing societal system.

One way we could show that the main principle for the sustainability of water resources is that the rate of extraction from both ground and surface water sources should not exceed the rate of renewal. Extraction must not jeopardize the biodiversity of the ecosystem (ESCAP, 1998). Equity is also an important objective of sustainability. It is often expressed as the equitable distribution of the benefits, as well as the mitigation of adverse impacts on people (as residents of reservoir areas) affected by such development (Little and Mirrlees, 1968, UNIDO 1972, Cernea 1988). Indeed, factors that affect temporal and spatial equity in water resources development can be either anthropogenic or natural, or both. Temporal equity is associated with resource depletion and long-term cumulative effects that may lead to disasters in the future, while spatial equity refers to the conflict between upstream and downstream areas in a river basin and often concerns the conflict between various water users (Cai, Mckinney, Rosegrant 2001). Water quality is also considered an equity issue. Conflicts arise when upstream users release excessive pollutants into the river and downstream users suffer damage resulting from the poor water quality. This is reflected in the widespread consideration of environmental impacts on water sustainability. In addition, upstream land use ranging from forest, agricultural and mining to urban and industrial may degrade downstream land, surface water and groundwater resources via runoff of sediments (e.g. pesticides, fertilizers, etc.). These effects are clearly shown in the loss of useful reservoir storage capacity caused by sedimentation from upstream, eutrophication of lakes and reservoirs from nutrients, salinization of downstream, and pollution of groundwater aquifers by seepage or injection of organic and non-organic substances. Even if there is no environmental deterioration such as erosion, sedimentation, salinizaiton, and other pollution, the finite amount of water availability is highly variable both seasonally and annually. The consideration of this physical resource should be undertaken in sustainability of water resources management.

A more fundamental issue with the philosophy of sustainability is the flawed logic of comparing a finite resource with exponential population growth. Sustainability is ultimately impossible for critical uses. At some point in the Malthusian argument (1798), population demand will outstrip resource supply (Wood, 2004). Therefore, there should be an obvious desire to minimize waste and misuse through maximizing efficiency for finite resources of water. Efficiency can be enhanced in several ways. Technology advances from time to time to enhance delivery systems, utilization techniques and extraction methods in such ways as to advance the sustainable use of water. Prendergast (1993) wrote in an article entitled 'Engineering Sustainable Development' that '*sustainable development is an effort to use technology to help clean up the mess it helped make, and engineers will be central players in its success or failure.*' He believes that future technology and professionals will use natural resources more efficiently through conservation measures and switch to renewable sources, waste minimization, greater recycling and reuse of resources and material. Thus, education and knowledge-based transactions can also facilitate further improvements for efficient use of water resources. Water efficiency is the long-term ethic of conserving water resources through the employment of water-saving technologies. Whatever is done to increase the level of sustainability of our water resources, we will ensure that water will be available for future generations. A good understanding of these aspects of finite resources of water, including quantity and quality of supply water, is required for long-term. It reflects on the future impact of the economy, the environment, on ecology, and on society that will result from decisions and actions taken in present days.

Therefore, there are needs enabling conditions that all parties can be involved in so as to be aware of the "rules of the game". The condition focuses on the changes within the framework of legal, institutional and economic development. All these three pillars are related to one another and each presents its own specific practices for directing resource distribution. The laws governing the use of water and the institutions created to manage them are a product of a country's history, society and economy (Winpenny, 1994). Hence, water resources management institutions should promote or at least not constrain the achievement of the multiple objectives of the water resources management plan particularly sustainability objectives (Hufschmidt and McCauley, 1990). These should be channeled to allow efficient and equitable use of resources on a sustainable basis, with appropriate accountability for unavoidable adverse environmental and social consequences.

Demographic society, economic and political factors interact to create an unfavorable environment for sustainability. The transition to new technologies, new management practices, and new institutions (or institutional leadership) must proceed in an orderly manner (Loucks, *et al*, Gladwell, 1999) to a more holistic concept where economic, environmental and social considerations are equitably handled. The roles of people must be changed for sustainability of water, the main actors will be individuals and groups in households and communities with new responsibilities for their use of water and water related services, as part of a cooperative strategy. Corporations are beginning to apply the concept of sustainability at a practical level in terms of corporate citizenship or corporate social responsibility. Corporate social responsibility is currently dominated by the notion of the triple bottom line (TBL) (Lenzen, Foran and Dey, 2006). A term (TBL) originally coined by John Elkington in the early 1980s to describe corporations moving beyond reporting only on their financial “bottom line” to assessing and reporting on all three spheres of sustainability: economic, social and environmental. The notion of TBL has many meanings to many people, and can be applied at different levels in society by different stakeholders. However, there is general agreement that the TBL principle is a useful approach for examining the operations of an entity, from a local to a major corporation. Planning must provide information that helps the public make judgments about which "needs" and "wants" can and should be satisfied. The sustainability principles can help bridge the gap between such diverse and competing interests (Gleick, 1998).

In summing up, *"sustainability" itself can be viewed as the maintenance of positive rate of improvement.* While development changes by improving a situation or condition over time, sustainability implies the continuance or maintenance of a certain situation or condition over time. In order to achieve a positive rate of improvement, water resource sustainability is not simply a scientific question of how to control water use but a social construct involving decisions over when, why, and where to do so.

Sustainable Water Resources Management

The paradox of water is that although it is one of the most common substances on earth only a fraction of it is freshwater suitable for human consumption. Most of the freshwater is underground water, ice caps, glaciers, and only 1% can be used or is available for human consumption (Serageldin, 1995). These figures suggest that water in fact is a scarce resource and should be treated accordingly.

The problem with water is that it is a "two faced" resource. On one hand, water is a scarce resource and on the other hand, it is a public good. The essence of public goods is that they should be accessible to everyone (Glieick et al 2002). Market forces govern management of scarce resources (EDI of the World Bank et al, 1995). From a managerial point of view, it is difficult to find a method, strategy or plan to combine these two aspects in a satisfactory way.

Water has no social or economic bounds, water supply management and development is the responsibility of national or city authorities in many countries. Therefore, these authorities should pay careful attention to water resource management because it can affect all sectors of society in the country. Each country, developed or developing must put together their own plan of action suitable for their hydrological conditions and needs. The plan and management for water must not only be developed in theory but should be feasible and carried out in reality.

Historically, water resources management, development and policy have evolved in a variety of ways and differed from country to country. Generally, water resources management includes development, control, protection, regulation, and beneficial use of surface and ground water resources. Services provided by a water sector include water supply for agricultural, industrial and municipal uses, wastewater collection and treatment, protection and enhancement of environmental resources, pollution prevention, recreation, navigation, hydroelectric power generation, storm water drainage, erosion and sedimentation control, and controlling floodwater and reducing damages due to flooding. Water resources planning and management activities include policy formulation, national, regional and local resource assessments, institutional arrangement, legislations, and regulations, related financial management, formulation and implementation of resource management strategies, planning, design, construction, maintenance and operation of structures and facilities, scientific and engineering research, education and training (Pykh & Pykh, 2003). Thus, water resource management develops an integrating process within a number of water sub-sectors.

In reality, no universal handbook on water resources management is exit but some managerial strategies and guides are more useful than others are. Water resources management aims at managing the tasks required to generate water and produce water related goods and services for the benefits of the society as a whole. The holistic management of freshwater as a finite and vulnerable resource, and the integration of sectoral water plans and programs within the framework of national economic and social policy are of paramount importance for the objectives of integrated water development and management from here to beyond (UN, Agenda 21, chapter 18, 2003). This approach creates a sustainable blueprint for water resources management. In 1977, the United Nations water conference in Mar del Plata, the International Conference on Water and the Environment in Dublin, and in 1992, the Earth Summit in Rio de Janeiro have articulated a set of principles for good water resources management. These are:

1. The "ecological principle", which requires that water, be treated as a unitary resource within river basins, with particular attention to ecosystems.
2. The "institutional principle" which recognizes that water management requires the involvement of government, civil society and the private sector, and that the principle of subsidiarity is respected. It also gives special emphasis to the role of women in water management.
3. The "instrument principle", which requires that water be recognized as a scarce economic goods and that greater use is made of "user pays", "polluter pays" and other market-friendly instruments.

In reality, several stakeholders, representing numerous administrative sectors, focusing on their particular area of interest, often plan how to manage water resources. This approach, on the other hand, creates an ineffective, scattered managerial strategy (Serageldin, 1995). With in ideologist thinking of good water resources management, water resources management planning should start at the macro level, the national level, with a clear definition of the "rules of the game" but must find its way to the lowest levels (Wnukowska, 2004). Water resources management starts to address resources issues with often-conflicting interests of the different beneficiaries. This means that new approaches and new concepts must be introduced. Thus, policies should be formally stated or they must be only implicit in an agency's actions. For example, although data collection may be inadequate to measure and assess environmental conditions or even to devise sound projects no policy is enforced to remedy the situation (Frederikksen, Berkoff and Barber, 1994). Therefore, it is favorable to look at the issues and problems from a centralized point of view, but solve them on a decentralized level. This statement does not suggest that a country should apply centralized water management schemes with a top-down approach. The authorities should acknowledge that a general nationwide agenda for resources management must exist as a blueprint for provincial and local management schemes. Such approach cannot be achieved by a single organization in isolation. It requires a sound framework for environmental management and also requires the coordinated efforts of the local, provincial and national government agencies as well as NGOs, community organizations and people.

Function of Water Resources System

Generally, water resources system includes various components such as the natural system, human made infrastructure, and the institutional arrangements to regulate and control the availability and access of users to these components (Dhaka, 2001).

Jain and Singh (2003) defined the water resources system as a set of water resources elements linked by interrelationships into a purposeful whole. For example, a water supply reservoir for a small city, linked with a water distribution network, would constitute a system. To an engineer, these systems may be dams and weirs, tunnels, levees, pipelines, electrical power plants, water treatment and reclamation, and similar physical works, which have been constructed to provide certain benefits. An economist views include economic efficiency, income redistribution and stimulation of economic growth. To a lawyer, a water resources system is a device for the implementation of water rights. To those living in an arid environment, water resources systems mean food and fiber, homes and jobs, laws and politics. To many conservationists, water resources systems are unwanted interventions, responsible for the destruction of wild rivers, scenic beauty and wildlife habitat. Indeed, water resources system includes all these points of view, which could be physical, technological, sociological, biological, legal, geological and agricultural.

In order to better understanding the assessment, development, and management of water resources system, Ertuna (1995) presented the fundamental function of water resources system in his article "Water Resources Development and Management in Asia and the Pacific" (Table 2.1).

Table 2.1: Functions of the Water Resources System

Functions	**Description**	**Examples**
Subsistence Functions	Local communities make use of water and water based products which are not marketed	- Local drinking water supply - Traditional fishing - Subsistence irrigation
Commercial Functions	Public or private enterprises make use of water or water based products which are marketed or otherwise given a monetary value	- Urban drinking water supply - Industrial water supply - Irrigation - Hydro-power generation - Commercial fishing - Transportation
Environmental Functions	Regulation functions, non-consumptive use	- Purification capacity - Prevention of salt intrusion - Recreation and tourism
Ecological Values	Values of water resources systems as an ecosystem	- Integrity - Gene pool diversity - Nature conservation value

Source: Ertuna (1995)

Sustainability Criteria for Water Resources Management

Water resources development and management is typically a public sector activity only but it has been many places now privatized. Any motivation to consider the future development depends on the ability and willingness to understand, the interactions of processes on very different spatial and temporal scales. Because of the nature of water resources management that everyone involved in these activities has an obligation to see that those systems provide sufficient quantities and qualities, at acceptable prices and reliabilities, and at the same time protect the environment, preserve the biodiversity and health of ecosystems for future generations (Loucks, & Gladwell, 1999).

Sustainability of water is a philosophical concept that designed and managed to meet the needs of people living in the future as well as those living today. This concept of sustainability can mean different things to different people, though sustainability criteria forces people to access the various impacts of proposed plans, policies and practices on future generations and on the present generations. Thus, water resource management professionals have to consider specific criteria for policy discussions and evaluation of water resource system specifying what, when, where and how much to do to satisfy these resources by the many economic, technical, educational, and regulatory means that are available. In contrast, without specific criteria to guide planning, unsustainable water policies are inevitable (Gleick, 1998).

Due to complex nature of water resources management, water sustainability views as a combination of high resilience and low vulnerability (Duckstein & Parent, 1994). On the other hand, sustainable criteria for water resources system on their behavior are described as performance indices (PI) which can classify as resilience, vulnerability, grade of service, availability, quality of service etc. In addition to performance indices, figures of merit (FM) are also used for the analyses of system behavior (IAHS, 1998). It can define as functions of performance indices. However, using FM in measuring sustainability is disparity. Thus, Loucks (1997) discussed in one idea identifying a new FM as a weighted statistical index to describe sustainability though decisions on a set of sustainability criteria are subjective. They are generally based on human judgment or social goals, not scientific theory. Yet another concept used assess planning decisions in terms of sustainability includes entropy (McMahon & Mrozek, 1997).

In practice, criteria for sustainability on decision-making are not yet in operation. However, to facilitate the water sustainability for this research, some criteria will discuss in this section, much of the contents below are based on "Water in Crisis: Paths to Sustainable Water Use" (Gleick., 1998), "Sustainability Criteria for Water Resource Systems" (Loucks, & Gladwell, 1999) and "Environmental Economics book" (Field, 2002, pp.183-193). The criteria for water sustainability in this study are:

Basic Human Water Requirements: The first criterion is a primary goal to provide a basic amount of water for meeting the essential needs of humans. For humans, insufficient access to potable water is the direct cause of millions of unnecessary deaths every year. The provision of a certain amount of fresh water to support human metabolism and to maintain human health should be a guaranteed commitment on the part of governments and water providers.

Table 2.2: Basic Water Requirements for Human Needs

Purpose	Recommended commitment (liter/ individual/day)
Drinking water*	5
Sanitation services	20
Bathing	15
Food preparation	10
Total	50

Source: Gleick, 1996 *This is a true minimum to sustain life in moderate climatic conditions and average activity levels.

A minimum amount of water requirement can only be defined for maintaining human or ecological survival. This amount (5 liter/individual/day) is under moderate climatic conditions and average levels of activities. Additional basic needs have been quantified, however, for providing sanitation services, preparing food, and bathing (Gleick, 1996) recommends that 50 liters/individual/day be committed to satisfy these needs (Table 2.2). No legal or institutional mechanisms exist, however, to guarantee even this basic requirement to present and future generations. The first sustainability criterion, therefore, guarantees access to this basic water requirement to meet the fundamental domestic needs of people.

Water Quality Standards: Different uses of water require different qualities of water. Thus, water quality standards for different purposes must be developed and water quality must be monitored and maintained to meet these standards. Water in most developed countries is protected from contamination by national regulations (WHO 1984, MNHW 1992, USEPA 1992). These water quality standards are supposed to ensure that potable water is reasonably free from contaminants known to affect human health. In many parts of the developing world, however, even minimal water quality standards are not in place, leading to widespread cases of waterborne diseases. Lack of sufficient clean drinking water lead to many hundreds of million of cases of water related diseases and deaths annually (WHO 1995). Water used for non-human consumption need not to be protected to the drinking water standards. For example, water used for many industrial, commercial, or landscaping purposes could be protected to a lower standard, with substantial economic savings. Similar water quality criteria need to be developed for ecological water requirements. Substantial effort should go into identifying these differences and developing ways of meeting various demands with water at appropriate levels of quality (Gleick, 1998).

***Data Collection and Availabi1ity*:** If water planning and management are to be effective, data on all aspects of the water cycle must be collected and made available in an unrestricted manner. At present, data on many aspects of regional and national water supply and water use are not collected. They are not widely available. At the extreme, some national governments continue to classify basic water data for so-called security reasons. This is unjustified and greatly inhibits effective water planning and management. Substantial data gaps exist on the condition of different groundwater basins, extraction amounts, current pumping practices, and recharge rates. Similarly, water-use information is sketchy or site specific, making actions for increasing efficiency or improving conservation programs hard to plan and implement. Information should be produced in reasonable time with reasonable resources, and it should be freely and widely shared. Recent advances in electronic communications makes sharing resource information easy and inexpensive. In particular, internet resources related to water are growing at a phenomenal rate, and many sources of information are already freely available. This trend should be encouraged and expanded (Gleick, 1998).

Equity: Equity or fairness is an important consideration in the selection of any environmental policy evaluation process (Field, 2002). Equity is a measure of fairness of both the distribution of positive and negative outcomes as well as the process used to arrive at particular social decisions (Gleick, 1998). Perhaps the greatest flaw with many water institutions is their failure to address adequately equity issues.

Some would argue that sustainability should be defined narrowly so that questions of equity are excluded. However, from this perspective, sustainability could be achieved under otherwise morally reprehensible conditions. Questions of equity overlap with sustainability when trying to determine what is to be sustained, for whom it is to be sustained, and who decides. In general, great disparities in wealth, inequities in power between women and men, and discrimination based on race, ethnicity, or age can lead to conflicts that undermine attempts to achieve sustainability. Thus, a fair political process is itself a necessary component of sustainability (Gleick, 1998).

***Efficiency*:** Efficiency means the water use efficiency for this research, which includes *any measure that reduces the amount of water used per unit of any given activity, consistent with the maintenance or enhancement of water quality* (Tate, 1994). Water use efficiency is closely related to other basic concepts of current environmental resource management, perhaps, it is water conservation. According to Baumann *et al* 1980, the most useful definition of water conservation is any socially beneficial reduction in water use or water loss. At the same time, the conservation definition suggests that efficiency measures should make sense economically and socially, in addition to reducing water use per unit of activity. The level of attention paid to water use efficiency is directly proportional to the prices charged for water servicing. Rising prices lead to increasing attention to water use characteristics, and over the long run, to more efficient water use. Water use efficiency is also partially a response to the property rights prevailing society, the greater the degree of private ownership, the greater the use of water efficient practices. Thus, private ownership is also considered for efficiency use of water.

***Incentive*:** A critically important criterion that must be used to evaluate any environmental policy is whether that policy provides a strong incentive for individuals and groups to find new innovative ways of reducing their impacts on the ambient environment (Field, 2002). For the water supply system, when water price reflect the full social costs of developing supplies, incentives are created to use the resource efficiently and rationally, reflecting its value in production or in its various other uses.

Introduction of technological change, flowing from programs of research and development, shifts the marginal abatement cost function downward. So, do education and training, which allow people to work and solve problems more efficiently. The greater these incentives, the better the policy cause at least by this one criterion (Field, 2002).

***Enforceability*:** The objective of enforcement is to get people to comply with an applicable law. There will always be people whose interests lie in not having environmental policies enforced. Enforcement is unlikely to happen automatically (Field, 2002). Often, large numbers of dischargers do not complain about the existing laws and regulations, particularly in the developing countries. The common practice of enforcement policy is costs or profits associated with enforcing pollution control regulation to create effectiveness.

The cost of enforcement, though perhaps not as large as overall compliance cost in most cases, is critical to the success of environmental quality programs and ought to be treated explicitly in evaluating the overall social cost of these programs. There are two main steps in enforcement: monitoring and sanctioning. Monitoring refers to measuring the performance of polluters in comparison to whatever requirements are set out in the relevant law. Sanctioning refers to the task of bringing justice to those whom monitoring has shown to be in violation of the law. If violators are found, the enforcement policy takes them to court and levies the penalties specified in the relevant law (Field, 2002).

***Moral Considerations*:** There are ethical issues on which different people will feel differently, but they are important for deciding on alternative public policies. Moral considerations extend beyond distributional concerns. The innate feelings that people have about what are right and wrong undoubtedly affect the way they look at different environmental policies (Field, 2002). By this criterion, policies that declare outright that certain types of polluting behavior or illegal usage are to be preferred to policies that do not.

Failure and Weakness in Water Resources Management

Governments have the difficult task to plan for sustainable water resources management without falling into managerial traps because water is considered as a strategic resource and public goods. The variable quantity and quality of water and the highly inter-dependent character of water activities make it difficult to use unregulated markets to deliver water efficiently or to allocate it among sectors. Serageldin (1995) discussed the four main failures for governments in water management that are summarized in this section.

1. Dependence on centralized administration

2. Fragmented management

3. Unwillingness to treat water as an economic resource

4. Neglect about the connection between water quality and health, the environment or economic development

The central government is the heart and brain of the managerial body in the most cases. However, a rigid top-bottom approach leads to ineffective and fragmented management on a decentralized level. Agencies on a local level lack control over decisions affecting their operation and development. The Central Government must look into the possibility to decentralize certain functions in order to increase the efficiency of the managerial machinery.

The third point is under constant debate. Advocates of economic management of water resources mean that treating water as an economic good will increase its value and create a more effective and sustainable use of the resource (Economist, 2003). The opposing side means that this can be accomplished without market based principles and methods. Water is more than an economic or public good. It is also a social good. As such, it has significant “spill over” benefits or costs (Gleick et al, 2002). Availability of clean and affordable water improves both individual and social well-being, which in turn affects the well-being of a country.

Clearly, management of water resources is a cyclic process. If the chosen managerial strategy complies with the described conditions, a chance of a sustainable development of water resources is possible. If, however, governing authorities fail to apply the methods described above the results will favor neither consumers nor the environment.

Incentives for Water Management

Incentives can be categorized as market-based or non-market based. The market-based incentives include water tariffs, pollution charges, groundwater markets, surface water markets, auctions and water banking. The non-market based incentives suggest the use of restrictions, quotas, norm, licenses and public participation (Merrett, 1997). The main goal with the incentives, both market based and non-market based, is establishment of a more efficient utilization of water. Water and wastewater are easy to quantify as the volume of water present at a certain place at a point in time. This makes the quantification of use and pollution easily; it means that it is relatively easy to put a price on water. The difficult part is to reinforce the incentives and control that they are being followed.

Methods governed by market forces are part of a greater scheme in water management. They are, however, the most direct means of encouraging conservation of water. The market can be used in two ways to promote more economic use of water.

1. Raising the price of water and
2. Raise the opportunity cost of water higher value uses. Tariffs, pollution charges or other volumetric fees can determine the price of water (Winpenny, 1994).

Recognizing water as an economic goods means, among other things, that water has a value in competing uses (Gleick et al, 2002). Allocation of water can be accomplished through water markets, transferable water-use permits and other incentives, which increase the economic value of water. They create a motive for consumers to relate their use of water to its marginal value and sell the rest. These, however, may be more suitable for the industrial sector rather than the public.

Putting a price on water is dependent on a number of factors. According to the Merrette (1997), the main objectives of water tariffs are 1) Affordability, 2) Cover cost of production and distribution, 3) Encourage water sustainability, 4) Discourage pollution.

The most important objective is to set a price so that all consumers are able to afford the water provided to them. This means that a water tariff program should exist. The easiest way for tariff setting is to give each volumetric quantity of water with the same price.

Considering the range and variety of consumer groups, setting the same price for all would favor high-income groups and burden low-income households. Price progression and identification of users is a good way of dealing with this problem. The concept behind price progression is that each volumetric quantity of water has a different price. This implies that the more water a consumer uses, the more they pay. An alternative to pricing every volume of water is that low-income households receive a basic amount of water, necessary for cooking, cleaning, etc. free of charge, or at a very low cost. However, volumes above the basic level are priced. It is so called two-tier water tariff structure. If these four objectives are successfully realized, other incentives such as pollution charges could be superfluous.

The Feasibility of Private Sector Participation in Water Utilities

There is a wide range of literature available on the various aspects of Private Sector Participation (PSP), including pros and cons, types, mechanisms, and risk averting measures for PSP (ADB 2000, Plummer 2002, Budds and McGranahan 2003, and Akinotoye et al., 2003). The recent focus is on pro-poor PSP, as there are various risks involved for private sector, communities, and government to introduce PSP in urban environmental infrastructure and services (Hardoy and Schusterman 2000, and Satterthwaite 2003). Human beings may say, "We can live without electricity but not without water" (ECFA, 1997: 18). However, there are some complex nature and important characteristics in water supply infrastructure and services, which make the involvement of private companies a particularly challenging venture. These are:

Natural Monopoly: The supply of water is typically a natural monopoly as it is not economical to duplicate the water and sewerage networks in city streets (Idelovitch, Ringskog, 1995). In addition, when there is an existing water supply network, it is difficult to facilitate competition in the water business. Although such forces suggest that it is more economical for a single business entity to monopolize water provision services, a private producer could easily exploit its monopoly status to gain unfair profits.

Price Elasticity: As water supply services are essential for the human life, the demand for water is perfectly price inelastic at survival levels (Galiani, Gertler and Schargrodsky, 2002). Of course, demand exhibits some price elasticity at levels for which water is used for other non-survival household and productive uses. It is that in unregulated private monopolies, output volumes, standards of service and investment levels will all be lower than under competitive conditions, while prices are likely to be higher and set to discriminate against customers with inelastic demands for water (Herrington and Price, 1987). Consequently, a single service provider could make unreasonable profit by setting an extraordinarily high charge.

Hidden Costs: The ratio of unaccounted-for-water (UFW) or non-revenue water (NRW) is extremely high in developing countries (Mclntosh and Yniguez, 1997). These are attributed in part to ordinary technical leakage, water theft by many people who regard water as being free of charge, and administrative losses. The slow installation of accurate meters due to budgetary constraints and under-charging due to erroneous meter reading, etc., produce a hidden cost. Other reasons involve the hidden costs of patronage and the political manipulation of the purchase of equipment and facility of water services.

Long- Term Capital and Capital-Intensive Investment, Sunk Costs and Risks: Water supply and sanitation sector requires long-term non-transferable capital to be implemented. Studies from the United States indicated that the ratio of investments in fixed assets to annual tariff revenue is approximately 10:1 as compared with 3:1 for telecommunications and 4:1 for the electric power (Idelovitch and Ringskog, 1995). The higher ratio for water supply and sanitation makes it more difficult to attract private sector financing because the payback period is long. Furthermore, the water supply and sanitation services demand a huge initial investment, which may be beyond the capability of many private businesses.

For the private sector, large-scale investments always involve significant risks particularly when the assets are sunk, i.e. they cannot be removed for use elsewhere or redeployed on site for other purposes. For example, if an airline operator fails to make an acceptable return on investment, the aircraft may be used in other markets or sold to another operator. Likewise most factories can be adapted to produce different goods if the initial venture proves unprofitable. Such options are largely unavailable in the water sector.

There are a variety of risks in water supply infrastructure and services. Rees (1998) stated some forms of risks are:

- Construction risks (the costs of new developments renovation exceed expectations)
- Commercial risks (the demand for products change or new competitors enter the market)
- Financial risks (interest rates on borrowed capital rise or exchange rates shift)
- Regulatory risks (regulators alter standards of service requirements, refuse price rises or fail to prevent the pollution of water sources)
- Political risks (political instability, asset expropriation or expulsion from the country)

Private companies will only invest in the water sector if risk and uncertainty are kept to acceptable levels. This is because private companies are not social services. They will only provide public goods or below cost water supplies, if they are to recover the costs involved, including their required return on any investments made.

Strong Political Intervention: Providing water and sanitation sector is attached to explosive political issues. Any change of the water charge or water charge collection system can result in direct negative consumer reactions. Politicians tend to be involved in various aspects of water supply services simply because of the grave political impacts of any change in the nature of the services. Moreover, water contamination and supply cuts have serious social impacts as they have profound implications vis-à-vis public safety.

Complicated Decision-Making: Complicated decision-making mechanism is involved in the water supply infrastructure and service provisions. For example, the formulation of a water supply development plan or water treatment services usually involves many government ministries and agencies. In the case of Indonesia, a total of 13 ministries and agencies are said to be involved (ECFA, 1997:15). In Vietnam, more than 20 ministries and agencies are said to be involved (Minh, 2003). Compared to the electricity and other sectors, the decision-making mechanism for a water treatment business, particularly in the capital area, is much more complex, posing serious problems in terms of project implementation efficiency.

More or less, all these factors are cited as reasons to keep water supply and sanitation sector in the hands of the central government or public corporations. The conventional perception is that public services are unsuitable for private sector investment due to the above-mentioned factors. The argument for private provision is also often linked to a broader claim that private enterprises are more efficient than public enterprises (Budds and McGranahan, 2003). However, this argument ignores the fact that not all private operators make profits from being efficient (e.g. they may be able to justify tariff increases on the basis of their inefficiencies, especially if the regulator is poorly informed) while some publicly operated utilities do face commercial incentives. There is ample evidence of satisfactory achievement of social and public service objectives through efficient public sector undertaking in transition and developing countries as well as developed ones. Some examples of efficient public owned enterprises for water services are the Netherlands water public owned enterprises, municipal water companies in Germany are as in developed countries, Debreceni Vizmu in Hungary, Lodz Water Company in Poland are as in Central and Eastern Europe, SANAA (Honduras), SABESP (Brazil), SAGUAPAC (Bolivia) in Latin America, and South Africa, Philippines in developing countries. For instant, water public owned enterprises in the Netherlands, almost all the 25 water companies currently existing are public limited companies whose shareholders are municipalities and in some cases provinces (Dane et al., 1999). In general, the level of the service provided appears good, as high quality water is provided at an affordable price (US$1.26 per cubic meter), which could yet decrease as a result of further concentration. The performance of the whole Dutch water industry includes the low UfW 4% of the water produced, and the high productivity of 792 connections per employee (Blokland et al., 1999a: 183-196). Water companies in Netherlands appear related to the institutional framework supporting the functioning of public limited companies. The managing director enjoys all the autonomy ensured by the statutory provisions governing the transparency and accountability in the conduction of operations is complemented by the representation of consumers' interest through locally elected bodies. The price cost principle is fully applied but cost recovery does not result in the realization of excess profits, due to the limited interest of public shareholders in maximizing the return on investments and to the practice of restricting the payment of dividends (Blokland et al., 1999b: 63-80). This has not impaired the public owned enterprises ability to finance investment programs by resorting to the financial market. Water companies' creditworthiness is in fact based on the stable business conditions in which they operate (Braadbaart et al., 1999a: 81-91).

In Philippines, water districts cover 480 municipalities including urban and peri-urban areas. The technical and financial performance of Philippine Water Districts, with particular reference to cost recovery, is well above the Asian average. This seems to be a result of the organizational structure, which allows for government shareholdings, insulates management from undue political interference and provides for customer representation.

The Local Water Utilities administration also has an important role as technical support agency, development bank and informal regulator (Braadbaart et al., 1999c).

In the light of these case studies, public owned enterprises in water supply can clearly function as modern, transparent, publicly accountable development oriented enterprises capable of reconciling commercial efficiencies with social considerations. Public owned enterprises appear no less efficient than privatized water companies do. It is clearly advisable for public authorities to develop a credible public sector, more explicitly on objectives of service delivery and other basic operating principles: continuity, equal access and universality, and enhancing the openness of the industry. Proposed restructurings can then be more precisely evaluated against these objectives, instead of a narrow consideration of the fiscal gains to the municipal or government budget.

The Myanmar government also has no plan for privatization in city water supply service. Recently even the city government lacks the finances for provision for the city water supply services. How should the city government improve their city development and save people lives with secure water vis-à-vis how do people help to improve their city environment so as to secure water for the preservation of life is an interesting question?

Emerging Challenges and Opportunities for WRM in Asia and the Pacific

The emerging challenge of water management in the present day world is how to achieve sustainability in the face of continuous expansion of population and economic activities and the pervasive problems of poverty and environmental degradation (Hufschmidt, 1993). In 1996, Frederiksen narrowed down the focal point and pointed out the most serious problems that are likely to strike in developing countries. He added that high rate of population growth (urban and rural), poverty and environmental degradation are persistent while major economic development activities are taking place simultaneously.

The world population is increasing with 5.4 billion in 2005. Asia alone had nearly half of the world's population, which is 2820.6 million in 1990 and 3369.1 million in 2002. Urban population growth rate in Asia (3.3%) is also higher than the world urban population growth rate (2.3%). At the same time, Asia and the Pacific region are increasing in economic development and the annual growth rate of gross domestic product (GDP) is 6.3 % in the 1999 and 7.2 % in 2000. The growth of population and the subsequent expansion of industry, the demand for water are exceeding supply in several regions of the world. Consumption of water increased up to 300% (Postal, 1999). The quantity of water consumed in Asia alone is 2.85 trillion cubic meters per year, more than any other region in the world. It will expect to rise 150% in the year 2025. Countries in Asia and the Pacific region have made great strides in managing their water resources. There is an increasing concern for water resources availability, not only about the importance of water resources sustainability but also of the impending shortages of water in the future due to excessive withdrawal. Numerous studies pointed out the factors responsible for the steady increase in water use and shortages (see in Jeffrey 1989, Gleick 1993). In the Asia and the Pacific region, the per capita availability of water is 3760m^3 per year in 1995, which is naturally decreasing with the growth of population estimated at 1.6 % for the region as a whole. The estimation for changes in water availability per capita by sub-region over the period from 1950 to 2000 is presented in Table 2.3. Simultaneous pollution is rising to such an extent that is reducing the amount of usable water. Suffice it to say, there will be an immense demand on the developing Asia and the Pacific nation's water resources and a challenging task in demand management to reduce consumption and conserve precious water resources as well as efficiency improvement to combat the waste of water.

Table 2.3: Estimate Water Availability per Capita in Asia & the Pacific (1950-2000)

in 1000 m^3/y

Sub-region	Area (M km^2)	1950	1960	1970	1980	2000
North China & Mongolia	9.14	3.8	3.0	2.3	1.9	1.2
South Asia	4.49	4.1	3.4	2.5	2.2	1.1
South-East Asia	7.17	13.2	11.1	8.6	7.1	4.9
Central Asia	2.43	7.5	5.5	3.3	2.0	0.7
Australia	7.62	35.7	28.4	23.0	19.8	15.0
The Pacific	1.34	161.0	132.0	108.0	92.4	73.5

Source: After Shiklomanov, I.A. The world's water resources; International Symposium to Commemorate the 25years of IHD/IHP, UNESCO, Paris, 1991.

Water resources management has been traditionally still supply oriented without sufficient attention to options for influencing water demand and increasing water use efficiency. With over viewing the level of water losses from public water supply systems exceed 50% in some large cities in Asia. High level of water losses in water supply system seriously affects the financial viability of water utilities through lost revenues and increased operational costs. At the same time, engineering and environmental cost are much higher for new water supplies than for sources already tapped. As a result, new challenges call for a new approach. The emerging challenges are the needs of concerted policies for integrated management on their water resources and action towards conservation of water resource that should be undertaken in order to achieve sustainability of water vis-à-vis the water conservation is to be enhanced by incorporating demand management activities and water use efficiency measures.

Managing water sustainability is extremely complex because of the cross-sectoral and cross jurisdictional nature of the urban and national political economy. Governments have often misallocated and wasted water as well as permitted damage to the environment, due to institutional weakness, market failures, distorted policies, and misguided investments. The spatial planning, pricing, service levels and management of all of these may have impacts on the water resources environment. Most of the countries in the region are rationalizing their institutions dealing with water resources development, management, and protection. The result shows that many countries have developed relatively sophisticated water management institutional machinery comprising sometimes a dozen governmental agencies dealing with various aspects in water sector. However, many governments lack the technical knowledge or the staff to adequately enforce environmental regulations and the fixing and collection of charges.

Yet, all described situations are not all bleak. Many innovative and effective approaches to water resources management have been taken or are being taken by cities around the world. A globally accepted water management system for water sustainability is contained within the Dublin Principles (see Box 1). Nations and cities are wisely corporative with these principles to manage water resources more effectively. A balanced set of policies and institutional reforms should be sought that will both harness the efficiency of market forces and strengthen the capacity of governments to carry out their essential roles because each city has its own unique circumstance. Hence, policy option for sustainability of water management should be city specific.

Box 1: Dublin Principles and Key Concepts for Water Resources Management

Dublin Principles and key concepts:

Principles

1. *Water is a finite, vulnerable and essential resource, which should be managed in an integrated manner.*
2. *Water resources development and management should be based on a participatory approach, involving all relevant stakeholders.*
3. *Women play a central role in the provision, management and safeguarding of water.*
4. *Water has an economic value and should be recognized as an economic good, taking into account affordability and equity criteria.*

Key Concepts

1. *Integrated water resources management, implying an inter-sectoral approach, representation of all stakeholders, all physical aspects of water resources and sustainability and environmental considerations*
2. *Sustainable development, which is sound socioeconomic development that safeguards the resource base for future generations*
3. *Emphasis on demand-driven and demand-oriented approaches*
4. *Decision making at the lowest possible level*

Source: Savenije and van der Zaag, 1998

Non-Revenue Water in Water Supply System Management

Reducing non-revenue water (NRW) in a water supply system remains one of the major challenging tasks in many water utilities of developing countries. Because the controlling NRW in many developing countries may be hampered by several factors such as lack of awareness of the practical possibilities, potential financial and operating benefits by senior management, lack of motivation at the operational level, lack of resources, etc. Such impediments may be more political and institutional than technical. Often a water utility has many problems but, first and foremost, the objective of the water utilities will be to provide enough water, at adequate pressure over the whole area served, to meet increasing demands. For this purpose, NRW control is a crucial step to improve financial health and to save scarce water for water utilities management.

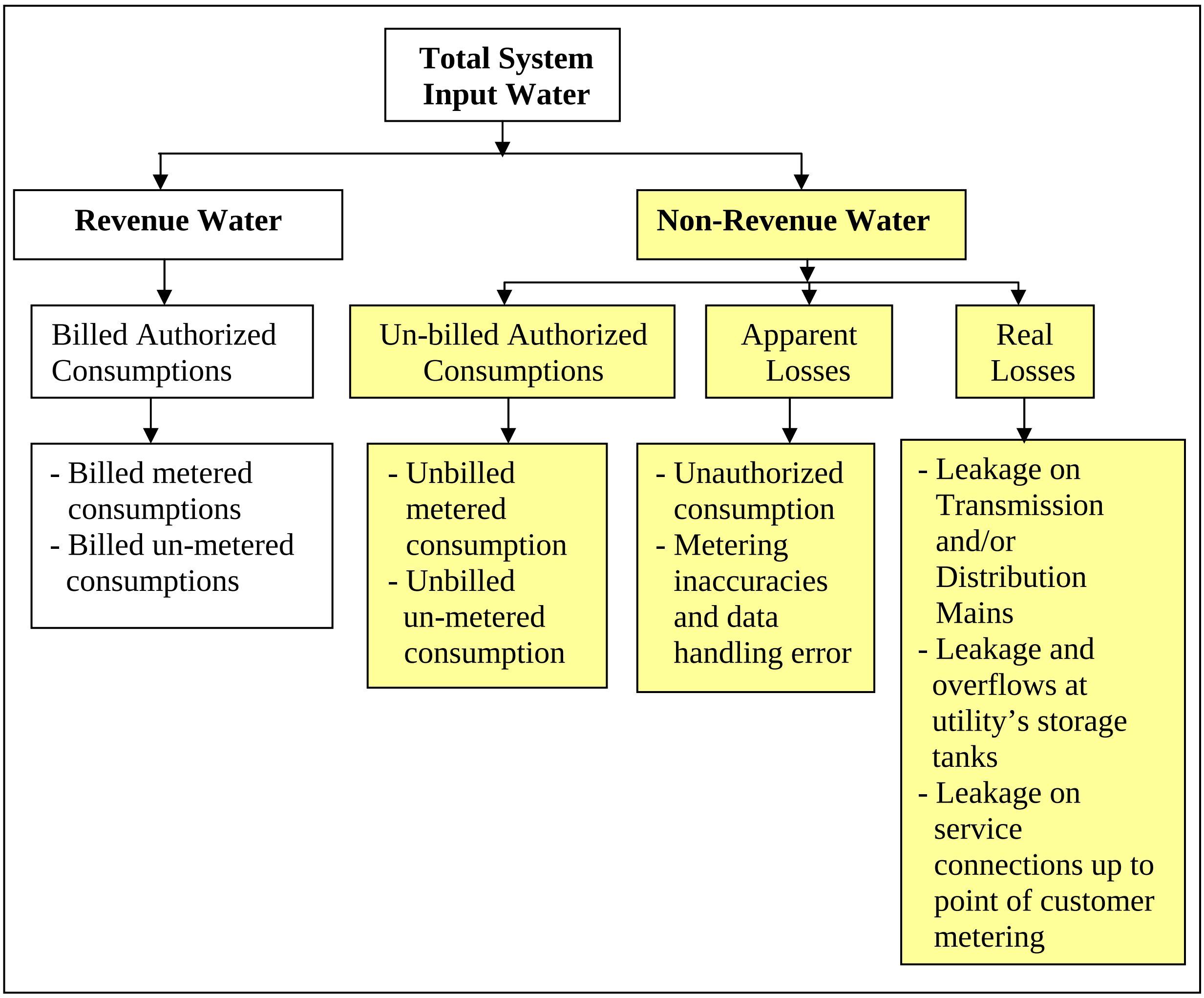
In practice, a water supply authority frequently concentrates on the established policy for improving water supply by developing new resources or by expanding existing networks rather than controlling NRW in existing water distribution systems. On the one hand, data relating to the existing system is not sufficient for a reasonable assessment of the existing supply situation and available figures on the quantity of water produced and consumed may be inaccurate for interpretation on the other. So, if NRW control is to be taken seriously and achieve its potential, it is necessary to accurately measure and assess the data to determine immediate and long-term strategy. The better the information available, the more the directed and undirected control over the network operations be the more cost effectiveness management. It is to be noted that this need for good information about the system applies equally to the general category of network management as to NRW control, of which the latter is really a subsidiary component. Therefore, better understanding of NRW terminology, explanation of the principles, activities were discussed in this section as "what, why, how is NRW".

What is Non-Revenue Water?

Of course, it is essential to clarify what is meant by “Non-Revenue Water (NRW)” in the Water Supply System (WSS). Actually, NRW in a water supply system is a concept has been recently introduced by the International Water Association (IWA, 2000) instead of Unaccounted for Water (UfW) (Farley and Trow, 2003).

In 1987, Jeffcoate and Saravanapavan defined a term UfW. It is the difference between net production (the volume of water delivered into a network) and consumption (the volume of water that can be accounted for by legitimate consumption, whether metered or not). The definition is simply identified, but determining the true figure can be difficult. Because the use of these terms has been confusing in systems where domestic supplies are metered, the volume of water accounted for should include water supplied without charge for central and local government establishments and for public purposes such as fire fighting, parks, lavatories, flushing streets, and so on. All such water can be authorized or accounted for and has to be included in consumption figures. Again, confusion has also arisen in many countries where domestic supplies are not fully metered. In these countries, there has been a tendency to regard all UfW as water lost through waste (that is not through leakage only) and to disregard the non-physical losses resulting from under-registration of bulk supply, industrial and commercial meters, even though such losses may represent a significant percentage of the total supply.

Part of the difficulty in determining the true UfW figure was the lack of a meaningful standard water balance. Being aware of the problem of different water balance formats, methods, and leakage performance indicators, the International Water Association (IWA) has developed a standard international water balance structure and terminology (Alegre et al, 2000). According to this international water balance structure, the definition for Non-Revenue Water (NRW) can be defined as the difference between the amount of water put into the distribution system and the amount of water billed to consumers in authorized meter and un-metered water consumption. NRW is comprised of apparent losses and real losses. Apparent losses include human management and metering errors and lead to consumption of water without charging. Real losses are some amount of water, which is wasted from the network, are categorized to water losses from reported and unreported bursts, background losses, reservoir leakage and overflow, leakage from valves and pumps. The clear understanding for NRW shows in Figure 2.1, which is based on International Standard Water Balance (IWA, 2000).



Based on IWA Best Practice, Water Balance and Terminology, 2000

Figure 2.1: Defining NRW by Standard International Water Balance

Finding the correct value for NRW in any system is often difficult, since in many instances considerable volumes of un-metered water are used, which have to be estimated. Where domestic water is not metered, much more of the volume of water actually consumed has to be estimated. For the control purpose, good quality data needs to be interpreted accurately and a clear understanding of supply boundaries gained. The components of NRW are determined by a field study with investigation of all properties in the study area and all the components of water distribution network such as reservoir, pumps, valves, pipes, etc. (Tabesh and Asadiani, 2005).

Network Flow Measurement and Water Balance

NRW control management is the function of network flow management. Flow measurement is an essential precursor for good network management and necessary for NRW control evaluation. As with a factory operator who wants to know how much goods he has produced and sold and what happened to any others, so the water supply utility needs information on the volume of water that it handles. A water supply network cannot also be well managed without at least some degree of flow measurement. Even measuring a real, accurate value can be very difficult. This difficulty is not however a reason for delay of starting a NRW control program. While NRW control is incorporated in network management, the calculation of NRW is also carried out using the water balance principle. The result of the water balance analysis depends on sufficient data being available. This enables not only NRW to be determined but also to prioritize which components are contributing the most to the losses.

(a) Determination of the System Input or Production Measure

The volume of water delivered into the distribution network should be accurately metered, but frequently meters are non-existent, out of operation, or seriously inaccurate.

When the entire system input is metered, the calculation of the annual system input should be a straightforward task. Ideally, the accuracy of the input meters is verified, using portable flow measuring devices. If discrepancies between meter readings and the temporary measurements are discovered, the problem has to be investigated and, if necessary, the recorded quantity has to be adjusted to reflect the real situation.

But, if there be some un-metered sources, the annual flow has to be estimated by using any (or a combination) of the following: (i) temporary flow measurements using portable devices, (ii) reservoir drop tests or (iii) analysis of pump curves, pressures and average pumping hours.

(b) Determine the Authorized Consumption

There is billed authorized consumption and unbilled authorized consumption. Billed authorized consumption includes billed metered consumption and billed un-metered consumption. Unbilled authorized consumption includes unbilled metered consumption and unbilled un-metered consumption.

<u>Billed Metered Consumption-</u> The calculation of the annual billed metered consumption goes hand in hand with the detection of possible billing and data handling errors, information later on required for the estimation of apparent losses. Consumption of the different consumer categories (e.g. domestic, commercial, industrial) has to be extracted from utility’s billing system and analyzed. Special attention should be paid to the group of very large consumers.

<u>Billed Un-metered Consumption</u>- The billed un-metered consumption can be obtained from the utility’s billing system. In order to analyze the accuracy of the estimates, un-metered domestic customers should be identified and monitored for a certain period. For example- measure a small area with a number of un-metered consumers.

Unbilled Metered Consumption- The volume of unbilled metered consumption has to be established similar to that of billed metered consumption.

Unbilled Un-metered Consumption- Traditionally, this includes water used by the utility for operational purposes, which is very often seriously overestimated. This might be caused by simplifications (a certain percentage of total system input) or overestimates on purpose to 'reduce' water losses. Components of unbilled un-metered consumption should be identified and individually estimated. For example:

• Mains flushing: How many times per month? How long? How much water is used?

• Fire fighting: Has there been a big fire? How much water was used?

(c) Determine the Water Loss

Water losses include commercial or apparent losses and physical or real losses. Apparent losses comprise unauthorized consumptions, metering inaccuracies and data handling errors. Real losses can be leakage on transmission and/or distribution mains, leakage and overflows at utility's storage tanks, and leakage on service connection up to point of customer metering.

Unauthorized Consumption- It is difficult to provide general guidelines of how to estimate unauthorized consumption. The estimation of unauthorized consumption is always a difficult task and should be done in a transparent, component based way so that the assumptions can later easily be reviewed. Unauthorized consumption includes illegal use, and this could be 1) sole illegal connections, 2) illegal connections to properties that also have legal connections, or 3) illegal connections for the purpose of selling water (Mclntosh, 2003).

Customer Metering Inaccuracies and Data Handling Errors- Metering inaccuracies can include malfunctioning water meters, estimated water consumption (when meters are not working), and misreading water meters (Mclntosh, 2003). The extent of customer meters inaccuracies, namely under or over registration, has to be established based on tests of a representative sample of meters. The composition of the sample shall reflect the various brands and age groups of domestic meters. Based on the results of the accuracy tests, average meter inaccuracy values (as percentage of metered consumption) will be established for different user groups. Data handling errors are sometimes a very substantial component of apparent losses.

Calculating Real Losses- The calculation of real losses in its simplest form is now easy. Volume of NRW minus volume of apparent losses – this figure is useful for the start of the analysis in order to get a feeling which magnitude of real losses can be expected. However, it always has to be kept in mind that the water balance might have errors and therefore it is important to verify the real loss figure by one of the following two methodologies: (i) Component Analysis and (ii) Bottom-up real loss assessment. To accurately separate, real losses into its components will only be possible with a detailed component analysis. However, a first estimate can be made using a few basic estimates.

Leakage on Transmission and/or Distribution Mains- Bursts on distribution and especially transmission mains are primarily large events – they are visible, reported and normally repaired quickly. By using data from the repair records, the number of leaks on mains repaired during the reporting period can be calculated, an average flow rate estimated and the total annual volume of leakage from mains calculated as follows: "*number of reported bursts* x *average leak flow rate* x *average leak duration*".

Leakage and Overflow at Utility's Storage Tanks- Leakage and overflow at storage tanks are usually known and can be quantified.

Leakage on Service Connections up to Point of Customer Metering- By deducting mains leakage and storage tank leakage from the total volume of real losses, the approximate quantity of service connection leakage can be calculated. This volume of leakage includes reported and repaired service connection leaks as well as hidden (so far unknown) leaks and background losses from service connections. As above determination of the water in a system that is metered or not fully metered, where billed to consumers must be derived for revenue of that system and unbilled consumption will be NRW for that system. Logically, NRW consist of unbilled authorized consumption and water losses as these are the component for which the utility does not receive revenue.

Factors Affecting Water Losses

Generally, physical or real losses and commercial or apparent losses are the main components in the water supply system. Other factors affecting on water losses are also briefly discussed in this section.

A. Factors Affecting Physical Losses or Real Losses

There are several factors, which affect the losses (leakage) from distribution system. According to the Queensland Environmental Protection Agency and Wide Bay Water Corporation, Manual 6 (2002), these factors can be put under seven broad headings as follows:

1. <u>Pressure</u>

Pressure can affect the losses from a system in number of ways. These are rate of leakage, frequency of bursts, and location of leaks, pressure surges and pressure cycling.

Rate of leakage: for a system with a number of leaking or broken pipes and leaking or faulty fittings, a change in the pressure will reduce the loss of water. The effect of pressure on leakage from a distribution mains system is greater than that predicted by the theoretical square root relationship.

Frequency of bursts: increasing system pressure, in some cases by only a few meters, can result in a number of bursts occurring within a relatively short period of time.

Location of leaks: higher pressures will increase the rate of water from an individual leak and may cause the leak to appear sooner. The higher rate of loss usually makes the leak easier to locate using sounding methods.

Pressure surges: sometimes greater than the design strength of the pipeline, can be caused when a pump set or booster is switched on or off or when a valve is opened or closed too quickly. Surges can cause the main or service to fracture, move thrust blocks or blows the joint sealant from the joint cavity. There is also some evidence that surges cause pipes to flex and move against rocks or other obstacles, resulting in local stress concentrations and sometimes failure of the pipe.

Pressure cycling: pipe material fatigue is caused by cycling the pressure between high and low values within the design pressure. Fatigue occurs when a pump set or booster switches on and off because of faulty pressure reducing valves. Although the contribution of pressure cycling to leakage is probably quite small, special care may be required during the design of plastic pipelines because they can be more susceptible to fatigue than other pipes.

2. <u>Soil movement</u>

Soil movement is sometime caused by changes in moisture content, particularly due to clay soils, changes in temperature, frost heave and subsidence, and drought. Countries that suffer from minor earth tremor will continually have problems with under-ground infrastructure. This may not be apparent above ground. In iron pipes, there is some evidence to suggest that small amounts of soil movement can cause stress concentrations, leading to the onset of fissure corrosion.

3. <u>Deterioration of water mains and pipes</u>

The most serious problems are the corrosion of metallic pipes. Internal corrosion is generally more severe in soft waters from upland sources. In the case of iron water mains, it takes the form of tubercles, on the pipe bore. The tubercles are associated with pitting. As corrosion of iron and steel pipe proceeds, the residual thickness of metal is reduced and hence the ability of the pipe to withstand internal pressure diminishes. Ultimately, this process leads to complete penetration of the pipe wall and failure of the pipe with leakage. The common forms of failure are hole formation and transverse or longitudinal fracture of the pipe. External corrosion can arise from a variety of causes including differential aeration, bimetallic collection, variations in concentrations of dissolved salts and microbiological action. The effects of external corrosion are similar to those of internal corrosion. Corrosion of concrete or asbestos cement pipes can be caused by soils or water containing high levels of sulfate.

4. Poor quality of fittings, materials and construction

Leakage caused from poor quality fittings, materials and construction can occur on the water mains up to the meter and the private pipe work after the meter. The careful design and specification of installations, coupled with a high standard of supervision during construction, will keep faults to a minimum.

5. Soil characteristics

An important factor, which affects the running time of individual leaks, is the permeability of the soil in which the pipes are laid. In some soils, water from underground leaks may show quickly on the surface, whereas similar leaks in chalky or sandy soils, for example, can run indefinitely without becoming visible on the surface.

6. Age

Many of the factors listed above are time dependent that is their effect will be greater as time goes on. Consequently, age of a pipeline can appear to be the most significant factor affecting the livelihood of leakage but on its own, age is not necessarily a factor.

7. Traffic loading

The effects of vibration caused by heavy vehicles and other traffic are thought to be a major factor affecting the failure of buried pipelines.

The above affected factors realize that the exception of pressure, none of these factors can easily be altered by a water utility once a pipeline has been laid. Therefore, it is extremely important that these factors are actively considered during the design and construction stages. Adequate supervision is given to ensure that the desired standards are achieved.

B. Factors Affecting Apparent or Commercial Losses

According to the IWA standard water balance definition, apparent losses consist of inaccuracies associated with production metering and customer metering, unauthorized consumption (theft or illegal use), data transfer errors, and data management errors (Queensland Environmental Protection Agency and Wide Bay Water Corporation, Managing and Reducing Losses from Water Distribution Systems, Manual 7, 2005).

1. Illegal or unauthorized consumption

It is water used that is not registered or paid for. This type of water loss can occur in various forms such as illegal access to water hydrant, illegal use of un-metered fire hose reels, illegal water connections.

Illegal access to water hydrant - this type of water theft occurs when water vendors or property developers access water hydrants without authorization. If access to designated fill points is not metered then the potential for water theft is increased.

Illegal water connections include unauthorized connections to the reticulation network, as well as attempts to tamper with or by-pass customer meters.

Illegal use of un-metered source from fire hose reels - this type of water loss occurs in commercial consumers. They are supplied with fire hose-reels and might use them for personal or commercial use like washing down driveways and footpaths as the most common example.

2. Inaccuracy of metering or errors in customer meter

It is usually inaccuracies caused by wear or failure in the recording mechanism of the water meter. Meters are not only the cash registers of water utility. These are essential tools for managing water loss. Metering also provides a means to determine usage charges as well as assessing NRW levels. Water bills (based on meter readings) are the principal method of communication between a water utility and its customers.

Correctly selected, installed and maintained metering throughout all levels of water utility operation is one of the most important components of total demand management and effective system management. Universal metering supports accurate data collection, which in turn enables water use monitoring and timely intervention when problems arise. It also enables appropriate user pays water pricing and ongoing customer service. Other benefits of accurate metering of the water supply system include the quantification of NRW and providing the data to analyze NRW in terms of real and apparent losses. It also provides the ability to communicate with customers regarding water use and conservation. Increasing expertise and accuracy in water accounting, particularly through effective metering, will pay financial, operational, environmental and community dividends, no matter what the size of water supply system is.

Thus, meter accuracy may substantially affect the revenue and the potential for water loss and demand reduction to a water utility. In case of bulk meters, under-registration can lead the water utility to underestimate its real losses, and its true level of NRW. It is important to remember that:

1.Under-registration of production meters and over-registration of customer meters leads to under-estimation of real losses

2. Over-registration of production meters and under-registration of customer meters, results in over-estimation of real losses.

In water loss management, accurate measurement of supply and consumption is an integral part of the process. Some of the key factors influencing meter accuracy are: consumption volume and meter age, incorrect meter installation, class or type of meter, inappropriate meter size, water quality, pressure and air surges and meter failure rate.

3. Data transfer and data management errors

It would be impossible to remove all potential for systemic and human error in water metering and data collection systems. Data handling errors are usually simple human errors- a wrong keystroke, miss reading a meter, or even reading the wrong meter are examples of data handling and transfer errors. Data management errors can occur when:

- a new service connection and meter is supplied, and is not added to the billing system,
- unbilled users are metered, and are not added to the billing system,
- a property changes ownership and new owners are not added to the billing system.

C. Other Factors Affecting Water Losses

Other water loss components are sources, head-works, and treatment losses. These are physical losses of water excluded in NRW. These losses occur before that water is put into the distribution system. They include leakages and overflows of untreated water from storage reservoirs and tanks, watershed leakage and bypasses inadequately controlled leakage from untreated water transmission lines and excessive use of water due to inefficient operation of the treatment process. These losses are normally regarded in a separate light, their control being a matter for the maintenance staff working on problems of source of supply, raw water transmission, and water treatment plants. They may add up to a significant loss, which merits close investigation, and it is appropriate that attention be directed at this problem concurrently with the instigation of improved control of NRW. These losses are excluded from NRW but can be of equal importance and require investigation by management at the same time (Jeffcoate, and Saravanapavan, 1987).

Methods of Leakage Control

There are a number of methods for leakage control currently practiced. Each method involves field leakage detection except pressure control, which can be considered supplementary to each of the other methods. Each method requires a different level of staff input and equipment and consequently each has different capital and operating costs. Each method will also maintain leakage at different levels. Commonly, leakage control includes regular survey and leakage monitoring. According to Farley and Liemberger 2005, regular survey is a method of starting at one end of the distribution system and proceeding to the other using techniques. Six methods of leakage control are currently in practice (Mclntosh, 2003) such as:

- Passive leakage control
- Regular sounding for leaks on pipe-work and fittings,
- District metering (detection by metering and analysis of flows into various pre-determined districts over a period of time, followed by systematic soundings),
- Waste metering (detection by metering of low flows at night from predetermined waste districts served by a single pipeline, followed by systematic soundings), and
- Combined district and waste metering
- Pressure control

These measures can be used in combination. For example, if passive leakage control is undertaken, regular soundings, district metering and waste metering methods can further reduce leakage. Leakage monitoring includes flow monitoring into zones or district metered areas (DMAs) to quantify leakage and to prioritize leak detection activities. Leakage detection is driven by both product availability and by economic considerations. An economic analysis is generally required to determine the most cost-effective method, but ultimately, a balance between doing nothing and attempting to stop every leak must be achieved. Potential target levels of leakage can be determined by selecting the most appropriate method. It would depend on the level of leakage, cost of leakage, and cost effectiveness of each method, because each method requires a different level of resources such as staff, equipment, capital and operating costs.

Brief descriptions of each method for leakage control are discussed as follows.

a. Passive Leakage Control

This method requires the least effort on the part of the water undertaking and in most cases results in the highest levels of leakage. No attempt is made to measure or detect leaks. Generally, only the leaks that are repaired the ones that are reported because of either water showing on the ground surface or of consumer complaints such as poor pressure or noise in the plumbing system. The police, public or water undertaking personnel going about some other duty normally make reports of this nature. Leak location may still be required for some of these self-evident leaks. This type of leakage control will not normally be cost effective except in areas where water is very cheap, and/or soil conditions are such that underground leaks quickly come to the surface. When the water authority is satisfied as to the total volume of water being put into their distribution network, the next step should be to learn more about how this water is being distributed. The overall objective is to supply the water as economically as possible. To fulfill this goal, the manager and his staff must have detailed knowledge of how the system performs. The quickest way to obtain this knowledge is to divide the network in separate districts of a convenient size (Jeffcoate & Saravanapavan, 1987). Flow meters are installed at strategic points within the system. Ideally, the district should include 2,000 to 5,000 properties, but if the authority has no previous experience with districts, it can begin with larger districts via meters and the integrated flow into each area measured for more convenience. Meters are normally read at regular periods, weekly or monthly, and the results analyzed to determine any areas in which significant increases in supply have occurred. If no legitimate measure can be found for the increases in an area, the inspection teams sound all stopcocks, hydrants, valves and other fittings searching for the characteristic noise of leaking water. District meters can benefit from the use of loggers. This method of leakage control has the advantage that the inspectors are always working in those districts where leakage is anticipated to be highest and therefore are likely to return the greatest benefits for their efforts. It also has the additional advantage that information regarding flows and use of water within the network is obtained which can be useful for the day-to-day running of the network and for the planning and design of future extensions or rehabilitation and reinforcement. District metering is not as sensitive as to change in leakage as is waste metering nor does it so clearly determine the position of leaks. This may be the most effective active waste control method (http://www.nrw.qld.gov.au/compliance/wic/pdf/reports/urban_wateruse/07_leakage_red.pdf).

b. Regular Sounding

Leaks are located by deploying teams of inspectors who systematically work their way around the system listening on consumers' stop taps, hydrants, valves and other convenient fittings. The arguments normally put forward in favor of these methods are based on the premises that area leaks are located by sounding and each part of the distribution system will always contain a certain number of unknown leaks. Consequently, time spent on metering can be more effectively used for locating leaks. These conclusions would be true provided leaks were evenly distributed throughout the system and occurred at evenly spaced intervals of time. This, however, is not normally the case. Therefore, although this method of leakage control normally costs less to implement than those incorporate metering, it results in higher average leakage levels. Regular sounding will probably be most effective in areas where the value of saving water is fairly low and where the soil conditions are such that large leaks show themselves fairly quickly and only small underground leaks need to be detected by inspection staff (http://www.nrw.qld.gov.au/compliance/wic/pdf/reports/urban_wateruse/07leakagered.pdf).

c. District metering

When the water authority is satisfied as to the total volume of water being put into their distribution network, the next step should be to learn more about how this water is being distributed. The overall objective is to supply the water as economically as possible. To fulfill this goal, the manager and his staff must have detailed knowledge of how the system performs. The quickest way to obtain this knowledge is to divide the network in separate districts of a convenient size (Jeffcoate & Saravanapavan, 1987). Flow meters are installed at strategic points within the system. Ideally, the district should include 2,000 to 5,000 properties, but if the authority has no previous experience with districts, it can begin with larger districts via meters and the integrated flow into each area measured for more convenience. Meters are normally read at regular periods, weekly or monthly, and the results analyzed to determine any areas in which significant increases in supply have occurred. If no legitimate measure can be found for the increases in an area, the inspection teams sound all stopcocks, hydrants, valves and other fittings searching for the characteristic noise of leaking water. District meters can benefit from the use of loggers. This method of leakage control has the advantage that the inspectors are always working in those districts where leakage is anticipated to be highest and therefore are likely to return the greatest benefits for their efforts. It also has the additional advantage that information regarding flows and use of water within the network is obtained which can be useful for the day-to-day running of the network and for the planning and design of future extensions or rehabilitation and reinforcement. District metering is not as sensitive as to change in leakage as is waste metering nor does it so clearly determine the position of leaks. (http://www.nrw.qld.gov.au/compliance/wic/pdf/reports/urban_wateruse/07_leakage_red.pdf).

d. Waste Metering

Waste metering involves setting up areas of ideally between 1,000 and 3,000 properties such that when appropriate valves are closed these areas can be supplied via a single pipe in which it is possible to place a flow meter. The flow meter used is one, which is capable of measuring low rates of flow and normally referred to as a waste meter. The waste meter may be permanently installed on a by-pass or carried as a mobile unit and connected temporarily into the system via hydrants or specially provided connections on a by-pass, is normally used only to measure night-flow rates. If the minimum night flow rate has increased above some predetermined level or if it is above the previously recorded minimum night flow in that waste district, then it is indicative of leakage and the area is inspected. The inspection may consist of sounding the entire area supplied by the meter or more commonly by repeating the measurement and successively closing valves within the district, thus isolating sections of the district and enabling the corresponding reduction inflow rate to be determined. A large reduction inflow rate indicates the existence of a leak within the section last isolated. This procedure obviously has to be performed at night and is generally known as either a step test or a valve inspection. At the end of the step test, those sections showing evidence of leakage are investigated by the inspectors (http://www.nrw.qld.gov.au/compliance/wic/pdf/reports/urban_wateruse/07_leakage_red.pdf).

Night-flow rate measurements are normally made on a regular basis, typically two to six times per year. This type of leakage control has the advantages that it is sensitive to small leaks and establishes the position of that leak between valves. The disadvantages are that time must be spent in monitoring districts where no leakage has occurred and hence no benefits obtained. This type of leakage control is likely to be appropriate in areas where the value of saving water is high.

e. Combined District and Waste Metering

This method of leakage control consists of a combination of the two methods discussed above. District meters are used to monitor large areas (ideally 2,000-5,000 properties) of the system. When these indicate an increase in consumption, waste meters are used downstream to determine more precisely the position of the leak. When the water authority is satisfied as to the total volume of water being put into their distribution network, the next step should be to learn more about how this water is being distributed. By suitable selection of district sizes and of meters, both waste and district meter areas can effectively coincide.

f. Pressure Control

Leakage reduction by pressure control is probably the simplest and the most immediate way of reducing leakage within the distribution system as detection of leaks is not involved. Pressure reductions may be achieved in a number of ways such as reducing pumping heads, installing break pressure tanks and most commonly, using pressure reducing valves. Although this method of leakage control has limited application, it has been found to be more beneficial than theoretical considerations suggest. It is likely to be most worthwhile not only in areas with generally high pressures but where the pressure rises to high levels at night. Measures to prevent or reduce surges are also part of pressure control for reducing bursts.

Performance Indicators for Leakage Control

In addition to the standardized water balance, the IWA has developed to investigate and recommend universal performance indicators, which could and should be used to measure and compare various components of non-revenue water in differing nature of distribution systems and utilities. The key elements of performance indicators are investigated and appropriate recommendations have been made in real losses, apparent losses, total losses and non-revenue water by IWA approach. The IWA approach of selecting different Performance Indicators (PIs) for different purposes (financial, operational, and water resources) are a clear step forward (see in Table 2.4).

Table 2.4: Selected Key Performance Indicators (PIs)

Component	Type	Basic PI	Detailed PI
Non-Revenue Water	Financial	Volume of NRW as % of System Input Volume	Value of NRW as % of cost of running system
Real Losses	Water Resources	Volume of real losses as % of system input volume	
Real Losses (In each case, this PI is calculated per day when the system is pressurized to allow for the effect of intermittent supply)	System Operational	Liters/service connection/day for system with 20 or more services/km mains (32/mile) Use m^3/km mains/day for systems with fewer than 20 services/km of mains	The Infrastructure Leakage Index: defined as the Ratio of Current Annual Real Losses to the Unavoidable ARL = CARL/UARL This indicator is fully explained by Lambert et al, 1999
Apparent Losses	Operational		M^3/service connection/year
Water Losses	Operation	M^3/services connection/year	

Source: McKenzie (2004)

a. Non-Revenue Water: Financial Performance Indicator (FPI)

While “percentage by volume” is still recommended as a basic financial PI for non-revenue water by a basic PI for real loss from a water resources viewpoint, it should not be used for assessing any aspect of operational performance management of water losses.

Other components of the water balance and the recommended PIs given in Table 2.4 should be used. The detailed financial PI for non-revenue water is based on the percentage by value of the water, rather than the percentage by volume.

b. Real Losses: Water Resources Performance Indicator (WRPI)

The basic water resources PI recommended by Lambert (1999) is "Real losses by volume". It is equal to volume of real losses as a percentage of system input volume (i.e., $V_{real\ loss} = V_{real\ loss} / V_{system\ input} \times 100$). No further work has been done on this PI by the Water Losses Task Force since 2000. As previously mentioned, percentages by volume are strongly influenced by differences and changes in consumption, and if improvements to this PI are to be considered. It would be useful to assess whether or not the "real losses" become available for re-use (McKenzie and Seago, 2005).

c. Real Losses: Operational Performance Indicator (RLOPI)

Operational Performance Indicators (OPI) also varies and the basic indicator applied is dependent on the density of service connection. Percent by volume is no longer used. The *IWA Best Practice Report (2)* clearly states that "percentages by volume" are unsuitable for assessing the efficiency of operational management of real losses. The basic operational PI for most distribution systems are (liter/service connection/day) for systems with (20 or more services/km of mains) and (m^3/km mains/day) for systems with less than (20 services/km of main). This basic PI is the best of the "traditional" PIs but it has certain limitations, as it does not allow for the following:

• Density of connections (per km of mains)

• Length of service pipe between the main and the customer meter, and

• Average pressure (leakage rates vary approximately linearly with pressure for systems with mixed pipe materials).

To address these deficiencies, the new and most advanced real loss performance indicator recommended by the International Water Association (IWA) and American Water Work Association (AWWA) is ILI (Infrastructure Leakage Index).

ILI (Infrastructure Leakage Index)

ILI is a relatively new performance indicator. It is a measure of how well a distribution network is managed for the control of real losses, at the current operating pressure. It is the ratio of the current annual real losses (CARL) to the unavoidable (technical minimum) annual real losses (UARL). It is calculated as follows (Lambert *et al*., 1999).

$$ILI = CARL / UARL$$

$$UARL = [(18 \times L\text{m}) + (0.8 \times N\text{s}) + (25 \times L\text{p})] \times P$$

Where,

UARL = unavoidable annual real losses (L/connection/day)

Lm = length of mains (km)

Ns = number of service connections

Lp = length of un-metered underground pipe from street edge to customer meter (km)

P = Average operating pressure at average zone point (m).

Being a ratio, the ILI has no units. Thus, ILI can facilitate for comparison purposes around the world. Different measurement unit was used such as U.S. metric or imperial. The calculation of ILI does not imply that the pressure management in the system being considered is optimal, but it is usually possible to reduce the volume of real losses (but not the ILI) by improved active pressure management. Thus, the performance indicator ILI provides leakage assessment, which can now be used to compare international data sets of utilities applying standard methods for water accounting and the results of other strategic initiatives to reduce system leakage.

d. Apparent Losses: Operational Performance Indicator (ALOPI)

The operational PI for water losses means the sum of real and apparent losses. Apparent loss in the PIs was (m^3/service connection/year). It is provide consistency with the basic PI for real losses (Alegre, *et al,* 2000). However, numerous international applications of the water balance since year 2000 have identified a need for more specifically focused practical operational PIs for unbilled authorized consumption (UAC), and the components of apparent losses (AL). When auditing and comparing volumes attributed to UAC and AL, it is necessary to check that these components are not excessive.

A practical approach undergoing further testing by the performance indicators team of the task force is to use 'percentage of water supplied' as a PI for checking the unbilled authorized consumption (metered and un-metered), and the un-authorized consumption. The most meaningful practical PI for the remaining component of apparent losses are mainly customer meter error which is likely to be 'percentage (+/-) of registered metered consumption'. This is the usual basis for presenting results from systematic testing of randomly selected customer's meters (McKenzie, 2004).

Challenges of Non-Revenue Water in Water Utility

Of particular significance is the use of the term "non-revenue water" (NRW) in place of the widely used "unaccounted-for water", due to the scope for misinterpretation and manipulation (McKenzie and Seago, 2005). The definition of NRW is simply explained as the difference between system inputs of water and billed for water. However, NRW reduction is difficult to control and not a simple matter to implement (Kingdom, Liemberger, Marin, 2006). Upper management often does not address water loss issues and this mindset can permeate an entire organization (Queensland Environmental Protection Agency and Wide Bay Water Corporation, Managing and Reducing Losses from Water

Distribution Systems, Manual 1, 2002). Root of this issue is not only do new technical approaches have to be adopted, but effective arrangements must also be established in the managerial and institutional environment. Understanding of the problem, lack of capacity, missing management focus, importance of enabling environment and incentives are the main causes for delay implementation of NRW reduction management.

Understanding of the problem: not understanding the magnitude, sources and cost of NRW is one of the main reasons for insufficient NRW reduction efforts around the world (Kingdom, Liemberger, Marin, 2006). Only by quantifying NRW and its components, calculation appropriate performance indicators, and turning volumes of lost water into monetary values can the NRW situation be properly understood and the required action be taken. Despite the fact that many utilities in the developing countries have implemented NRW reduction programs with donor funding, it is rare that a comprehensive water balance was actually developed and calculated. Therefore, there is no doubt that the end results often fail to match expectations. NRW management is not technically difficult, but it is complex. Properly understanding the baseline situation is a critical first step in moving toward an effective reduction program.

Lack of Capacity: Many governments and water utilities can find it difficult to identify accurately the amount of water they lose each year through problems such as theft, system leakage, un-metered water use, and inaccurate meters. All these actions are the reason of lack of capacity for reducing NRW activities. NRW reduction activities require a range of skilled staff, including managers and professional engineers at one end of the spectrum right through to street crews, technicians, and plumbers at the other. “NRW reduction,” in its broadest sense, staff with necessary skills is not widely available. Addressing this issue will require both an acceptance of the widespread challenges and consequences associated with NRW and then the development of appropriate training materials, methods, and institutions. A major initiative is required to build such capacity.

Missing management focus: establishing and maintaining an effective NRW program is, besides all other difficulties, a managerial problem, because managing NRW calls for effective institutional management systems that are comprehensive and operational. Day to day operations and future planning should have this important factor in their perspective. This implies that human beings and machinery should be planned and managed in such away. They would timely and effectively react and prevent any water losses (Tumuheirwe and Lutaaya 2005). Physical loss reduction is an ongoing, particular activity with few supporters among the following:

• Politicians: there is no “ribbon cutting” involved.

• Engineers: it is more “fun” to design treatment plants than to fix pipes buried under the road.

• Technicians and field staff: detection is done primarily at night, and pipe repairs often require working in hazardous traffic conditions.

• Managers: it needs time, constant dedication, staff, and up-front funding

Moreover, the reduction of commercial losses is very popular among the following:

• Politicians: unpopular decisions might have to be made (disconnection of illegal consumers or customers who don’t pay).

• Meter readers: fraudulent practices might generate a substantial additional income.

• Field staff: working on detecting illegal connections or on suspending service for those, who do not pay their bills is unpopular and can even be dangerous.

• Managers: it is easier to close any revenue gap by spending less on asset rehabilitation (letting the system slowly deteriorate) or asking the government for more money.

• Except for those customers who do pay their bills, it might appear that there is no support from any party (Kingdom, Liemberger, Marin, 2006).

Given this situation, a utility manager trying to establish an NRW program to reduce high levels of losses will face frustrating responses from his or her own staff and from the utility owners. Engineers and operational staff will assure him or her that the levels relate solely to commercial losses (that is, there is no leakage problem) while the commercial staff will say that it is all leakage.

Enabling Environment and Incentives: Most of the above challenges do apply to both private and public utilities, but in general, private operators have incentives to reduce NRW because this can generate more revenues and reduce operating costs, in addition to specific contractual targets in several cases (Brocklehurst, Janssens, 2004 and Ringskog, Hammond, Locussol, 2006a). It is, however, more difficult for publicly managed utilities because they often lack an adequate enabling environment and a proper incentive framework for performance. For instance, a lack of flexibility in human resources management could make it difficult to reorganize working shifts and pay bonuses for staff who works at night on leakage detection. Recent findings suggested, however, that the right incentives can be put in place in a public utility within a broader framework of encouraging autonomy, accountability, and market and customer orientation (Baietti, Kingdom and Ginneken 2006). It is improving NRW performance in clearly a major outcome that would be desired from such an initiative. It is instructive to consider the incentives related to NRW programs in a little more detail and wonder why, despite the obvious benefits of NRW reduction, the NRW performance of utilities in the developing world is so poor. A commonly voiced answer is that politicians are mostly interested in the utility management to obtain a new water treatment plant or project than for a leakage reduction program.

In reality, implementing a NRW reduction program is inherently complex. It requires addressing, in a comprehensive manner, the various problems that lie at the root of the poor performance of a water utility. This represents a challenge that goes beyond just NRW performance. NRW reduction is risky that utilities manager feel uncertain and civil servants tend to be risk averse. Therefore, when confronted with a choice between reducing NRW and increasing production capacity, they choose the second one. This might not make much sense in economic terms, but at least they feel confident that they will have something tangible to show to their constituency that the expected benefit can be realized.

Therefore, the key obviously overlooked message is that NRW must not be considered in a vacuum, but it should be within the broader context of utility reform. The designer of any NRW program needs to look carefully at the *incentives for the managers and staff* of the program, as well as all the parties involved. Any program should ensure, as far as possible, that the incentives are properly aligned with the objective of developing an efficient and effective utility that meets the needs of its consumers (Kingdom, Liemberger, Marin, 2006).

Benefit of Non-Revenue Water (NRW) Reduction

Although NRW reduction has a number of challenging tasks, effective NRW reduction has enormous benefits overtime under a reasonable objective. It is not realistic to expect water utilities to eliminate all commercial and physical losses, however in developing countries, it is certainly not unrealistic to expect that the high levels of physical losses could be reduced by half (Kingdom, Liemberger, Marin, 2006). Yet, making the paradigm shift towards water loss management and reduction is a proactive process in the reactive world of operations.

The benefits of water loss management or NRW reduction can be:

- Reducing water losses helps stretch existing supplies to meet increased needs. This can help defer the construction of new water infrastructure such as treatment plants and defer augmentation of water supplies such as dams. Wastewater facilities may also be deferred.

- If leakage or loss of water is reduced in water distribution system, already treated water would be available to service customers. So that, more people could gain access to water supply, without increasing demand on endangered water resources.
- Acting on NRW reduction saves money through reduced power costs to deliver water and reduced chemical costs to treat water, i.e., the total cost of supplies, operation and maintenance costs can decrease.
- Water utilities would also gain access to additional money in their self-generated cash flow and without affecting in any manner the debt capacity of those countries.
- Due NRW fairness would be promoted among users by acting against illegal connection and those who engage in corrupt meter reading practices.
- Consumers would have improved service delivered by more efficient and more sustainable utilities.
- Finally, more economic growth with new business opportunities would be created for NRW reduction activities, with thousands of jobs created to support labor-intensive leakage reduction activities.

In practice, these potential benefits should be considered on a case-to-case basis against the actual cost of implementing a water losses reduction program. In the case of commercial losses, the implementation of a loss reduction program is likely to be financially beneficial with short payback periods. In the case of physical loss reduction, the key issue is deciding on the appropriate level of loss reduction and its related investment. In developing country’s water utilities with high levels of physical losses, there will be a good financial case for initial loss reduction by picking many of the “low-hanging fruit,” which can provide short payback periods (Kingdom, Liemberger, Marin, 2006). As these low-hanging fruit disappear, the cost of reducing physical losses will rise. Whether for commercial or physical loss reduction, a cost-benefit analysis must be carried out, comparing the unit cost of saving water from network leakage with the value of the water saved. There are a number of well-written documents on this subject which readers can find further guidance. *For example: D. Pearson and S. Trow, "Calculating Economic Levels of Leakage," Conference Proceedings, International Water Association (IWA) Leakage 2005 Conference in Halifax, Nova Scotia, Canada (download http://waterloss2007.com/Leakage2005.com/index.php),"Leakage Control Policy and Practice," DoE/NWC (Department of the Environment/ National Water Council), reprinted by WAA/WRc (Water Authorities Association / Water Research Centre) Report 26 (1980, 1985).*

The State of Research on Non-Revenue Water in Developing Countries

In the last decade, a comprehensive set of analytical tools for strategy of water loss reduction and specialized equipment has been developed. However, NRW level in developing countries is very high, there are still deficiencies in the accurate data availability due to very few data available in the literature and actual figures. Most water utilities in the developing contries do not have adequate monitoring systems for assessing water losses, and lack of consolidated information on water utility performance. Besides, NRW data are usually not readily available, and they are always unreliable because it is common for the management of poorly performing utilities to attempt to conceal the extent of their own inefficiency (Kingdom, Liemberger, Marin, 2006), they called "window dressing" practice.

There is a recent report "Non-revenue Water: A Governance Challenge" by the Asian Development Bank (ADB, 2006) that mention a study performed by the South East Asian Water Utilities Network (SEAWUN) analyzing NRW levels of 47 water utilities across Indonesia, Malaysia, Thailand, Vietnam and the Philippines. The study concluded that the average level of NRW is 30 percent of the water produced, with wide variations among individual utilities ranging from 4 percent to 65 percent. The other found that more than 900 utilities in 44 developing countries around the world have approximately 35 percent in NRW level (the World Bank database on water utility performance, http://www.ib-net.org/). The actual figure for overall NRW levels in the developing countries is probably more in the range of 40-50 percent of the water produced due to large developing countries with known high level of NRW are still not covered in the World Bank database. Thus, the need of research for NRW reduction will base on specific utility performance: "Where We Are and Where Can We Go" which can be clearly exemplified in Table 2.5.

Table2.5: Utility Performance: Where We Are and Where Can We Go

Utility performance in majority of developing countries	Currently recorded	Attainable levels*
UFW (or) NRW	>45%	<25%
Staff/1,000 connections	>20	>6
Bill Collection Period	>18 months	<3 months
Working Ratio	>1	<0.7
Connection Charges (% GDP/capita)	5-60%	20%
Service Continuity	<12hrs/day	24hrs/day

*Based on the performance of the top 23% of utilities in the data set Source: Jenssens (2005)

Moreover, there are several deficiencies in the literature on NRW in water utility among developed and developing countries. Currently, most of the national and international publications have identified the problem of NRW, but little has been done to relate it to the conditions in developing countries (UNCHS-Habitat, 1998). Water utilities around the world have always established water balances but unfortunately, a wide diversity of formats and definitions is used, often within the same country. So it was (and still is) virtually impossible to compare NRW, leakage or water losses of different utilities.

Potential for Private Sector Involvement in NRW Reduction Activities

There is little incentive for the private sector to invest in urban environmental infrastructure and service projects because the capital investment requirements are usually large and cannot be easily transferred (Stein 1990, Hardoy *et al.*, 1992). The World Bank (1994) conducted an analysis of the feasibility of private sector participation in various urban environmental service projects with different criteria, such as potential for competition, characteristics of goods or services, potential for cost recovery from user charges, public service obligations, environmental externalities, and marketability index (Table 2.6).

Table 2.6: Feasibility of Private Sector Participation in UES Projects

Indicator	Potential for Competition[a]	Characteristics of Goods/ Services	Potential for Cost Recovery from User Charges	Public Service Obligations (Equity Concerns	Environmental Externalities	Market - ability Index[b]
Water						
Urban Piped network	●●	Private	●●●	***	●●●	2.0
Non-piped systems	●●●	Private	●●●	**	●●●	2.4
Sanitation						
Piped sewerage and treatment	●	Club	●●	*	●●●	1.8
Condominium sewerage	●●	Club	●●●	**	●●●	2.0
On-site disposal	●●●	Private	●●●	**	●●●	2.4
Waste						
Collection	●●●	Private	●●	*	●	2.8
Sanitary disposal	●●	Common property	●●	*	●●●	2.0

[a] Due to either absence of scale economies or sunk costs, or existence of service substitutes

[b] Marketability index is a average of ratings across each row.

Marketability index: 1.0 = Less marketability, 3.0 = Most Marketability

Note: ●●● High *** = Many

●● Medium ** = Medium

● Low * = Few

Source: World Bank (1994: 115) cited in Lee (1996: 32)

This table shows that only waste collection enjoyed a relatively high marketability index (2.8). The marketability indices for other services were varied from 1.8 (for conventional sanitation system) to 2.4 (for water vending system). That is, unlike other kinds of infrastructure such as telecommunication and power generation where there are promising sustained commercial demands, most aspects of the urban environmental service provisions are simply not attractive investments for private companies (Lee, 1996). The arguments that the table show the potential of private sector participation in urban environmental services projects is not high because it has environmental and public health externalities and public sector obligation. It reduces their suitability for private sector provision. In addition, the potential for competition is low for some of them on account being natural monopolies particularly in water supply services.

Though attracting the private sector in providing those services is neither difficult nor easy, many governments will need to work hard to develop mechanisms that make the provision of urban environmental services attractive for the private sector without compromising on their environmental and public health externalities. Because the developing country governments have found that their tax revenues are not providing sufficient resources to meet their needs, and ODA has not been able to fill the gap, they operate under an inadequate incentive framework. They typically lack expertise, technology, and the practical experience of putting in place such programs. They therefore need external assistance. An obvious source of assistance is the private sector, where involvement can take many forms, ranging from long-term public private partnership (PPP) arrangements to service contracts or subcontracting of certain tasks (Kingdom, Liemberger, Marin, 2006). Depending on the option chosen, the private sector can bring the followings:

1. New technology and the know-how to utilize it efficiently
2. Better incentives for project performance

3. Creative solutions for the design and implementation of the program
4. Qualified human resources
5. Flexibility for field work (for example, night crews)
6. Investment, under certain conditions

Options/ Types of Private Sector Involvement for NRW Reduction Activities

A number of options for the private sector involvement in NRW reduction are presented below.

1. Delegated Management under a Public-Private Partnership (PPP) Contract

There are a number of established and well-studied PPP models for the delegated management of utilities, such as concessions, lease/affermage, and management contracts. Long-term PPP contracts as concessions are not designed solely for NRW reduction. However, the private operator typically has strong financial incentives to reduce the NRW level because NRW translates into higher revenues and lower operating costs, as well as the deferment of costly investments to increase production capacity.

Even, in the case of lease/affermage contracts where specific objectives for NRW reduction were included in the contracts, with bonuses or penalties for the private operator in case of compliance or noncompliance. These are, under the lease/affermage contracts, the private operators bear a substantial commercial risk because they have to generate an operating surplus sufficient to cover their remuneration (Ringskog, Hammond, and Locussol, 2006b). However, during 1990-2004 about 340 contracts involving public-private partnerships in water supply were closed in developing countries. About a fifth was management and lease-affermage contracts[1].

[1] Data are from the World Bank and PPIAF Private Participation Infrastructure (PPI) Project Database (ppi.worldbank.org)

The situation is slightly different for management contracts, which are typically of shorter duration and targeted toward certain specific improvements. But, even management contracts can be designed to address NRW reduction through the use of specific contractual targets and performance payments. Empirically, typical management contract period is 3-10 years, but extendible based on performance. Management contract undertakes planning and managing program but funding is provided externally and though workforce employed by Water Service Agency, actually workforce is under management contractor supervision. Under management contracts, therefore, the financial risks to private operators are rather low because their fees are usually financed by government budgets or loans from international financial institutions (Ringskog, Hammond, and Locussol, 2006b).

In all of these cases, the private operator can bring much-needed expertise and knowledge, not only for the implementation of the NRW program but also for its design, as long as the contract provides sufficient flexibility. The private sector is fully responsible for identifying the most economical NRW activities and is accountable for the end results, among its other management responsibilities. However, large-scale delegated management PPP arrangements remain a controversial topic in many developing countries, and there is growing recognition that many water utilities in the developing world will remain under public management. Therefore, Kingdom *et al* (2006) state that there is demand for contractual schemes involving the private sector, without delegated management of the utility to the private sector.

2. Outsourcing of NRW Reduction Activities

At the opposite end of the spectrum, outsourcing of elements of NRW reduction activities is a widespread approach in public utilities of developed countries. Under this approach, a water utility subcontracts specific elements of an NRW reduction program to a private firm. This can range from a specific activity through to overall management of the

NRW program. In all but the latter case, the utility remains in charge of the overall implementation of the program. This approach is particularly appropriate for all fieldwork such as leak detection, pipe repairs, minor civil works, meter replacement and reading, updating the cadastre, and identification of illegal connections (Kingdom, Liemberger, Marin, 2006). There are several advantages for the utility in adopting such an outsourcing approach, including reduced unit costs through competitive bidding, more flexibility for night work, and mobilizing additional resources for dealing with backlogs. It also brings access to a specialized workforce and equipment.

Outsourcing of leak detection is nothing new. Many water utilities in Europe, the United States, and even in some developing countries use private leak detection contractors to survey the distribution network periodically. Frequently, NRW and other water utility management issues can be addressed by outsourcing the management of the utility through a performance-based management contract (Stein & Wolf, 1998). The management contractor will be paid through a fixed fee with bonuses against baseline targets. Given the major institutional changes involved in implementing a management contract, their acceptance by all the stakeholders (customers, staff, management and the Board) is essential. An effective external and internal communications strategy is also essential (O'Leary, 2005). The World Bank is building up experience with existing or planned management contracts in Africa, Asia and South America. However, this approach is unfortunately limited in many developing countries by three major constraints:

- Lack of capacity of the water utility to implement a comprehensive program, and to coordinate the work of various contractors.
- Often undeveloped nature of the local private sector depending on the country, simple labor-intensive tasks such as meter reading and pipe repairs can be

subcontracted, but local firms with the capacity to conduct more, technical tasks such as leak detection and network zoning are often not available.[2]

- Lack of knowledge about the existence of the various options and lack of guidance materials (for example, sample contracts, target setting, and payment mechanisms).

3. Technical Assistance Contracts

Technical assistance is one of the most heavily criticized forms of aid. Damning critiques go as far back as 1969, with the Pearson Commission noting that it was, "little related…to development objectives". By 1993, the critiques had hardened, with then World Bank vice president Edward Jaycox describing it as, "a systematic destructive force that is undermining the development of capacity." Bilateral donors have been equally scathing, with Eveline Herfkens, then Dutch Minister for Development Co-operation, noting in 2002 that: "The presence of so many experts in Africa in particular has undermined the confidence of countries in their own abilities. Technical assistance has not done enough to give poor countries the ability to stand on their own two feet." Even the typically understated OECD acknowledged recently that there was little evidence of the effectiveness of technical assistance, and that higher levels have shown no positive impact on economic performance.

The traditional option for delivering NRW technical assistance in developing countries is one in which a public utility will contract a private company to design and/or provide implementation capacity building for an NRW reduction program. Such companies are typically consulting engineering firms or subsidiaries of private operators and construction companies engaged through the technical assistance/capacity building contracts. Often the water utility *believes* that it has delegated the entire NRW reduction

[2] In the case of many PPPs, international private operators have played an active role in developing the capacity of the local private firms by subcontracting many activities as part of their drive to improve labor productivity.

program to the private partner, even though the contractor has to implement the project through existing utility staff who have no real incentives to deliver results and are unsure whether they should report to the contractor or to the utility management. In some cases, the budget allocated for field works such as leak repair and equipment installation (such as meters and valves) was not sufficient, given the overall deterioration of the networks and the magnitude of the problems.

The fundamental weakness of this approach is that the private sector has limited control over the implementation program and thus cannot be accountable for the end-result, but only for providing advice. The private contractor cannot and does not guarantee that at the end of the project, the levels of NRW will have been reduced according to any specific target. Not surprisingly, therefore, there are countless examples in developing countries of NRW technical assistance/capacity-building contracts that have failed to reach their objectives.

Another frequent problem is that the NRW program is a small part of a larger development project. There is limited focus, and the NRW work often takes a lower priority compared with that of the physical investment program. The result is that everyone (the utility, the contractor, and the donor) enters into the assignment on a "best endeavors" basis, and the poor results are the inevitable consequence. In addition, the improvements made by the main project component (for example, construction of a new water treatment plant) can result in increased supply hours and improved pressure, which too often offset the achievements of the (insufficient) leakage reduction program (Kingdom, Liemberger, Marin, 2006).

4. A Different Approach: Performance-Based Service Contracting

Performance-based service contracting offers a potentially new approach to the NRW challenges (Kingdom, Liemberger, Marin, 2006). The concept is to contract a private firm to implement an NRW reduction program, as for the outsourcing approach described above, but with the difference that the private firm is not paid solely in exchange for services delivered, though paid also against meeting contractually enforced operational performance measures. It is in the spirit of the output-based aid (OBA) approach advocated by the World Bank (Brook, & Smith 2001, and Marin 2002), which is based on the idea of paying the private sector for delivering results (that is, outputs), instead of a series of activities (inputs). In exchange for taking risks on project performance, the private contractor is given enough flexibility and resources to carry out the work according to its best judgment and experience. It effectively reduces the risk that the public utility will end up financing a large program with no or limited results by shifting the risks for meeting project objectives to the private contractor.

In practice, the applicability of performance-based service contracting to an NRW reduction program depends on the level of risk that the private sector is willing to take, which is itself linked to overall country risk, the specific conditions of the water utility, and the detailed contractual form. Performance-based service contracting is a relatively new concept for the water sector in the developing world, but it is increasingly contemplated in other infrastructure and utility sectors as a way to improve efficiency and accountability of contracts with private providers.

NRW Control Plan

The NRW control plan is one element of the overall Master Plan for improvement of water supply. More realistically, once NRW control is properly established it should be regarded as a routine facet of good network management practices. Towards the latter stages of the planning period, therefore, NRW control activities will progressively integrate with the operations and maintenance functions of network operations.

Readily defined, NRW is not so easily calculated and requires the collection and analysis of a great deal of data to be evaluated. The results of this analysis and the planning decisions based on it will only be as good as the data input allows. For this reason, it is very important that the data collected should be detailed, reliable and accurate.

The collection and analysis of data and resulting NRW control action is not a one-off remedial exercise. It requires the permanent commitment of considerable resources in manpower, materials and equipment as part of comprehensive operation and maintenance of the distribution system to reduce and then maintain level of losses. If stopped than the losses will soon rise again and the situation deteriorates. Therefore, water utility authorities are careful to consider the existing facility for efficient use of water that are becoming popular in planning for reducing water losses or minimizing wastage or non-revenue water from the water supply system. The implementation of success NRW control plan has to be taken seriously and achieve its potential. It is essential to accurately measure and assesses these various elements of water use. A loss of this information will come from flow measurement around the network and therefore clearly requires installation and maintenance of flow metering equipment.

The background information on the existing situation, which is frequently encountered and required for building awareness and setting up realistic targets. It is important to recognize the problem of high levels of NRW, after estimating the extent of and affect of the losses, develop a plan to take appropriate action. The level of losses and the extent of action to control NRW should be cost effective at all times. The target is not an arbitrary level, but the economic level of losses determined on a cost benefit basis. This level may vary and should be reviewed periodically.

As a first step to introduce NRW control, where there is clearly a problem of NRW, a framework plan must be prepared. Activities, initial target figures, and progress rates should be cited, as a basis for preliminary planning. Once implementation is under way and detailed data becomes available, the target and planning should be reviewed and modified according to cost benefit analysis. As a final point should be emphasized that NRW control will require a lot of sustained effort and it is essential for the success of a program that there is the political will and continued support to implement it properly.

Strategy for NRW Control Plan and Implementation

Traditionally, water loss management and leak detection have been treated as an afterthought in network operations. However, in recent years a water loss strategy has become one of the major operational tasks of the distribution network. This has consequences by a combination of global water shortages, privatization, regulation, and making companies increasingly accountable to customers, shareholders and regulators.

Any strategy for managing NRW control must obviously address to gain a better understanding of the reasons for NRW and the factors, which influence its components. It is then that techniques and procedures can be developed and tailored to the specific characteristics of the network and local influencing factors, to tackle each of the components in order of priority. Currently, Liemberger, and Farley (2005) adopted an analytical approach for practical implementation of achievable NRW reduction strategy that can be applied to any water company, anywhere in the world, for NRW management.

The recommended strategy includes some questions about network characteristics and the operating practices, the typical questions and each task required to address each question will be summarized in Table 2.7.

Table 2.7: Tasks and Tools for Developing a NRW Reduction Strategy

Questions	Task
1. How much water is being lost? -measure components	**Water Balance** - Improved estimation/measurement techniques - Meter calibration policy - Meter checks - Identify improvements to recording procedures
2. Where is it being lost from? - Quantify leakage - Quantify apparent losses	**Network Audit** - leakage studies (reservoirs, transmission mains, distribution network) - Operational/customer investigations
3. Why is it being lost? - Conduct network and operational audit	**Review of network operating practices** - Investigate: - Historical reasons - Poor practices - Quality management procedures - Poor materials/ infrastructure - Local/Political influences - Cultural/social/financial factors
4. How to improve performance? - Design a strategy and action plans	**Upgrading and strategy development** - Update records systems - Introduce zoning - Introduce leakage monitoring - Address causes of apparent losses - Initiate leak detection/repair policy - Design short/medium/long term action plans
5. How to maintain the strategy?	**Policy change, Training and O & M** Training: - Improve awareness - Increase motivation - Transfer skills - Introduce best practice/technology O & M : - Community involvement - Water conservation and demand - Management programs - Action plan recommendations - O & M procedures

Source: Farley, and Liemberger, (2005)

Basic Elements of NRW Control Plan

A NRW control program can be developed in many different ways depending on the circumstances and the interest of governments. NRW control program should be established based on adopted NRW strategy with local, provincial, or national basis for plan of NRW reduction. It is preferable to develop a new and adaptable program for every country to deal with the NRW reduction. Any new program should include the following basic elements:

1. Defining NRW Control Activities (long term & short term plan)

Most of the long-term control activities require conscientious management of relatively simple activities along with the collection of considerable quantities of data in order to enable effective control, directed and prioritized interventions (e.g. repairs analysis and high leakage areas selected for rehabilitation schemes). Thus, the long-term plan for NRW control should be repeated cycles to collate data, analyze, review and plan, prioritize/modify, and implement required measures. This will be continued many times to work towards achieving the target set.

For the immediate future, the short-term plan can be defined more clearly. No program of NRW control can begin to effectively and sustainably reduce losses and implement control measures until the current situation is properly established. Much of the emphasis for immediate action needs to be placed on determining the NRW control level, comprised of the following:

a. Procedures for collecting the required basic data
b. Implementation of means for collecting the required data (e.g. installation of flow meters)
c. Establishing the contributions of NRW components

As the program commences and proceeds, the NRW level will first be calculated as an estimated figure and then progressively determined with increasing accuracy and with more elements as more means are put in place (e.g. progressing from production meters towards district metering). At whatever level of accuracy and detail, an assessment will be made of the largest contributing elements and the bulk of the remedial effort concentrated on those.

2. Specific Policy, Rules, Regulations, and Bylaws

The first step associated with an effective NRW control plan must be the preparation or up dating of by-laws and standards that are adapted to the present local situation. Once implemented by-laws should be periodically improved in content, and coverage upgraded with new techniques. Then, the prepared by-laws need to be implemented. Particular emphasis has to be placed on public relations and if necessary, on proposed enforcement methods that may be necessary to ensure compliance with the by-laws (Jeffcoate, and Saravanapavan, 1987). However, the following points can be suggested:

a. People need time to get used to new standards
b. Simple enforceable standards are the best
c. The requirements should be reasonable and equitable for all customers
d. The division of responsibilities between the consumer and the utility must be clear and equitable.

There is no benefit having a set of by-laws, if they cannot be or are not enforced. It is, therefore, a prerequisite that political will is behind this policy to introduce it, see it through and make it work. In the preparation of by-laws and implementation mechanisms, other policy matters such as metering is required so that it will be consistent.

3. Implementing Agency and Manpower

It is importance that an effective and responsive institutional structure is made available for implementation of the provisions of the policy that supports linkages between practice, science, policy and decision. This is done to facilitate at various choices of sustainable solution for planning, development and management. It is recognized that an effective institution is the one that has a clear mandate, a legal framework, a well structured organization with clear responsibilities and accountability at various levels. The existing institutions are critically reviewed and identified (Pakistan Engineering Council, 2004). It is important to have well trained and motivated staff engaged in NRW activities. Manpower levels need to be monitored against NRW targets over the years to ensure that staff levels have been both adequate and appropriate to fulfill the NRW reduction targets.

4. Goals, Objectives and Standards

One of the most difficult problems for the agency will be to set realistic goals and standards. It is tempting to use Asia Development Bank (ADB), World Bank (WB), International Water Association (IWA) or similar standards since they are available (e.g. IWA standard water balance, etc.). However, this approach may be costly and may or may not effectively deal with the problems experienced in the country. Thus, the first phase of the implementation agency should focus on carrying out a comprehensive situational analysis of the entire system in order to determine its current status. After assessing the current status of the system, a set of objectives and standards are established to guide the area in planning for what it intends to achieve. This includes the improvements to be made and the time frame as far as NRW is concerned. These goals must be made clear to all staff in the area for ownership of the process. The main objectives that are set generally include:

i. increasing the ability to measure NRW for smaller geographical areas and know exactly the problematic areas and find solutions for them so as to reduce the overall NRW for acceptable level or economic level of losses (ELL) in target period,

ii. making staff more accountable for their actions by making it very possible and easy to apportion blame and success,

iii. increasing depth of performance monitoring being able to fairly reward extra individual and group efforts

Setting Acceptable Level or Economic Level of Losses (ELL) for NRW

The ultimate goal of the NRW reduction plan is to reduce the level of losses to a point where the “acceptable level” or “economic level of losses” is reached and maintained. This point itself varies in time and requires monitoring to ensure cost-effective allocation of resources to NRW control. The factors, which influence the NRW, depend on various parameters. These are supply time, pressure level, per capita consumption, accuracy and frequency of meter readings.

Experience in many NRW reduction programs has shown that the following indicators are realistic guidelines for NRW in water supply systems, which were not well maintained. These are:

- Good condition of system……… < 250 Liters/connection /day
- Average condition……………… 250 - 450 Liters/connection/day
- Bad condition ………………..…. 450 Liters/connection/day

(Or) expressed in Liters/km mains/day:

- Good condition of system………..< 10, 000 Liters/km main/day
- Average condition ……………….10, 000 – 18, 000 Liters/km main /day
- Bad condition ………………..…..18,000 Liters/km main/day

Source: Zimmerl, (undated)

The acceptable level of NRW depends mainly on two parameters, the "economics" and the "availability of raw water". It is obvious that limited water resources will force the utilities to reduce physical losses as much as possible in order to satisfy the demand and the economics will play a lesser role. Economical considerations on the other hand shall be used under all other circumstances to determine the economic level of NRW and in particular, the economic level of leakage (Zimmerl, undated).

However, in many water utilities, there is insufficient information available to determine reliably the current global level of NRW. Hence, it is not feasible to attempt any estimate of an initial ELL.

Nonetheless, in order to provide an initial reference point for the start of the program, a preliminary target is proposed. This target must be modified and reset on a periodic basis as more reliable and greater quantities of data become available so as to improve network rehabilitation, reinforcement, extension and water supply management.

5. Funding Methods and Sources

A major constraint on the development of sustainable water resources projects will always be the financial one. Obviously, a large-scale development project cannot be effective if the financing is insufficient. Financing is required not only for construction, maintenance and operation, but for planning and operation studies. The Board of Directors or concerned ministry should prepared budget allocations and financial support for implementation control program by initial calculations. Water authority itself has to consider appropriate pricing for water as an economic good.

6. Operation and Maintenance

Operation and maintenance is crucial to successful management and sustainability of water supply networks, whatever the level of technology, infrastructure and institutional development. It requires forward planning and technology transfer at all stages from installation of plant and equipment, through operator training and hand-over, to routine operation and upkeep. O&M, therefore, encompasses equipment selection, spares purchasing and repair procedures as well as the best practice in operating and maintaining the system. It is essential that an O&M program be built into the project from an early stage and not as an afterthought.

7. Technology Transfer and Training

The control agency should concern itself with operations and training of personnel assigned to control facilities. Training staff in new skills and techniques features highly in developing a leakage management strategy and for ensuring sustainability. It encompasses the motivation of staff, transfer of skills in the techniques and technology of leakage management, and system operation & maintenance. Mostly, this training should be undertaken by the consultant's staff in association with employees of a water authority in a developed country. It should include lectures on theoretical aspects but should be devoted to practical training under working conditions using traditional methods as well as modern equipment for leak detection, introducing a leakage management program, an understanding of the principles of the program, the steps in its design and implementation and support for the tasks involved. Generally, a training program will include awareness seminars for senior staff and decision makers (and to raise public awareness), training for engineering and technical staff, continuous practical training for operation staff.

8. Monitoring, Surveillance

Monitoring which shows whether an activity is improving, stagnating, or deteriorating is a more reliable basis for prediction. To benefit fully from a monitoring system, managers must have access to its information on a timely basis, and be prepared to act expeditiously on critical issues. For example, the monitoring of flows is important to leakage managers who use the details to prioritize their leak location effort. The technique of leakage monitoring is considered the major contributor to cost-effective and efficient leakage management, which can be applied to all networks as a methodology.

9. Co-ordination

Co-ordination will be necessary to co-ordinate continuously with other concerned departments in order to maximize the benefits. These include, but are not limited to:

i) New Works and Network Rehabilitation

Co-ordination for items such as: Design criteria, Rehabilitation priorities

ii) O&M Departments

Co-ordination for items such as: Repair teams, meter checking and testing

iii) District Inspectors

Select top-grade district inspectors to have the sole responsibility for all maintenance and operation of valves, including initial location and subsequent guarding of surface boxes.

iv) Senior Management & Government Organizations

Co-ordination for items such as: Bylaws and regulations, public relations

10. Benchmarking

According to Bramham (1996), at its simplest level, benchmarking consists of comparing your organization with another. In this way, you can decide whether your organization's performance is in some way falling short of the standard against which you compare yourself. Using benchmarking in NRW management is also useful, as it enable utilities to compare themselves with others. Moreover, benchmarking helps utilities compare their performance during one period with their performance during another.

Experiences for Non-Revenue Water Management in Developing Countries

Phnom Penh Water Supply Authority

Cambodia's Phnom Penh Water Supply Authority (PPWSA) is unlike a typical water utility in Asia. PPWSA has efficient services performance (see Table 2.8) with a model public sector water utility that provides 24-hour drinking water to Phnom Penh.

Table 2.8: PPWSA-Before and After 1993 Water Supply Condition

Indicators	1993	2006
Staff per 1,000/connections	22	4
Production Capacity	65,000 m3/day	235,000m3/day
Non Revenue Water	72%	8%
Coverage area	25%	90%
Total connections	26,881	147,000
Metered Coverage	13%	100%
Supply Duration	10	24
Collection ratio	48%	99.9%
Total revenue	0.7 billion riels[3]	34 billion riels
Financial situation	Heavy subsidy	Full cost recovery

Source: Phnom Penh Water Supply Authority, 2007

Years of Deterioration and Neglect: Cambodia's 20-year civil war and the Khmer Rouge rule destroyed much of Phnom Penh's buildings and infrastructure. The water supply system, whose capacity shrank from 155,000 m^3/day (1960s) to 65,000 m^3/day (1993), was reduced. With century-old pipes and a poor distribution network, roughly only a quarter of the population received piped water.

PPWSA, the government-owned water supply utility, was having trouble meeting its challenges. Employees were demoralized, underpaid and under-qualified. Only 13% of connections had water meters, leading to inaccurate billing. Only 28% of water production was actually sold, with the collection rate not even reaching 50%. Illegal connections were prolific. Unaccounted for water was at a high 72%. What was worse? PPWSA employees were responsible for the water theft; they were installing illegal connections at $1,000 per connection.

[3] Riel = Cambodia currency, 1US$ = 4084.30 riels

Restoration of Phnom Penh's Water Utility: The year 1993 marked the beginning of the restoration of Phnom Penh's water infrastructure. With the assistance of external funding agencies, particularly the Asian Development Bank (ADB), and through internal reforms, PPWSA transformed itself into an efficient, self-financed, autonomous organization in a city still recovering from long years of war and civil strife. Ek Sonn Chan, a young engineer who took PPWSA's rudder, initiated a "culture of change" within the organization, starting with the education and motivation of PPWSA's staff. This was followed by a spell of reforms, including

- Streamlining the organization's workforce (e.g. - giving more responsibility to higher management, promoting promising staff, giving higher salary and incentives to staff, fostering the spirit of teamwork, etc.)
- Improving collection levels (e.g. installing meters for all connections, computerizing the billing system, updating its consumer base, confronting high ranking non-payers and cutting off their water if they refuse to pay, etc.)
- Rehabilitating the whole distribution network and treatment plants (e.g. hiring locals in stead of international consultants for the job, manually looking for the pipes as all blueprints were destroyed during the civil war, mobilizing the communities to report leaks, etc.)
- Minimizing illegal connections and unaccounted for water (e.g. setting up inspection teams to stop illegal connections, penalizing those with illegal connections, giving incentives to the public to report illegal connections, etc.)
- Increasing water tariffs to cover maintenance and operating costs (e.g. proposing a 3-step increase in tariffs over 7 years, although the 3rd step did not push through anymore because revenues already covered the costs by then.)

Water service now covers 100% of inner city of Phnom Penh and is being expanded to surrounding districts, with priority given to urban poor communities. In particular, PPWSA now serves 15,000 families in 123 urban poor communities, giving the poor extra privileges such as subsidized tariffs or connection fees, installment connection fees and more. Non-revenue water has also decreased from 72% to 8%, while bill collection is now at 99.9%. Its 147,000 connections, up from 26,881 in 1993, bring reliable and safe drinking water to all of Phnom Penh's one million inhabitants 24 hours a day.

Lessons Learn from PPWSA (Cambodia)

1. Water Doesn't Have To Be Free

The story of Phnom Penh demonstrates that access to water does not mean that it has to be free and that the urban poor will be considerably better-off paying for safe, piped water than they would be buying water of questionable quality from private vendors. For instance, Phnom Penh's unconnected residents used to pay 1,000 riels per day (US$0.25 per day) for water bought from private water vendors. Today, they only spend about 5,000 riels per month (US$1.22 per month) for PPWSA-supplied water.

2. Cost Recovery is Vital

By developing a tariff structure, the utility fully recovers its cost of water production and transmission. The utility has become financially viable, and now able to invest in the water infrastructure. The PPWSA reached full cost recovery in 2004 and is now making modest profits.

3. The Operator Must Be Autonomous

Although the PPWSA is still government-owned, it has enough autonomy to develop its own payment structure and culture with an enthusiastic and motivated staff responsive to consumer demand, and efficient operations where revenues pay for infrastructure development.

4. Government Support is Crucial

The tariff restructuring, which paved the way for PPWSA's greater revenues, would not be possible without the support of the Government of Cambodia and its development agencies. PPWSA would also not have the freedom to innovate if the government had not declared the utility an autonomous body in 1986.

5. Civil Society Must Be Involved

The remarkable increase in bill collection and reduction in illegal connections has also highlighted the importance of involving users and civil society in a service that they want and are willing to pay for. The key has been to develop a utility-customer relationship, based on long-term community building rather than short-term contractual relationships. Effective awareness campaigns also enabled PPWSA to increase tariffs with broad public support.

6. Investing in Staff Yields Radical Results

Today, PPWSA takes pride in its team of people who are hardworking, responsible and self-motivated. PPWSA professionalized its workforce, building its technical capacity (each staff receives an average of 12 days of training each year) and instilling in its employees a work ethic of discipline, competence and teamwork.

7. Water Champion at the Helm Drives Reforms

When Ek Sonn Chan introduced the "culture of change" to PPWSA, he started the utility on the road to recovery. With each reform that PPWSA has taken, he has been its driving force, leading his staff and the community by example. PPWSA has shown that through a transparent environment where water utilities have sufficient autonomy, where tariffs can cover costs, where service is equitable to all and where there is the active involvement of staff and civil society, clean water targets can be met. Ek Sonn Chan says, "It doesn't matter whether water distribution is done by the private sector or a public agency, as long as these institutions are transparent, independent from political pressures, and accountable."

ADB's Phnom Penh Water Supply and Drainage Project (2007) provided the opportunity for PPWSA to collaborate with ADB. PPWSA demonstrate its capacity for catalyzing water sector reforms. The project advocated the transfer of more managerial autonomy to PPWSA to enable it to use its own funds on maintenance and rehabilitation programs. As a result, PPWSA became financially and operationally autonomous, achieved full cost recovery, and transformed into an outstanding public utility in the region.

Experiences from Singapore's Water Management

Singapore is a city-state water scarce country. Thus, it imports its entitlement of water from the neighboring Johor state of Malaysia, under long-term agreements. When Singapore became an independent country in August 1965, the long-term water security was an important consideration for this newly independent nation. Singapore made a special effort to register the Separation Agreement in the United Nations Charter Secretariat Office in June 1966. Singapore has developed a new plan for increasing water security and self-sufficiency with increasingly more efficient water management, including formulation and implementation of new water-related policies and other similar actions.

The Public Utilities Board (PUB) has managed the entire water cycle of Singapore since 1 April 2001. The PUB developed a holistic policy, which included protection and expansion of water sources, storm-water management, desalination, demand management, non-revenue water control, catchments management, outsourcing to private sector specific activities, and public education and awareness program. Non-revenue water was 9.5 % of the total water production in 1990 and the PUB managed to reduce NRW to around 5% in the year 2000 and beyond. Unlike other South and Southeast Asian countries, Singapore simply does not have any illegal connections to its water supply systems (Mclntosh, 2003). Today, Singapore's NRW management would still be considered one of the best examples in the world (Tortajada, 2006).

Lessons Learn from Overall Performance

The overview of NRW control for Singapore water supply management is:

- Meter accuracy is very high. Production meters are calibrated every month. Domestic consumer meters are replaced every 7 years and industrial meters are in every 4 years.
- The volume of water used for fire fighting is estimated or measured and fire departments are billed.
- The commercial system is highly reliable and controls are in place to prevent tampering.
- Billing complaints are dealt with promptly.
- High and low consumption patterns are investigated.
- Average water rates are close to the incremental cost of water.
- The entire distribution system is surveyed for leaks every year.
- Water districts can be fully isolated to monitor for leaks. Distribution pipes are cement lined to reduce corrosion and are replaced if the number of breaks exceeds three per kilometer per year. House connections are made of stainless steel or copper.
- Certified plumbers do in-house repairs and installations.

Many of these approaches can be adopted by developed and developing countries to improve their water management systems (Tortajada, 2006). Singapore has been very successful in managing its water and wastewater. This can be attributed to its concurrent emphasis on supply and demand management. This includes metering, leak surveillance, proper billing procedures, strong management, and institutional effectiveness. It is also very important to create an enabling environment, which includes a strong political will, effective legal and regulatory frameworks and an experienced and motivated workforce.

Supply management: To protect its water sources, expands its available sources by desalination, reuse of wastewater and storm-water, use technological developments to increase water availability, improve water quality management and steadily lower production and management costs. At present, PUB has an in-house Centre for Advanced Water Technology, with about 50 expert staff members doing necessary research and development support. The water utility is reclaiming wastewater after secondary treatment by means of advanced dual-membrane and ultraviolet technologies. This treated water is mainly supplied to industries and commercial customers. The source of water is further expanded by reducing NRW, which is defined as actual water loss due to leaks and apparent losses arising from meter inaccuracies. Singapore has hundred percent metering, leak surveillance, proper billing procedures and strong management in water supply.

Demand management: Concurrent to the diversification and expansion of water sources, PUB has put in place a well thought out and comprehensive demand management policy. As part of this discussion, it is useful to review the progress of water tariffs for water during the 1997-2000 periods. The water tariff used is the block rate system. Minimum first rate was 20m^3 in 1997 and 40 m^3 in 2000. The progressive tariff structure is presented in Appendix B, Table 1. In addition, the water conservation tax and water borne fee are promulgated. The average monthly household consumption has steadily declined. In 1995, it was 21.7 m^3 per month per household but by 2004 was 19.3 m^3 per month per household. The consumption in 2004 was 11 % less than in 1995. This is a positive result of introducing demand management policy in water management at Singapore. However, the Government provides water specially targeted help for the lower income families such as households living in 1- and 2- room flats. These households are eligible to receive social financial assistance. This is a much more efficient policy in socio-economic terms, instead of providing subsidized water to all. Commercial and industrial users are not subsidized.

Water Institution: The PUB has a competitive remuneration, incentives and benefits package. The salary and benefit package is generally benchmarked against the Civil Service. It provides strong performance incentives, which are commensurate with the prevailing pay packages for the private sector. In addition, its pro-family policies, commitment to train its staff for their professional and personal development and rewarding good performers, ensure good organizational performance and development. With a good remuneration package, functional institution and strong anti-corruption culture, therefore, corruption is not an issue at PUB. Furthermore, PUB has a high level of autonomy and solid political and public support, which have allowed it to increase water tariffs in progressive steps between 1997 and 2000. This increase not only has reduced the average monthly household water demand but also increased the income of PUB, which has enabled it to generate funds for good and timely operation and maintenance of the existing system as well as for investments of future activities.

As a result, PUB invariably comes to the top of all the urban water utilities of the world (Tortajada, 2006). Only a few of these indicators will be noted:

- Hundred percent (100%) of population has access to drinking water and sanitation.
- The entire water supply system is 100% metered and 0% illegal connection.
- Unaccounted for water as a percentage of total production was 5.18% in 2004.
- The number of accounts served per PUB employee was 376 in 2004.
- Monthly bill collection efficiency is 99% in 2004.
- Monthly bill collection in terms of days of sales outstanding was 35 days in 2004.

Operational Definition

Non-Revenue Water: Differences between total water volume input to the treatment plant for distribution of supply water and total billed water volume, which actually achieved money from the department of water authority.

Water Sustainability: The use of water in a manner, that provides current ecological and societal needs while not compromising the requirements of the future both ecosystem and society.

Conceptual Framework for the Study

Figure 2.2 presents the conceptual framework for this research. NRW water management is a way of achieving sustainability. On the one hand, it is based on the performance of water authority that must be involved in right decision making and identifying programs that affect their management lives. The other is that a good NRW management in the water supply system leads to the expanded water supply service and reduces extraction of water from their sources. Therefore, the research provides a holistic conceptual framework for linking non-revenue water management and water sustainability. This framework involves the identification of issues on the research.

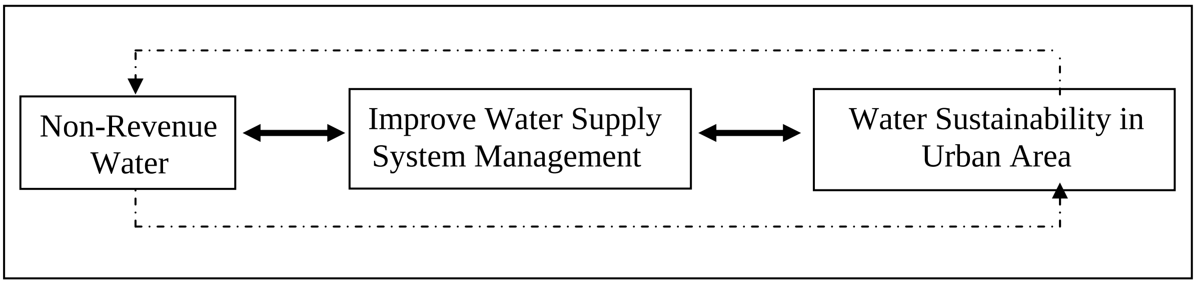


Figure 2.2: Conceptual Framework of the Study

CHAPTER 3

RESEARCH DESIGN AND METHODOLOGY

This is a descriptive and exploratory analysis type of research, which totally relies on qualitative and quantitative data. Briefly, the sense of exploratory study involves investigating the awareness and perception of the people on water supply management in the study area. The data obtained from qualitative interviews targeting environmental management personnel, local community and leaders groups are used to evaluate their perspectives on the policy formulation of water supply system improvement. Secondary data and quantitative data are used for descriptive analysis. The combination of both analyses will be used to identify the past, present and future opportunities and challenges of reducing non-revenue water for water sustainability.

Research Design and Process

The research is based on a one shot case study design. It deals with the research strategy adopted and the steps that would be followed to achieve the objectives of the study. The overall research process adopted for this study is given in Appendix A, Figure 1. It includes three phases. Phase one started with identification of research questions. The research questions were converted into research objectives and assumptions outlined. The second phase is the collection of relevant primary and secondary information from a variety of sources and a number of analytical methods, which were employed in phase three to come up with expressive discussion and conclusion. Finally, the findings from the analyses were translated into recommendations of NRW control policy for water sustainability in urban areas.

Selection of the Study Area

Yangon city is divided into four districts - Yangon East District, Yangon West District, Yangon North District, and Yangon South District. According to administrative conditions, there are 33 townships. Considering the available time and funds for conducting the survey, it is impossible to make an extensive survey for all 33 townships in the city. The study excluded religious buildings, hospitals and dispensaries, schools, educational building, hotels, boarding house, hostels, prisons, home for the aged from the scope of the survey. Using stratified method of sample, therefore, only one ward per township per district of Yangon City was selected based on population density and available water supply facilities. To achieve the objective of the study, four areas have been selected as the study area for this research.

(a) Ward No.13, South-Okalapa Township for Yangon East District

(b) Ward No.4, Sanchaung Township for Yangon West District

(c) Ward No.2, Kamayut Township for Yangon North District and

(d) Ward No.3, Puzundaung Township for Yangon South District

Sampling Method

The study used purposive and random sampling methods to get the required information from government officials and two groups of water users included YCDC water supply customers both metered and non-metered users, and non-YCDC water users.

The survey was conducted on a sample basis and covered all households in the study area. All households will be included in the “sampling frame”. The design of the sample used in this research is three stages stratified sampling. The first stage involved the selection of sample townships in each district. The second stage focused on the selection of sample wards in each township and the third stage is sample households selection. The frame used in the sample selection process was based on population density in each township. The frame used in the third stage (sample households) was the year 2003-YCDC official use population record. In line with questionnaires survey, sample households were picked up in consultation with township WSS officers in the study area.

Sample Groups and Sample Size

The selected sample groups were water user groups and key informants group (government officials). Water user groups included YCDC water users (YCDC metered customers and un-metered customers) and Non-YCDC water users. In the result of stratified sampling method, the following sample frame was used. The number of households in each selected wards (Ew13, Ww4, Nw2 and Sw3)[4] are 1952, 1506, 850, and 270 households respectively. The population density of each township in the study area was shown in Appendix B, Table 2. The total numbers of households in this study area are 72591. These 72591 households were used as a "sample frame" for this study.

The sample size (n) for the survey in the study area was determined by using "Table for statisticians" (Arkin and Colton, 1950). In this Table, 95% confidence interval (0.05) and attributed sampling 10percentage was used for statistically adequate (the Table for statisticians was described in Appendix B, Table-3). The total number of samples for this study is 364 households summarized in Table 3.1. The proportion of sample distribution on each sample group were used probability proportional to size sampling (*pps*) which is a related variant in each of the sample groups existed in each sample wards.

[4] Ew13, Ww4, Nw2, Sw3 = Ward number 13, 4, 2, and 3 in each selected township of East, West, North and South Districts respectively.

Table 3.1: Require Sample Groups and Size in the Study Area

Name of Sample Ward	Total HHs in sample ward	Name of sample water user	Sample HHs in each Wards	Total No. of samplings
Ew13 S.Okalarpa	1952	Metered connected Non-metered connected Non-YCDC water user	20 34 41	95
Ww4 Sanchaung	1506	Metered connected Non-metered connected Non-YCDC water user	1 22 72	95
Nw2 Kamaryut	850	Metered connected Non-metered connected Non-YCDC water user	28 38 25	91
Sw3 Pazundaung	270	Metered connected Non-metered connected Non-YCDC water user	25 58 -	83
Total	4578			364

Source: Field survey 2006

Total number of households, three hundred and sixty four (364) was selected for the consumer survey in the study area. After selection, 364 household respondents were contacted for discussion and for completing the questionnaires. However, after screening the data and information from these questionnaires, two hundred and ninety five (295) questionnaires could be utilized for this study (Table 3.2). The remaining 69 results were rejected for the analysis, because most of them were incomplete and inappropriate. Thus, these questionnaires (69) results were excluded from the analysis. List for checklist interview or key informant group (government officials) was shown in Table 3.3.

Table 3.2: Total Actual Sample Size of Households Survey, 2006

Type of respondent	**Actual Selected Townships/Ward**				**Total actual sample size**
	S.Okkalarpa Ew13	**Sanchaung Ww4**	**Kamayut Nw2**	**Puzundaung Sw3**	
YCDC metered water users	12	1	20	21	54
YCDC un-metered water users	42	30	40	39	151
Non-YCDC water users	23	47	20	0	90
Total	77	78	80	60	295

Source: Field survey 2006

Table 3.3: List of Key Informants

Department /Office	Position	Number of person
YCDC Head Office		
WSS Department Head	Chief Engineer	1
WSS Department Head	Dy. Chief Engineer	1
Administrative and Finance Department Head	Finance Officer	1
Pollution Control and Cleansing Department	Dy. Head	1
Reservoir Division	AE	1
Water Distribution Division	AE	3
Electrical and Mechanical Division	ACE	1
Pipe Plant	ACE	1
Water quality and monitoring	Head (AE)	1
Township office	AE	4
Leakage/repair	Team leader	1
Operation and maintenance	Team leader	1
Tax collection and meter reading	Section head	2
Private water company (Bottle Water)	Managing Director	1
Water venders in the selected townships	Owner	3
Total		23

Source: Field survey 2006

Method of Data Collection

Primary data and secondary data have been collected for this research study by using a number of data collection methods. Primary data were collected from following methods: reconnaissance survey, investigation and observation, formal and informal interviews, structured questionnaire survey and institutional survey in the study area of Yangon City.

The reconnaissance survey was particularly helpful in generating a preliminary view of the socio-economic condition, existing situation of water supply and its non-revenue water (NRW) in the study area. Investigation and observation were used to compile qualitative information on the selected study area on their water consumption and leakage control practices, water meter reading and billing practices and their living environment conditions. This method of observation also helpful identifies the relationship between the water authority and the water users.

Formal and informal interviews, meetings and discussions were conducted with local government leaders and officers, field engineers, and other professionals who related to water and environmental management, private water vendors, and community leaders. This kind of interview method was made to find out the current status of water supply situation, their opinion and suggestions. Much of the qualitative information used in this research is based on these discussions and interviews. Other methods used such as checklists and note-sheets to gather additional information were excluded on the structured questionnaires.

A structure questionnaire survey and institutional survey were made to collect primary data from three different selected groups. They are YCDC customers (both metered water users, un-metered water user), non-YCDC water users and key informants at local and provincial level involved in the field of water and environmental management (Government officials and experts). The questionnaire survey procedure was described in the following section. During the primary survey period, photographs of the study area showing the current situation were also taken.

Data from secondary sources were collected at different levels and different sources. Information on such issues as water supply management, water user charge, tariff, water pricing policy, non-revenue water, sustainable water management issues and practices, as well as population data, economic data, meteorology and hydrology data, and other related data and information were collected. The principle sources for the information were collected from published and unpublished documents from international institution and organizations such as the World Bank, United Nations Development Program (UNDP), and the Asian Development Bank (ADB). This information was collected through library work in Thailand (Asia Institute of Technology), Japan (National Diet Library, JICA Library, and APU Library), Myanmar (Yangon University Library and Yangon Technological

University Library), YCDC head office and WSS Department, and JICA office of Myanmar. Some secondary data, map and chart were also collected from the participation in international conferences related to topic in this research and from the internet search.

Questionnaire Survey Process

Based on characteristics of water users, structured questionnaires were prepared for detailed interviews of selected groups (see Appendix C). Questionnaire included three parts. The first part asked about socio-economic information. The second part was their water sources, water consumption, expenditures, and satisfaction of current water supply and awareness of water leakages. Respondents conveyed their perception of current water supply management and their needs. The third part assessed the water supply connection, billing and their willingness to pay for improvement of water supply system.

The questionnaire interviews were carried out by the researcher herself with one interviewer and the help of WSS's township office staff. Interviews were mostly made Saturdays, Sundays, holidays, and in the evening of weekdays to increase the likelihood that heads of family/household would be available. When the head of household could not be interviewed, one person who is over eighteen years old was interviewed instead. If, for any reason, a listed household could not provide an interviewee, the nearest house was chosen as substitute respondent.

Interviews with government officials aimed to discuss current management practices, perceptions, financial and political constraint, influences and plans. From discussion with operational staff and field engineers, the following data were obtained. These are 1) physical data (supply arrangements, mains length of services, number of service connections, customer meter location, average pressure, etc.), 2) drawings, 3) estimated system input volumes, 4)estimated authorized and unauthorized consumption, 5) non-revenue water components and performance, 6) current practices (staffing structure, staff numbers and skills), 7) equipment repair program and economic data (cost of water etc.).

Data Processing and Analysis

All collected data/information both questionnaire surveys data, interview information, and related secondary data were screened for quality accuracy. The primary data were compiled from the questionnaire survey and formatted by using electronic spreadsheets (Microsoft Excel). Statistical Package for Social Science (SPSS) software was used to analyze for qualitative data. Simple statistics like relative frequency mean and percentage were calculated and presented in descriptive tabular and graphical forms by using Microsoft Excel.

CHAPTER 4

FINDINGS AND DISCUSSION

Background of the Study Area

The Union of Myanmar, formerly known as Burma, is situated in South East Asia between Longitude 92° and 101° (E) and between Latitude 10° and 28° (N). The country is sharing its borders with Bangladesh, India, China, Laos and Thailand. On the south and southwest, it has a long coastline of 2,832 km in total length with Bay of Bengal and Andaman Sea (See Figure 4.1). The total area of Myanmar is 678,000 km^2 and is administratively divided into 7 States and 7 Divisions. According to the statistics of 1998-1999, the population of the country is estimated at 51.4 million and the population growth rate is 1.84 percent. The GDP growth rate at 1997-1998 is estimated at 4.6% (MFF, 2001).

Figure 4.1: Map of Myanmar

Geographical Characteristics of the Study Area

The study area "Yangon City" is the former capital city of Myanmar. The City occupies the southern portion of the country as shown in Figure 4.2. It is situated in the delta of the Ayeyarwady River, the main part of the city lying on the area between the Yangon River and the Pazundaung Creek. The topography of Yangon City is made up of slightly undulating and hilly land in the city centre and low, flat land on the fringes. Natural drainage channels, which generally originate in the hills run in all directions and finally drain into the Yangon River and Bago River. Administratively, Yangon City's municipal area covers 33 townships with a total area of 729.7 km^2.

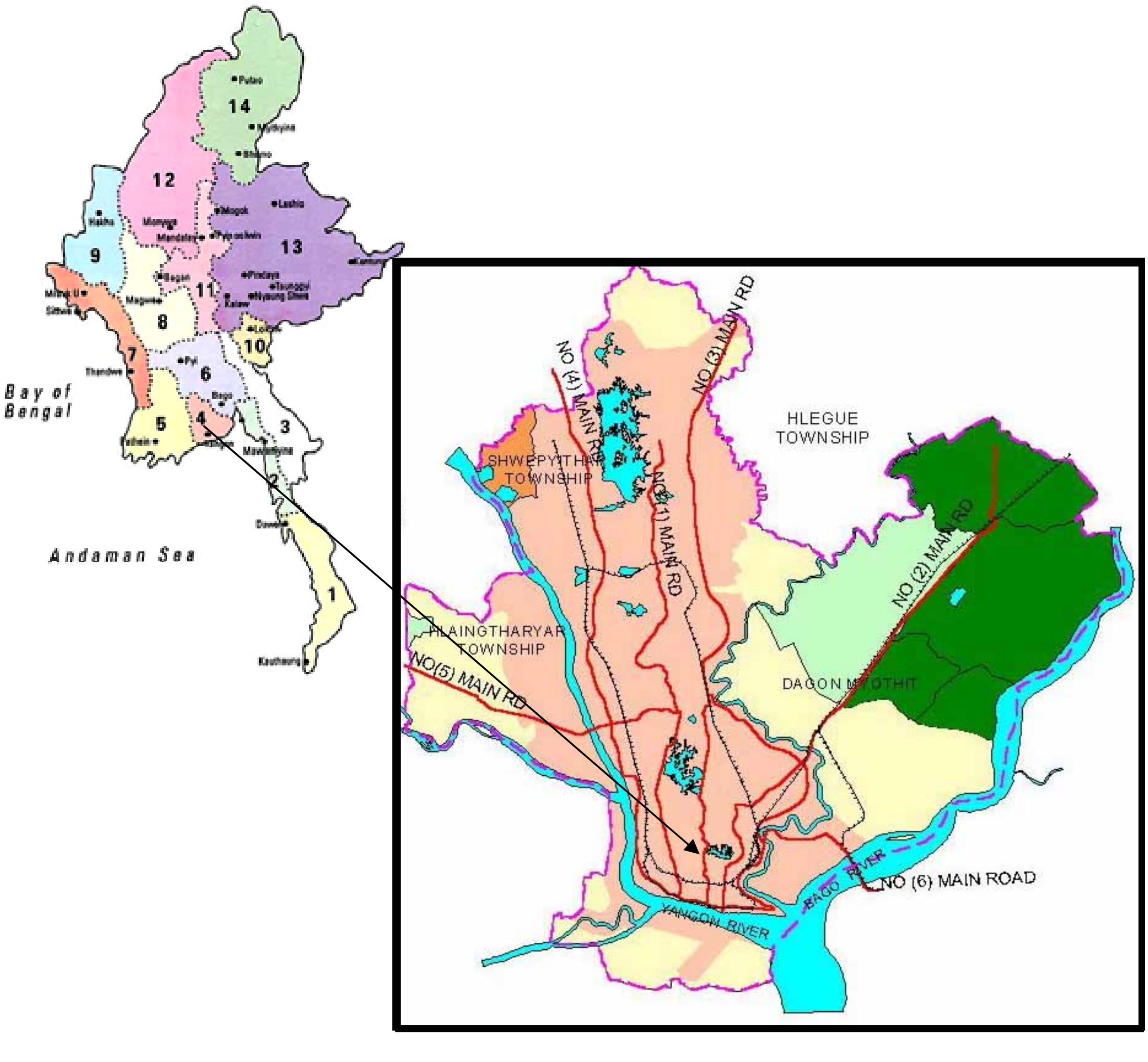


Figure 4.2: Map of Yangon City- A Case Study Area

Climate

Myanmar has a monsoon climate, with three different seasons - summer, rainy season, and cold season. December and January are the coldest months and April and May are the hottest. Yangon City also has three seasons. The minimum temperature during the cold season is 21 (°C) and maximum temperature during summer season is 32.2 (°C). Annual rainfall varies from 500cm in the coastal regions to 75 cm and less in the central dry zone (YCDC, 2002).

The city has an average rainfall in excess of 100 inches (250 cm) during the rainy season. The highest temperature being 33 (°C) and the lowest 21.8(°C) as taken from a ten-year record (1991-2000) in climate elements at the key stations name of Kaba-Aye, Yangon. Due to its proximity to the sea and the seasonal southwest monsoon, the daily average relative humidity for the same station and period of weather records was 72–77% (DOMH, 2003).

Land Use Pattern

Yangon city is formed with four districts - Yangon East District, Yangon West District, Yangon North District, and Yangon South District. According to the socio-economic condition, Central Business District (6 Townships), Suburban Townships (22 Townships) and Satellite Towns (5 Townships) are also divided into these districts (YCDC 2001). Recently, industrial development of the country together with open door economic activities in the districts contributed to an accelerated population growth in Yangon City. After 1988, the government developed the new satellite towns (DHSHD, 2001), which are Hlaing Thayar, Shwe Pyi Tar, Dagon Myothit South, Dagon Myothit North, and Dagon Seikkan Township. New satellite townships areas were used to resettle squatter families, government employees housing, religious compounds, and new industrial zones. The new satellite towns have been constructed with necessary social services and infrastructures on "site and service" basis. Industrial zones were provided in each of the new satellite towns for creating job opportunities and encouraging productivity for the enhancement of local economies, including privatization, which is in line with the "Market Economy" policy adopted by the State.

Table 4.1 shows the present land use of Yangon City. About 9.1% of the total land area of Yangon City remains forest area. These forests are located mostly in the central and northern lowland hills of the City. Agricultural land occupies 43.8% including areas of farm, paddy, open land and grassland (MI, 2005). Primary settlements are concentrated along the port side and the major transport routes. The remaining forestland must be preserved to primarily serve as watershed. Opening the remaining forestland to other uses will restrict its function as a watershed.

Table 4.1: Present Land Used of Yangon City

Land Use Category	Area (km^2)	Percentage (%)
Forest land	66.4	9.1
Farm/grass/open land	41.6	5.7
Built-up (residential)	308.7	42.3
Paddy (rice field)	278.0	38.1
Swamp (including fishponds)	35.0	4.8
City total area	729.7	100.0

Source: MI, 2005

Population of Yangon City

Yangon ranks first in Myanmar population density with 55,700 persons per square kilometre in some inner townships of the city. However, population density in Yangon City is very diverse from 314 persons per square kilometre to 55,700 persons per square kilometre (YCDC, 2001). The city population is increasing while the estimated population in Yangon city was over 4 million in year 2005. The historical population trend was shown in Table 4.2 and Figure 4.3. The city population data were obtained from three sources

(Yangon the City (1995), Statistical Abstract (1996), and Manpower & Immigration Department data). The national census was carried out in 1921, 1931, 1953, 1973, and 1983 by Manpower & Immigration Department.

Table 4.2: Past Population Trend and Growth Rate from 1836 to 1998

Year	Population (Persons)	Annual Growth Rate (%)	
1836	30,000	1836-1855 (1.26 %)	1836-1872 (3.35 %)
1855	38,055	1855-1856 (20.88 %)	
1856	46,000	1856-1860 (7.56 %)	
1860	61,570	1860-1865 (2.56 %)	
1865	69,866	1865-1872 (4.97 %)	
1872	98,138	1872-1921 (2.58 %)	1872-1973 (3.04 %)
1921	341,962	1921-1931 (1.59 %)	
1931	400,415	1931-1953 (2.81 %)	
1953	737,079	1953-1973 (5.19 %)	
1973	2,027,256	1973-1983 (2.00 %)	1973-1998 (2.43 %)
1983	2,472,176	1983-1998 (2.71 %)	
1998	3,691,941		

Sources: 1836-1872, Yangon the Garden City, 1995, 1973-1998: Manpower & Immigration Department, 1992-1953: Statistical Abstract, 1996 Central Statistical Organization

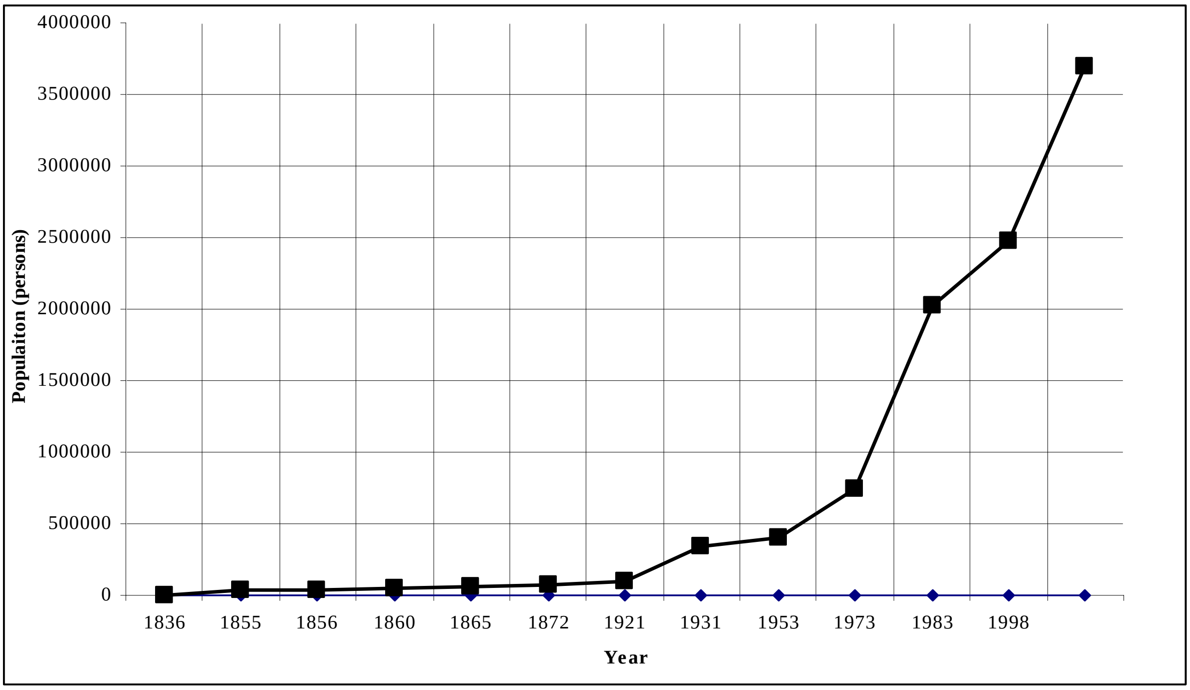


Figure 4.3: Historical Population Trend in Yangon City (1836-1998)

The City population by township figure (see Appendix B, Table 3) showed that the growth rate during 1983 to 1998 in each township was different. In year 1998, population has decreased in 3 townships namely Seikan, Ahlone, and Landmaadaw. The steady growth rate is less than 1% in 12 townships (Latha, Pazundaung, Bahan, Dagon, Mingalartaungnyunt, Pabedan, Kyauktada, Sanchaung, Botathaung, Tamwe, Kamayut, and Hlaing) and the remaining 13 townships are more than 1% growth rate in each township population. This figure can be criticized that twenty-five (about 75%) townships out of 33 have increased in population. New satellite townships were established around the city municipal area in recent years. According to the JICA study team (2002), estimated population in Yangon will reach over 6 million in year 2020. These populations were also considered for the future plan of water supply system development and impact on water sustainability.

Population Estimation for Future Yangon City

Population was estimated here with the collected data and different estimation methods. Table 4.3 shows the projection methods for this study.

Table 4.3: Population Projection Methods

Method	Collected data	
By Annual Growth Rate	Growth rate: 3.02%	1836-1998
	Growth rate: 2.43%	1973-1998
	Growth rate: 2.18%	1998-2000 (estimated by Manpower & Immigration Department
By Linear Line	Annual increase: 67,750 persons	1973-1998
By Power Curve		1973-1998

Source: JICA Study Team, 2002

The results from the above calculation were shown in Figure 4.4 and Table 4.4. The highest population at the target year 2020 is 7,097,412 persons with 3.02% annual growth rate. The lowest estimation is 5,124,302 with linear estimation, where this value is low and R^2 value is low. 2.43% GR estimation has little bit high R^2 value compared with the GR value 2.18% estimation. R^2 value for power curve estimation is 1 because it needs 3 data points to estimate, thus, this R^2 value is not comparable with other R^2 value. 2.43 % GR estimation and Power curve estimation are almost the same. However, due to the characteristic of the power curve, annual growth rate becomes smaller (see Figure 4.4) and makes it more likely. Thus, power curve estimation should be used for the population forecast. Where, R^2 means the coefficient of determination.

Table 4.4: The Results of Population Projection

Year	Annual GR (GR= 3.02%)	Annual GR (GR= 2.43%)	Annual GR (GR= 2.18%)	Linear	Power
1836	30,000				
1855	38.055				
1856	46,000				
1860	61,570				
1865	69,866				
1872	98,138				
1921	341,962				
1931	400,415				
1953	737,079				
1973	2,027,256	2,027,256	2,027,256	2,027,256	2,027,256
1983	2,472,176	2,472,176	2,472,176	2,472,176	2,472,176
1998	3,691,941	3,691,941	3,691,941	3,691,941	3,691,941
2000	3,917,950	3,873,312	3,854,459	3,769,296	3,887,045
2005	4,545,369	4,366,683	4,292,746	4,108,047	4,402,558
2010	5,273,263	4,922,899	4,780,870	4,446,799	4,954,885
2015	6,117,722	5,549,964	5,324,498	4,785,551	5,541,135
2020	7,097,412	6,256,902	5,929,942	5,124,302	6,158,975
R^2	0.9938	0.9953	0.9942	0.9784	1.0000

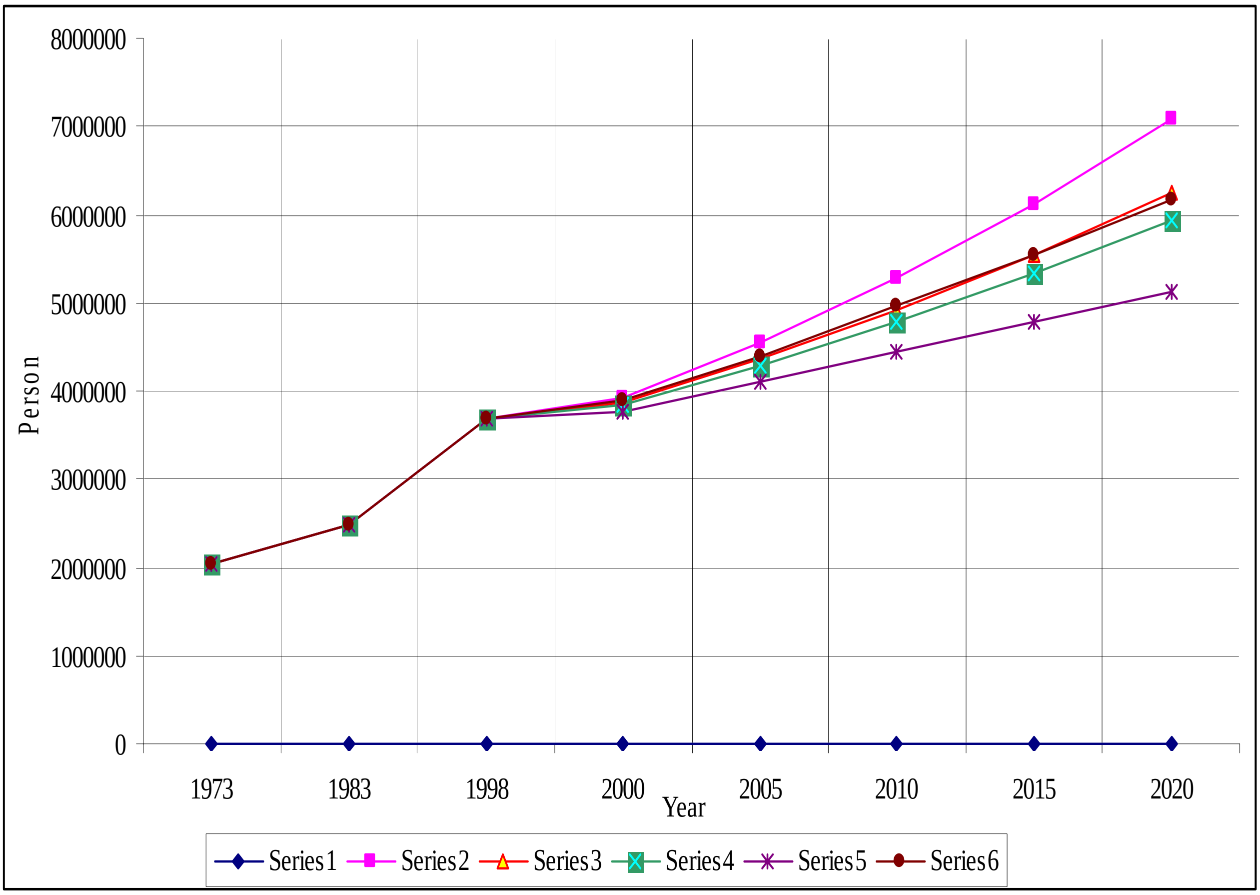


Figure 4.4: Population Projection

Educational Attainment and Environmental Awareness

Education is a vital prerequisite to protecting the environment and influencing the capacity of people to address environment and development issues. One expects that the level of education has increased among household members. Those households would be more likely to use improved services if these were available. According to the UNICEF Myanmar 2000, the vast majority (89.7%) of the population over age 15 years in Myanmar is literate and Yangon is 98.2 % literate.

The National Commission for Environmental Affairs (NCEA) in cooperation with Government ministries, particularly, the Ministries of Information, Education and Forestry have been promoting environmental awareness through the mass media. Information materials on environmental affairs and environmental education are also distributed to schools and to the government information centres through out the country. At present, there is a lack of public education and awareness related to water sustainability due to the limited availability of resource persons and base line information. Nevertheless, environment related news is published in Myodaw Newspaper, which comes out daily and in the Myodaw Magazine which is published monthly. Other publications like the Yangon-Green City of Grace, Shwedagon-Symbol of Strength and Serenity also write about environmental issues.

Economic Situation

Yangon City is an economic centre, is playing a crucial role in the transformation process of Myanmar's economy from a socialist into a market-oriented economy in the late 1980s. Yangon's economy is the largest in Myanmar. Since then, Myanmar has partially liberalized economic activities and reduced obstacles to foreign trade and investment. As a result, Myanmar's economic structure has been changing slowly but steadily. Economic growth has been fairly achieved by active participation of the private sector and inflow of foreign direct investment and expanded trade. According to CSO 2006 and ADB outlook 2006, real GDP growth rate is 13.7%, 11.3%, 12.0% 13.8%, 13.6% and 13.2% in FY2000, 2001, 2002, 2003, 2004, and 2005 respectively.

The economy is heavily dependent on agriculture, which constitutes about half of the economy. Industry accounts for roughly 15%, followed by services and trade. With the goal of "transforming the agro-based nation into an industrialized one", the government has organized scattered factories (13,538) into four industrial zones in Yangon City (MFF, 2003). With increasing economic development, the quality of life and living standards have been improved.

Existing Water Supply System Management in Yangon

Historical Background of the Water Supply System

Water supply in Yangon City has a long history that started since 1842 with 30 wells near the center of the City. In 1879, City water supply was introduced using water pumps and conduce pipe from Kandawgyi Lake. The short history of reservoir development in City water supply system is shown in the following Table 4.5.

Table 4.5: Water Reservoirs Development in Yangon City Water Supply System

Year	Name of Reservoir	Remarks
1879	Kandawgyi Lake	Water supply had stopped in 1906
1884	Inya Lake	Water supply had stopped in 1906
1904	Hlawga Reservoir	27km away from the City (currently use)
1940	Gyobyu Reservoir	64km away from the City (currently use)
1989	Phugyi Reservoir	70km away from the City (currently use)
1995	Ngamoyeik Reservoir	48km away from the City (currently partial use)

Source: Tun., 2005.

Generally, Myanmar is blessed with abundant water, but this resource is poorly distributed both in space and in time (Maung, 1996). Yangon City has also an abundance of natural resources of water from the Hlaing River, Panhlaing River, Yangon River, Bago River and Punzundaung Creek. However, most of the water sources near the City are not utilized for water supply due to water quality with saline intrusion. There is a natural tidal effect in each river near the southern part of Yangon City where is the mouth of Adman Sea and Bay of Bengal. Most of the water sources for City water supply are from the northern part of the City (see Figure 4.5). It is far from the City center. Most of the dams for supplying water to the City were constructed in the northern part of Yangon City. This is quite far from the city area, so generally, conducted pipe length for water supply is from 16 miles to 40 miles (25.75 km to 64.37 km).

In addition, many social and economic amenities, government ministries, educational institutions, religious establishments, hospitals and a large number of industries are also found in the City. Water is needed by all these players both as a basic commodity in itself and an important raw material in the production process.

This section is to provide a description of the status of water supply for the current city population, and then identify the issues, which are related to non-revenue water and water sustainability, on the existing water supply system management.

Status of City Water Supply Service Coverage and Facilities

Recently, City water supply service serves 46% of the total City population. The rest 54% have their own dug/tube wells. (See Table 4.6)

Table 4.6: City Water Supply Service Ratio

<table>
<tr><td colspan="2">YCDC water supply</td><td rowspan="4">46%</td></tr>
<tr><td>1. Pipe system</td><td>37 %</td></tr>
<tr><td>2. Tube Well</td><td>2 %</td></tr>
<tr><td>3. Pond</td><td>7 %</td></tr>
<tr><td colspan="2">Non YCDC water supply</td><td rowspan="4">54%</td></tr>
<tr><td>1. Dug well</td><td>1 %</td></tr>
<tr><td>2. Tube well</td><td>52 %</td></tr>
<tr><td>3. Others</td><td>1 %</td></tr>
<tr><td>Total</td><td></td><td>100 %</td></tr>
</table>

Sources: Tun, 2005

The existing water supply in Yangon City has two main categories, namely YCDC owned facilities and private owned facilities. YCDC owned facilities included YCDC owned in-house connection, communal tanks, standpipe and other arrangement facilities such as boat, tanker (See Table 4.7). The visual explanation on these two categories is shown in Figure 4.6.

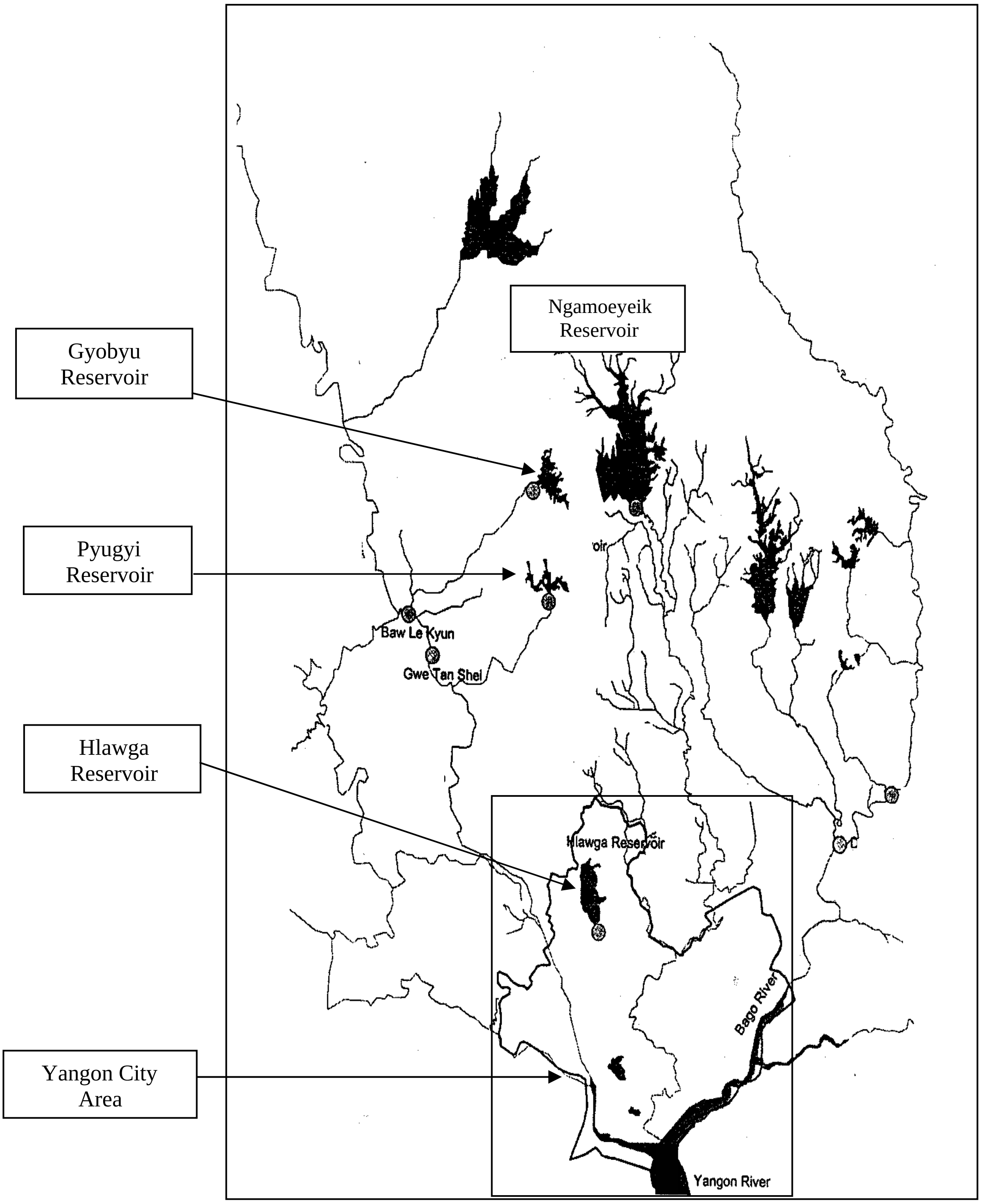


Figure 4.5: Water Sources for City Water Supply System in Yangon City

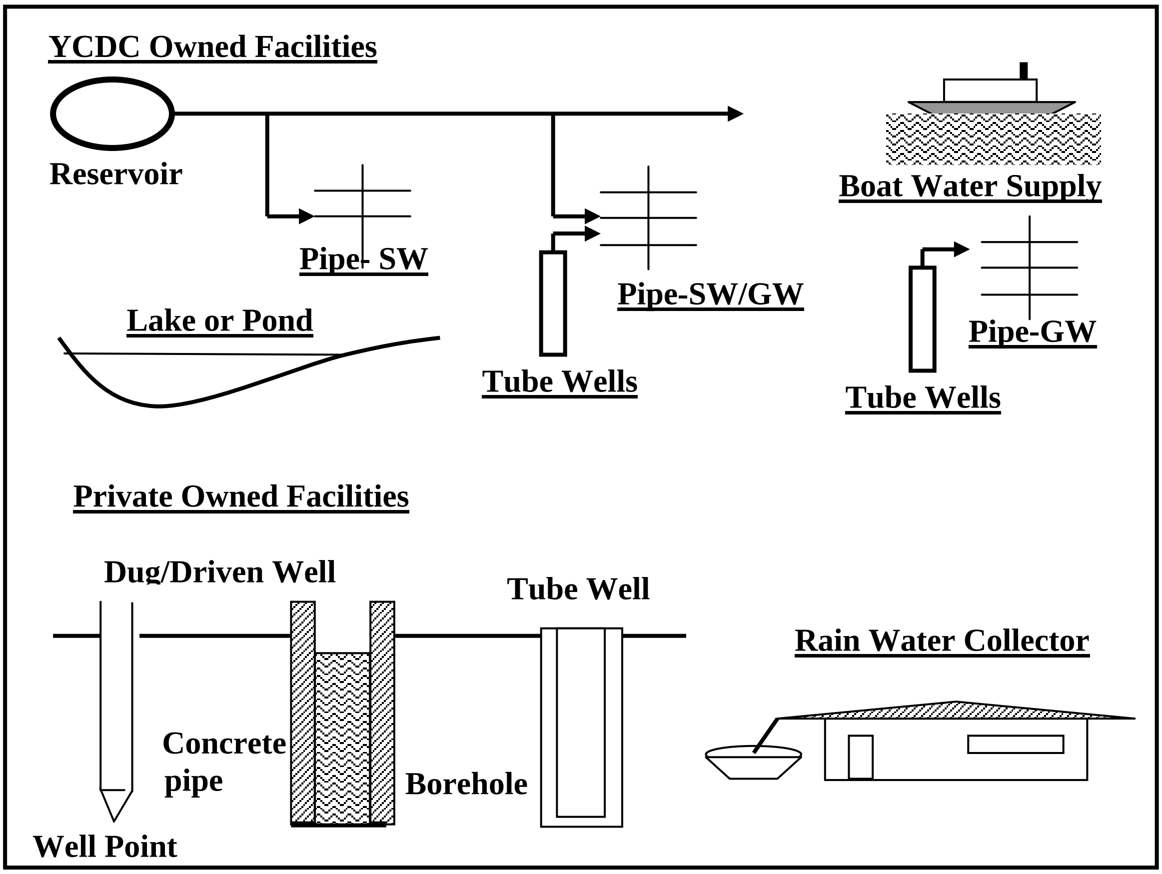
Table 4.7: Classification of City's Water Supply Services

Category	Water Source (See Fig: 4.6)	Service level (See Fig: 4.7)
YCDC owned facilities	Piped Surface Water (Pipe-SW) Piped SW and GW (Pipe-SW/GW)[a] GW with independent network (Pipe-GW)[b] Tube well without network (T/W) Boat Pond	L-II & III L-II & III L-II & III L-I L-I L-I
Private owned facilities	Dug/Drive Well Tube Well Pond Rain Collector	Indiv:, L-I & II Indiv:, L-I to III L-I Indiv:

Source: YCDC, 2002

Note: a: Network receiving surface water and pumped ground water

b: Some tube wells have their own network within township, not connected to the SW, or SW/GW network



Source: JICA Report 2001

Figure 4.6: Water Supply Facilities in Yangon City

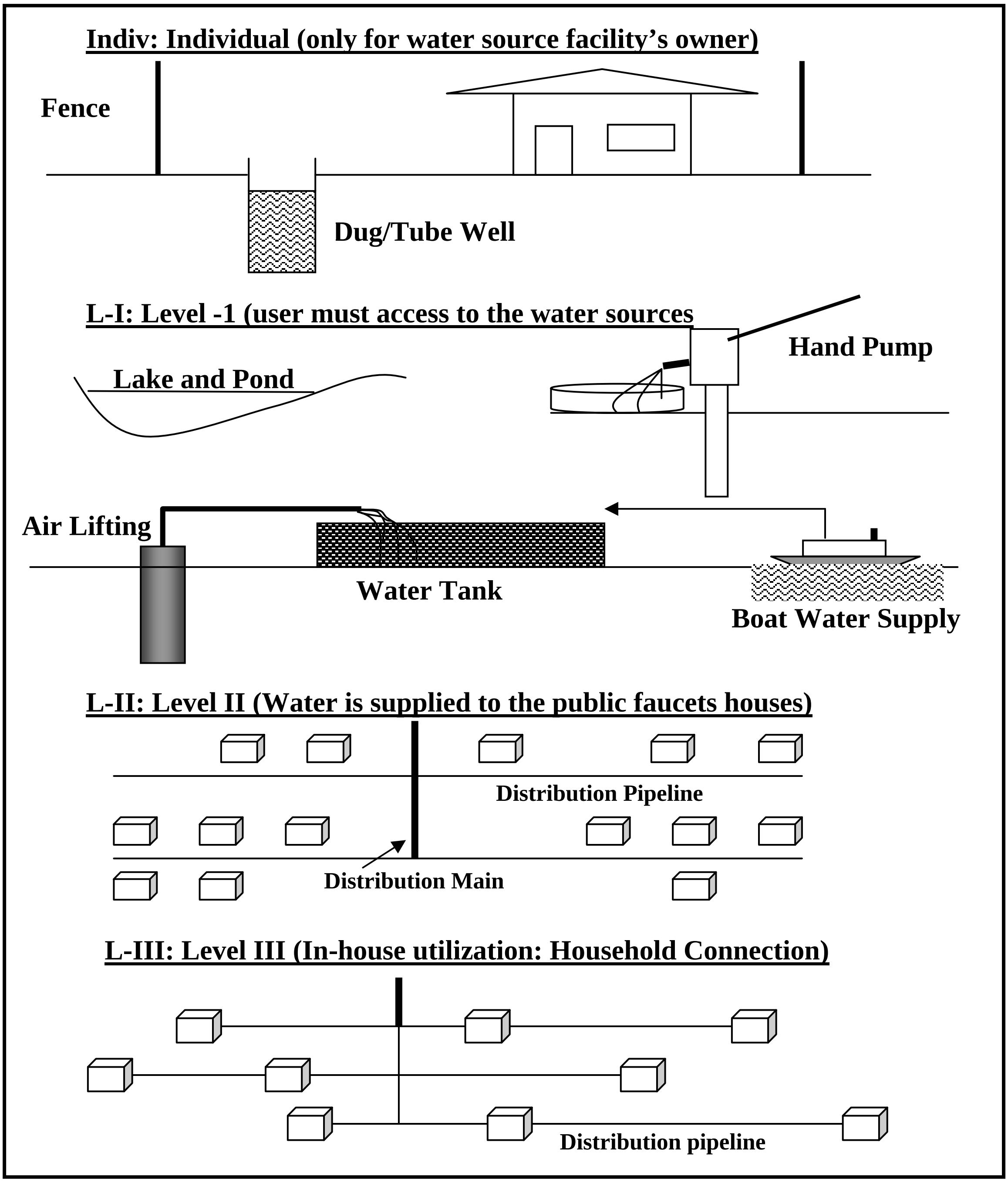
There are four levels in YCDC owned facilities. YCDC supply services level means the level of accessibility of water, which can be defined as individual level, Level I, Level II, and Level III. Visual explanation of YCDC supply service level is shown in Figure 4.7.

Individual: there is a water source without pipeline network supply, only house owners can access the water source facility

Level I : there is a water source without pipeline network supply, beneficiaries' access to the water source facility

Level II : there is/are water source(s) with pipeline network supply, however beneficiaries access the water from communal/public faucets.

Level III : there is/are water source(s) with pipeline network supply; beneficiaries can utilize the water from the in-house faucet (house connection).



Source: YCDC, 2002

Figure 4.7: Explanation of YCDC Water Supply Service Level

YCDC and its predecessors have initiated a system of water supply to poor communities via communal tank facilities. In this case, a masonry tank was built and connected to the YCDC supply network. The capacity of existing tanks size is from 400 gallons to 20,000 gallons. The customers collect water through taps fixed on the tank. Detail records on the number of communal tanks and the customers who benefit from this facility are not available. It appears that no one in the department is responsible for the communal tanks. However, during the survey period, relevant data on the number of communal tanks in use and estimated number of customers using this facility at present were collected (see in Table 4.8) by interviewing with township authorities.

Table 4.8: Distribution of Communal Tanks and Its Customers in the Study Area

Townships	No. Tanks in Use	Households (No.)	Water Charges
Bahan	2	10	Free
Botahtaung	5(9)	130*	Free
Dagon Myothit (South)	32	832*	3.25% property tax
Dawbon	2	100	Free
Hlangthayar	8	260*	Free
Insein	2	52*	Free
Kamayut	1	20	Free
North Okklapa	317	8242*	Free
Mingalardon	6(8)	156*	Free
Shwepyitha	8	208*	Free
South Okklapa	50(62)	1300*	Free
Thaketa	230(240)	5980*	Free
Thingangyun	100(196)	2600*	3.25% property tax
Total Townships = 13	765	19,890	

Sources: Survey period (2006), JICA report 2002, *Estimated by JICA Study Team 2001

Standpipes have also been provided for the use of pedestrians in the past. The Myanmar General Consultants (1993) reported that 2,500 standpipes existed in 1980, but that these had later declined to 825 in 1993. The current policy appears to be to get rid of them gradually. Though data on the number and location of standpipes are not currently available, in-depth discussions with township staff revealed that there are 245 standpipes in four townships (see Table 4.9). Beneficiaries from standpipes do not pay any charge for water. Similar to communal tanks, these facilities are proper for low-income communities.

Furthermore, there is still a practice of water delivery via a tanker. Water is collected from YCDC's own boreholes. It was carried by boat to the township across the river and delivered via a tanker. This township is a water deficit area in Yangon City, especially in dry season.

Table 4.9: Distribution of Standpipes in the Study Area

Township	Number of Standpipes
Dala	7
Kyeemindaing	3
Thaketa	230
Thinganchaung	5
Total	245

Source: Survey Period 2006, JICA Study Team Survey 2001

Main Sources of Water for Existing City Water Supply System

The main sources of water for City water supply system are surface water, ground water and rainwater. Surface water is the main source for city water supply system. The main surface water sources are Gyobyu Reservoir, Phugyi Reservoir, and Hlawga Resevoir. Ngamoyeik Reservoir is now being constructed for future City water supply. The existing water sources and available water supply facility are presented in Figure 4.8.

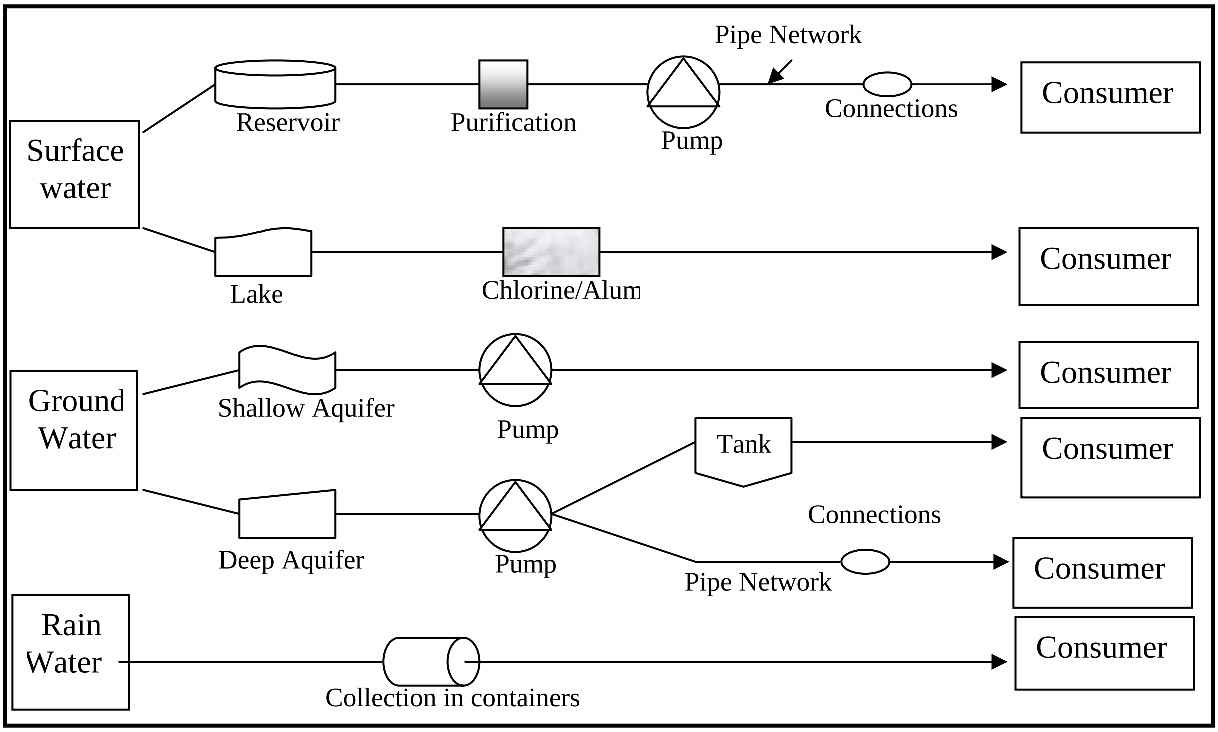


Figure 4.8: Water Sources and Available Service in Yangon City

Hlawga Reservoir: This is situated at about 27 km (17 miles) north of Yangon City and was built in 1904. The catchments area of Hlawga Reservoir is 27.2 sq. km and water surface area is 11.4 sq. km in full water level. Maximum storage volume is approximately 54.6 million m^3. It has dependable yield of 75,000 m^3 per day (16.5 mgd)[5]. The crest level of reservoir is +18.9m above mean sea level. Water is withdrawn from the intake tower and it has three ports to cope with water level fluctuation.

1st intake port	+16.8m
2nd intake port	+14.9m
3rd intake port	+13.0m

Gyobyu Reservoir: This was built in 1940. Gyobyu Reservoir has a total catchment area 32.9 sq. km. and water surface area is 7.25 sq. km at full water level. Gyobyu Reservoir is a homogeneous, rolled earth fill structure. It is approximately 700 ft (0.2134 km) long and located above mean sea level of 215 feet (+65.5m). This reservoir area is heavily forested and is non-populated. Total capacity is approximately 75.5 million m^3. Gyophyu has dependable yield of 93,300 m^3 per day (20.5 mgd). Water is withdrawn from the intake tower and it has three intake ports to cope with water level fluctuation.

1st intake port	+61.3m
2nd intake port	+54.9m
3rd intake port	+42.1m

Phugyi Reservoir: Construction work on Phugyi Reservoir was launched in 1973 and completed in 1988. The extent of the whole watershed area is 70.6 sq. km and water surface area is 17.61 sq. km at full water level. Maximum storage volume is approximately 104.6 million m^3. The crest level of the spill way is 35.1m above mean sea level. Phugyi

[5] mgd = million gallon per day (UK gallon unit)

Reservoir has dependable yield of 245,700 m^3 per day (54 mgd). It is 53 km from Yangon City. Water is withdrawn from the intake tower and it has two intake ports.

1st intake port	+32.0m
2nd intake port	+27.4m

Ngamoyeik Reservoir: Ngamoyeik dam was constructed in 1995 by the Irrigation Department under the Ministry of Agriculture. It is located about 48 km from the north of Yangon City. The reservoir is to be operated by the Irrigation Department for multipurpose. It was built to provide irrigation water for farms about 70,000 acres, flood control for the lower area, tidal reaches of the Creek, and will supply water up to 135 mgd. At present, the Ngamoyeik water supply project is under-construction and this project has three phases in the construction process. The first phase was completed in October 2005, distributing water from this project to the eastern part of Yangon city. Distribution capacity is about 45 mgd. After the completion of the Ngamoyeik water supply project, the water reservoir will supply 135 mgd for Yangon City population.

Groundwater Resources

Ground water extraction facilities in the City are divided into two categories in terms of ownership, YCDC owned tube wells and Non YCDC dug/tube wells. Non YCDC dug/tube well will not be discussed here. YCDC has 217 tube wells. Water produced from these tube wells are directly injected into nearby YCDC pipelines or service reservoirs, being mixed with surface water from reservoirs. Twenty-one (21) service reservoirs for groundwater serve in the main water supply system, which are located in (7) townships (see in Table 4.10). Annual estimated ground water production managed by the YCDC is 16.02 MCM/Y (MCM/Y = million cubic meter per year). Average pump operation hours was from three to twelve hours per day.

Table 4.10: Existing Service Reservoirs for Groundwater in Main Water Supply System

Type of Service Reservoir			**Volume (m^3)**		**Location (Township)**
Identification		Qty.	Avg.	Total	
Elevated	Gravity	5	64.2	320.9	Botataung, Sanchaung, South Okkalapa, Insein, and Thaketa
Ground	Pump	11	134.0	1473.8	Kyeemyindaing, North/ South Okkalapa and Thaketa
	Gravity	5	28.4	141.9	North/South Okkalapa and Thaketa
Total		21	92.2	1936.6	7 Townships

Source: JICA, 2002

Rain Water

Traditionally, rainwater is collected by private owned facilities such as drums, small tanks, containers, etc. Rainwater is used for their individual purpose in many places. Being an area across the river, without any reliable water source, rainwater is the only main source of water for the people especially in Dala and Seikkyikanoungto Township. But, up to now a systematic method of collecting rainwater or improved techniques that have proven to be more efficient in collecting water in other Asian countries has yet to be introduced to this area.

Existing Water Supply Condition

The schematic flow diagram of existing water supply system was presented in Figure 4.9. Water is transmitted through Yegu pump station by four transmission main pipes from Gyobyu reservoir, Phugyi reservoir, and Hlawga reservoir 1 and 2 to the City water distribution networks. Water pumped by Yegu pump station sent to Kokine Service Reservoir and Shwedagon Service Reservoir. The central service reservoir has not been in operation due to heavy leakage from the reservoir's walls. Each reservoir has its own pumping station, and operates when water level fluctuates. All pumps in the pump station are good in operation during the survey period 2006. Pumps are seldom used due to the frequent power failure. The specifications of transmission pipes, its operation ages and lengths were shown in Appendix B, Table 5. The service reservoir's specification was shown in Appendix B, Table 6.

Distribution pipes in the City water supply system are very old, over 100 years aged pipe are still operating especially in downtown area. Table 4.11 and Table 4.12 showed approximate distribution of existing network pipe material, lengths, and age. Sixty-seven percentage of network pipe occupied cast iron (see Table 4.11), and more than 50 years-old aged distribution pipes occupied over 50% of the City's water supply network (see Table 4.12). They are causing a lot of leakage and some small pipes are already blocked and cannot supply water properly.

Table 4.11: Approximate Distribution of Existing Network Pipe Lengths and Material

Material	Length (ft)	% of Total
Cast Iron	1,722,600	67
Ductile Iron	101,500	4
Galvanized Iron	113,300	4.5
Polyvinyl Chloride	377,800	15
Mild Steel	126,150	5
Reinforced Concrete	125,100	5
Total	2,566,500	100

Source: JICA Report, 2001

Table 4.12: Approximate Distribution of Existing Network Pipe Lengths and Age

Pipe Age (yr)	Pipe Length (ft)	% of Total Length
<20	574,800	22
20-50	605,900	24
50-70	338,000	13
70-100	1,047,700	41
>100	0	0
	2,566,500	100

Source: JICA Report, 2001

The City water supply system is unable to provide 24 hour service for all customers. The duration of water supply varies among customers. It depends on the distance between customer's premises and the main distribution source. Duration of water supply means supply hours per day. Many townships have only a couple of hours of available water in the supply pipeline. But, the townships, located near the main distribution line, can get 24 hour water from the supply pipeline. Those far away from the distribution line may have their supply lasting only for a short duration. Customers in Central Business District of Yangon do not enjoy 24 hours water supply. Water supply duration in each township is shown in Appendix B, Table 7. The provided information was found to be inaccurate and inconsistent as well due to lack of regular monitoring in the whole network. However, it will be used for the discussion purposes of this study and further investigation will be needed.

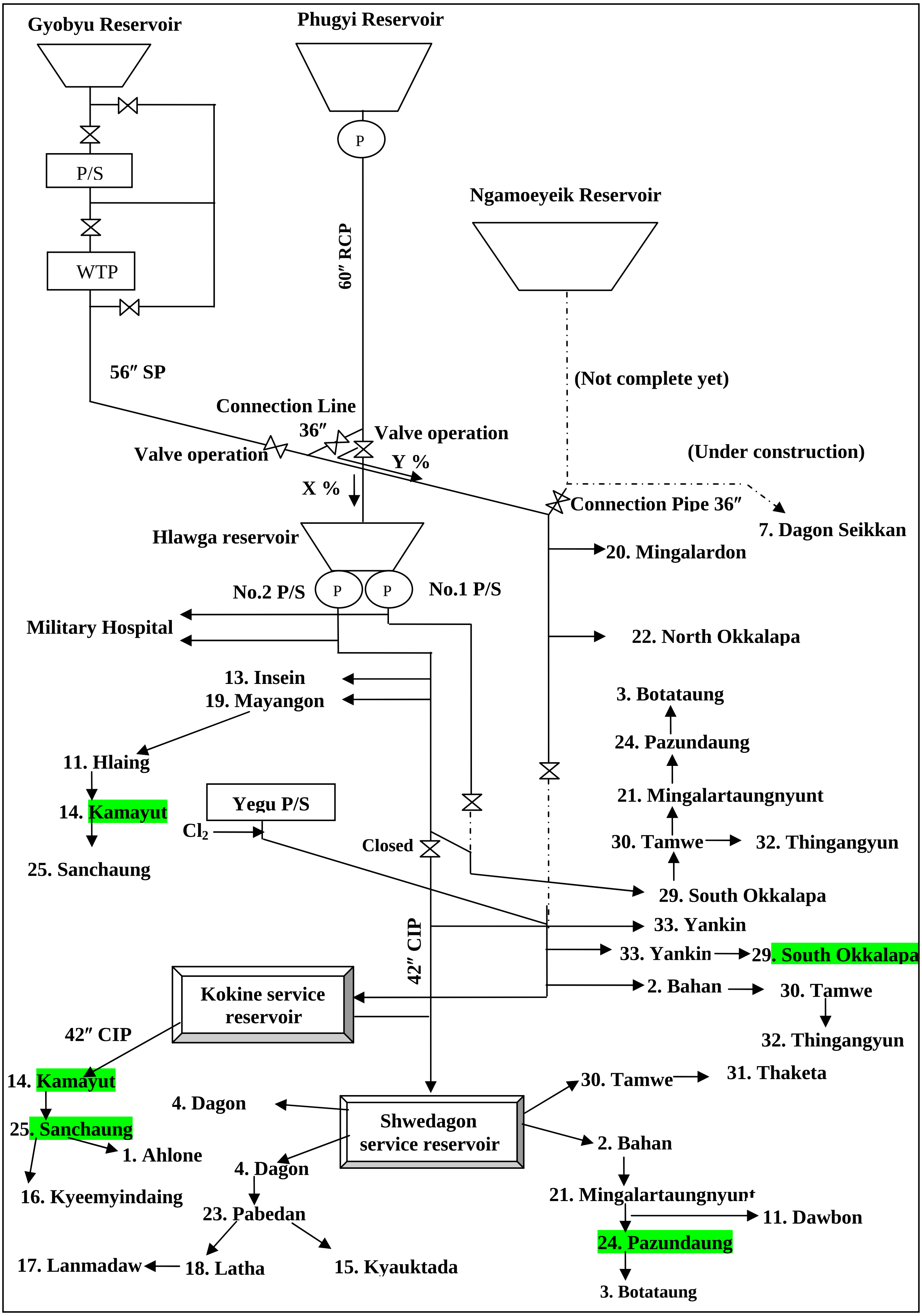


Figure 4.9: Schematic Diagram of Water Supply System

Due to the short duration of water supply, many customers have attempted to overcome this problem by installing electric water pumps fitted on the individual supply line. Water supply duration “24 hours” does not mean that every customer gets water throughout the day. It just means that water is still available inside the supply line for the whole day but water could not be used properly due to the pressure deficit. Thus, the pressure investigation is an important factor for water supply lines.

The pressure investigation is based on a system analysis of the distribution network. It is important to understand and analyze the distribution system, starting from the point of production to customer end use. Pressure control can saves water, decreases wear and tear on the system, reduces unnecessary losses and maintains a healthy supply of water for both customer needs and emergency demands (Environmental Protection agency (Queensland) and Wide Bay Water Corporation, Managing and Reducing Losses from Water Distribution Systems, Manual 4, 2002).

However, there is only one record available for water supply pressure investigation in Yangon City water supply. The report was studied by the JICA study team in year 2001. According to this report, the relatively high pressure points in the City water supply were found in Bahan, Hlaing, Insein, Mayangone, Tamwe and Yankin Townships. The high pressure is however a relative term. Yegu pumping station and near Shwe Dagon Service reservoir areas have relatively high pressure (1.0, 1.5 and 3.0 kg/cm^2). Typical minimum service levels in many countries are 2 kg/cm^2, but almost all in the City water supply area has below this minimum pressure. Detail of pressure investigations for each township is shown in Appendix B, Table 8 and 9.

Water Quality

Water quality for existing reservoirs is almost satisfactory (YCDC reports, 2000, 2001, and 2002), which is detected by 26 water parameters with the Myanmar water quality standard (see in Appendix B, Table 10). But, the ground water from tube wells are expected to have water quality problems, especially high concentrations of saline (Cl^{+}), iron (Fe^{+2}, Fe^{+3}) and acidity (pH). Because Yangon City is located near the Andaman Sea and Bay of Bangle, saline intrusion has reached well into the inland area especially in southern part of Yangon City. Chloride (Cl+ ion) content is between 1,000–10,000mg per liter somewhere in Yangon City. River water contains high turbidity. According to JICA study team report 2001, high value of ammonia-nitrogen was observed in some sampling points along Hlaing River site particularly in down streamside. This river is one of the main river water sources of future water supply in Yangon City.

In order to secure public health and improve the living environment, distributed water must be disinfected properly and appropriate treatment is indispensable to allow the existing water to be used as a source of drinking water. Recently, there has been no groundwater treatment facility for the City water supply system. Only one treatment plant is available for surface water at Gyophyu reservoir. However, current disinfection is quite insufficient, only flocculation and sedimentation process for turbidity removal are utilized in the treatment plant. It is seldom operated due to lack of chemicals (Alumn, Chlorine agent, etc.).

Water Connection

City dwellers connect water from connection pipe provided by WSS to the main supply line of WSS either right into the house or to the compound. In the formal case, customer has to have the internal connection approved by the department before connecting to the WSS network. Currently, there are four main types of water connection by customers namely domestic, commercial, governmental and foreign customers. The type of customers and available service connection in WSS Department are given in Table 4.13. The domestic water user is the highest number of customers (93.13 percent), followed by commercial and industrial customers (5.72 percent). Departmental users are currently 1.12 percent and foreign users are the lowest, only 0.03 percent of total supply water connections. Free of charge users data is not available. At present, the total number of connections is 112,315 including metered customer 25,692 (22.86%), and un-metered connection 86,663 (77.14%). Detail connected customer's list was described in Appendix B, Table 11. Connection policy and procedure will be discussed in the next section.

Table 4.13: Types of Water Connection and Available Service Connections

Type of connection	**Description**	**Available connection**		**Total connection (%)**
		Metered (%)	**Un-metered (%)**	
Domestic	Residential units such as houses, apartments and housing estates	20.13	73.00	93.13
Commercial	Hotels, restaurants, shops, factories, industries and other establishments involved in carrying out commercial activities.	2.62	3.1	5.72
Government	All government ministries departments and defense establishments	0.08	1.04	1.12
Foreign	Any organization or residence registered under the foreign registration Act. e.g. foreign companies	0.03	-	0.03
Free	Religious organizations (e.g. temples, pagoda, monastery, church, mosque) and diplomatic establishments (e.g. Embassies)	-	-	-
	Total	22.86	77.14	100

Source: YCDC head quarter, 2005

Water Supply Management Institutions

Although the YCDC has the legal authority to supply water to the City, the present level of supply by this institution is hardly adequate for the entire population. There are a number of government water supply agencies with a varying water pricing policies and little coordination in Yangon (http://www.unescap.org/esd/water/publications/water/wrs/85/06%20WRS85-Myanmar.pd). Several large water users have problems in meeting their demands even within the central business district (CBD) area. Because of YCDC supply limitation, a host of other institutions and organizations have evolved out to supply water as well as to provide many services needed to provide water. The institutions responsible for water supply and the provision of other related services within the study area can be grouped under five types as listed below:

1) Government Ministries including the Yangon City Development Committee
2) Private entrepreneurs and organizations
3) Other state institutions (Mandalay City Development Committee, Ministry of Progress of Border Areas and National Races and Development Affairs)
4) Community Based Organizations (CBO)
5) Non Governmental Organizations (NGO)

Many of the above institutions are directly involved in the supply of water while a few others implement activities which strength water supply capacity of institutions. The first groups of institutions are direct water supply institutions while others are assisting water supply institutions. The main activities of institutions and organizations involved in water supply within the study area are shown in Appendix B, Table 12. In spite of varied attempts made by the study to contact the government institutions listed in the table, the main water supply institution (Yangon City Development Committee) is discussed detail in below.

Yangon City Development Committee (YCDC) is the main institution, which has the responsibility for providing water to the citizens and carrying out all water related services within the City Municipal Area. In carrying out its tasks, YCDC is currently assigned with 20 departments for city development and management. The organizational structure for YCDC is presented in Appendix B, Figure 1. The Water Supply and Sanitation Department (WSS) is one of them. All water supply and related tasks are the functions of Water Supply and Sanitation Department. This department is responsible for planning and implementing all activities related to water supply and sanitation within the City. Organizational chart for WSS department was shown in Figure 4.10.

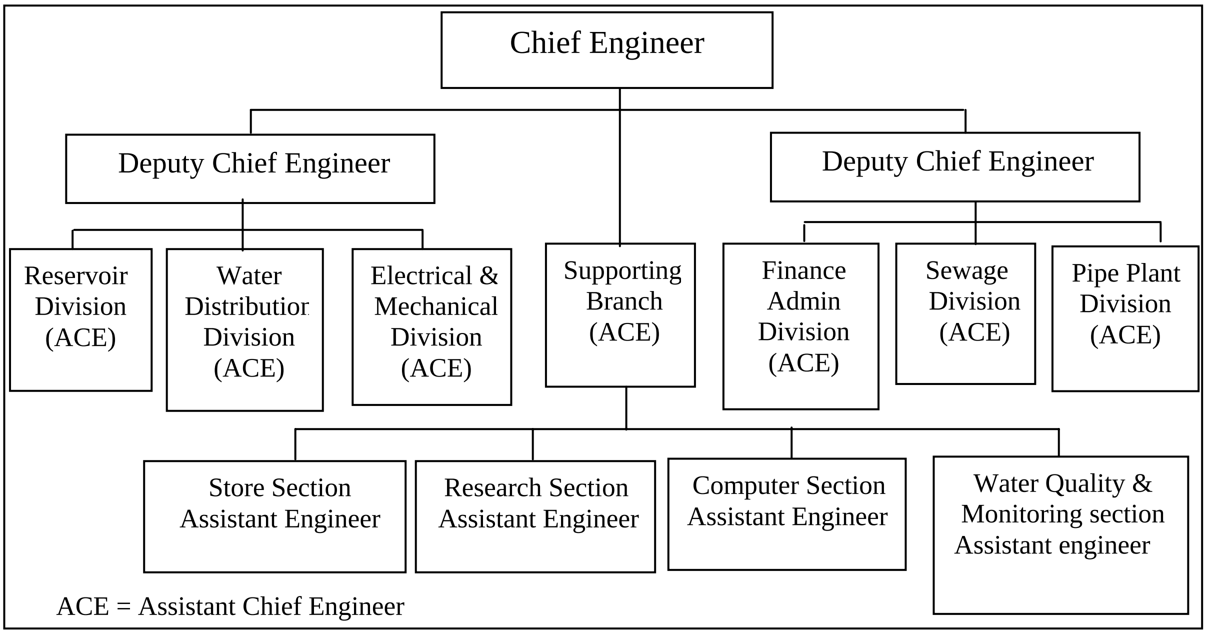


Figure 4.10: Organization Chart of Water Supply and Sanitation Department

Since Notification No. 6/99, the YCDC has been empowered with the management and distribution of water for people living in the City of Yangon. As overall agency with the responsibility for the city water supply, YCDC is committed to supply water to the City dwellers in sufficient quantity. The statement of YCDC City water supply management system is as follows:

***"**The Committee shall manage and perform to distribute adequate water of suitable quality for people living in the City frontier"*

(YCDC Notification No. 6/99, 17th December 1999)

"Where YCDC has given public notice that sufficient water is available from its water works for furnishing a reasonable supply of water for domestic purposes, it shall forthwith take measures to ensure the supply of such water"

(The Rangoon Municipal Manual, 1922, Section 114)

In practice, the WSS department is organized into six (6) divisions and four (4) sections for the purpose of water sector management through out the city. The head of office is Chief Engineer (CE) who is assisted by two (2) deputy chief engineers (Dy. CE). An Assistant Chief Engineer (ACE) heads each division while an Assistant Engineer (AE) is in-charge of a section. The ACE and the AE has to report directly to the CE.

Role and Functions of Division/Sections in Water Supply Department

The main activities of the six (6) divisions and four (4) sections of WSS department are briefly described as follows:

1. Reservoir Division**:** This division is responsible for the operation, maintenance, repair and protection of the three reservoirs for City water supply. It is also responsible for the development of new reservoirs. All of its 487 staff organized into three clusters based in the reservoir sites namely Gyobyu, Hlawga and Phugyi. Each staff cluster is headed by an Assistant Engineer (AE) follow by a team of skilled and unskilled workers. The head of the reservoir division is based in the head office.

2. Water Distribution Division has three sections namely house connections section, operation and maintenance section, and pipeline section. The division is responsible for the

operation, maintenance, and repair of the entire water supply network pipe from the main pumping stations to the customer off take pipelines. The main activities are:

i. Implement water distribution activities in 28 townships

ii. O&M and major repair of the transmission mains, distribution mains and pipes

iii. Inspection and control of water leakage from the transmission and distribution line

iv. Decisional authority for application on - new water connections, installation of meters, authorize change for one type of connection to another type upon request by the customer, approval of internal connections and other applications relating to the management of water supply system.

v. Provide leadership and guidance to township teams in all work areas pertaining to the division

It is also highlighted that leakage control and pipeline major repair work teams are currently attached to this division. The relevant work teams are established by picking up professional staff members from different areas of the organization on an ad-hoc basis. This arrangement is not conducive for the development of specialized skills and professional advancement members of the relevant task-oriented teams. In practice, these sections do not exist yet. The division is marching under the leadership of ACE together with the supporting staff. This division is located in the head office.

<u>3. Electrical and Mechanical Division</u>**:** The main responsibility of this division is to undertake repairs for electrical and mechanical equipment such as pumps and compressors for water pumping. The division has several mobile work teams ready to be dispatched out to different locations where problems are reported. The task of teams is to identify and subsequently repair defective electrical and mechanical gadgets. This division is headed by an ACE and together work with a team of engineers, technicians, skilled and unskilled workers.

4. Pipe Plant Division**:** This division is responsible for the construction of three types of reinforced concrete pipes and their laying in designated areas. It operates a production factory, carries out quality checks of products manufactured and administers a team of engineers, technicians, skilled and unskilled workers and office staff.

5. Sewage Division: This division is responsible for the operation and maintenance of the sewage line collecting the sewer from eight townships in downtown area of Yangon City.

6. Administration and Finance Division**:** This division has two branches namely finance and administration. The division is responsible for all financial and administrative matters pertaining to the work of WSS. Staff salaries and wages however, are paid directly by the Finance and Budget Department of YCDC Headquarters. Preparation of revenue and expenditure forecasts, monitoring the actual level of revenue and expenditure, monitoring and recording revenue collected by townships and advising the township office on financial matters are the main functions.

Store Section: WSS has a small store, the management of which is the responsibility of this section. The staff includes two engineers and security guards. The stocks are not computerized nor are movement of parts and fixtures.

Computer Section: This is a newly established section in WSS. Data computerization and production of flat rate water bills are the main function of this section.

Research section: This is also a newly established section. It has not started carrying out its work program yet, partly due to the unavailability of research staff.

Water Quality and Monitoring Section: It is also a newly established section. The main role of this section is to secure the public health and to improve the living environment. Monthly water sampling is carried out in different sites such as reservoirs, tube wells, exact location of faucet, river water, etc., analyzes the quality of these water samples and reports the results. However, this section does not have a laboratory yet. All the collected samples are sent to National Health Laboratory for water analysis.

Field Organization in the Water Supply Department

The organization in the head office is backed up by four district offices, an office in each of the 33 townships to carry out all relevant activities. At present, one township office has not been established yet.

Four District Organizations: The 33 townships are grouped under four district offices in order to facilitate supervision and coordination of work. The group of townships by each district was shown in Appendix B, Table 15. The head of district office is the district water supply and sanitation engineer. Other technical staff in the district office includes one assistant district engineer, 1-2 senior assistant engineers, one overseer and 1-2 laborers. The function of the district office is mainly supervisory. All reports and correspondence from the township office to the head office is channeled via district office. The district staff is expected to check, verify and correct reports, if needed, before forwarding them to the water distribution division.

Township Organization: The township water supply and sanitation office assigned 1-3 engineers, 1-2 technicians, other field staff and clerical staff. Water supply and sanitation activities within townships are the main responsibility of the township engineer. The main tasks of township engineers are to attend all water supply technical matter i.e. O&M of the pipe network, repair, prevention of leakage, cleaning communal systems, to attend sanitation matters, regulatory matters of water supply and administrative matters. In order to meet the main tasks, the staff of township WSS is organized into four main teams namely 1) operation and maintenance team, 2) breakage detection and leakage control team, 3) meter reading and collection of water charges, and 4) administration.

Laws and Regulations for Water Supply Management

According to the above statement for the city's water supply, YCDC is committed to supply sufficient water to the city. There is no formal policy document outlining the main objectives of the organization. Some areas where a coherent policy is lacking include overall policy regarding water supply connections, meters installation, coordination of water supply work, supply planning and improvement. A coherent policy is one of the main obstacles to achieving the basic task of the department of City water supply management. A strategic plan for city water supply management was initiated in 2006 for future development projects.

Certain bylaws and regulations pertaining to water supply have been framed under YCDC. The bylaws and regulations are aimed at conforming to certain standards in water supply on the one hand and to reduce water wastage on the other. Many of these regulations have their origin in the Rangoon Municipal Manual of 1922, which are still applied in the present. The organization is in the process of revision and adaptation of a set of new bylaws, regulations by using the 1922 Municipal Act as the basis. Regulations covering all areas of water supply, measurement of water use, protection of water bodies, supply networks and facilities, water misuse, and connections including plumbing work done by licensed plumbers are in operation. Some of the regulations and the penalty with violations are shown below Table 4.14.

Table 4.14: Some of the Regulations and Penalties Existed in Yangon City's WSS

Item	Penalty (Kyats)
Re-connection fee for HH and commercial units	1,900
Illegal connection	25,000
Illegal electric pump fitted to pipeline	25,000
Illegal septic tank	25,000
Use of illegal size of septic tank pipe	10,000

Source: YCDC, 2001

Private Sector Involvement in Yangon City Water Supply Management

Yangon City authorities do not accept the idea of individual (private) water management. The privatization of water resources is therefore currently not feasible.

However, the private sector is involved in Yangon City water supply and consists of individuals who plan and manage their own water supply systems, entrepreneurs who provide other water related service to individuals and companies, and private organizations providing a large number of services for the water supply sector. This private sector consisting of complex and varied individuals or organizations is responsible for the supply of water to some City dwellers and a large number of industries. Appendix B, Table 13, Table 14 indicates the water related activities of private sector and other organizations.

Moreover, formal and informal private sector organizations are involved in Yangon City water supply system. These are private water vendors, water resellers, pioneers of small water pipe connections, bottled water selling company, etc. Private water vendors include mobile water truckers, carters, water carriers, and household resellers. A pioneer small water pipe network connection means they bring piped water from their own tube-well to communities where water utilities have not yet expanded their networks.

Among private owned water facilities, non-YCDC dug/tube wells are more popular and economical for use in the development of satellite towns and suburban areas of the city. The YCDC township offices possess a private well inventory as of the year 1996, called "Non-YCDC" wells in accordance with forms of ground water development. This well inventory, without any up dating until now was estimated using water rights registrations obtained from the Department of Housing, Ministry of Construction. Administrative information was collected from the YCDC. However, engineering and technical data were inadequate. As per YCDC data, there are 69,172 wells within 30 townships, and the majority of wells are classified as domestic use (68,823 wells). The estimated private ground water production and total numbers of non-YCDC wells are given in Table 4.15.

Table 4.15: Total Number of Non-YCDC Wells and Its Annual Estimated Production

Sector	Number of Wells	Production Amount (MCM/Y)
Domestic	68,823	10.96
Industrial	346	8.89
Commercial	3	0.08
Total	69,172	19.93

Source: JICA report, 2001 Note: MCM/Y = Million Cubic Meter per Year

In Yangon city, many brands of bottled water companies are also involved in the city water supply services. As the level of investment and initiatives, and financial risks taken by these various types of water providers, are quite different. The price of bottled water also varies with brand and quality. The present rate of bottled water prices is shown in Table 4.16.

Table 4.16: Current Bottled Water Price in Yangon

Bottle Water Type	Price at Factory	Price at Market
1 liter Water Bottle (PET Bottle)	240-280Ks. (US$-0.2-0.23)	500-600Ks. (US$-0.42-0.5)
1 liter Water Bottle (PE Bottle)	180-200Ks. (US$-0.15-0.17)	300-400Ks. (US$-0.25-0.33)
20 liter Water Bottle	150-200Ks. (US$-0.13-0.17)	250-350Ks. (US$-0.21-0.29)

Source: Field Survey 2006 Note: 1US$=1200Kyats

People's Perception of the Existing Water Supply System and Management in Yangon

Consumer surveys were conducted to determine people's perception of existing water supply management and future improvement of water supply management in the study area. During the survey period, the study carried out about:

a) Sources of water supply,

b) Time taken for fetching water,

c) Drinking water use practices,

d) Using electric/fuel pump for getting water,

e) Water meter installation and satisfaction of water pressure and duration of getting water from YCDC water supply line,

f) Sufficiency of water, satisfaction of water quality from existing water supply and

g) Water consumption

a) Respondent's Sources of Water Supply

This survey identified 12 water supply sources in Yangon City in which five were YCDC water supply sources and seven were non-YCDC water supply sources. In this survey, 205 (69.5 %) respondents were from YCDC supply water users. The remaining 90 (30.5%) respondents were from non-YCDC supply water users. Water supply sources for YCDC water users are YCDC pipe water connections to in-house tap, YCDC supply public water tap, YCDC supply communal tank, YCDC water tanker, and YCDC owned lakes and ponds. Non-YCDC water users can get water from private piped water, common tube well, protected dug well, private water tanker, neighbors' tap and/or well, bottled water, water vendors, and rainwater.

Many households use several water sources. Most of the households use water from at least two sources. Even YCDC supply water users need to buy bottled water for drinking purposes. The average number of water sources is 1.5 per household for all sample respondents, while 1.2 sources for YCDC customers and 1.9 sources for non-YCDC customers. Non-YCDC customers rely on more water sources than YCDC customers do.

Figure 4.11 showed the YCDC water customers use in each source of YCDC water. This survey result is shown in Appendix D, Table 1. Most of the respondents 110 (54%) connected in-house taps from YCDC water service, 36 (18%) respondents used in yard tap and 27% (56) respondents used both in-house tap and yard tap. Communal tank user is 3 (1%) respondents. Fifty-six (56) respondents are using both in-house tap and yard tap due to limited time to get water from YCDC supply water (e.g. 4:00-6:00 AM, 4:00-6:00 PM).

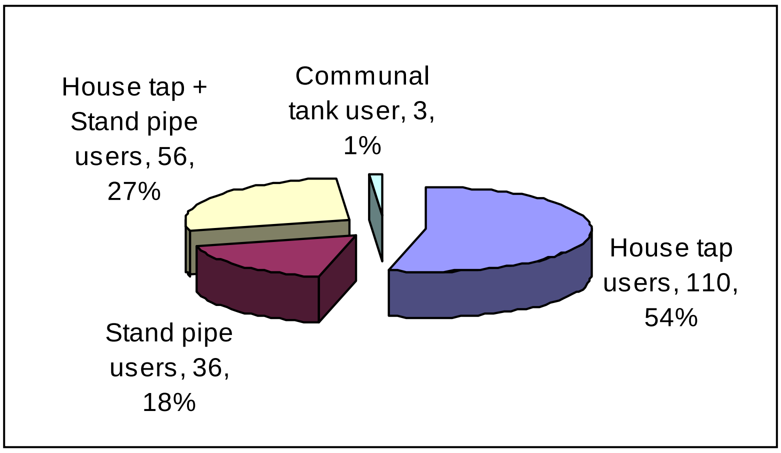


Figure 4.11: Main Water Sources for YCDC Supply Water Users

Figure 4.12 showed the non-YCDC customers and its source of water. This result is shown in Appendix D, Table 2.

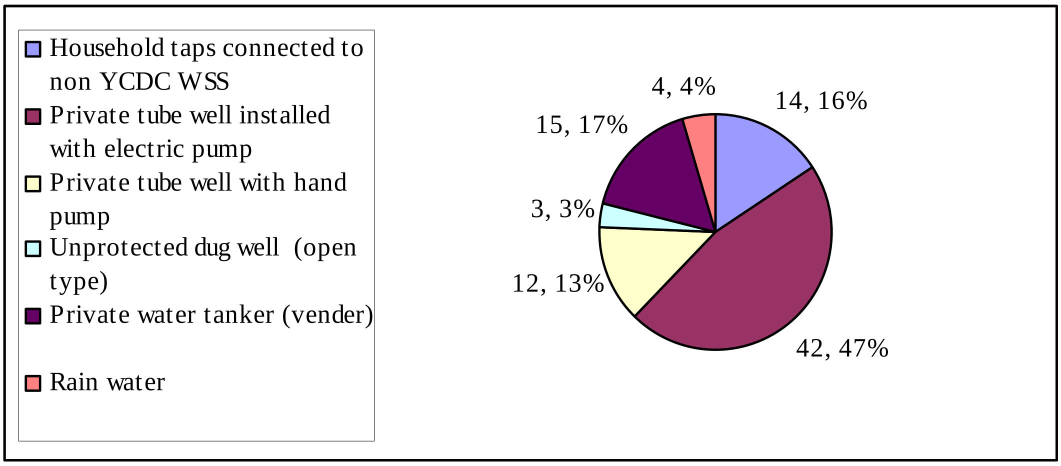


Figure 4.12: Main Water Sources for Non-YCDC Water Users

The most popular source of non-YCDC water is private owned tube wells 42 (47%) respondents with electric water pump, followed by 15 respondents (17%) purchase from private vendors. Fourteen (16%) respondents said they connected to their neighbors' tube well with their own pipe and pay money for their water paying on a monthly basis. The rest 12 (13%) respondents own private tube wells installed with hand pump, three (3.3%) respondents use unprotected dug well and four (4%) respondents use rainwater.

b) Time Taken for Fetching Water

During the dry season, most of the respondents have to buy water from private water vendors or fetch the water from remote areas where there is free water or low priced water for their household use. In the rainy season, they fetch rainwater by their own way. Table 4.17 showed that out of 295 respondents, fifty-nine respondents have to fetch water from remote water sources. Among them 19 respondents are non-YCDC water users and 40 respondents are YCDC supply water users. Thirty-five respondents spend less than 5 minutes for fetching water and twenty-four households spend within 5-10minutes. Mostly adult man and woman fetch water for their household used.

Table 4.17: Time Taken for Fetching Water from Remote Area in the Study Area

No.	Time taken for fetching water	YCDC water customer (f)	Non-YCDC water customer (f)	Total	
				f	%
1	Less than 5 minutes	26	12	35	59
2	5 -10 minutes	14	7	24	41
Total		40	19	59	100

f = frequency, % = percent of total respondents who time taken for fetching water

c) Drinking Water Use Practices

No households use water for drinking purpose without any treatment from YCDC water supply and non-YCDC water supply. Ways of water treatment used for drinking purposes of YCDC supply water and non-YCDC supply water is shown in Figure 4.13 and the survey results are shown in Appendix D, Table 3, and Table 4. Eighty six (42%) of YCDC supply water users filtered water for drinking purpose, 41 (20%) respondents used filtering and boiling water for drinking purpose. Some respondents 24 (11.7%) boiled water and 38 (18.5%) respondents purchased bottled water for drinking purposes. For the non-YCDC water customers, 37 (41.2%) respondents filtered water for drinking purposes, 22 (24.2%) respondents bought bottled water for drinking purposes and 22 (18.9%)

respondents used filtering and boiling water for drinking. Only (5.6%) respondents boil water to clean for drinking purpose.

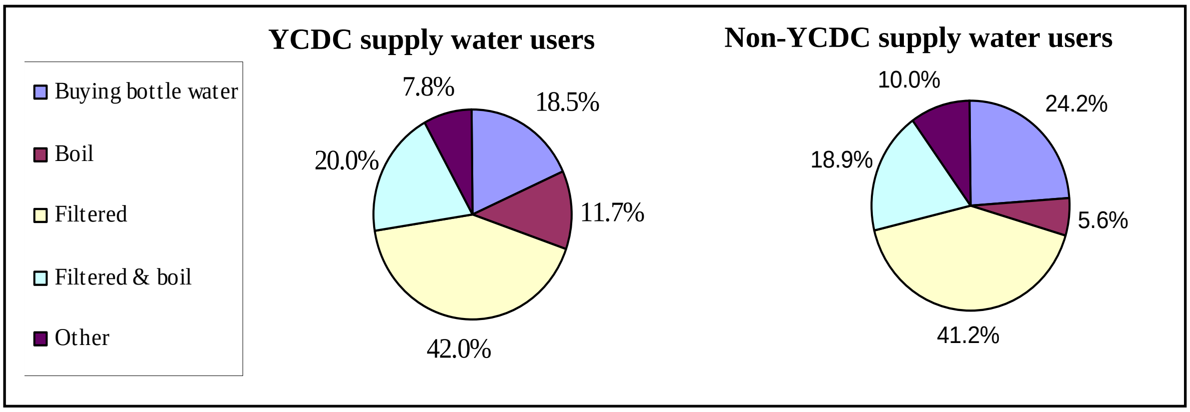


Figure 4.13: Way of Water Treatment for Drinking Purpose

Most of the respondents needed to store water for their daily use. Two hundred and ninety (290) out of (295) households needed to store water, only five (5) respondent's households used water directly from tap (see Table 4.18). About 101 (35%) households stored water in drums, 93 (32%) respondents stored water in ground tank and 87 (30%) stored water in overhead tanks. The remaining (3%) households store water in plastic containers, pots (which made with clay or cement), etc.

The nature of overhead tank capacity is mostly 100 gallons to 400 gallons cast iron coated with plastic epoxy paint. On-ground tank is usually concrete tanks with an approximate tank capacity of 100 gallons to 500 gallons. Some respondents use drums, which were approximately 50 gallons, and each household uses 2 to 4 drums.

Table 4.18: Type and Capacity of Water Storage Tank by Respondents in the Study Area

Respondent's Type of Storage Containers	Frequency of Storage Capacity					Total
	50gal	100 gal	200 gal	400 gal	600 gal	
Ground Water Tank	-	-	23	67	3	93
Overhead Tank	-	17	51	19	-	87
Drum	101		-	-	-	101
Others (pots, plastic containers, etc.)	-	-	-	-	-	9
No storage tank	-	-	-	-	-	5
Total						295

Source: Field Survey, 2006

d) Using Electric/Fuel Pump for Getting Water

Out of 205 YCDC customers, 188 (92%) households used electric/fuel pump to get water from YCDC supply pipes. Only 17 (8%) do not use water pumps for getting water from YCDC supply pipe (See Table 4.19). People use water pumps with different capacities such as 0.5 HP, 1.0 HP, 1.5 HP and 2 HP. There is a very interesting respondent in Sanchaung Township, who used the hand pump for getting YCDC supply water because of intermittent supply of electricity and interruption of water supply in Yangon. His reason for using hand pump to fetch water from YCDC supply pipes is that there is water in YCDC water supply pipes for the whole day in near his premises but water pressure is very low.

Table 4.19: Ratio of Using Electric/Fuel Pump for Fetching YCDC Water by Its Customers

Type of Customer		Using Electric/Fuel Pump for Fetching YCDC Water		Total
		Yes	No	
YCDC Customer	F	188	17	205
	%	92	8	100

Source: Field Survey 2006

e) Water Meter Installation and Satisfaction of Water Pressure and Duration of Getting Water from YCDC Water Supply Line

Out of a total of (205) YCDC customers, 54 (26.3%) installed water meters and almost all water meters are functioning. The rest, 151 (73.7%) YCDC customers have not yet installed water meters. Among un-metered customers (Table 4.20) shows that 80 (53%) respondents are willing to install water meters but 56 (37%) respondents do not want to install water meters because they said, "we have a time limit to get water and they do not believe in meter reading practice." The rest, 15 (10%) did not answer.

Table 4.20: Willing to Install Water Meter by Un-metered YCDC Customers

Type of customer	Willing to install		Do not want to install		No answer		Total	
	No.	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**
Un-metered customers	80	53	56	37	15	10	151	100

Source: Field Survey 2006

Survey on satisfaction of YCDC water supply pressure result (Table 4.21) showed that 148 (72.1%) respondents said "sometime high pressure /sometime low pressure", 52 (25.5%) of respondents said "low pressure". The rest 5 (2.4%) said "always low pressure".

Table 4.21: Respondent's Perception on Water Pressure from Existing Water Supply

Count	Sometime high/sometime low pressure	Low pressure	Always low pressure	Total
Number of respondents	148	52	5	205
Percentage	72.1%	25.5	2.4%	100%

Source: Field survey 2006

Almost 100 (49%) respondents answered "no". They are not satisfied with current water supply pressure because getting a steady supply of water from YCDC water supply lines is a very rare opportunity without using electric/fuel pump. Only 78 (38%) respondents said they are quite satisfied. It may be because their premises are located near the main distribution pipe. The rest 27 (13%) respondents did not answer (see Table 4.22).

Table 4.22: Satisfaction on City Water Supply Pressure by YCDC Water Customers

Count	Satisfied	Not satisfied	No answer	Total
Number of respondents	78	100	27	205
Percentage	38%	49%	13%	100%

Source: Field survey, 2006

Figure 4.14 (Appendix D, Table 5) showed the respondent's answer for their opinion on "duration of getting water from YCDC supply pipeline by using a water electric/fuel pump". When a pump is used for taking water from water pipeline, 97 (47.3%) respondents can obtain water for about 24 hours, 2 (1.2%) respondents said about 18 hours, 37 (18%) respondents said about 12 hours, 57 (28%) respondents said about 6 hours, and 2 (1.1%) respondents said about 4 hours. Eight (4.4%) respondents get less than 4 hours a day.

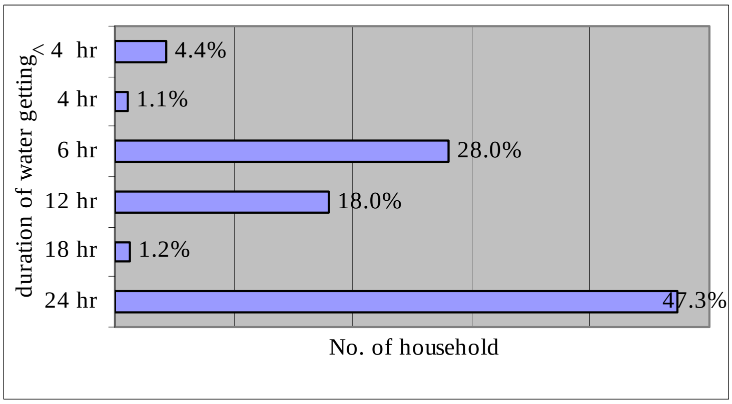


Figure 4.14: Duration of Water Getting from YCDC Supply Line by Using Water Pump

If electric water pump is not used for taking water from the water supply pipeline, the respondent's results Figure 4.15 (Appendix D, Table 6) shows that respondent's getting water about 24 hours were decreased to 60 (31.7%) respondents. But, the result of short duration hours of getting water such as 12 hours, 6 hours was increased to (51) 27.3%, (57) 30.3% respectively. However, most of the respondents said, "if they do not use water pump for getting water from YCDC water supply line, water can be obtained with low pressure". A few respondents said "no water in their house."

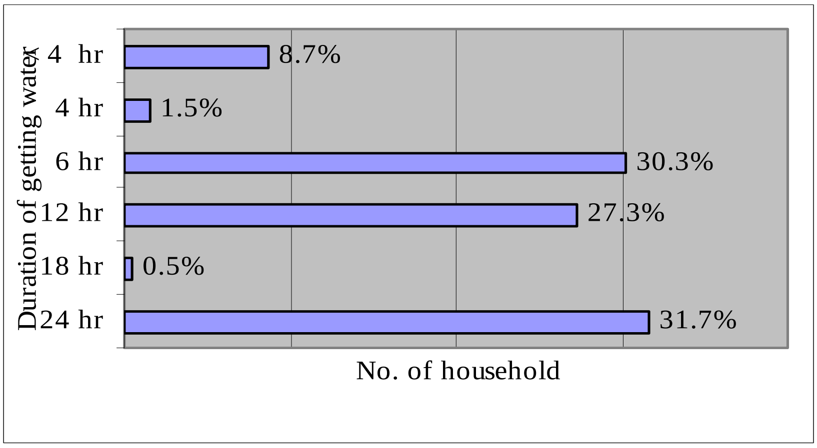


Figure 4.15: Duration of Getting Water from YCDC Supply Line without Using Water Pump

f) Sufficiency of Water, Satisfaction of Water Quality from Existing Water Supply

The survey result of the YCDC customer's perceptions of water supply sufficiency in the study area showed in Figure 4.16 (Appendix D, Table 7). Among

YCDC customers 64 (31.2%) respondents feel supplied water is sufficient for the whole year. Seventy-nine (38.6%) respondents said insufficient in dry season and 55 (26.8%) said sometimes insufficient supply of water not only in dry season but also in rainy season. Seven (3.4%) respondents did not answer the question.

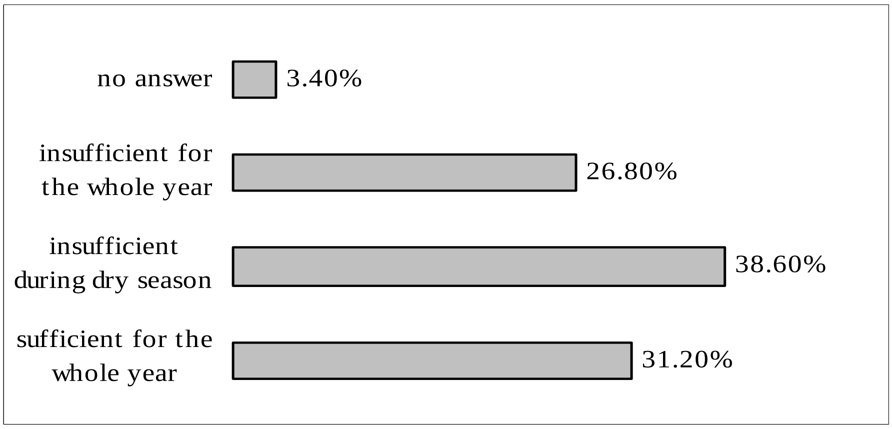


Figure 4.16: Sufficiency of Water Supply (YCDC Customers)

Figure 4.17 (Appendix D, Table 8) shows the non-YCDC customer's perception of their water supply. Most of the respondents from non-YCDC water users 77 (86.2%) said there was sufficient water for the whole year by their water supply sources. Eight (8.5%) said insufficient supply during dry season and four (4.2%) said sometimes insufficient in both dry and wet seasons, they use rainwater during the rainy season. Only one (1.1%) respondent did not answer this question.

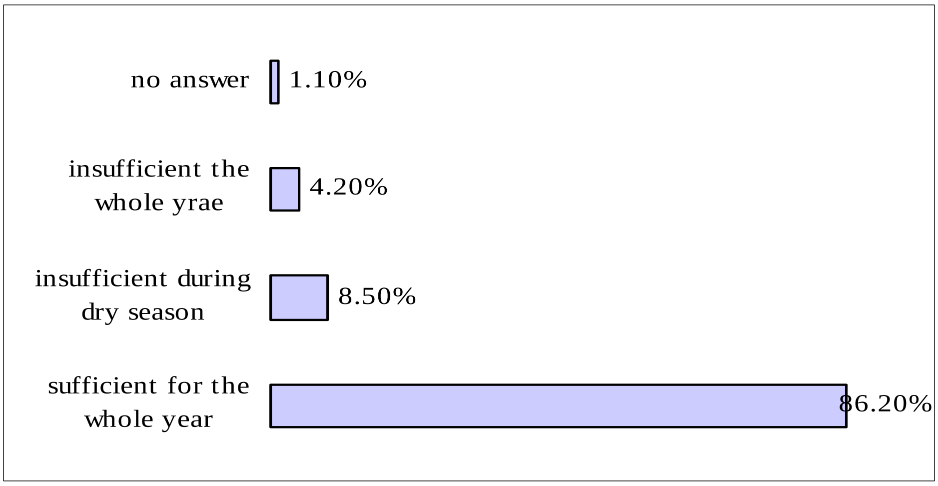


Figure 4.17: Sufficiency of Water Supply (Non-YCDC Water Customers)

The perceived water quality from YCDC supply water was reported to be quite satisfying, 195 (95%) respondents said water had acceptable taste, 170 (82.8%) said "no color" and 177 (86.3%) said "no odor" (see in Fig 4.18 and Appendix D, Table 9). Almost all customers said that they are satisfied with current water quality by using potable water (bathing, cleaning, washing, etc.) but every household reported that they do water treatment for drinking purposes or buy bottled water for drinking. About 92% said there is a need to improve current water quality for drinking purposes.

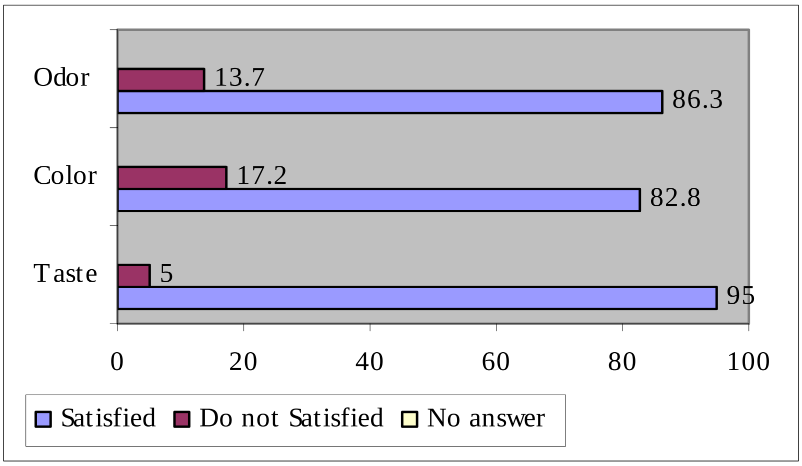


Figure 4.18: Satisfaction of Current Supplied Water Quality (YCDC customers)

Non-YCDC water customer had complaints on the quality of their water supply. Table 4.23 showed that only 60 (66.7%) of non-YCDC water customers were satisfied with the quality of their water supply, 13 (14.8%) of the respondents were not satisfied with their water supply quality. The remaining (18.5%) did not answer this question. Even if they were satisfied with their source of water supply, 62% of non-YCDC customers wanted to connect with YCDC supply service because Yangon city's ground water quality has a high content of iron (Fe^{++}, Fe^{+++}), hardness (Ca^{++}, Na^{+}) and chloride (Cl^{-}) and the price of privately supplied water is higher than the price of YCDC supplied water.

Table 4.23: Non-YCDC Customer's Satisfaction on Supply Water Quality

Count	Satisfy	Do Not Satisfied	No Answer	Total
Number of respondents	60	13	17	90
Percentage (%)	66.7 %	14.8%	18.5%	100%

Source: Field Survey 2006

g) Water Consumption

According to the last 3 months meter reading, YCDC metered water customer's water consumption is in averages 31 m^3 per household per month. While the survey for un-metered YCDC water customer's water consumption shows an average of 37 m^3 per household per month. Therefore, the average water consumption for YCDC customers is 34 m^3 per household per month. At the same time, the average consumption of non-YCDC water customer is 24 m^3 per household per month. Summary of average water consumption by each customer is shown in Table 4.24. This result clearly shows that average monthly water consumption of YCDC customer is higher than the non-YCDC water customer. The reason may be low price with flat rate and inadequacy of water meter reading. To control this high water consumption, YCDC needs to install water meters in both production sites and customer's sites and it should be maintained periodically. Meter reading practices needs restore customer's trust and water should be supplied regularly.

Table 4.24: Average Water Consumption by each Customer in the Study Area

Type of customer	Water Volume Consume (m^3/month)		
	Average	Minimum	Maximum
YCDC water metered customer	31	18	40
YCDC water un-metered customer	37	25	49
Non-YCDC water users	24	12	36

Field survey 2006

NRW Control in Yangon City's Water Supply Management

NRW Control Measures for Water Sustainability

A NRW control plan can be developed in many different ways depending on the circumstances and the interest of water authorities and governments. As shown in Chapter 2, basic NRW control plan elements were used for discussing NRW control in water supply management of Yangon City.

1. Legal Measures (specific policy, law and regulation)

a. Leakage Control Policy, Law and Regulation

Policy is the result of a broad consultative process. A satisfactory, efficient and economically viable water supply management cannot be achieved if it lacks definite policies for managing tasks. Thus, the water authority must adopt a policy for water supply system management. The most appropriate leakage control policy for a particular utility will be dictated mainly by the characteristics of the network and local conditions, which may include financial, equipment, and other resources. Proper management of water supply system requires sufficient quantities of clean water to provide human needs. Authorities will require careful consideration to manage water supply systems of the institutions in place, including the role that might be played by the private sector.

However, the WSS department has not been able to obtain detailed quantitative or specific data concerning the issues of leakage control. Therefore, the information presented here is based on discussions with WSS officials, primary field survey and a few secondary data collected from previous study teams. A principal result of these discussions and site survey was that there is no definite policy relating to NRW control and implementation in Yangon City's water supply management. It is one of the main obstacles to achieving the basic task of the WSS Department. The current leakage control practices are mainly passive and carried out as part of network operations at the township level or the respective sections of the main transmission system.

b. Water Supply Connection Policy, Connection Procedure and Maintenance

Water supply connection policy in Yangon City is universal metering for all domestic (and commercial) consumers. At present, City water supply service has only partially completed meter installation about 23% of the total service connections. Once installed, water meters are left in place until unless they are reported as broken. Water meters are not replaced on a periodic basis. Many water meters are likely to be under-registering significantly. YCDC does not collect any information or perform any studies on representative samples of un-metered consumers to establish and maintain up-to-date per capita consumption by group or category.

The current policy with regard to house connection is not clear. YCDC water pipe connection depends on the request from all applicants. Water connections are granted if the premise where the requesting applicant is located in an area where there is already a network and water is adequate for the existing customers. Currently, total 112,315 connections are registered in the Water Supply Department.

There is no data on waiting applications for house connections to establish the current practices and the capacity of the organization to cope with the demand. If the new customer wants to apply to YCDC water service connection, there are three distinct steps for obtaining YCDC water supply connection, which are:

1) Obtaining an approval for the use of water for construction of a building

2) Approval for the internal house connection (Plumbing),

3) House connection to YCDC supply network

YCDC charged a new service connection pipe based on the following (Table 4.25). The standard connection pipe size is ¾ inch (1.91cm) for new service connection pipe.

Table 4.25: Water Service Connection Fees for Newly Customer

Service Items	Fee (Kyat[6])
Basic Payment of a Connection Fee	1,900
Approval Fee (Sanitary Fittings)	1,000
Approval Fee (Tapping from YCDC Pipe)	800
Total	3,700

Source: YCDC head quarter, 2006

Furthermore, if the customer wants to install a water pump in the connection system for lifting water to high elevation, approval fee 1,600 Kyats will be charged additionally by YCDC. While, the water pump capacity is limited to 0.75 HP. If the customers would like to use more pump capacity, YCDC will charge more (see Table 4.26). Official said "some people illegally install the water pump without permission from YCDC". If water meter-reading staff found such a case, they inform the township staff for them to take actions. But, illegal water pipe connections still exist.

Table 4.26: Pump Installation Fee

Pump Capacity	Fee (Kyats)	Fee (US$)
0.75 HP	1,600	1.33
0.75 - 1.5 HP	10,000	8.33
2 HP	15,000	12.5

Source: YCDC Headquarter, 2006 1US$ = 1200 Kyats (market price in 2006)

Once a connection is provided, the department may disconnect the supply due to three main reasons. They are:

a. Change of status of water use from one type to another. In this case, the already installed connection will be changed to a new type of connection.

b. Non-payment of water bill within the stipulated period

[6] Kyat = Currency in Myanmar (1US$=1200Kyats)

c. Change of supply from YCDC to a private source when removal of the dwelling and at the request of the customer to do so.

Data on disconnections were very hard to collect either from townships or from the head office. Most of the townships indicated, they did not have any records on this area. Many indicated that disconnections were very rare. It was noted from various discussions that disconnections due to non-payment of water bills are very rarely authorized.

2. Implementing Agency and Manpower in City Water Supply Management

The main institution for water supply management in Yangon is the Department of Water Supply and Sanitation under Yangon City Development Committee as discussed above in this Chapter, section 2. The total number of staff in the department is posted at 2,425 persons with salaries. However, currently the permanent (salaried) staff is composed of 1,239 persons of whom 76% are in the field. The established positions are composed of 182 professional engineers and 1,057 post of other ranks (Table 4.27). There are 1,186 vacancies through out the department. Out of the vacant positions, 39 positions are professional engineering posts while the balance 1,147 positions are for other ranks including one vacancy for Deputy Chief Engineer. The staff strength is 11 staff per 1,000 connections, which is one person less than FY 1997 figure in staff strength.

Table 4.27: Distribution of Permanent Staff of Water and Sanitation Department

Staff Category	Numbers of Staff		
	Professional	Other Ranks	Total
Head office	80	222	302
Pipe plant Division (site)	10	101	111
District Offices	15	10	25
Township Offices	26	370	396
Other sites	23	98	121
Reservoir sites	28	256	284
Total	182	1057	1239

Source: Finance & Administrative Division, WSS, 2006

The professional staff means one who has qualifications and/or experience as a sub-assistant engineer or above. The hierarchy of professional positions within the department is listed currently as: Chief engineer (CE), Deputy Chief Engineer (DyCE), Assistant Chief Engineer (ACE), Executive Engineer (EE), Assistant Engineer (AE), and Sub-assistant Engineer (SAE). Of the 1,239 positions in service, only 182 positions are professional engineers. Therefore, the ratio of professionals to other rank is 1:6.8 for the entire organization.

Concerning the township staffing indicates that the majority is assigned by at least one engineer in each township. Table 4.28 shows the professional staff in township water supply operation. This table shows that eleven townships have no qualified water supply engineers to manage water supply operations, i.e., the work in these townships is undertaken only by a supervisor who is an experienced staff in WSS but does not have professional engineering qualifications. It seems to be an apparent shortage of qualified engineers within the department. In the meantime, there can be seen an imbalance professional staff employment in the department. For instance, three townships (South Okkalapa, Mingalartaungnyunt and Bahan) have more than one engineer for each of the three townships while others are under-staffed with regard to the same position. The study suggested that the existence of the above problems is counter-productive as far as the improvements needed for staff within the City water supply sector are concerned.

Table 4.28: The Professional Staff in Township Water Supply Operations

Township	Type of Profession and Number in each Township		
	AE	SAE	Supervisor*
Dagon Myothit East	**	**	*
Dagon Myothit North		1	
Dagon Myothit Seikkan		1	
Dagon Myothit South			1
North Okkalapa			1
South Okkalapa		2	
Thingangyun			1
Hlaing		1	
Hlaingthaya			1
Insein		1	
Kamayut			1
Mayangone		1	
Mingalardon		1	
Shwepyitha		1	
Botataung		1	
Dala		1	
Dawbon		1	
Mingalartaungnyunt		2	
Pazundaung			1
Seikan Port	**	**	**
Seikkyi Kanaungto		1	
Tarmwe			1
Thaketa			1
Yankin		1	
Ahlone		1	
Bahan	1	2	
Dagon		1	
Kyauktada		1	
Kyeemyindaing		1	
Lanmadaw			1
Latha		1	
Pabedan		1	
Sanchaung			1
Total	1	24	11

Note: * Non-engineer grade,   ** Staff not established, work undertaken by staff from other townships

Source: WSS Township offices, 2001

Salaries, Wages and Other Incentives in WSS

The department currently has salaried positions and flat rate (Temporary) positions. The mean monthly salary of an employee in the department is Kyats34,786 (US$28.99 per month). While a private sector employee in Yangon receives average Kyats50,000 per month (US$41.67 per month). The department employees are under paid compared to their counterparts in the private sector (See Table 4.29).

Table 4.29: Comparison of Average Salaries by Public and Private Sector

Sector	Salaries/wages		Incentives		Total	
	Kyats	US$	Kyats	US$	Kyats	US$
Public Sector	34,786	28.99	5,000	4.17	39,786	33.16
Private Sector	50,000	41.67	-	-	50,000	41.67

Source: field survey 2006 Note: 1US$ = 1200Kyats (market prices in 2006)

Although the salary itself of YCDC staff is rather low, they are eligible for several other non-salary benefits such as free rice, low house rent, allowances and other incentives. But, these total benefits would not add more than Kyats5,000 per employee per month (US$4.17 per employee per month). This suggests that the effective salary of a public employee should equate with the private sector's salaries. The study suggested other benefits amount to the equivalent of Kyats10,000 (US$8.33) up.

Job Analysis

It is important to determine which tasks are performed by which staff. This analysis indicates the types and number of staff needed to perform the main tasks of the organization. The analysis helps to achieve the objectives of the organization through the best utilization of existing human resources. The starting point for job analysis is the job descriptions for different staff. At present, the department has no job descriptions for the staff. What is available in the task list is to be performed by direction of the head of the department, the deputy head and the heads of divisions and sections. There is no task list for other positions including the frontline staff of the townships. The available task list is too general which is more related to the cadre positions rather than the specific tasks, the officers are expected to perform. The absence of job descriptions makes it impossible to evaluate the performance of staff, which in turn is a major hindrance towards achieving the objectives of the organization.

3. Financial Management

By State Law No. 11/90, the YCDC is empowered to carry out the city development work of its own accord. The YCDC is financially independent and carries responsibility for its own financial matters.

This section provides a general discussion on budgetary policy of current operations of the Water Supply Department under Yangon City Development Committee (YCDC) and their financial status. It specifically discusses sources of revenue, expenditures, and their past and present trends as well as the analysis of different components of revenue and expenditure items.

The YCDC is a separate financial body in its own right since it is an institution of Ministerial status in the Union of Myanmar. Similar to other viable financial institutions, the current policy of YCDC is to collect money from customers for the services rendered. This includes the policy of charging for water supply and other connected services such as connection fees from its customers. As mentioned in YCDC bylaw 5/99, not only YCDC is empowered to collect revenue and impose penalties on defaulter by the law, but also YCDC must disburse its own funds for the City's development.

The current budgetary policy envisages that all revenues collected by each of the 20 departments within the committee including water supply department are credited to the General Account (GA). The Budget and Finance Department is responsible for the management of the General Account. Funds from this account are allocated to each department based on their individual annual operational budgetary requirements. Under the current policy, the individual departments including the WSS have no authority to determine areas for capital expenditure within their operation. Each department prepares a budgetary forecast of its intended revenue and expenditure for the period 1st April to 31st March of the following year and is submitted to the Finance and Budget Department for approval. It is the responsibility of each department to operate within the approved budget during the financial year. The annual forecast is reviewed during mid-year in order to determine any financial short falls and/or excesses. This exercise is followed by the actual adjustment of revenue and expenditure against the approved annual budget. So, the budget policy current operation noted that the departments are not authorized to include items of expenditure requiring policy directives in their forecasts. Such matters have to be cleared by the executive committee of the YCDC before sanctioning. Although the revenue collected is credited to the GA and the expenditure incurred in the provision of water service is provided from WSS account. The actual revenue and expenditure accounts of WSS are kept separately. This makes it possible to analyze the water sector financial position fairly accurately.

Financial Analysis of the Water Supply Department

According to the water supply department separate account, annual revenue is from Kyats 58 millions (US$48,333.33) in 1991/92 to Kyats 1,910millions (US$15,91,666.67) in 2005/06. This figure presents as an increased trend in revenue by 33 times for the past 15 years.

Revenue for the WSS comes from three main sources namely water tariff, water pipe connection fee and other revenue. Revenue trend of water supply department was shown in the Table 4.30. The total revenue itself and the contribution to the total by each source have registered consistently increase (except revenue for 1998/1999) in the past fifteen years. The lower value of revenue of that year might be caused by the civil disturbance in Yangon. A clearer understanding of revenue will be shown in Figure 4.19.

Table 4.30: Revenue Trend in WSS Department from 1991 to 2005

FY	Total revenue forecasts	Actual Revenue (million Kyats)				Total	
		Tariff from		Connection Fee	Others	Million Kyats	US$
		Government	Private				
1991/92		20.87	27.75	8.34	1.09	58.05	48,375
1992/93		27.87	35.77	10.34	3.09	77.07	64,225
1993/94		28.42	44.40	11.02	1.25	85.09	70,908
1994/95		44.63	96.77	19.55	2.68	163.63	136,358
1995/96		48.77	193.61	59.52	9.39	311.29	259,408
1996/97	405	58.45	206.86	74.39	8.95	348.65	290,542
1997/98	500	58.02	282.41	125.7	6.64	472.77	393,975
1998/99	600	63.40	244.81	104.34	13.18	425.73	354,775
1999/00	600	74.44	259.47	201.02	17.59	552.52	460,433
2000/01	660	74.89	292.09	153.93	9.64	530.55	442,125
2001/02	580	82.48	325.88	87.72	14.37	510.45	425,375
2002/03	700	82.83	416.25	107.22	149.27	755.57	629,642
2003/04	800	79.06	492.15	107.22	77.51	755.94	629,950
2004/05	800	100.42	509.35	125.97	55.23	790.97	659,142
2005/06	1800	233.09	1393.06	164.71	119.64	1910.50	1,592,083

Source: Finance and Administrative Division, YCDC, 2006 Note: 1US$=Kyat1,200 (market price 2006)

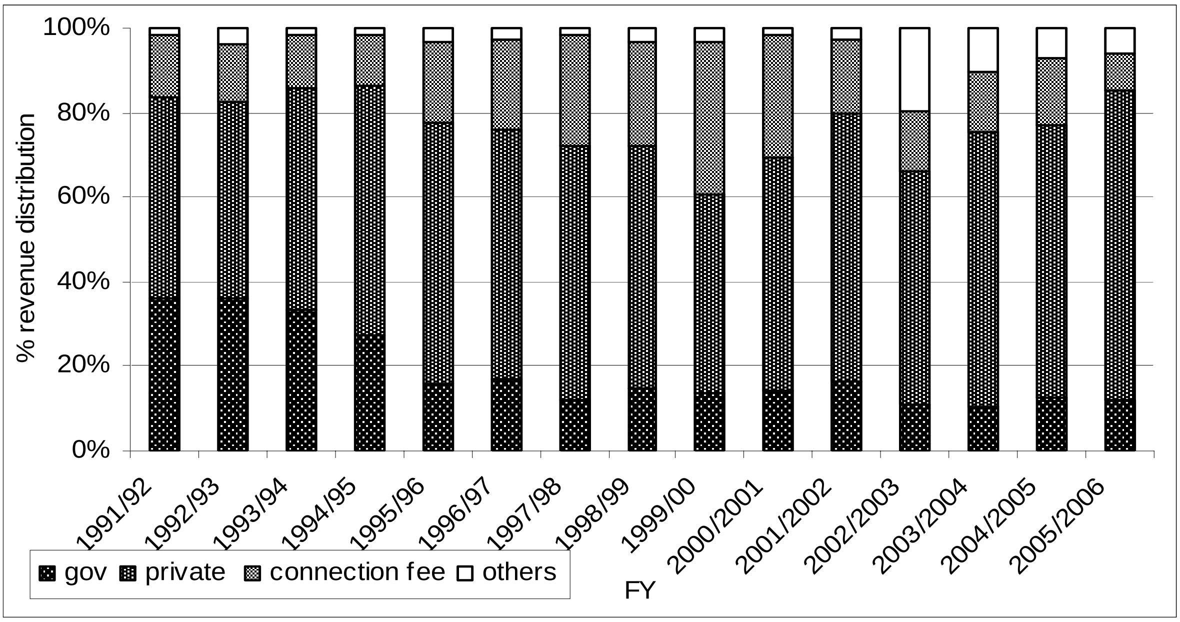


Figure 4.19: Revenue for Water Service by Source FY 1991-2006

The figure clearly shows that dominant revenue comes from water tariff, which was over 80 percent of total revenue in 1991/92 and declined to 60 percent in 2000/01. It appears to be a lowering in the water tariff collected from government departments (See in Figure

4.19, a high value (35) percent in 1991/92 as low as (13) percent in 2000/01). Though private customer's water tariffs increased in the mid 1990s, it subsequently leveled up to about 50 percent of the total revenue. Revenue from water tariff made up as much as four-fifth of the revenue in early 1990s declined to three-fifth of revenue by 1999/2000 and steadily climbed up in FY 2004, 2005 and 2006.

The second largest share in revenue comes from connection fees. It includes the combined connection fee by the customers for new water supply connections. The revenue from connection fee was 14 percent of the total revenue in 1991 and sharply rose to reach 36 percent of the total revenue in 2000/01. Then in later years, 2002 to 2006, the collected connection fee was not revised. It can be noted that there were not too many new connections or new customers in the department during these years. The last component of the revenue is other income, which includes penalty charges, over-due tariff, water meter rent, plumber's license, etc. This type of income is the smallest component of the overall revenue for WSS department. This value is not much except in 2002-2003 FY due to the water-meter installation project in selected townships.

At the same time, an analysis of the Water Supply Department's expenditure in the provision of water services includes the salaries and wages paid for its staff, cost of maintenance of water infrastructure, and the operational costs. The capital expenditure incurred by the WSS department is not available for analysis. It is also to be noted that the maintenance cost does not include operational costs of vehicles in connection with the provision of water services. Figure 4.20 presents the proportional change in expenditure over the last 15 years while the actual and forecast expenditure amounts are found in the Table 4.31. This table shows that the department has been able to operate within its forecast only in 1991/92 and its actual expenditure has out weighed the forecasts for all other accounting years. The actual expenditure has nearly doubled the forecasts in 1997/98 and again in 2000/01 years.

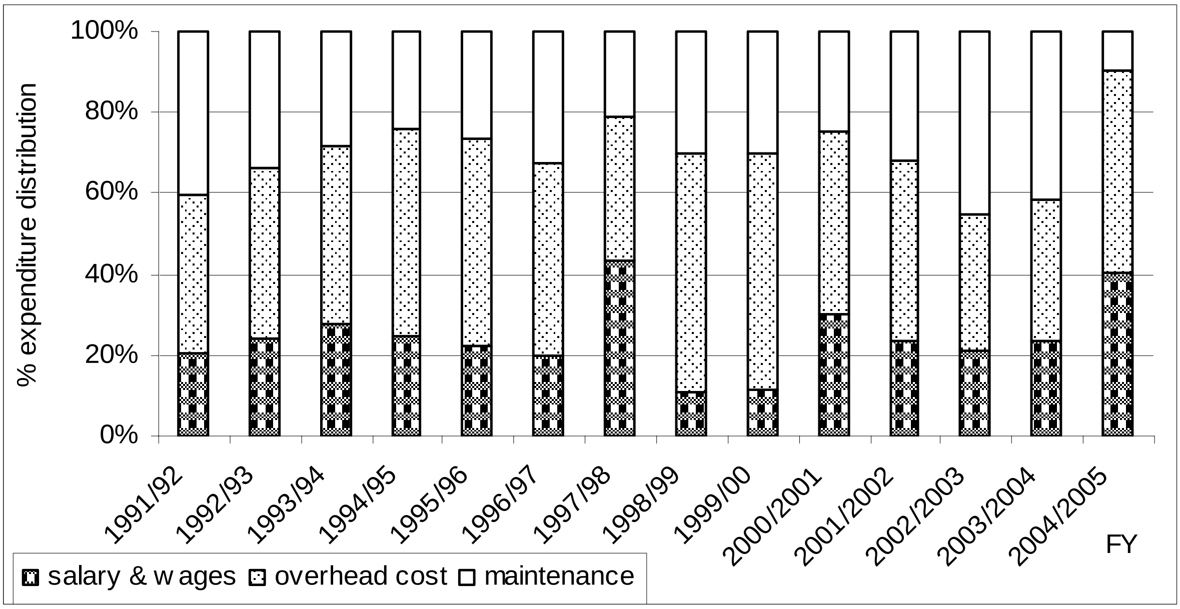


Figure 4.20: Expenditure for Water Service by Financial Year (1991-2006)

Overhead costs are the dominant sharing expenditure, which is about 50 percent of total expenditure, followed by maintenance cost. The maintenance cost includes machinery operation costs, maintenance of pipelines and the operation and maintenance of the reservoirs, tube-wells and pumping stations. Maintenance cost has registered a sharp decline in its proportion from 40 percent in 1991/92 to as low as 31.76 percent in 2001/02. Then in the year 2005, O & M cost was only 9.7 percent of total expenditure. The share of salaries and wages, which stood at 20 percent in 1991/92, had jumped to 43 percent in 1997/98 then coming down again to 30 percent in 2000/01 and share of salaries again reached 40.6 percent in year 2005.

Table 4.31: Expenditure Forecast and Actual Trend of WSS in 1991 to 2005

Year	Expenditure Forecast (million Kyats)			Total Forecast Expenditure		Actual Expenditure (million Kyats)			Total Actual Expenditure	
	Salary	O/H Cost	Maintenance	Million Kyats	US$	Salary	O/H cost	Maintenance	Million Kyats	US$
1991/92	16.07	19.83	13.22	49.12	40,933	10.20	19.19	19.75	49.14	40,950
1992/93	15.75	29.23	16.20	61.18	50,983	13.30	22.90	18.55	54.75	45,625
1993/94	17.80	27.48	17.70	62.98	52,483	15.95	25.44	16.58	57.97	48,308
1994/95	18.30	33.12	20.70	72.12	60,100	15.62	32.38	15.14	63.14	52,617
1995/96	19.10	36.22	22.20	77.52	64,600	14.85	34.55	17.63	67.03	55,858
1996/97	18.80	37.65	23.20	79.65	66,375	14.54	35.16	23.96	73.66	61,383
1997/98	18.80	37.65	23.50	79.86	66,550	64.66	52.65	31.27	148.58	123,817
1998/99	18.80	47.56	31.60	97.60	81,333	15.60	84.34	43.64	143.58	119,650
1999/00	18.80	60.50	32.30	111.60	93,000	18.01	92.00	47.34	157.35	131,125
2000/01	18.80	76.10	30.30	125.20	104,333	73.00	108.02	59.91	240.93	200,775
2001/02	90.00	110.75	35.30	236.05	196,708	71.85	137.11	97.25	306.21	255,175
2002/03	75.00	117.65	45.50	238.15	198,458	75.77	121.30	160.63	357.70	298,083
2003/04	80.00	119.82	49.50	249.32	207,767	100.76	147.58	176.22	424.56	353,800
2004/05	170.00	160.03	190.00	520.03	433,358	161.58	197.59	38.50	397.67	331,392

Source: Finance and Administrative Division, YCDC, 2006 Note: 1US$=Kyats1,200 (market price in 2006)

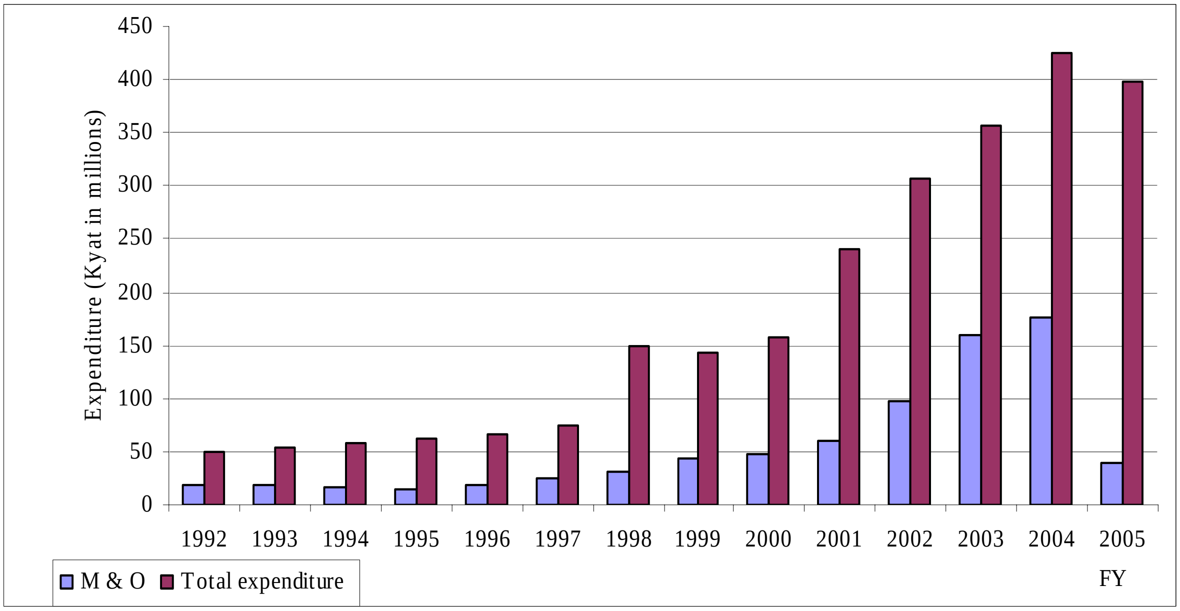


Figure 4.21: Comparison of O&M Expenditure and Total Expenditure of WSS by FY

Figure 4.21 shows the comparison of O & M cost and total expenditure. In year 2005, O & M expenditure was very low (9.7 % of total expenditure) whilst the other expenditures including salary & wages and overhead cost were sharply high (40.6%, 49.7% respectively) due to government employee's salaries were unexpectedly increased to 10 times by SPDC's law. It is one example of political interference in the City water supply management at Yangon.

The above paragraph to be noted is that reducing maintenance cost will have a negative impact on the longevity of operational efficiency of machinery, equipment and the distribution network which in turn will negatively affect the performance of the water supply system in the long-run.

Furthermore, comparing the WSS department's revenue and expenditure reveals that the revenue from water services has exceeded expenditure of the water service throughout the fifteen years period as shown in Figure 4.22. Until year 1994-95, the expenditure is not thoroughly raised, but the registered revenue is sharply increased.

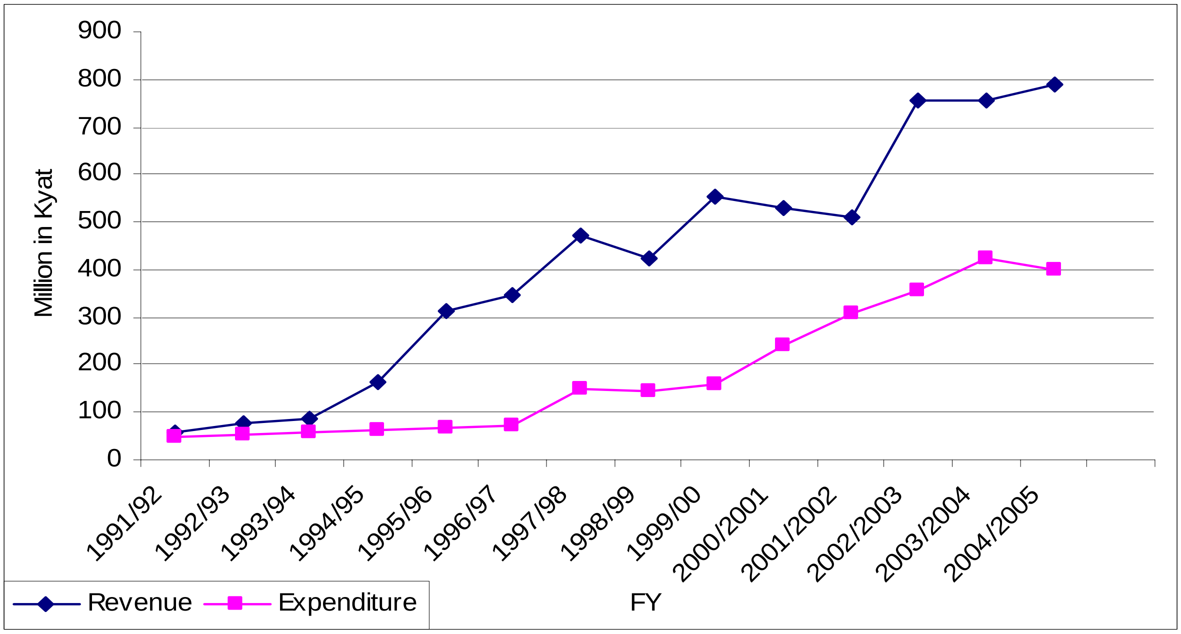


Figure 4.22: Comparison of Revenue and Expenditure for Water Service by FY

According to the financial point of view, Figure 4.22 seems to be financially viable in WSS as far as the operational expenditure and the revenue are concerned. However, this figure carefully considered the capital expenditure including depreciation cost, which is not included in the above analysis because data for capital expenditure is not available.

The current situation reveals that WSS operates independently of any subsidy or financial assistance to run the water program for the City. YCDC is standing alone on their incomes without financial aid from other countries and central government. Central government also struggles to cope with financial deficits because the foreign aid receipts were reduced since 1998/99 budget year. Financial deficit has been increasing gradually while revenue decreased in 1999/2000 budget year.

According to Bahl & Linn (1987), budget deficits do not always occur, but fiscal gaps are commonplace. The fiscal gap means $\hat{D} = \Sigma \hat{E}_i - R$, where $\hat{E}_i$ is the required expenditure for service i, and R is the local government revenue. By contrast, the actual budgetary deficit, $D = \Sigma E_i - R$, where E_i is the actual level of expenditures for public services. This formulation clarifies the distinction between the fiscal gap, which reflects the shortage of revenue available to provide required services and the budget deficit, which reflects the actual shortfall of revenues. According to these formulations from the present situation of the water supply system, it can be concluded that YCDC is facing a fiscal gap. Therefore, YCDC should not be satisfied with the present revenue situation without investment for extension network and repairing or replacing new pipes.

4. Tariff Structure and Related Policy Analysis

Tariffs on water are the main source of revenue for operation of water supply system. Revenue from tariffs is also the main source of financing of the improvement of water supply sector in future. The Government policy should clearly support the collection of water charges in a way that is not a burden on the people. The review of the water tariff is important to determine a coherent tariff policy and thereby to eliminate inconsistencies. Thus, this section analyses water tariff structure, and related current policies, bylaws, regulations, penalties, and enforcement.

In terms of the authority vested in the YCDC Act, WSS has the power to collect water tariffs from customers. The relevant sections of the authority stipulates that: "*If the water user fails to pay water charges or fails to observe any directive relating to use of water, the connection may be severed.*" (Section 13, YCDC Water Supply Bylaw)

Historically, water tax has been made in the Rangoon Municipal Manual of 1922. According to that Manual, the earliest water tariff took the form of property tax where customers obtaining water from the works owned by the Rangoon (Yangon City) Development

Committee (RDC) had to pay a specified amount. It is likely that a water tax was levied by the RDC for the first instance. The Metcalf & Eddy study team (1981) stated that the tariff rates in Yangon were revised in October 1978 and implementation was planned from January 1980. However, there was no reference as to whether or not actual collection began as per the new rates announced in 1978.

Discussions with YCDC staff indicated that the collection of water tariff was begun in 1991. YCDC started with two types of tariff categories, namely tariff based on meter readings and a non-metered tariff or flat rate. The tariffs introduced in 1991 and the subsequent revisions are shown in Table 4.32 for the type of tariff based on water metered customers and Table 4.33 for the type of flat rate water customers. Besides, the water tax which was collected based on the property tax and had its origin in the RDC was continued. However, certain categories of customers were exempted from payment of tariffs.

Table 4.32: Water Tariff Based on Water Metered Customers (per m^3)

Period	Types of customer (rate in Kyats except for foreign customers)						
	Domestic		Government		Commercial		Foreign
	Kyat	US$	Kyat	US$	Kyat	US$	US$
1991 April - 1995 March	2.20	0.0018	3.30	0.0028	19.82	0.0165	*
1995 April – 1997 June	3.30	0.0028	3.30	0.0028	19.82	0.0165	
1995 April to 1997 June	3.30	0.0028	4.40	0.0037	29.74	0.0248	*
1997 July to 2004 March	6.60	0.0055	4.40	0.0037	29.74	0.0248	
2004 April – at present	55.00	0.0458	55.00	0.0458	77.00	0.0642	

*US$0.44/ m^3 for households used and US$0.88/$m^3$ for commercial used Source: YCDC, 2006

Table 4.33: Un-metered Water Tariff or Flat Rate (per month)

Period	Types of customer(rate in Kyats/month except for foreign customers)						
	Domestic		Government		Commercial		Foreign
	Kyat	US$	Kyat	US$	Kyat	US$	US$
1991 April to June 1994	30	0.0250	60 to 80,000	0.0250 to 66.6667	NA	NA	25
1994 July to March 1995	60	0.0500	60 to 80,000	0.0250 to 66.6667	NA	NA	25
1995 April to June 1997	90	0.0750	60 to 80,000	0.0250 to 66.6667	NA	NA	25
1997 July to March 2004	120	0.1000	80 to 107,000	0.0667 to 89.1667	405 to 25,000	0.3375 to 20.8333	25
2004 April - at present	1125 (Dom- I)	0.9375	1125 to 1080,000	0.9375 to 900.0000	3376 to NA	2.8133 to NA	25
2004 April - at present	1875 (Dom- II)	1.5625	-	-	-		-

Note: Min – Max Kyats for Government and Commercial customers Source: YCDC, 2006

According to the above data, each type of water tariff had four different groups of customer. This tariff structure appears to be threefold. Firstly, tariffs related to the volume of water used are charged directly to customers who have connected water with metered connections. Secondly, customers who have no meters are charged a flat rate, which is determined by YCDC considering the volume of water probably used. Thirdly, customers who are provided with water through communal systems such as communal tanks, ponds and lakes are supplied without charge or are charged only water tax or levy. It may be appropriate to exempt the poorest of the poor from payment of water tariffs and the imposition of the water tax (based on property tax).

Table 4.34 summarized the current different customer types and the relevant tariff based on year 2006 data.

Table 4.34: Current Water Tariff Structure

Category	Flat Rate		Meter rate	
	Kyats/month	**US$/month**	**Kyats/m^3**	**US$/m^3**
Religious (temple, mosque, church, pagoda), Embassies and communal tanks in 11 townships*	Free*	-	Doesn't apply	-
Communal tanks in 2 townships	3.25% on property tax	-	Doesn't apply	-
Household (Domestic I)	1125	0.94	55	0.0458
Household (Domestic II)**	1875	1.56	55	0.0458
Government	1125 - 1080,000	0.94 -900	55	0.0458
Commercial/industry	1750 -***	1.46- ***	77	0.0642
Foreign (Commercial)	$25 estimated	25	$4	4
Foreign (Households)	$25	25	$2	2

Note: * see table 4.8 for 11 townships

** Means a large house with a compound or condominium apartments. If more water is needed the policy makes it possible to obtain a separate line where the rate would still be Ks.1875 per month.

*** Minimum flat rate is Ks.3376 per month. The actual rate is very diverse.

The tariff structure originally introduced in 1991 had been changed over the years though the rates for foreign customers remained unchanged during the last fifteen years. A review of the tariff rates for the last five-year period indicated that the rate for domestic consumers increased by 9 times for the flat rate customers and 8 times for metered customers while tariff rate for commercial metered customers increased by 2.6 times during the same period. The government establishments have the highest rate of increase at 12.5 times in the same period. However, the water tariff rate is still very low compared with other cities in Southeast Asia (Table 4.35), when the same usage amount of household (29 m^3 per month) is used as the base.

Table 4.35: Comparing the Water Charges in Southeast Asia Countries

City	Water Tariff	Water Charge	
Vientiane	329 Kip/m^3	9,541 Kip	1.10 US$
Yangon	55 Kyat/ m^3	1595 Kyat	1.33 US$
Manila	4.36 Peso/m^3	126Peso	2.30 US$
Ho Chi Minh	2,500 Don/m^3	72,500 Don	4.70 US$
Bangkok	8.5 THB/ m^3	246.5 THB	5.80 US$
Cebu	14.07 Peso/m^3	408 Peso	7.50 US$
Phnom Penh	1010 Riel/m^3	29,290 Riel	7.50 US$

Note: usage amount of household is 29 m^3 per month, 1US$ = 1200 Kyat (2006)

Source: Nagashio, 2004 & YCDC Head Quarter 2006

Remember that property tax based on water tariff is still collected in Yangon City as levied on customers using water from within 300 feet of a public water tank or standpipe. This tariff was 3.25% of the property value which is levied on customers in only 2 townships obtaining water from communal tanks (see in Table 4.8), while customers in 11 townships who obtain water from the same source (communal tanks) are not charged. At public taps and households without a water meter, the consumption is more wasteful. It seems to be inconsistent that the current YCDC's policy on water tariffs almost depends on the relative poverty of the customer or is political in question. This policy needs to be consistent throughout the city and be a proper water pricing policy or program.

Furthermore, all user groups could be charged more especially big industries and foreign users. These groups have the financial capacity to pay more. However, they do not pay for it due to several of the big water consuming industries or institutions are Government owned. As such, the Government does not acknowledge the environmental gain in raising their tariff, merely the economic inconvenience.

From discussion with the staff, the government is reluctant to intervene for fear of civil disturbance if water prices are increased. Current pricing policy is that "the user charges are not a burden to people who are using the services of water supply". But, the line of demarcation of "wealthy" from "poor" category is also not clear. Current pricing mechanism is poorly organized and tariff rates do not reflect the true market costs. It is, therefore, not surprising that there are perpetually accumulated arrears under the current account. The need for action on this situation is underlined by the fact that because of budgetary constraints, the government can no longer afford to subsidize the provision of water supplies. It should not allow water users to continue thinking that water is abundant and cheap - the very signal it is sending if it does not correctly price raw water.

As Gerard Mestrallet (CEO of 'global services' company), the world's biggest water company likes to say, "God provided the water, but not the pipes." Wherever that capital investment comes from, somebody has to pay for it, if not users, then taxpayers or aid donors. For the people who now have no access to clean water, what matters is whether water comes out of the tap, not who delivers it. Therefore, a Two Tier Water Rate structure should be considered for sustainable water supply system improvement anywhere and particularly for Yangon City due to the long distance of the water source from the city. The basic concept of a two-tier tariff structure is that there are certain costs that are fixed and others that vary with the amount of water consumption. The essence of this new water tariff is that it aims at keeping the price of water low for the poor. Under this structure, consumers who use less water than for basis human needs would pay less for their water than those who consume more. Thus, the authorization of justified Two-Tier Water rate structures would go along way towards providing communities with satisfactory water services (James et al., 2002). As an alternative, the price of water should reflect the opportunity costs of competing uses, as well as the environmental costs of resource extraction and consumption (Francisco 2002). A Two-Tier Tariff structure can be viewed as a potential solution for the utilities, which would like to reflect in tariffs efficiencies of serving large customers, encourage conservation or recover the cost of holding unused capacity available for peak demand time (Babak, Byrne, 2002).

5. Billing Mechanism

Billing system and collection mechanism are important for checking in NRW reduction strategies. It will be found in the literature that water bills are the principal method of communication between water utility authorities and its customers. Accurate water meter reading, calculation and collection will directly effect on reduce NRW in any water utilities. On the one hand, human errors in water metering and data collection systems are impossible to remove all potential for systemic way. Therefore, careful meter reading, bill collections and maintain collected data are potentials for NRW controlling in a water supply system and water authority can get them who used water from water authority trust.

In the Yangon City's water supply management, there are two categories for billing system namely water meter bill and bill for un-metered customers based on the water tariff structure. With regard to metered rates, water-meters are read by a team of township staff in every month. The task of these teams is to visit each household where a water-meter is fixed, read the meter, and prepare to issue bill to customer. Customers pay according to the meter reading.

The un-metered customers are served with a computer-generated bill produced by the Computer Section of the Head Quarter of WSS in accordance with the rate relevant to them. The bills are distributed among customers by the meter reading team referred to above. A bill based on flat rate is issued to each occupant of the premises.

In both cases, the bills are given to customers in person, who is required to pay the amount shown in the bill that has to be paid within 10 days. Failure to pay the water bill within the stipulated time period results in two reminder notices being delivered to the customer followed by the final notice for water disconnection. The disconnection notice when approved by CE (Chief Engineer) is effected by township WSS staff.

In practice, the billing system has not been able to analyze performance in payment of water bills due to absence of accurate records. However, the WSS staff indicated that the performance in payment of water rates (both flat and meter) appeared to be high in 8 years ago (since 2000). Customers are expected to pay the bill either at the office of township engineer, office of the executive or at the head office depending on the type of bill (see Table 4.36). All customers except for the government category have to pay the bill in cash.

Table 4.36: Bills Payment in Relative Office by Customer Type

Customer Type	**Flat Rate Bills**	**Metered Bills**
Domestic	EO's office	Township Engineer's office
Commercial	Township Engineer's office	Township Engineer's office
Government	Head Office (FE Section)	Head Office (FE Section)
Foreign	Head Office (FE Section)	Head Office (FE Section)

Source: WSS Township Staff Communication, 2005

At present, the meter reading and billing teams are faced with some inconveniences in all of the 27 townships where water tariffs are in force. The main problems are:

- not having access to the meter as the compound is found to be locked up
- not able to meet the responsible person of the house during the day time

- refusal by customers to pay the bill as the amount shown presumably is higher than their expectation
- difficulty on the part of the meter reading teams to persuade customers to pay the bill

It seems to be a main issue affecting the work performance of meter reading staff. So, the strategy being adopted by the staff to overcome the problems is to visit the same customers several times. They have also reported the challenging nature of their task having to explain to customers about their rates, how they are calculated. But, the absence of a strategic awareness and an information delivery program aimed at customer education is yet another main issue affecting work performance of the frontline staff of the township. It is clearly noted that the billing system is consistent in certain levels though the bill collection and meter reading was not a suitable affair on both sides (water authority and water customers). The adopted strategy shows much time spent and less efficiency for collecting water charges. On the one hand, discussion with WSS staff in head quarter and townships showed that the junior staff mostly were not aware of existing regulations and penalties of water services. They did not have any training related to water services and specific fields, always accomplish with ad-hoc basic under guidance of senior staff. Information dissemination depends on budget allocation and they have to expend under budget limitation. Therefore, the level of information dissemination is not adequate on both sides (service delivery staff and customers).

6. Training

To deal with the scope of work needed and to achieve the current objectives, YCDC still lacks any of the technical assistance required for NRW control planning and implementation. A technical assistance program should provide on the job training and experience during the implementation process.

Training is both an investment in personal and professional development, and a contributor towards stronger business performance and productivity. The analyses of training were to identify the present status of staff training and to ascertain areas where training is lacking. During the year 2004-2005, WSS provided some training for their staff as presented in Table 4.37.

This table clearly showed that staff of only 13 out of 33 townships had training opportunities. Of all staff 396 numbers attached to townships, only 78 staff (17%) have had the opportunity for attending training. Trainings are predominantly biased on administrative aspects.

Table 4.37: Township Staff Training during 2004-2005

Township	No. of Training Programmes	Number of Participants by Type of Training				
		Administrative	Clerical	Accounts	Management	Eng. Mangt. (preliminary)
Dagon (Seikkan)	4	2	2	1	5	
Dowbon	5	8	5	3	6	
Hlaingthayar	5	2		1	2	
Kyeemyindaing	3	7				18
Latha	3	*	*			*
Mingalardon	1			1		
Mingalartaungnyunt	2				2	1
North Okkalapa	1	1				
Pabedan	2		1		1	
Pazundaung	1				1	
Seikkyi Kanaungto	1				1	
South Okklapa	4	4		2		
Thaketa	1	1				
Total	33	25	8	8	18	19

Source: YCDC training school, 2005

During the survey period 2006, the current training practices available in the department can be analyzed as follows:

i. The most common system is for the senior staff to impart on-the-job technical training to junior staff. This type of training is unsystematic and is inadequate if not combined with formal technical training.

ii. The second type of "technical" training for sub-assistant engineers and assistant engineers is provided by the YCDC training school. This training syllabus mostly focused on administrative aspects of engineering rather than technical aspects per se. The number of trainees for this particular course is 50 persons, which are far in excess of the number who can effectively be trained on a technical subject, at one time.

iii. The third type is clerical staff training and the fourth type is training of accountants. Both these courses are conducted by the training school.

iv. Notwithstanding the above, the importance for the new recruits to undergo a course of orientation training before the work is begun and exposure to in-service training after sometime on the job are to be noted.

In the mean time, the formal training facility available in the YCDC's training school for WSS's staff would be summarized as follows:

i. Though, the school has a reasonable syllabus covering administrative and accounting subjects, the syllabus on engineering is inadequate while there is no syllabus on water supply engineering. Current syllabus does not focus on institutional, customer relations, planning, programming, evaluation, and coordination.

ii. The school facility includes one large lecture-hall, which is not suitable for interactive training. Moreover, school does not have any facility such as workshop, laboratory etc., to offer technical training.
iii. Training aids are insufficient and are limited.
iv. Almost all the resource persons or trainers are drawn from YCDC and other ministries. They have only a limited time to spend with the trainees at school.

It is necessary to address the above concerns in an attempt to develop an effective program of training for the technical staff of the water supply department. The emphasis of current training is administrative rather than technical. The absence of any engineering training focused on water supply in this predominantly engineering organization is not appropriate. Thus, the design of a well-balanced water supply training program should be a main priority. It is to be highlighted that the important institutional issues should also be included in the program.

The WSS officials need strategies for effective interactions with customers, commercial orientation and a higher degree of professionalism. Different skills, new reorientation and an enhancement of existing skills are needed to address the challenges of future demands. Well designed, planned and properly implemented training on management, technology, communication, customer relations, consumer awareness creation, training and education, monitoring, and planning surveys, data collection and reporting skills are needed by the staff in all areas.

Current education and information dissemination practices are very weak. Occasionally the department used media (the radio and television) to make announcements for water rates and repair work to the network. Of particular concern is the non-utilization of opportunities available such as the public educational campaigns organized by their counterparts in the health department. For instance, township health officers plan and organize several educational activities among the public every year. However, there is no educational campaign related to the water leakage control.

7. Operation and Maintenance of NRW Control

The current responsibility for operation and maintenance of the water supply facility is vested mainly on WSS while the customer is responsible for his supply line and all internal connection work. The department is responsible for the O&M and repairs of reservoirs, transmission main and distribution lines, other facilities, and water pumps. The customer is responsible for any repairs or leaks from the service connection supplying water to his/her premises. Therefore, the division between the customer and WSS is at the stop-tap practice. Customers have to repair their service pipe leaks. Each house connection is supposed to have a stop-tap installed just after the ferrule. The stop-tap does not have a valve box and is usually buried.

The township staff fixes minor repairs and/or leaks in the secondary distribution lines. Major O&M problems, repair and/or leaks to the distribution lines become the responsibility of a special team of technical staff in the head office. Minor and major O&M tasks and repair works is generally vague and varies between townships, according to the capabilities of the repair team and the advance fund of each township office. If the repair cost exceeds the advance fund Kyats 50,000 (US$41.6) of township engineer, the task is accomplished by the relevant district engineer or by a special work team of the head office.

Another main problem faced by the township engineering staff is the lack of required tools and sometimes spare-parts in WSS's store. In this case, the relevant staff has to purchase spare-parts and fittings from shops where the parts of the correct standard and specifications are reported to be unavailable. The staff is yet to find a solution for the lack of tools. On the other hand, O&M and repair works can be affected only after site checking, auditing and making adjustments for payment has been completed. However, in practice, the special work teams or leakage control teams undertake to repair or maintain work immediately after detection utilizing 'borrowed' funds or spare-parts obtained on credit. Unlike the township engineer and the district engineer, these special teams do not have the benefit of an advance fund or a store under their charge to facilitate repair and/or maintenance task. Thus, the WSS department has to seriously address this special work. The work team does not have a proper place within the bureaucracy. Placing the team in a proper division may lead to further recognition of their work and thereby bring about a better reputation to the work team. Such a strategy would also enhance their professional advancement. The current leakage control method in the Yangon city is presented as follows.

8. Method of Leakage Control in Yangon

Recent leakage control method practicing in Yangon largely relies on passive leakage control and low activities. Current practices are mending only visible leaks and carried out as a part of the general duties of the network maintenance staff concerned, rather than as a specific leakage team. There are some relative activities for leakage control, which solely depend on the perspective of township WSS staff due to the particular needs of their area concerns.

Measurement of Bulk Flows Consumption

Presently, there is no flow measurement or assessment made by the staff. Flow meters are not installed at any point in the network and there is no collection of flow data for use in NRW control. Customer meters are read monthly for revenue purposes, but no assessment of the information is practiced for estimation of consumption.

Leakage Inspection

Water Supply Department staff routinely inspects their area and the network. This inspection was done by walking the route of the pipes and making visual checks for evidence of leakage and other problems. They also investigate any reports from the public. The inspection may be done daily and weekly for smaller areas or less frequently for larger areas. Besides, YCDC staffs are supposed to monitor the condition of customer connections. While visiting properties, they will note any leaks, problems with meters, illegal connections etc. are reported them to the customer for further action. A sizable leak can be expected to migrate readily to the surface due to the relatively low soil permeability in Yangon City.

The YCDC water supply network is mostly buried, but many service pipe works are visible on the ground. These pipe works have leakages on a significant proportion of those seen, which is considered to be an appreciable contributor to the total volume of losses. These observations are collaborated by the operational staff's experiences and opinion who expressed during the interviews that the majority of leakage was on service pipes.

Once a leak is identified, repairs are quickly made by either township staff or "major" repair team. This is a timely response and minimizes water lost. Mainly, leakage control methods are ad hoc. The teams do not have necessary materials and equipments to make proper repairs. There is a high risk that the leak will recur. Most water leakage can result from structural deterioration of the pipeline, generally corrosion or pipe barrel failure or failure of the joint sealing mechanism. Thus, most common repairs in city water supply system are lead joints on cast iron pipes.

Operational losses are not given a high priority for repair unless they cause problems. The government officials also said, service reservoir losses are not recognized at all and no information is available on that matter. It is impossible to estimate whether there is any significant loss from the three reservoirs. Operational service reservoir (namely Kokine and ShweDagon) are over 70 years old. They are all ground tanks and there may be some leakage without its presence being visible.

Leak Detection and Repairs

Before investigating any possible reduction in leakage, a study must be done to know existing leakage and effectiveness of leak detection already being undertaken by the authority. As discussed above, there is no team of employees actively engaged in looking for leaks, action results are only taken from loss of supply or actual leaks observed at ground surfaced by employees, the police or the general public. Reports are received and action is then taken by inspectors to trace the source of leakage before a repair team is called in.

Townships' staff respond to leaks found or reported and determine what is needed. They do the minor repairs themselves, but the major repairs are reported to YCDC Head quarter for further action. If major repair is needed, a special team will be sent with more equipment and the work teams undertake the repair work immediately.

In case of customer connection, customers are responsible for maintenance and repair of the pipeline, taps and other fittings fixed to customer's service line. The relevant work has to be accomplished by a licensed plumber hired by the customer.

A licensed plumber means a private plumber who passed the conducted examination held by WSS department and registered as a plumber under regulation of WSS department. The department keeps a list of plumbers who are licensed water and sanitation engineers, licensed plumbers and working plumbers. A list of registered plumbers is shown in Table 4.38. Customers are expected to engage registered plumbers to get their internal connections done and to fix defects.

Table 4.38: List of Plumbers Registered in Water Supply and Sanitation Department

Type	Responsibility	Number of registered plumbers	Annual registration fee	
			Kyats	US$
Licensed water & sanitation engineer	Permitted to undertake designs and plumbing work	12	10,000	8.33
Licensed master plumber	Permitted to do all plumbing work	261	6,500	5.42
Working plumber	Permitted to work only under the supervision of the above two types.	164	4,000	3.33

Source: YCDC headquarter, 2005 Note: 1US$ = Kyats1200

Installation of Pipe and Pipe Joint

Distribution main pipes and larger diameter pipes are laid under roads or along side with 3 to 7 feet cover in depth. Smaller and secondary distribution pipes are sited at the edge of the roadway or alongside with 2 to 3 feet depth cover. Pipe installation and joint fitting are given less attention in practices. The long length of service pipes for house connection also indicates that the secondary distribution network is weak. The joints used have been changed periodically. The majority of joints in the system are “lead” material joints, and the most common type of repair carried out is “lead” material joints, which are done manually with minimal specialist tools and equipment. These situations also indicate a potentially high background of leakage. Presently the network is subject to only very low supply pressures, sometimes negative, and intermittent supply, which limits the potential for losses, especially at joints, because these are pressure dependent and have greater chances of leakage.

9. Status of NRW in the City Water Supply System

Although, assessing the correct value for NRW in any system is often difficult, for control purposes, good quality data needs to be interpreted accurately and a clear understanding of supply boundaries is therefore most significant. Currently, there are two main methods for estimating system leakage. These are the total integrated flow method and the total night flow method. Both of these methods involve subtracting the measured output (i.e. water consumption) from the measured input (i.e. water production). The remaining unaccounted for water is non-revenue water, the majority of which is related to system leakage. NRW includes errors in measurement of inflow, and outflow, which may be either positive or negative. Water is used legitimately but is not metered including mains flushing, fire fighting and supply to un-metered premises, illegal connections and system leakage (http://www.nrw.qld.gov.au/compliance/wic/pdf/reports/urban.pdf).

Total integrated flow method is calculated by subtracting all measured consumption based on customer meters from the measured supply recorded by all bulk inflow meters. It is normally calculated annually after consumer meters have been read for water billing purposes. The changes from one accounting period to another are influenced by water meter error, particularly slow reading meters, water meter failure, seasonal variations in demand and the timing when water meters are read. Even though, this method is not very accurate as large quantities, subject to certain errors, are subtracted from each other to obtain a small quantity of water with a potentially large error, to investigate the NRW status in Yangon City water supply. This study was using the total integrate flow method and water balance terminology adopted by International Water Association (IWA 2000). Consequently, the method is only suitable for broadly assessing the level of system leakage.

As combined with the operational definition and total integrated flow method, NRW is the difference between the amount of water put into the distribution system and the amount of water billed authorized consumption both metered and un-metered consumption. Therefore,

$$\text{NRW} = \left(\begin{array}{c}\text{Amount of water put into}\\ \text{the distribution system}\end{array}\right) - \left(\begin{array}{c}\text{Amount of water billed}\\ \text{authorized consumptior}\end{array}\right)$$

A review of previous studies on Yangon City water supply system showing available data are quite varied in percentage of un-accounted for water (UfW) (see Table 4.39) due to uncertainty and lack of accurate data information. These figures are for overall UfW value. It does not attempt to define the amount of actual losses or derive values for any of the constituent components. Nevertheless, it can be considered as a reference for investigating NRW status in the recent days.

Table 4.39: Available Data for UfW Value from Previous Studies

Study team	Year of study	UfW value or ratio (%)
Metcalf & Eddy	1980	62.4
CSO**	1997	38.0
YCDC*	2000	12.4

* YCDC's estimation

**Statistical Profile of Children and Women in Myanmar 1997 (Central Statistical Office)

For the existing water supply system in Yangon City, status of NRW was investigated as follows:

Water Input to Distribution Network System

The volume of water delivered into the distribution net work should be accurately metered, but meters are often not installed, unserviceable or markedly inaccurate in Yangon City. Therefore, probable production capacity was estimated from nominal pump capacities and combined with operation hours of each pump. The average daily water input volumes from three main reservoirs to city water supply network were estimated as below Table 4.40.

Table 4.40: Estimated Water Input to the City Water Supply System

Location of pumping stations	Unit capacity (m^3/hr)	No. of units (No.)	Running Hours (hrs)	Efficiency factor (%)	Volume Pumped (m^3)	Estimated Daily production (m^3/day)
Gyobyu	3,310	2 (1)	24*	80	127,000	127,000
Hlawga P.S -1	4,980	1	24*	80	96,000	
	4,980	1	8*	85	34,000	130,000
Hlawga P.S- 2	1,500	2	8*	80	19,000	
	2,700	1(1)	12*	80	26,000	45,000
Estimated water input to supply system from surface water sources						302,000

( ) stand-by pump * estimated running hours Source: Field survey 2006, and YCDC 2001

Despite surface water sources, there is ground water extracted from over 200 tube-wells owned by WSS. Production amounts of ground water extraction were estimated in accordance with parameters of system, service level, and pump running hours in Township. Estimated data are based on the annual production rate for year 2005 from January to December (See in Table 4.41).

Table 4.41: Estimated Ground Water Supply Volume Input to the Supply Network

No. of Tube-wells	Service Level			Production (m^3/day)	
	L- I	L-II	L- III	Total	Input to Supply Network
214	74	5	135	43,890	38,000
%	35	2	63	100	87

Source: YCDC, 2006 Note: L-III is the category that pumps to the distribution network

As all above information, total amount of water volume input to the network system can be estimated, which is combined with surface water and ground water supply (Table 4.42).

Table 4.42: Estimated Total Volume of Water Input to the Water Supply Network

Source of Water	Avg. Daily Vol. (m^3/day)	Percent Distribution (%)
Surface Water	302,000	88.8
Ground Water	38,000	11.2
Total	340,000	100

Source: YCDC, 2006

<u>Amount of Billed Water Consumption</u>

It is necessary to calculate for NRW estimation. The amount of billed water consumptions include water sold by metered and un-metered customers with bill. The total number of customer connected in accordance with metered and un-metered users are shown in Table 4.43. It was noted that the total number of connections is 112,315 of which only 23% (25,652 connections) are metered connections.

Table 4.43: Number of Metered and Un-metered Connection by Different Customers

Tariff structure	Domestic	Department	Com. & Ind.	Total	% Total
Metered	22,612	101	2,939	25,652	23
Un-metered	82,020	1,171	3,472	86,663	77
Total	104,632	1,272	6,411	112,315	100

Source: YCDC, 2002

Account on billed water consumption in Yangon City was categorized by current water tariff structure. At present, water meter bills are issued every month for all YCDC water meter customers. The bill for un-metered domestic and commercial & industry customers are issued bills in each quarter[7] and for department customers are issued bills by

[7] Quarter = 4 times a year or 3 month one time within a year

once a year. Total numbers of issued bills for domestic customers by both metered and un-metered water consumption during the last 5years period 2000-2006 are shown in Table 4.44.

Table 4.44: Total Domestic Water Bill Issued in FY 2000 to 2006

Year	Number of issued bill metered	Number of issued billed un-metered
2000-01	22,612	303173
2001-02	25,690	318,599
2002-03	36,380	285,493
2003-04	45,779	268,810
2004-05	49,739	262,738
2005-06	55,138	260,717

Source: Finance and Budget Department, WSS, 2006

Table 4.44 can say that there has been very slow installation of water meters within the YCDC customers due to the total bill issued for metered consumers are higher and higher. Total domestic water consumption will be estimated by using the number of issued bills per year, average bill value and estimated average water consumption per capita. For instance, the total revenue 1393.06 million Kyats (US$-1,160,883.33) has been collected in the year 2005-06.

By using the unit conversion method, the volume of billed un-metered water consumption was calculated as follow.

$$\text{Total water consumption (Un-metered consumers)} = \text{Total bill issued per year} \times \text{Avg. bill value} \times m^3/\text{Kyats}$$

$$= 260{,}717\ \frac{\text{bills}}{\text{year}} \times 3375\ \frac{\text{Kyats}}{\text{bill}} \times \frac{1\ m^3}{55\ \text{Kyats}}$$

$$= 15{,}998{,}543.18\ m^3/\text{year}$$

Where,

Avg. bill value = 1125 kyats/ month x 3 month = 3375 kyats/quarter (2.81US$/quarter)

Note: water charge 1125 kyats/month is based on 150 gal/HH/day or 20 m^3/HH/month.

(Source: calculation of un-metered water bill issued YCDC, 2006)

In this above calculation, water charge for condominium or large compound buildings were excluded which is 1875 Kyats/month based on 250 gallon per household per day. Estimated an average person per household is seven persons for this calculation. While, total volume of metered consumers' billed water consumption are:

$$\text{Total water consumption (Metered consumers)} = \text{Total bill issued per year} \times \text{Avg. consumption / household /month}$$

$$= \frac{55{,}138 \text{ bills}}{\text{year}} \times \frac{1\text{yr}}{12\text{month}} \times \frac{36 \text{ m}^3}{\text{Bill or HH}} \times \frac{12\text{month}}{\text{yr}}$$

$$= 1{,}984{,}968 \text{ m}^3 / \text{year}$$

Where, estimated averge water consumption for meter customers is 36 m^3 per household per bill, which is calculated from seven persons per household. The highest consumption is 271 lit per capita per day in Yankin Township and the lowest consumption is 75 lit per capita per day in Alone Township (JICA study team 2002). The figure for average water consumption per capita in each township is presented in Appendix B, Table 16. The calculated estimation of total billed water consumption for domestic consumers in FY 2005-2006 were summarized in the following Table 4.45.

Table 4.45: Amount of Estimated Domestic Billed Water Consumption in FY 2005-2006

Type of customer	No. of bills per year	Unit charge (Kyats/m^3)	Total water charge		Total water consumption (m^3/year)
			Kyats/year	US$/year	
Metered	55138	55	109,173,240	90,977.70	1,984,968
Un-metered	260,717	55	879,919,875	733,266.56	15,998,543
Total			989,093,115	824,244.26	17,983,511

Note: 1US$ = 1,200Kyats (2005-2006 market price)

Meanwhile, department and commercial & industrial water consumption can be calculated (see Table 4.46). According to the finance and budget division of WSS, the collected total revenue is 233.09 million Kyats (US$-194,242) from Department customers and 403.97 million Kyats (US$-336,639) from commercial and industries customers in FY 2005-06. While, the water tariff both metered and un-metered consumptions, for Department and Commercial & Industrial customer was 55 Kyats per m^3 (US$-0.05/$m^3$) and 77 Kyats per m^3 (US$-0.06/$m^3$) respectively.

Table 4.46: Water Consumption of Department, Commercial and Industrial Customers

User	Category	Bill Amount		Water Charge		Consumption (m^3/year)
		Kyats/yr	**US$/yr**	**Kyats/m^3**	**US$/$m^3$**	
Department	Metered	6,232,270	5,193.56	55	0.05	113,314
	Un-metered	192,888,080	160,740.06	55	0.05	3,507,056
Total		199,120,350	165,933.63			3,620,370
Commercial and Industries	Metered	176,266,860	146,889.05	77	0.06	2,289,180
	Un-metered	227,700,025	189,750.02	77	0.06	2,957,143
Total		403,966,885	336,639.07			5,246,323

Source: Finance and Budget Division, WSS, YCDC, 2005-06.

At the same time, the larger departmental water consumption bills were collected separately as follow (Table 4.47).

Table 4.47: Larger Departmental Water Customers in FY 2005-2006

Township	Name	Metered/ Un-metered	Avg. Water Consumption (m^3/month)	Avg. Water Charge per month	
				Kyats	US$
Bahan	Directorate of Industry	u	13,636	749,980	624.98
Kyauktada	Strand Hotel	u	7,855	432,025	360.02
Latha	Yangon General Hospital	u	7576	416,680	347.23
Dagon	Military Compound	u	196,364	10,800,020	9,000.02
Mayangone	Inya Lake Hotel	u	24,318	1,337,490	1,114.58
	Paychiatric Hotel	u	6,818	374,990	312.49
	No.2 Hino Factory	u	18,296	1,006,280	838.57
Mingalardon	Yangon Air Port	u	45,818	2,519,990	2,099.99
Tamwe	General Worker's Hospital	u	7,364	405,020	337.52
	Kanthayar Hospital	u	7,364	405,020	337.52
Thaketa	Electric power station	m	11,005	605,275	504.40
Yankin	Industry 1	m	17,385	956,175	796.81
	Ministry of Mining	u	6,818	374,990	312.49
Total water consumption per month			370,617	20,383,935	16,986.61

Source: Finance and Budget Division, WSS, YCDC, 2005-06.

Total billed water consumption for the study area in FY 2005-2006 is shown in Table 4.48. The comparison of metered and un-metered water consumption in each type of water customers are shown in Figure 4.23. The above estimated calculation totally depends on the revenue collected from finance and budget section of water supply and sanitation department in year 2006.

Table 4.48: Total Billed Water Consumption in FY 2005-2006

(m^3/year)

	Domestic customers	Department Customers	Com./Ind. Customers	Large water user	Total Water Consumption
Metered	1,984,968	113,314	2,289,180	340,680	4,728,142
Un-metered	15,998,543	3,507,056	2,957,143	4,106,724	26,569,466
Total volume	17,983,511	3,620,370	5,246,323	4,447,404	31,297,608
% Total	57.46 %	11.57 %	16.76 %	14.21 %	100 %
(Total Domestic Water Consumption per day)					(85,747)m3/day

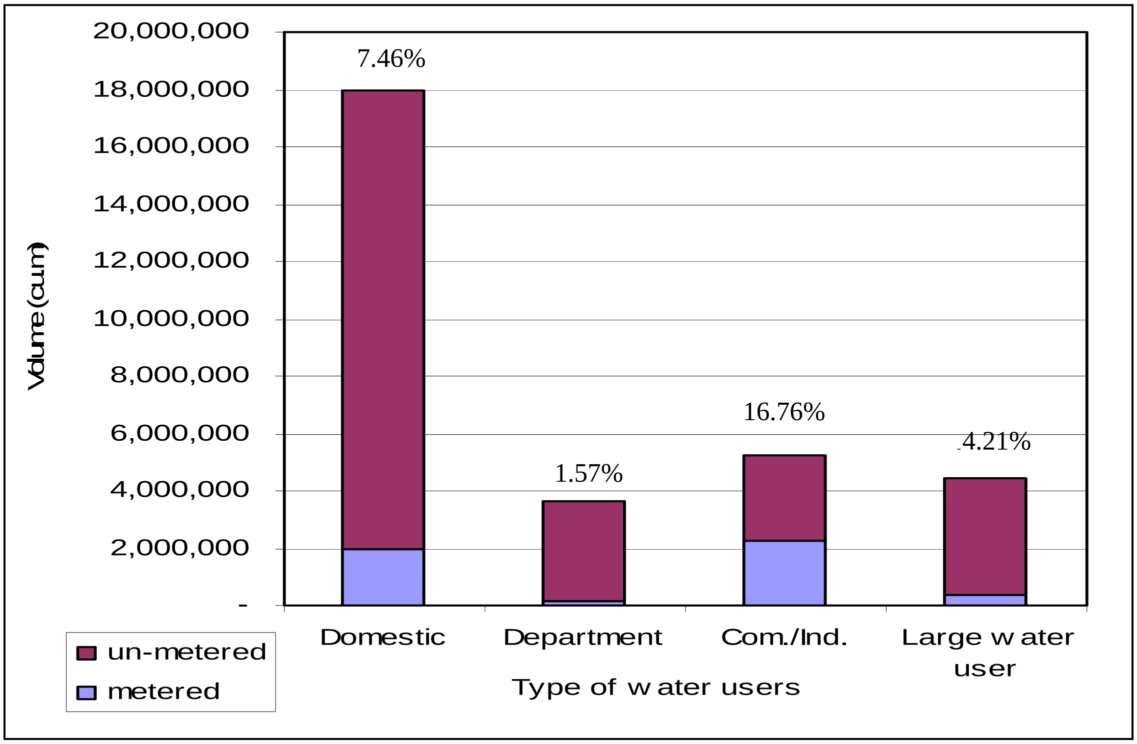


Figure 4.23: Comparison of water metered and un-metered consumption by each type of water customers

In addition, un-recorded billed water was also estimated. However, total apparent loss in water supply management, total unbilled authorized consumption and actual real losses cannot be calculated due to the lack of available data (See Table 4.49).

Table 4.49: Estimation of Percent Un-recorded Bills in FY 2005-2006

Total Connections	Est. issued bills per year	Actual Issued bills per year	Est. Losses of total bills per year	Est.% Total Loss
Metered (22,612)	271,344	55,138	216206	79.68
Un-metered (82,020)	328,080	260,717	67,363	20.53

Source: Field survey, 2006

If one connection in one household issued by one bill, estimated billed losses per year by metered water consumption is 216,206 bills and un-metered water consumption is 67,363 bills. According to YCDC's population data, average family household size is seven persons per household and average per capita consumption 173 liter per capita per day. Therefore, estimated water losses from un-recorded bills are:

For metered water consumers' bills,

Estimated water losses from un-recorded water bills = 216,206 bills/year x 36 m^3/bill

= 7,783,416m^3/year

= 21,324.43m^3/day

For un-metered water consumers' bills,

Estimated water losses from un-recorded water bills = 67,363 bills/year x 3375Kyats/bill x 1 m^3 / 55Kyats

= 4,133,638.64m^3/year

= 11,325.04m^3/day

Therefore,

Total estimated water losses from domestic consumers' bill = 21,324.43 + 11,325.04

= 32,649.68 m^3 per

= 9.6% (of total water input per day)

This figure 9.6% of total estimated un-recorded losses may include unbilled authorized consumption and apparent losses (such as metering inaccuracies, and data handling errors).

Therefore, using all the above data (total water production, estimated billed water consumption and un-billed water consumption), the estimate of NRW value for water supply management in Yangon City were calculated as follow:

Total production (System Input Volume) = 340,000 m^3 per day

Total billed meted consumption = 12,953 m^3 per day (3.8 % of total input volume)

Total billed un-metered consumption = 72,793 m^3 per day (21.4% of total input volume)

Total estimated apparent losses = 32,649.68 m^3 per day (9.6% of total input volume)

$$\text{NRW value} = \left(\begin{array}{c}\text{Amount of water put into}\\ \text{the distribution system}\end{array}\right) - \left(\begin{array}{c}\text{Amount of water billed}\\ \text{authorized consumptior}\end{array}\right)$$

$$= \left(\begin{array}{c}\text{Amount of water put into}\\ \text{the distribution system}\end{array}\right) - \left(\left(\begin{array}{c}\text{Total billed metered}\\ \text{water consumption}\end{array}\right) + \left(\begin{array}{c}\text{Total billed un-metered}\\ \text{consumption}\end{array}\right)\right)$$

= 340,000 – (12,953 +72793)

= 254,254 m^3 per day

= 74.8 % (of total water volume input)

This value of NRW is too high. It could be **countered checking** by follows:

Total production or total input of water = 340,000m^3/day x 365 day/year

= 124,100,000m^3/year

Total revenue from billed water = 1,626,150,000 million Kyats (US$-1,355,125)

Average Tariff for billed water = 66Kyat/ m^3 (US$-0.06)

Therefore,

Total amount of billed water = 24,638,636.36 m^3

Total amount of un-billed water = 124,100,000 – 24,638,636.36

= 99,461,363.64 m^3

Percent total loss of water or NRW = 80% (on average estimation of NRW based on average water tariff).

Therefore, Non-Revenue Water in Yangon City Water Supply System is 74.8% accurately estimated by this study.

On the other hand, possible NRW can be concerned with network length, total connections, and total population served, which can also be calculated in average because the loss of water from network and connections depends on the length, and pressure.

Anyway, this figure can be employed as an indicator in the present water loss of Yangon City water supply system that can be used for controlling NRW management plans for the future and comparing network efficiency in each year within the same system.

NRW / network length = 254,254 m^3/day / 782.27 m = 325.02 m^3/ m / day (avg.)

NRW / total connections = 254,254 m^3 /day/ 112,300 = 2.26 m^3/connection/day (avg.)

NRW / total population served = 254,254 m^3 /day / 1,750,000 = 145.29 lit/person/day

In conclusion, the above estimates were calculated using subtraction method based on available data (total production volume, total number of bill issues, and total financial revenue and expenditure of WSS). It is recommended for promoting the best practice of NRW control that WSS should follow IWA water balance terminology in order to improve ties and advance in water supply management.

People's Perception of Water Loss Control in Yangon

Consumer surveys were conducted to know people's perception on existing water leakage control management and future improvement of water supply management in the study area.

Water Leakage Control Practice

Water is precious and the most important natural resource for all human life. Almost all households agreed to this statement. Water is important for our lives and they are willing to prevent the loss of water from their sources and their neighbors. The survey result showed in Table 4.50. When the water leakage problem is in or near their household, 177 (86%) respondents immediately repair the fault by themselves or call the private plumber to repair the fault due to the leakage problem. The reason is that if water supply is interrupted, it will cause a lot of inconvenience by disrupting household chores, washing, and bathing. They also incurred additional expenses for households because they had to buy water from private water vendors. Very rarely did, 21 (10.2%) respondents call YCDC staff to repair the fault or leakage. Eight (3.8%) respondents did not answer for this question. The result shows that current practices for water leakage control have a lot of risks due to lack of standard materials and most of people rely on self-repair practices.

Out of 90 non-YCDC customers, 80 (89%) respondents said they immediately repaired the leak by themselves or sometime they called private plumbers to fix the leak. The remaining (11%) of respondents did not answer this question.

Table 4.50: Water Leakage Control Practices in Study Area

Control Practices	**YCDC customers**	**Non-YCDC customers**
Immediately repair by themselves or call plumber	177 (86%)	80 (89%)
Call YCDC staff for repair	21 (10.2%)	-
No answer	8 (3.8%)	10 (11%)
Total	205 (100%)	90 (100%)

Source: Field Survey 2006

Opinion on Water Cost and Billing

Table 4.51 showed the water consumption and expenditure of each water user. Average monthly water cost for YCDC customers was from 990 to 2,200Kyats per month (US$-0.825 to 1.83 per month) excluding water metered customers who pay 2 Kyats (US$0.002) for maintenance of water meter and electricity cost for water pumped for fetching water from YCDC water pipe line as an additional cost for water expenditure.

Monthly average water cost of non-YCDC water customers was Kyats 3000-9000 per month (US$2.5-7.5 per month). Water price is 200 to 300 Kyats per 50 gallons or one drum. If respondents connected from their neighbor's private tube-well, the water cost varies from 2,500 Kyats to 6,000Kyats per month for getting two drums of water per day.

Table 4.51: Average Water Consume and Water Expenditure by each Customer

Type of customer	Water volume consume (m^3/month)			Average Monthly Water expenditure					
				Kyats/month			US$/month		
	Avg.	Min	Max	Avg.	Min	Max	Avg.	Min.	Max.
YCDC water meter customer	31	18	40	1597	992	2202	1.33	0.83	1.84
YCDC water un-meter customer	37	25	49	1500	1,125	1875	1.25	0.94	1.56
Non-YCDC water users	24	12	36	6,000	3,000	9,000	5.00	2.50	7.50

Source: Field survey 2006

Therefore, the study results reveal that water expenditure is higher among non-YCDC water users than the YCDC customers are. On the average, non-YCDC customers have to spend three times more than YCDC customers do for getting water.

Opinion on current water price by YCDC customers showed that 86% of respondents answered, it is the right price, 7 % said the price was expensive, 4.8 % said it was above the right amount and 2.2 % said price was cheap (See Figure 4.24 and this result table showed in Appendix D, Table-10)

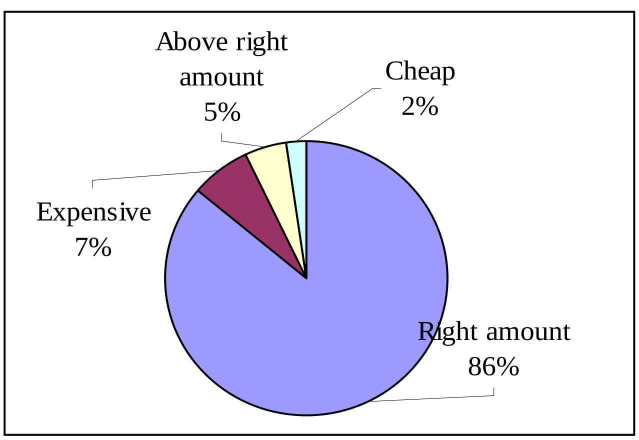


Figure 4.24: Respondent's Opinion on Water Price (YCDC customers)

The non-YCDC water customer's opinion on current water price was presented in Figure 4.25 and Appendix D, Table-10. Among non-YCDC customers, fifty-one (56.5 %) respondents said current water price was expensive. Twenty-seven (30%) respondents said it was right price, nine (10%) respondents answered it was above the right amount, and only 3 (3.5%) respondents said it was cheap.

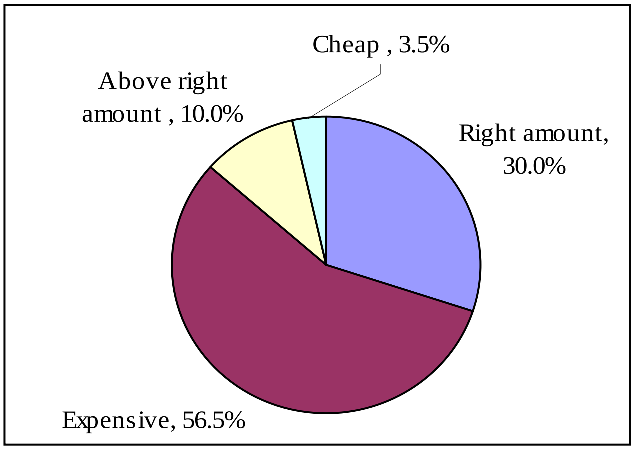


Figure 4.25: Respondent's Opinion on Water Price (Non-YCDC customers)

Respondent's satisfaction of water bill collection mechanism result showed that 133 (65%) YCDC water customers said, "YCDC staff came and collected water charge and gave them the water bill". The rest 72 (35%) respondents said, "They have to go and pay at township Water Supply and Sanitation Department". Nearly half of respondents 98 (48%) were satisfied with the current water bill collection system and 106 (52%) of respondents were not satisfied (see Table 4.52) because they do not believe who read the water meter and wrote down the amount. They do not know if it was correct or not. Sometimes, WSS staff did not regularly read the water meter and write down the estimated amount for water unit. As a result, the cost for water consumption is high in one (current) month and low in the later (i.e. fluctuation of water consumption volume). Customers do not like to pay too much money for water in one month. So, customers are expected to pay the bill either at the office of the township engineer or the office of the executive officer or at the head office depending on the type of bill. They also want to know, and ask some information about changing water price, meter reading, repair network and frequent announcements of WSS department. The department has no posters, leaflets or other brochures to share with customers to increase their knowledge or awareness about water related activities.

Table 4.52: Respondent's Satisfaction on Water Billed Collection Mechanism

Respondents	Satisfied		Do not Satisfied		No Answer		Total	
	f	%	f	%	f	%	f	%
YCDC Customers	98	47.8	106	51.7	1	0.5	205	100

Source: Field Survey 2006 Note: f = frequency

Summary of Findings and Discussions

Upon dealing with the mechanisms, policies, and actions that water supply organizations perform in order to establish and maintain water supply system and management, it becomes pertinent to ascertain their views on how best they believe their performance on water supply sustainability in the City can be enhanced. To do so, this study found out the weaknesses and shortcomings of the water supply system and management institution at Yangon City and suggest recommendations for improvement of water supply sustainability in the city.

The most obvious finding based on the results of my survey is the excessive wastage of water in Yangon and the reluctance to acknowledge and change this behavior. Poor water use practices by both private and public consumers and a lack of NRW control aware in management institution.

The residents of Yangon have several sources of water supply. The most popular sources among residents are YCDC supply water and private owned tube well. The present YCDC water supply network service is not sufficient for all residents. Only 37% of the total population is served by YCDC supply water pipes. Even within this low service area, the city water supply network data is out of date and incomplete, operational information is irregularly collected and analyzed, few records are kept and recorded data are fragmented. The system pressures are very low, lower than the minimum pressure of service level $2kg/cm^2$ in many countries and large areas have intermittent services. Out of 33 townships in Yangon, only 6 townships can get 24 hours of continuous water from supply pipe line and many townships only have a couple of hours for water in their available water pipe network. The average duration of getting water from the network is 8 hours per day, and depends on the location of premises and the water distribution main. Almost all respondents have to use an electric/fuel pump for getting steady supplied water from the YCDC water supply line.

The quality of water from the YCDC supply water is acceptable for daily potable use. However, the private owned tube well water is not all placed in acceptable levels. Yangon city ground water has a high content of iron, hardness, and high chloride level. It is noted that every respondent needs to have their water treatment for drinking purposes or to buy bottled water. As per the questionnaire survey, over 80% of the respondents are satisfied with the current water quality from the city water supply. About 62% of respondents are saying that existing water quality needs to improve for drinking water purposes.

The city water supply system is operating with a high level of non-revenue water, estimated at about 74.8%. The principal components for consideration in high NRW include - network leakage, customer pipe leakage, unrecorded consumption, free supplies, underassessment of use, meter under-registration, and operational use by WSS department (e.g. main flushing), etc. At present, YCDC does not collect information or evaluate any of these components individually, so it must be remembered that any calculation of NRW includes them and the contribution of any single element can only be presumed as the volume of actual leakage remains unknown. This study pointed out several factors affecting the high level of NRW in the city water supply's present situation, which are:

Age of pipeline: Over 50% of total water supply network was laid out over 50 years ago. These include cast iron, ductile iron, galvanized iron, polyvinyl chloride, mild steel and reinforced concrete. Most of these materials have suffered from degradation over time due to operational pressure, environmental conditions and general wear and tear. The result is increased leakage in the network.

Lack of meters in the network and on customer sites: There is no flow meter in any point of the network. For the customer's site, water meters are fitted in 23% of total number of 112,315 connected customers. During the questionnaire survey period in 2006, out of 151 households, 80 (53%) un-metered customers were willing to install water meters but 56 (37%) respondents did not want to install a water meter in any case because they said "we have time limit to get water and they do not believe meter reading practice." This may mean that there is a widespread distrust of the water authority.

Poor maintenance of network: The city water supply has been plagued by poor maintenance of its system. There is totally no material standard and pipe installation and joint fitting are given less attention in practice. The majority of joint material in the system is "Lead". This is changed periodically and the work is done manually. The performance team has minimal specialist tools and equipment. The water officials acknowledged that a large number of joints could be leaking at a low flow rate, i.e., most of the joints are leaking in even low flow pressure and water quality is unsaved. Leakage detection is the main responsibility of the leakage control and pipeline repair teams under the water distribution division of WSS department. These teams are organized with professional staff members from different areas of the organization on an ad-hoc basis. This arrangement is not conducive for the development of specialized skills and professional advancement of the relevant tasks. On the other hand, customers are responsible for maintenance and repair of pipeline, taps and other fittings of customer's service line accompanied by a licensed plumber hired by the YCDC customers.

Almost all households agreed that water is important for their daily lives and they are willing to take care of water leaking from their sources and their neighbors. The survey result showed that 86 % of respondent immediately repair local faults their own way. Very rarely do they inform YCDC staff for repairing the faults or leakages. The maintenance of YCDC water supply system thus seems to be weak and needs to control the specification of material standard used in the supply system, qualification of installation (qualify plumbers), and regular supervision to keep faults to a minimum. At present, the registered plumbers are 433 in Yangon; they are not enough to give service to customers in the whole City. These situations lead to a potential high risk for water leakage.

Customer use in the network supply area: There is a lot of leakage evident in service pipelines and wastage by customers due to customer's own installations is a subject in its own right. YCDC does not have direct control over the pipe work and fittings on the customer's site. Most people pay flat rate tariffs. There is no incentive to be careful about water use or waste. Besides, not all large users and commercial customers have meters. In reality, a big amount of consumption goes to large non-revenue or unaccounted for connections, which are probably institutional including military bases. YCDC policy is for all new connections to have water meters but the policy on metering of existing connection is not clear and not enforced.

Water tariff structure: The current water tariff structure does not reflect the cost recovery for supplying water throughout the whole city. The tariff structure should be based on people's willingness to pay and their affordability to pay for 24 hours water supply. A progressive rate structure will ensure that the poorer sector of the population can afford the services. One hundred and seventy six (86 %) of the respondents were satisfied with the current water price. But, even the low rate of water tariff in the City water supply, 7% of respondents said it was expensive and 4.8 % said it was above the right amount. Only 2.2% of respondents said it was cheap. The right design of the tariff structure will not only facilitate equity, for the poor will have access to the system as much as the rich (Ghooprasert, 1996). This would also encourage conservation and financial sufficiency of the department, if the average tariff is not lower than the real cost.

Lack of professionals, staff strength and training: WSS department posted total number of staff strength at 2,425 with salaries. Currently, the total permanent staff is 1,239 persons, including 182 professional engineers and 1,057 post of other ranks. Among them, only 78 persons have attended training courses. Most of the training courses involve clerical and administrative training. Professional training is inadequate while there is no syllabus on water supply engineering training. It is necessary to address the above concerns in an attempt to develop an effective training for technical staff of the department. There is no public training or education program.

Mixed nature of institutions and lack of coordination in the water supply sector: Although YCDC has the legal authority to supply water to the City, the present level of supply by this institution is hardly adequate for the entire population. Several other institutions and organizations are involved in the City water supply. It is essential that their work is coordinated in an effective manner. Coordination is an important tool to avoid work duplication, make use of available resources to the best, resource coordination and also to avoid any possible collusion among different players. At present, however, work coordination with other ministries and departments is occasionally undertaken leaving out several other ministries. WSS has no coordination arrangements with other institutions. These several institutions have several water supply system of their own in operation within the City. In the mean time, WSS is not involved in any coordination of water supply related work for non-governmental organizations in the study area. Even, the township staff have no knowledge of which organizations and agencies are working in their area and what water supply standards they bring into the City. Staff do not undertake inspection of work and the quality of hardware installed by other organizations particularly the other Ministries, organization and the NGOs.

Absence of definite policy: under the current arrangements, there is no definite control policy relating to NRW control planning and implementation. This reflects the overall network management situation, which can be characterized as a policy of 'firefighting'. There are some factors of leakage control included as part of the network operations like passive leakage control practice. There is no flow measurement policy and no attempt to evaluate NRW value is practiced.

On the contrary, if the city authority does not attempt to consider leakage control in the water supply, leaks will increase over time. This situation will get worse if there is no action or if leaks are left unattended. The high leakage level makes the situation worse in low network pressure areas. Poor services, low coverage mean that the city authority cannot afford the needs of demand and supply provisions as a result of loss of revenue in the institution. This appears to be a vicious cycle of NRW in Yangon city water supply management.

To clearly understand the situation of NRW in city's water supply system, the study used the last 5-year NRW value of City water supply (see in Table 4.53 and Figure 4.26).

Table 4.53: Estimated Average NRW per day Results during Year 2000-2006

Year	Total water production per day (m^3/day)	Total Billed water consumption per day (m^3/day)	Avg. Water Tariff	NRW value (%)
2000-01	340,000	138,504	7.26	59.3
2001-02	340,000	137,345	8.15	59.6
2002-03	340,000	132,948	10.25	60.9
2003-04	340,000	122,381	12.79	64.0
2004-05	340,000	126,943	13.16	62.7
2005-06	340,000	85,747	51.96	74.8

Sources: WSS and field survey results 2006

The NRW value is steadily increases every year. The value is in the order of 60 to 75 percent. It is not surprising that the level of NRW is higher and higher, because the network suffers from old pipes and poor installation practices, damage of fittings by poor material quality, very low pressure, lack of operation & maintenance and weak in investment on rehabilitation, and the absence of NRW control action.

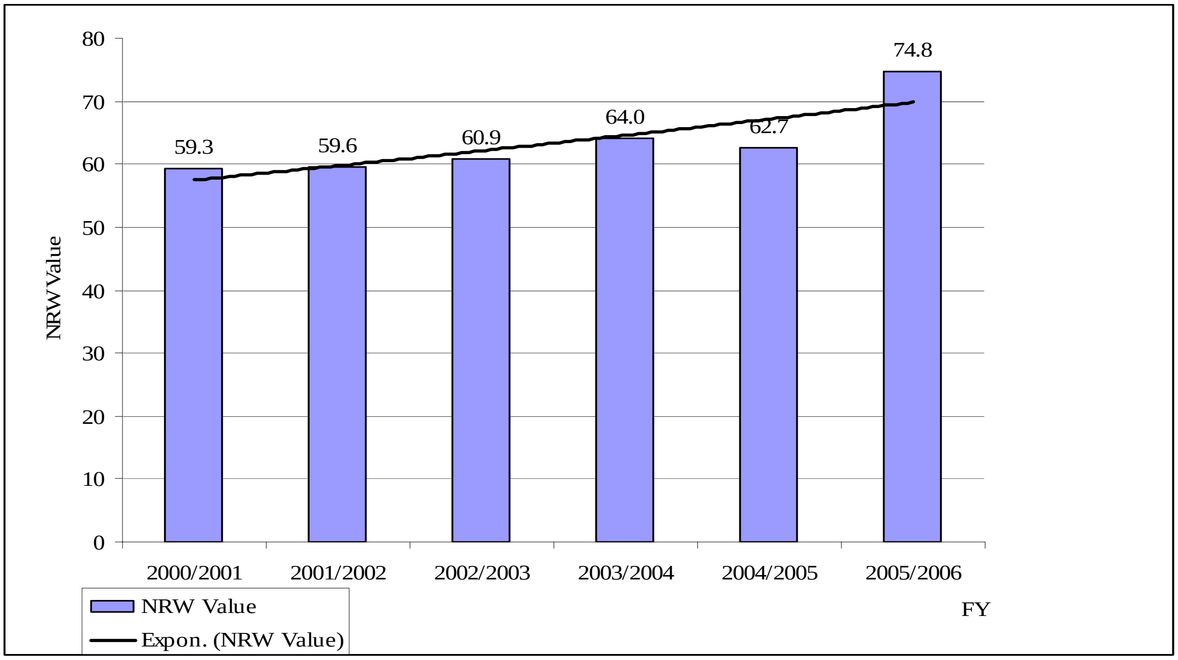


Figure 4.26: Illustration of NRW Trend in Yangon City Water Supply Management

The study suggested that reducing NRW has its role to play in improving the water supply system not only by increasing its financial strength but also by improving efficiency of water supply management for private benefits. The following calculation illustrates the role of NRW reduction in water supply system. This figures involved are based on considerations of operational expenditure and revenue of WSS department. Estimation of daily loss of revenue for WSS Department was calculated as follows for the financial year 2000-2001:

Water Expenditure per year = 59,000,000 Kyats/year

Water Expenditure per day = 161643.84 Kyats/day

Water Revenue per year = 366,980,000 Kyats/year

Water Revenue per day = 1005424.66 Kyats/day

While, NRW = 59.3% for 2000-2001 (See in Table 4.53)

Estimated water production = 340,000 m^3/day

Estimated water consumption = 138,380 m^3/day

Loss of Water Volume = 201,620 m^3/day

Average Tariff = 7.26 Kyats/m^3

Estimated daily loss of revenue = 1,462,861 Kyats/day (US$1,219/day)

Based on the above calculations, daily loss of revenue for the year 2001 to 2006 is shown in the following Table 4.54.

Table 4.54: Estimated Average Daily Loss of Revenue by NRW in FY 2000-2006

Year	NRW value (%)	Total Billed water consumption (m^3/day)	Total Loss of Water ((m^3/day)	Avg. Water Tariff (Kyats)	Total loss of Kyats/day	Total loss of US$/day
2000-01	59.3	138,504	201,496	7.26	1,462,861	1,219
2001-02	59.6	137,345	202,655	8.15	1,651,638	1,376
2002-03	60.9	132,948	207,052	10.25	2,122,283	1,768
2003-04	64.0	122,381	217,619	12.79	2,783,347	2,314
2004-05	62.7	126,943	213,057	13.16	2,803,830	2,336
2005-06	74.8	85,747	254,254	51.96	13,210,986	11,009

Note: 1US$ = 1200 Kyats, 2005-2006 market price

To analyze this situation carefully, the city water authority could distribute water to more than the currently served population if they reduced loss of water from the supply line. For instance, in FY 2005-2006, loss of revenue amounted to 13,210,986 Kyats (US$-11,009.15) which amounted to distribute water volume 254,254m^3 for 1,452,880 people (with average 175 lit/capita/day), if water supply system has no leakage at all. But, it is not possible to eliminate it at once. The City government monitored and operated water supply system should strive to keep the percentage of non-revenue for water (NRW) to below an average amount as in other developing countries, or like other neighbor Asian countries (e.g. NRW value 30 percent in Bangkok, Thailand) with long turn objectives. Therefore, YCDC should consider an economic approach to the supply and pricing of water. If the price of water reflects the full economic cost of it supply, past research studies clearly showed that efficient water allocation among competing users would occur (Environmental Protection Agency Queensland and Wide Bay Water, Manual 3, 2004). These economic costs are preferably derived from a triple bottom line accounting approach, incorporating the opportunity cost of foregone alternatives. The notion of reporting against the three components of economic, environmental and social performance is directly tied to the goal of sustainable development. If this approach is properly implemented in the institution, it will provide information to enable an organization to assess its long-term risks. For an organization to be sustainable, it must be financially secure, it must minimize negative environmental impacts, and it must act in conformity with society expectations. Triple bottom line reporting seems to be easier to talk about than to actually do. The difficulty is integrating the three dimensions. The consensus that the financial and economic aspects are best established first, followed by environmental with social bringing up the rear. However, such approaches imply moving towards a single set of accounts. For this moment, it is intended to aim for convergence, recognizing that different indicators will often need to be assessed in different ways, sometimes quantitative or sometimes qualitative. This study suggests that YCDC should set up the program based on Triple Bottom Line approach for controlling the current NRW in water supply system and make a concrete policy for implementing NRW control for sustainability of water supply in Yangon City.

CHAPTER 5

POTENTIAL IMPROVEMENT OF WATER SUPPLY SYSTEM MANAGEMENT IN YANGON CITY

Water Authority Perception for Improvement of Water Supply Management

Due to a combination of population pressure, city area expansion, economic growth and little upgrading over the years, the gap between needs and available water supply has become wider in Yangon. Neither the national nor the local government of Yangon has enough resources to meet these needs. Furthermore, current policies and management practices are not sustainable from the social, economic and environmental perspective. The city government does not have enough financial strength, lacks of technology development and human resources. The local private sector is also weak, lacks of opportunities and financial strength to fill the gap. With this situation, the City Government is trying to make the strategic plan for the development of urban water supply system by reducing NRW for future water supply system management in Yangon.

Strategy for NRW Control Initiatives in Yangon

The recent NRW is high, approximately (74.8 %), which remains one of the major challenges facing water utility in Yangon City just like in other developing countries. The current development in the region raises some prospects in this regard. For example, most of the major Asian cities, including Yangon, have experienced in water crisis. International development and financial organizations have also become more active in the urban view. They are relentlessly pushing the agenda of demand management for improving NRW reduction and sustainability of water in the urban water supply management. The City water authority made the starting point for the strategy that will need to be implemented in order to achieve the ambitious targets of future water supply and demand by year 2020. The target for NRW control must be reduced by 50% of current NRW ratio in the year 2020 in Yangon City's water supply management. The principles of the directions to be followed to achieve this target are:

a. Find and repair the leakage to reduce physical losses
b. Meter for all customers
c. Pay special attention to larger use customers
d. All Maps, network data, customer information and records should be kept in good order and regularly updated
e. Investigate and rectify problems and relevant issues and
f. Divide the network into metered areas, to provide information and enable leak data work to be prioritized

The strategy also includes:

a. Major programs of rehabilitation and new work to reduce and avoid recurrence of leaks
    - specification of good material,
    - specification of good installation standards,
    - best practice design and network layout
b. Policy reviews and action to create the right conditions including:
    - tariff structure to encourage savings and waste reduction,
    - by-laws, regulations and standards for customer connections, and
    - Rapid achievement of Universal customer metering

An Action plan for the above long-term strategy was made as follows:

a. Operational action plan

- Implement NRW control measures for physical losses and non-physical losses
- Create a special NRW team for this work
- Improve the mapping system and network data
- Actively search for leaks and improve pipe repairs
- Divide the network into zones and districts

b. Metering and billing action plan

- Prepare and implement a plan to achieve universal customer metering
- Review and modify tariff policy

Water Resources Potential for City Water Supply System

The water resource potential and future water estimation needs to be investigated before a strategy for NRW control can be developed and implemented.

Table 5.1 showed the existing water supply capacity by each source. Currently, 439,440m^3 per day (96.7 MGD) which come from both surface water and ground water input to the city water supply system.

Table 5.1: Current Water Sources and Its Water Capacity for City Water Supply

Source of Water	**m^3/day**	**m^3/day**
Surface Water		395,550
• Gyobyu Reservoir	118,200	
• Phygyi Reservoir	245,400	
• Hlawga Reservoir	75,000	
Ground Water		43,890
Total		439,440

Source: WSS Head office 2005

Newly constructed Ngamoeyeik reservoir plans to supply up to 90 million gallons per day (409,146 m^3 per day) to city dwellers. At present, phase one water treatment project from Ngamoeyeik reservoir has been distributing 30 million gallons per day (136,382 m^3 per day) since October 2005. Second phase water treatment project for Ngamoeyeik reservoir is in an on going process.

In addition, there are two surface water sources potential for future water supply development. They are flowing into the city boundary, namely Bago River and Hlaing River. The prospects for Hlaing River as a future source of water is better compared to Bago River because water from Bago River is difficult to tap with zero cubic meter per second in drought season. City authority considered Hlaing River as a future source of water supply. Hlaing River flow is 11.4 m^3 per second and river water is obtainable through out the year (Tun, 2005). City authorities said Hlaing River water treatment plant would be built for future water supply (field survey 2006). Carefully consider that Yangon city is blessed with natural water resources but there is not well blessed of sources for water supply. City authority (YCDC) should consider the leakage factor due to old supply system and technical constraints in water supply system management.

Future Water Demand Estimation

Based on water consumption data, population projection, and future estimation on industries and commercial sector (YCDC, 2000), the following water demand estimation was calculated in the YCDC strategy for improvement of water supply management.

In this estimation, the following factors were used. Per capita consumption for the target year 2020 is set to 200 lpcd (liter per capita per day). For the domestic water users, per capita consumption applied for different years is 140 lpcd at FY2000, 150 lpcd at FY 2005, 170 lpcd at FY2010, 190 lpcd at FY 2015 and 200 lpcd at FY 2020.

For the Department customers, the current ratio (except large users) to domestic customers was (7%) and the larger users (as per present actual value, FY 2000) were used. For commercial and industrial customers, it was planned to use the current ratio to domestic customers (8%) and the conversion factor (2.12). Thus, the 17% of ratio to domestic customer was applied for future demand estimation. For the nine industrial Zone (include 7 existing and 2 planned), the water demand is estimated using built up ratio (using plot number in the Industry zones) and consumer surveys result (average water use for industry: 598 m^3/month/company) are shown in appendix D, Table 11.

Table 5.2: Estimation of Water Demand for FY 2000-2020

Year				**2000**	**2005**	**2010**	**2015**	**2020**
Total Population			persons	3,887,000	4,403,000	4,955,000	5,541,000	6,159,000
Service Ratio			%	37	50	60	65	70
Service Population			persons	1,443,441	2,201,500	2,973,000	3,601,650	4,311,300
Daily Average Consumption	Domestic	Per capita	lpcd	140	150	170	190	200
		Total	m^3/day	202,703	330,225	505,410	684,314	862,260
	Department	Total	m^3/day	46,480	63,838	76,101	88,624	101,080
	Com. & Ind.	C. & I.	m^3/day	7,123	56,138	85,920	116,333	146,584
		Industrial Zones	m^3/day	0	44,930	65,581	81,467	85,532
		Total	m^3/day	7,123	101,068	151,501	197,738	232,116
	Total		m^3/day	256,206	495,131	733,012	970,738	1,195,456
Leakage	Ratio		%	50	45	40	35	25
	Amount		m^3/day	256,306	405,107	488,675	522,705	398,485
Daily Average Demand			m^3/day	512,612	900,238	1,221,687	1,493,443	1,593,941
Daily Average Demand per capita			lpcd	355	409	411	415	370
Daily Maximum Demand			m^3/day	615,134	1,080,286	1,466,024	1,792,131	1,912,729
Daily Maximum Demand per capita			lpcd	426	491	493	498	444

Source: Tun, 2005

As can be seen in the table, the goal for city authority's initiated strategic plan is as follows:

a) Seventy (70) % of service ratio is recommended at the target year, which is about twice as much as the existing one (37%).

b) Current leakage ratio is considered as 50%, which will be reduced to half 25 % at the target year.

c) As a result, the total demand in the target year 2020 becomes 1,912,700 m^3 per day, which is about 3 times than the FY 2000 demand (615,134 m^3 per day).

However, NRW ratio in current water supply system is higher than the estimated NRW ratio at FY 2000. Implementing NRW reduction for water sustainability is not an easy task for Yangon City. NRW control programs are engaged to create economic, financial and political functions. The city government needs to be further empowered to facilitate such activities. The national government needs to create a concrete water sustainable policy that is conducive to private sector partnership in infrastructure development and encourage private sector involvement in NRW reduction plan.

In reality, consumers are the main beneficiaries of successful management but they are often disregarded in the planning process. Public participation means the cooperation between consumer population and governing authorities. To reach positive effects, education and capacity building should be done with a bottom-up-approach (Gleick, 2002).

Therefore, a clear understanding is needed of consumer requirements, their practices, interests and City authority's efforts on water supply system. In a series of interviews conducted in the study area, the officials realized that there are ambiguities in government policies in this regard. They think NRW control on demand management will increase in the future. Also, more than three fifth of the interviewed consumers said they would be interested in participating in water supply management, specifically in paying water tariff, taking care of water leakage and obey laws and regulations related to water and environmental concerns. Detailed discussions of consumer survey results are presented in detail below.

People's Perception of Future Improvement for Water Supply Management in Yangon

Socio-Economic Characteristics of Respondents

The overall mean age range was 40-60 years old. The relatively high mean ages can be explained by the way in which preferred respondents were selected, i.e., heads of families or respondents who were at least 18 years old.

The gender ratio in overall respondents figure shows that 41% (122) of respondents were male while 59% (173) were female. The sex ratio for the Yangon City was 98 males for every 100 females (CSO, 2005).

The data regarding educational attainment showed that most of the respondents had attended school. Only 10 (3.4%) respondents went to elementary school, 16 (5.4%) respondents went to secondary school. Some 50 (16.9%) had finished high school, and 106 (35.9%) had reached college level, and 111 (37.6%) had graduated. Very few respondents 2 (0.7%) had higher education as Ph.D. level.

The high proportion of respondents employed in the private sector 133 (45.1%), while respondents employed in government sector were 37 (12.5%). Thirty-one (10.5%)

were retired. Fifty-seven (19.3%) respondents who met the minimum age eighteen years old were students. The remaining respondents were housekeepers 35 (12%) and two (0.7%) respondents were dependents. They are mostly unemployed people often at home, who are at the minimum age of eighteen years, and they are available for interview.

The mean household size for this study was 5.29 persons. Maximum household size was 5.79 persons and minimum household size was 5.26 persons. One or two household members were employed in each household for their household income. Two hundred and twenty five (76.3%) of respondent's income was between Kyats 100,001 and 200,000 per month (US$83.33 – 166.67) (See Appendix D, Table 12).

The average household's overall expenditure is 114,881 Kyats (US$95.73) per month, while the average expenditure for utilities is 28,763Kyats (US$23.97) per month. Two hundred and two (68.4%) of respondents live in their own houses or apartment. The rest 93 (31.6%) live in rented houses or apartments. Detail survey result was shown in Appendix D, Table 13.

The socio-economic characteristic of the respondents summarized in Table 5.3.

Table 5.3: Socio-economic Characteristic of Respondents

Variables	Categories	Frequency	%
Gender	Male	122	41.4
	Female	173	58.6
Age	18-20	25	8.5
	21-40	71	24.1
	41-60	118	40.0
	Above 60	81	27.5
Education attainment	None	0	0
	Elementary school	10	3.4
	Secondary school	16	5.4
	High school	50	16.9
	College school	106	35.9
	Graduated	111	37.6
	Higher education	2	0.7
Occupation	Government sector	37	12.5
	Private sector	133	45.1
	Retired	31	10.5
	Housekeeper	35	11.9
	Student	57	19.3
	Dependent	2	0.7
Household size	Mean overall household size	5.29	
	YCDC water users with meter	5.79	24.4
	YCDC water users with un-meter	5.26	43.1
	Non-YCDC water users	5.28	32.5
House Ownership	Independent house: Owned	91	30.8
	Rented	22	7.5
	Apartment: Owned	111	37.6
	Rented	71	24.1
Monthly income	<100,000	41	13.9
	100,0001-200,000	225	76.3
	>200,001	29	9.8
Monthly expenditure for utilities	Mean expenditure for utilities	23,357	
	Minimum	<10,000	
	Maximum	60,000	
Monthly average household expenditure	Mean expenditure 120,001-140,000	126,238	
	Minimum	40,001	
	Maximum	>200,000	

Source: Field survey 2006

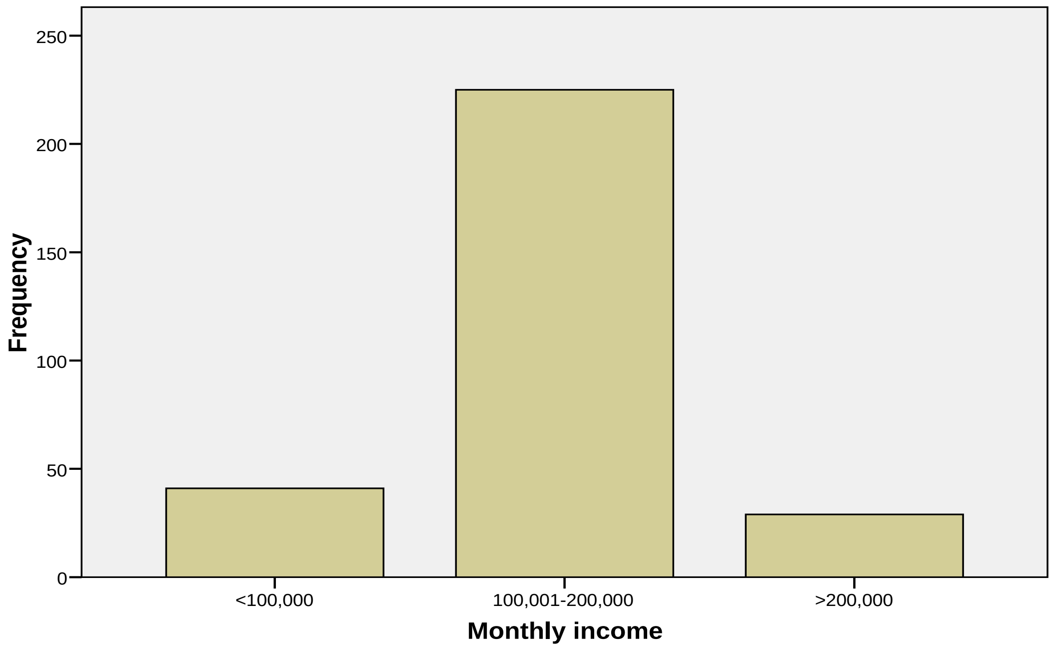


Figure 5.1: Histogram of Household Income

According to 2001 Household Income and Expenditure Survey, the estimated average monthly overall expenditure was 21,763 Kyats per household (US$21.76). If the value is adjusted to the present value in 2005 using the consumer price index (430.56 on March in 2005 based on the year 2001), the average expenditure becomes 46,074.56 Kyats (US$38.40). The average household's overall expenditure range is 126,238 Kyats (US$105.20) of this survey result, it was (1.7) times higher than the 2001 survey result. If the previous result is assumed to be correct, it indicates that this survey selected higher expenditure households or higher income households. Figure 5.1 showed the histograms of household incomes and Figure 5.2 showed household overall expenditures. The highest frequency range of the income is 100,001- 200,000 Kyats. In a typical frequency curve of household income, the curve is inverted 'U' shape (see Figure 5.1). It clearly showed that majority of those selected in this survey were middle-income households.

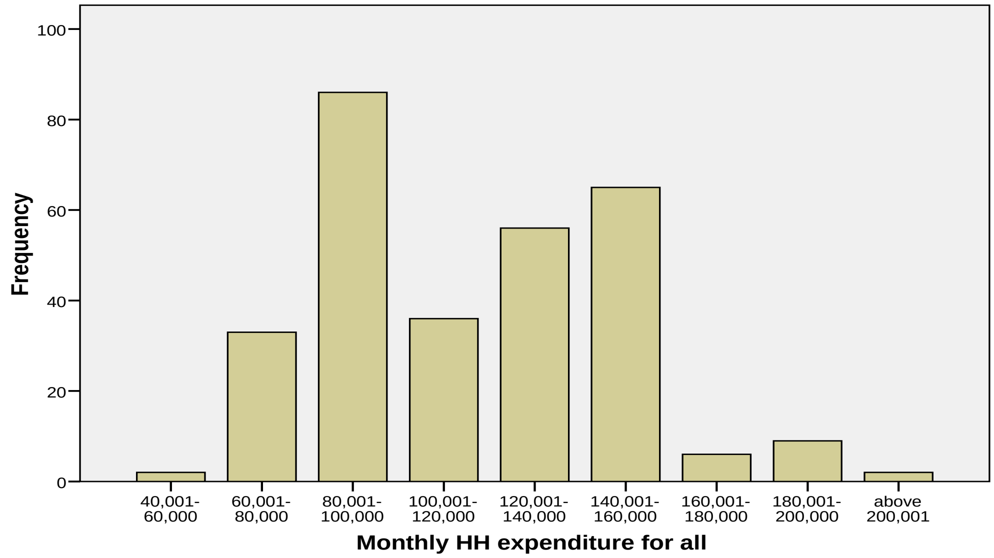


Figure 5.2: Histogram of Household's Overall Expenditure

The average utilities expenditure was 28,763 Kyats (US$23.97) which included waste water disposal fee, solid waste disposal, gas for cooking, electricity, fuel for cooking and lighting, telephone and water cost. Electricity is the highest one for utilities expense in all households. Figure 5.3, 5.4 and Appendix D, Table 15 presented the average composition of the expenditure for utilities per household in the study area. The comparison of household average monthly expenditure was shown in Appendix D, Table 14.

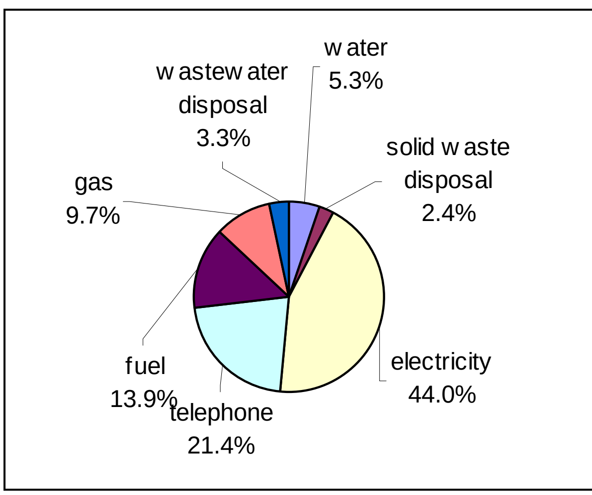


Figure 5.3: Average Expenditure for Utilities (YCDC customers)

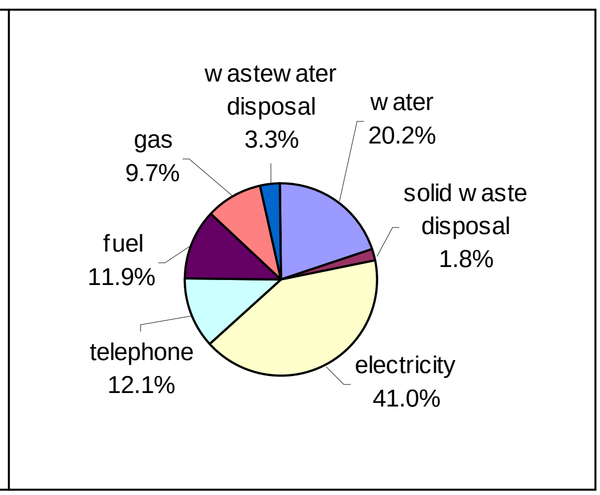


Figure 5.4: Average Expenditure for Utilities (Non-YCDC customers)

These two figures show that the expenditure for water was 5.3% and 20.2% of total household utilities expenditure in YCDC customers and non-YCDC customers respectively. The water expenditure for non-YCDC customer is 3.8 times higher than the water expenditure for YCDC customer due to high cost of water from private water vendor. Water price in case of private water vendor were shown in Table 5.4.

Table 5.4: Water Price in Case of Water Vendor Using Water Cart

Description	Figure
Water volume packed in a drum	50 gallons or 227 liters or o.227 m^3
Water price per drum	200-300 Kyats or US$0.2-0.25 (in average)
Average water volume consumed/month	5,279 gallon or 24 m^3 per month (in average)
Total amount of expenditure/month	31,674 Kyats /hh/month
Unit price of water	1320 kyats/ m^3

Source: field survey 2006

In practice, non-YCDC water customers obtain water from several sources. Among private water sources, prices of private water vendor using water cart is the highest one. There is no systematic way to get water except from water vendors using water cart. The people must take water from water cart vendors at a rate of 1,320 Kyats/m^3. Therefore, this amount should be assumed as the upper limit of willingness of people to pay for getting water.

Awareness of Improvement in Water Supply Management

Among other things, the study sought to evaluate the levels of awareness of improvement in water supply management with "knowing current water bylaws, regulation and penalties" promulgated by City authority. Willingness to participate and pay for improvement of water supply service was also conducted. Out of the total number 295 respondents, only 18% knew current water related bylaws, regulation and penalties (see

Table 5.5). This lack of awareness was slightly higher non-YCDC customers than YCDC customers (86% and 81% respectively). Eighty-six (86%) of respondents knew about the role of water leakage in ensuring water supply sustainability.

Table 5.5: Knowledge of Current Water Bylaws, Regulations and Penalties

Total Respondents	Knowing current water bylaws, regulation and penalties	
	Know	Does not know
(205) YCDC respondents	39 (19%)	166 (81%)
(90) non-YCDC respondents	13 (14%)	77 (86%)
(295) Total respondents	52 (18%)	243 (82%)

Sources: Field Survey 2006

Based on the above results, the study wants to reveal some causes of illegal activities in the institution. For instance, current penalties are very costly. If people want to access supply water facilities, they have to pay only 5,300 Kyats (US$4.42) including a permit to install pump, which is cheaper than penalty 85,000 Kyats. Why are people connecting supply water illegally? Because of lack of knowledge on current water related bylaws, regulation and penalties or people want to use water without paying charges. For instance, when the staff found an illegal water connection, they sometimes charge according to current penalty provisions and sometime they negotiate with illegal connectors instead of warning them on illegal activities and giving educational awareness or information. This is of course one kind of corruption in water supply projects. Water authority should promote water related education, knowledge and awareness programs for both staff and water customers.

In contrast, the survey conducted people's willingness to pay and to participate in improvement of water supply service and water related activities. The result shows that above 50% of the respondents were interested in improvement of water supply, particularly, 60% of respondents interested in paying water tariff regularly. Concern over people's participation in water related activities, 56% of respondents are interested in activities for reducing water usage and wastage, 57% said they will take care for running water away or water leakage, 58% said they obey laws and regulations and 43% said they want to participate in the movement for water related activities. Only 12% acknowledged the important role of sharing information and knowledge for improvement of water supply and sanitation projects. Of those consumers interested in participating in the improvement of water supply service, the results are shown in Table 5.6 consumers' preferences for elements of the improvement of water supply system and their interests. Almost all consumers said that they eagerly want to obtain regular clean water supply for 24 hours from City water supply service.

Besides, this survey result shows that consumers are more interested in individual activities rather than group related activities. It might be due to some situational difficulties (e.g. politic, economic) or lack of knowledge in this field.

Table 5.6: Way of Willingness to Participate in the Process of Improve Water Supply Services

Category	Ew	Ww	Nw	Sw	Total	%
Total number of survey respondents	95	95	91	83	364	100.00
Total number of analysis respondents	77	78	80	60	295	81.04
	Frequency					%
Paying water tariff regularly	58	41	37	40	176	59.66
Reducing water usage and wastage	50	40	38	38	172	56.27
Taking care of running water away	55	35	34	45	169	57.29
Obey laws and regulations	51	37	40	42	170	57.63
Participate in movement of water related activities	38	42	27	21	128	43.39
Sharing information and knowledge	7	9	12	7	35	11.86
Others	3	1	-	2	6	2.03

Source: Field survey 2006

People's Willingness to Pay for the Improvement of Water Supply Services

So far, households who do not have YCDC water supply service are more willing to pay for 24 hours clean water supply than the YCDC water customers are. Figure 5.5, Table 5.7 shows the amount of willingness to pay for 24 hours' clean water supply by YCDC customers and when compared with Figure 5.6, Table 5.8 shows the amount of willingness of people pay for 24hours' clean water supply from YCDC service by non YCDC water users.

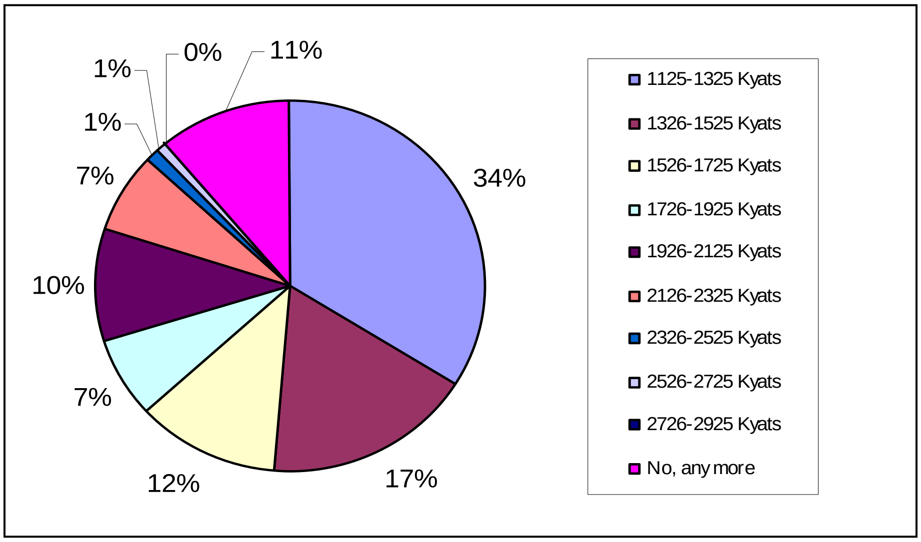


Figure 5.5: WTP for 24 hours Clean Water Supply (Kyats/month) by YCDC Customers

Table 5.7: WTP for 24 hours Clean Water Supply by YCDC Customers

Amount of WTP (Kyats/month)	Number of Respondents (f)	Percentage (%)
1125-1325	70	34
1326-1525	35	17
1526-1725	25	12
1726-1925	14	7
1926-2125	21	10
2126-2325	14	7
2326-2525	2	1
2526-2725	2	1
2726-2925	-	-
No, any more	22	11
Total	205	100

Source: Field survey, 2006

Table 5.7 shows the result of WTP by YCDC customers. Among YCDC customers, 22 (11%) said “No, no more” to pay more for current YCDC water supply services. The rest 183 (89%) respondents said they willing to pay more for improvement of WSS and get clean water supply. The above Table 5.7 shows the minimum amount (1,125 to 1,325 Kyats per month or US$0.94-US$1.10 per month) they were willing to pay for improvement of water supply service. Maximum amount they were willing to pay was if the amount was between 2526 and 2925 Kyats per month (US$2.11-US$2.44 per month). Therefore, mean willingness to pay for improvement of clean water supply by YCDC customers was 1,560.83 Kyats per month (US$1.30 per month).

Figure 5.6, Table 5.8 shows the amount of willingness of people pay for 24 hours' clean water supply from YCDC service pipeline by non-YCDC water users.

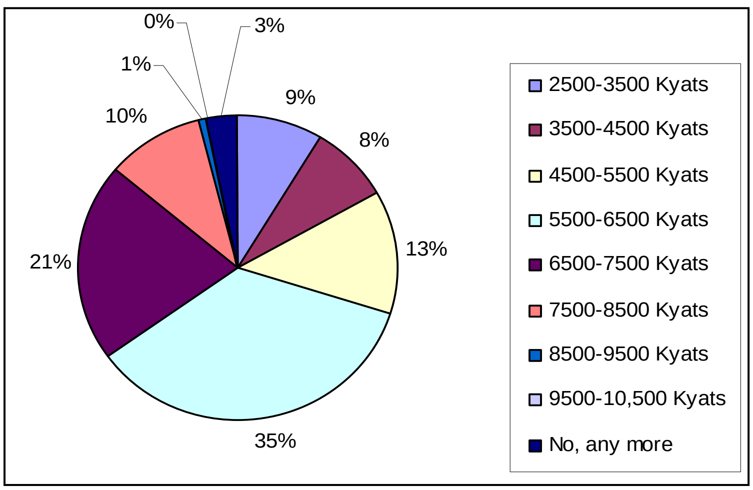


Figure 5.6: WTP for 24 hours Clean Water Supply (Kyats/month) by Non-YCDC Customers

Table 5.8: WTP for 24 hours Clean Water Supply by Non-YCDC Customers

Amount of WTP (Kyats/month)	Number of Respondents (f)	Percentage (%)
2500-3500	8	9
3501-4500	7	8
4501-5500	12	13
5501-6500	31	35
6501-7500	19	21
7501-8500	9	10
8501-9500	1	1
9501-10,500	-	-
No, any more	3	3
Total	90	100

Source: Field Survey, 2006

Out of 90 non-YCDC customers, only 3 (3%) do not want to pay any more for getting clean water supply because they have private own tube-well and water quality from their own tube-well is acceptable. They do not want to connect YCDC water supply pipe. The rest 97% of respondents were willing to pay more for getting YCDC clean supply water. The minimum amount they were willing to pay was 2,500-3,500 Kyats per month (US$2.08 – US$2.92 per month) and amount of maximum willingness to pay was 8,501-9,500 Kyats per month (US$7.08 – US$7.92 per month). Therefore, mean willingness to pay for improvement of clean water supply by non-YCDC customers was 5,885.51 Kyats per month (US$4.90 per month).

These two results reveal the willingness to pay for clean water. Non-YCDC water customers is willing to pay more than YCDC water customers due to the ground water quality in Yangon city is high iron and hardness concentration or high water price or localism. Anyhow, this result clearly showed that people are willing to connect YCDC clean water supply service.

Summary of Findings

This section summarizes the policies required for potential improvement of water supply management in Yangon City based on the above survey results as follows:

1. Most of the residents in Yangon are educated and work in the private sector. Average household size is 5.29 persons per household. People are living in their own apartment or independent house. Their average income is 100,001-200,000 Kyats per month.
2. The respondent's daily water consumption averages 189 liter per day (34 m^3/ household/ month) for YCDC water users and 133 liter per day (24 m^3/household/ month) for non-YCDC water users. This survey result shows the needs for installing water meters to control water consumption but it should be accurate customers believe and there should be a regular water supply system for YCDC water users.
3. The analysis of water consumption in this survey is not clearly identified for the future water demand but it can be estimated for the future water supply.
4. Yangon residents are willing to pay more for the improvement of the water supply services. Over 60 % from 295 respondents expressed their willing to pay for the improvement of water supply in the study. The highest amount is 8,500 Kyats per month (US$7.08 per month) and the lowest amount is 1,125 Kyats per month (US$0.94 per month). The range of their willingness to pay for getting clean water is too high. The highest amount may be insignificant to some water users, but substantial to others. There is a need to study and identify the right amount of water prices. The survey result showed that non-YCDC water users (62%) want to connect YCDC water supply service. They are willing to pay more than YCDC customers do and willing to participate in water related activities.

5. Out of 295 respondents, 127 (43%) respondents are willing to participate in the movement of water related activities and 32 (11%) of respondents, they want to share their knowledge and information to other. Besides, only 52 (18%) respondents, they know about water related laws, and regulations. The results show that there is a need to promote water related knowledge, training, advertisement, education and information.

6. Despite many weaknesses in government policy, the city government has placed a strategic plan for sustaining water supply management. The study suggest that city government should provide leadership, commitment and a focus on principle to direct an effective water sector development process in making policies which create alternative conditions such as limited private participation. In order to achieve water sustainability in Yangon City, the City and the Central Governments need to tap the possible opportunities for resource development. That is not easy, but the findings presented in this research indicate, it is the most preferable approach. Imaginative forms of participation with city government's involvement will have mutual benefits for both the city government and the residents.

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

This chapter discusses the conclusion, policy implications and recommendations for better management of the water supply system and water sustainability in urban area of Yangon city.

Synthesis of the Research

In recent years, one of the major issues affecting water utilities in many developing countries is the non-revenue water (NRW). NRW is an important determinant for water institutional economy as well as the growth of water sustainability in several developing countries. With rapid urbanization in these countries, existing water supply services have been unable to cope with the increased demand for water arising from growing population and rapid economic growth. For instance, due to high levels of NRW in these countries, water utility accounts reflect huge volumes of water being lost through leaks, not being invoiced to customers or both.

Although NRW is a well-researched field of study and research on water sustainability has also been growing in recent years, the nature of the link between NRW and water sustainability in developing countries has not yet been systematically studied. The environmental impacts (both positive and negative) on water resources caused by deterioration of water supply systems and a high level of NRW in city water supply management have not been adequately investigated. Most studies on the NRW discuss only the economic issues as to whether NRW control is more economically viable.

In this regard, some key questions were coming up: "What is NRW in the present Yangon City water supply system? Why is there needed to investigate NRW in Yangon? Which water institution is doing water sustainability in Yangon City water supply system? And what is the people's perception of the city water supply system and their interests? This dissertation attempted to answer these questions through a case study on the current nature of utilization of water supply in selected four (4) townships and directing people's perception for improving water supply in Yangon City. As a former capital city in a typical developing country, Yangon has significance for such a study. Just as many other cities in developing countries, city population is increasing rapidly and likely to increase even faster in the future. With increasing population, there is a widening gap between the provision of water supply services and people's needs. Yangon is also an interesting case study area because there has been an increase in its population and its economic activities. The trend is still rising in the future. In order to conduct this study, a conceptual framework was developed.

Extensive fieldwork over a period of several months in 2006-2007 was conducted for primary and secondary data collection. A wide variety of secondary data was also collected throughout the duration of this research study. The obtained data were then used to analyze the current and potential role of water supply improvement and for recommending policies to reduce NRW in water supply management so that the improvement of water supply management becomes achievable.

The main objective of this study has been identified:

- To investigate NRW for water sustainability in the water supply system to meet current and future water needs in Yangon City, and

- To provide needs of vital water resources data and the experience of other countries in reducing NRW management of implementing water supply management for future development objectives in Yangon.

Specific objectives were also set out for this research (see-Chapter 1, Section 1.5).

The above noted objectives were addressed in the following order. After the introduction, a critical review of the literature relating to the two main themes of this dissertation was carried out. The literature review was followed by a detailed layout of the research methodology, in particular the field survey conducted. The account of methodology was followed by an in-depth analysis of NRW in the water supply management issues of Yangon. Finally, this study was carried out by using findings from survey data and from the secondary data sources.

The literature review covered publications on water sustainability and NRW management. This review elaborated on the magnitude of NRW, conceptual issues, benefits of NRW control and possible methods. It also examined the possible ways of NRW control for water supply projects and then explored modes, mechanisms on case studies in cities of developing countries to draw lessons from successful cases. In addition, it examined the nature of sustainable water management, challenging task of water supply privatization and possible way for attractive in situations where the government has decided to keep the water utility under public management, but is looking for ways to capitalize on the technical expertise and potential efficiency of the private sector.

Following the literature review, the background of study area, an overview of the water supply system, and it related regulatory frameworks and institutional setting, then estimate the NRW value for water supply system in Yangon City. As a part of this overview, it also included the basic facts and figures on water supply infrastructure and services situation in the city. This was followed by an analysis of the consumer survey on people's perception and willingness to pay for the improvement of water supply infrastructure and making policy recommendations for improving city water supply management. The investigation of the current and potential use of YCDC water users and non-YCDC water users in the city water supply system covered the following:

a) Investigate sources of water, usage and supply situation
b) Check on water supply condition and people's perception
c) Examine water demand condition
d) Satisfaction of water cost and billing
e) Observe awareness on improvement of water supply by willingness to pay and participation of water users

A brief account of the conclusion and policy recommendation for this research investigation is presented in the following section.

Conclusion

Recently, NRW value has exacerbated in the Yangon City. The evidence of analysis of the extent to which the estimation of NRW value in recent years have been responsible for the deterioration of water supply system and water supply management problem, contained in chapter 4, suggests the urgent need of a leakage control program for management of water sustainability.

The population in Yangon is now over 3.8millions, which does not include the floating population. By population projection of JICA study team 2002, Yangon population will reach over 6 million in the year 2020. Water demand will also annually increase with growing population. The existing water supply system and management cannot afford to meet water demand needs to all citizens due to low priority in assigning resources to this area. Based on survey results and observation the study concludes as follows:

1) Existing Water Supply System

The study summarizes that the current water supply serves 37% of the total population with average 173 liters per capita per day consumption. Generally, the water quality seems to be good but most of the services areas have very low pressures even in areas with so called 'relatively good pressure' and large areas have intermittent supplies. The efficiency level for the water supply system was exposed by an NRW value of about (74.8 %) reflecting use of public taps and only 23% metering of customers out of total 112,355 connections.

The network pipes are aging. Over 50% of the network has pipes more than 50 years old, 80% of the network is cast iron and most of the joints are leak prone from lead caulked joints. Network data is out of date and incomplete so even the schematic diagrams do not accurately indicate the situation of the network in the ground. There is a lack of operational maintenance resources and lot of leakage on service pipes due to long service pipe lines, and the customer is responsible for the repair of his/her own service line directed from the YCDC main distribution pipe.

2) Water Supply Institution

Institutional analysis in Chapter 4 showed that the current water supply organization does not have a vision statement to guide its own operations, in spite of the fact that WSS is entrusted with planning and implementation of an important service for the City. There are no goals of any kind set out for accomplishment during a specified time at present. Some areas among several others where goal setting and development of strategies would be relevant in the present context are:

a) Provide water connections to the majority of city dwellers

b) Conversion of flat rate connections to metered connections

c) Revenue enhancement based on proper targets

d) Staff training

e) Reduction of loss of water supplied through the pipe network

f) Increase water production to supply the entire population

Furthermore, there is no formal policy document outlining the main objectives of the organization. Some areas where a coherent policy is lacking include overall policy regarding water supply connection, meters installation, coordination of water supply work, water supply planning and improvement, and almost all other issues pertaining to this department's role. Specifically, there is no definite policy for controlling NRW planning and implementation. This reflects the overall network management situation. Passive leakage control is in the practice. The technical standards relating to connections and the extent to which they are enforced are important considerations. The functions of division/sections are not specified within the water supply department, which in many cases are in the minds of senior staff rather than on paper.

3) Non-Revenue Water (NRW) Condition and Water Sustainability

The result of NRW in Yangon City water supply is as high as 74.8%. The estimated NRW ratio goes higher and higher from 59% to 74.8% during the past half decade. The tariff rate was raised from 4.4 Kyats per m^3 to 55 Kyats per m^3 (US$0.0033 to US$0.05 per m^3) for domestic customers and departmental customers, and 29.7 Kyats per m^3 to 77 Kyats per m^3 (US$0.03 to 0.06 per m^3) for commercial and industries during the last 5 years period. The increasing total annual loss of revenue from water is US$444,953 in year 2000-2001 to US$4,018,341 in year 2005-2006. The result showed that there is a 9-fold increase in the loss of revenue from water during the last 5-year period. The production amount (340,000m^3 per day) has remained unchanged, and the service coverage is about 37 %. But, total population trend in the City is increasing. The water consumption is also rising dramatically. There is a plan to increase city water supply in 2005-2006. According to this plan with the construction of the Ngamoeyeik water treatment plant in October 2005, the City authority can supply 30million gallons per day (136,000m^3 per day) to City dwellers. At the same time, ground water extraction from city dwellers is increasing with private own tube/dug-well but the controlling ground water policy is not sufficient at present. There are several groundwater problems in terms of quality, quantity and environmental problems. Land subsidence as a serious groundwater environmental problem in the city urban area caused by groundwater over exploitation has not been reported (JICA, 2001). Aside from this problem, several water quality problems are reported which are saline water intrusion, brackish water and high iron concentration, etc. Therefore, the survey result are clearly shown in the following curve was drawn for the conclusion of this research study. The city authority should consider these for the future of water sustainability in the urban area of Yangon City.

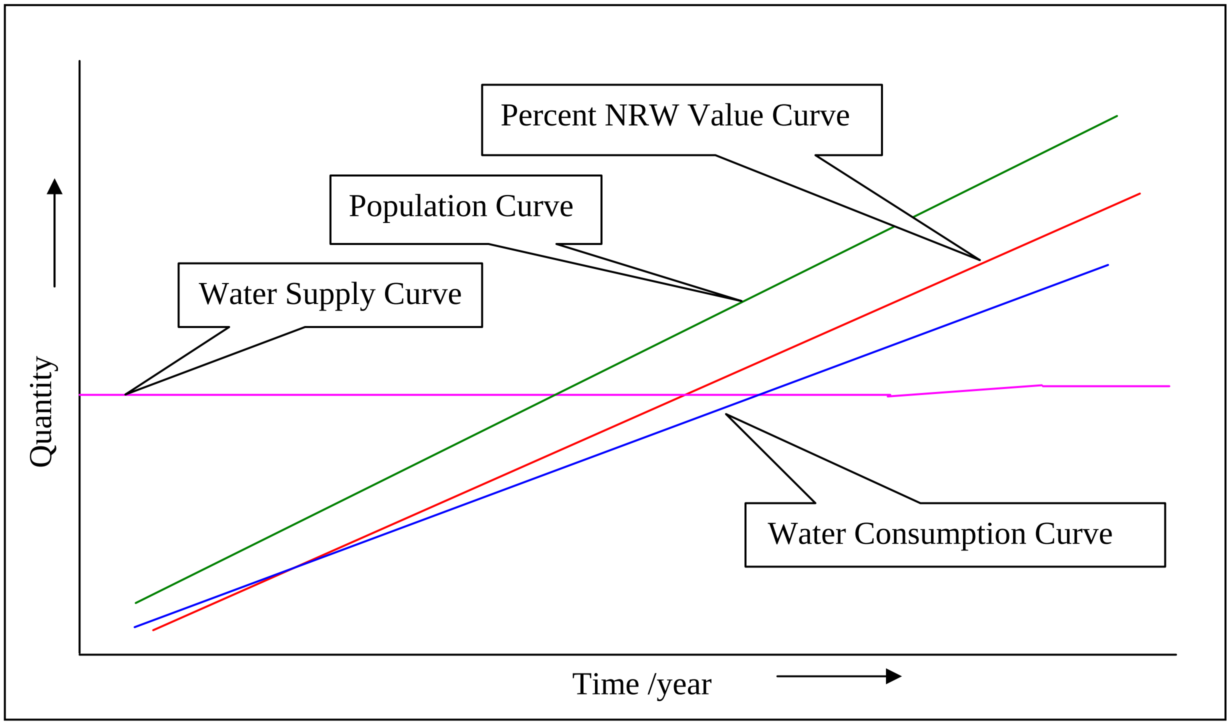


Figure 6.1: Survey Result of Existing Water Supply System Situation in Yangon City

4) Potential Issues for Improvement of Water Supply System Management

The analysis of consumer survey on domestic customers showed that almost all respondents want to connect City water supply service and are willing to pay for improvement of water supply services and willing to participate in the movement of water related activities. There is, however, no improvement of current water supply infrastructure project. Only one project has been invested in the new water reservoir project for city water supply source in Yangon. Very few old age pipes are rehabilitated in some parts of the City water supply. But, even if the water supply services have no new material provision, the potential use of water supply service in Yangon City remains an attractive destination of water supply.

In view of the severe shortage and deficiencies in the City water supply system, the City Governments have developed strategic plans for the improvement of water supply system in the city. The financial burden is heavy for the Yangon City Government because there is no financial support from Central Government subsidies and the local budget is also extremely inadequate to meet the financial needs for improvement of water supply system. The present system has created an odd situation, violation of bylaws, regulations, penalty, and standard of material. This situation also contributes to revenue losses. There is 74.8 % NRW. High level of NRW can be a cause for high losses of revenue in city water institutions. Therefore, Yangon City authority has started to consider reducing non-revenue water programs in their strategic plan. However, the present non-revenue water reducing program in Yangon is still new and weak, and does not have enough financial resources, technical capabilities, management expertise and monitoring capability for the complex nature of urban environmental management. The City authority has no scheme for reducing NRW implementation in water supply project due to political interference. In this situation, NRW has continued to increase.

It could be argued in another way. The current debate over the provision of NRW in water supply system is not aligned with the real experience in poor countries like Myanmar though exchange of world experience on NRW provides means for more effective and economical measures of reducing NRW. Very rare visits, proposals and recommendations have made for WSS by foreign experts in the field of NRW in Yangon. While discussing the NRW reduction of WSS in Yangon, there are difficulties associated in different phases of WSS projects and policy measures. The difficulties involved in different phases of WSS projects in Yangon are classified as financial, technical, legal, political risks. The result of the analysis on these difficulties showed that both political and legal constraints are still many in Yangon. Many people (respondents) are reluctant to participate in the movement of WSS project since Yangon is still considered as very highly vulnerable in water supply. These problems include the country's underdeveloped capital markets, inadequate legislation, lacks of technical expertise, inadequate current water supply system data and information, lack of public education and unfavorable public opinion for private sector participation in water supply services and heavily political interferences.

Recommendations

NRW control policy is not a one-time activity, but an ongoing process, to keep on improving the water authority organization's management system on the administrative as well as the water conservation aspect.

YCDC is starting from nothing in respect to NRW control and has considerable problems related to all the various aspects and activities concerned. Therefore, the three underpinning principles were adopted for establishing effective NRW control policy.

1) YCDC has to get involved in action on all fronts of NRW control to a greater or lesser degree.
2) It is not possible to do everything at once and immediately, so the approach should be to start small and expand progressively until the entire network is effectively covered.
3) It should be an economically justified action. National water policy should also create a framework for appropriate economic development on water resources.

Alternatively, NRW control is often prepared and implemented in a relatively stable context, where the water supply utility has fully established the service coverage and has a fully developed network. It will be important to ensure good co-ordination and integration with such general water supply improvement activities as increased in duration and pressure of supply to areas, expansion of the service area, rehabilitation and reinforcement of the existing network, and organizational strengthening. Together with water supply improvement activities, YCDC start to reform NRW control policy based on education, motivating and disciplining its staff and the public by influencing the water demand management (WDM) and water conservation concepts. A brief discussion of water demand management and water conservation concepts are as follows.

Water Demand Management (WDM)

WDM places much more emphasis on the socio-economic characteristics of water use. Demand management is much more aggressive in its use of economics to influence the origin of water demands to provide incentives for satisfying given "ends" in the cheapest possible manner. It can be said that the various water uses are seen by consumers, who can be influenced and governed, by incentive structures, technology modifications, public education and other means. This is no more than applying public concerns and arrangements to currently unmarked natural resources. It is not to say that traditional supply management actions are no longer required, only that they need to be significantly re-evaluated and changed. Because the water supply management approach considers water needs as requirements that must be met, and not as demands that are variable and changeable (UNCHS- Habitat, 1998). This water supply management strategy will lead to overuse of the resource, over capitalization, resource wastage, pollution problems, and many other problems of varying severity. This approach is required to rethink into the creation of physical structures and the use of the law to provide answers to certain behaviors. Thus, the city authority of all levels is beginning to understand that these types of problems require a fundamental change in order to be solved efficiently and effectively. The new approach of water demand management (WDM) will focus on the use of economic instruments to influence water use, the fostering of new technologies and increased levels of public awareness and education about water uses (UNCHS-Habitat, 1998). Structural components of demand management include- comprehensive metering, leak detection and repair, installation of water savings techniques, water auditing, changes in water pricing concepts and others.

Water Conservation

Water conservation is the most cost-effective and environmentally sound way to reduce our demand for water (Mono Lake Committee, 2007). Water use in developing countries is increasing at an accelerated pace, due not only to growing populations, but also as a result of the higher standard of living, increased per capita consumption, rapid industrialization, and the expansion of irrigation to supply the needs of the population growth. This forecasted growth has serious implications for environmental sustainability locally and globally. Neither economic development nor environmental management is expendable, both are essential. A wise strategy that reconciles economic development and environmental health must include both. Governments will have to follow innovative and clear strategies to accommodate this huge economic development without the further destruction of the environmental infrastructure. Water resources management and water conservation are essential components of a strategy aimed at achieving these goals of sustainable development

(Arlosoroff, 1999). Governments should initiate creative approaches, courageous policies, regulations and their enforcement. They should gradually test the use of incentives and sanctions, tax measures, new technological modification and realistic full-cost pricing of water. The strategic plan for urban water sustainability must include these policy instruments.

Policy Implications of Non-Revenue Water for City Water Supply Management

Based on the above two concepts and three principles, a proposed water policy for Yangon City is made as "*Sustainable water resource development is covered by an overarching policy for 'management and development' of the water supply sector in Yangon City*". To implement this adopted water policy, NRW control policy in city water supply management will be proposed as: *"NRW ratio will be reduced from over 60 % to 30 % in targeted year 2020 by leading of WSS department under YCDC"*. To do so, the immediate action on managing NRW in water supply management are adopted as legal and institutional, technical, economical and social aspects.

Legal and Institutional Aspect

Specific Bylaws and Standards: A large number of users share the same water source. Aside from its optimal use source, protection should be a priority. It is foreseen that YCDC will have to own drinking water facilities throughout the city in the future. Thus, several legal issues relating to the ownership and management of water resources and facilities are likely to emerge in the future. Given the above context, it is critically important that water law is prepared as a matter of priority. In this regard, a review and updating of the existing bylaws and regulations is required to ensure among other things, effective standards for installation and materials used on connections as well as clarification of duties and responsibility between the customer & YCDC. This will also require long-term efforts to educate and inform the public. It is noted that YCDC has already embarked on the development of some laws relating to aspects of water use and management in the city. It should actively enforce and frequently announce them for public awareness of all water users.

Consistency and continuity in policy regime: An important requirement for the success of the policy on effective NRW is that the city government has to guarantee continuity of an announced policy. The overwhelming strength of the ruling party should provide political stability. What is required is to assure that NRW reduction and management of water supply system will be sustained. The government should strengthen public administration reform to reduce the number of cumbersome rules, lengthy administrative procedures, corruption and bureaucratic red tape. There is a need for deeper national water policy and enforcements in Myanmar.

Co-operation and Co-ordination: it must be emphasized that water loss control is the duty of all water supply department staff, not only NRW team. Equally, all sections or departments such as new works and network rehabilitation departments, O & M departments, district inspectors, Senior Management & Government Organizations, etc, are involved in the work and should be co-operate with NRW control team.

Institutional Restructuring of the Whole Organization: The present structure of WSS department (already discussed in Chapter 4) is in principle considered adequate to improve City water supply management. The first step should be taken within WSS department of

YCDC city authority in general. Higher management has to give more direct responsibility. Members of the more dynamic younger generation who possess better qualifications should be promoted to higher levels and given more responsibilities. Inefficient "old timers" in high positions may keep their positions, but should be moved to more dormant roles. The younger generation should be given much training in the various skills required to run WSS effectively. Incentives such as higher salaries and bonuses for good performance are introduced, together with penalties for bad intentions and enforce promulgated rules and regulations actively. Managers are also taught to be responsible, and the spirit of teamwork is stressed. The work responsibility of the staff is more streamlined and the number of employee should be reduced to half of present situation (i.e. less than 5 persons per 1000 connections). To implement this situation, certain changes are suggested for the existing divisions and sections to strengthen their capacity. The proposed organizational charts are presented in Figure 6.2. The expected functions of all new divisions/sections are defined and a functional analysis is performed to identify any overlapping as well as unassigned functions shown in Figure6.3, 6.4 and 6.5.

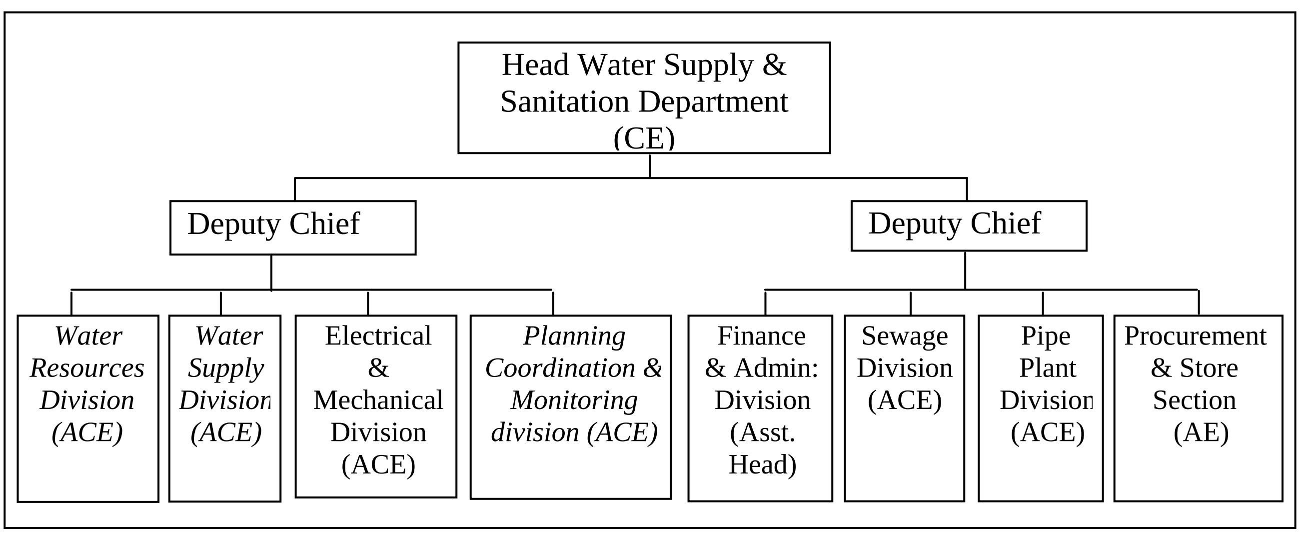


Figure 6.2: Proposed Organizational Structure of Water Supply and Sanitation Department

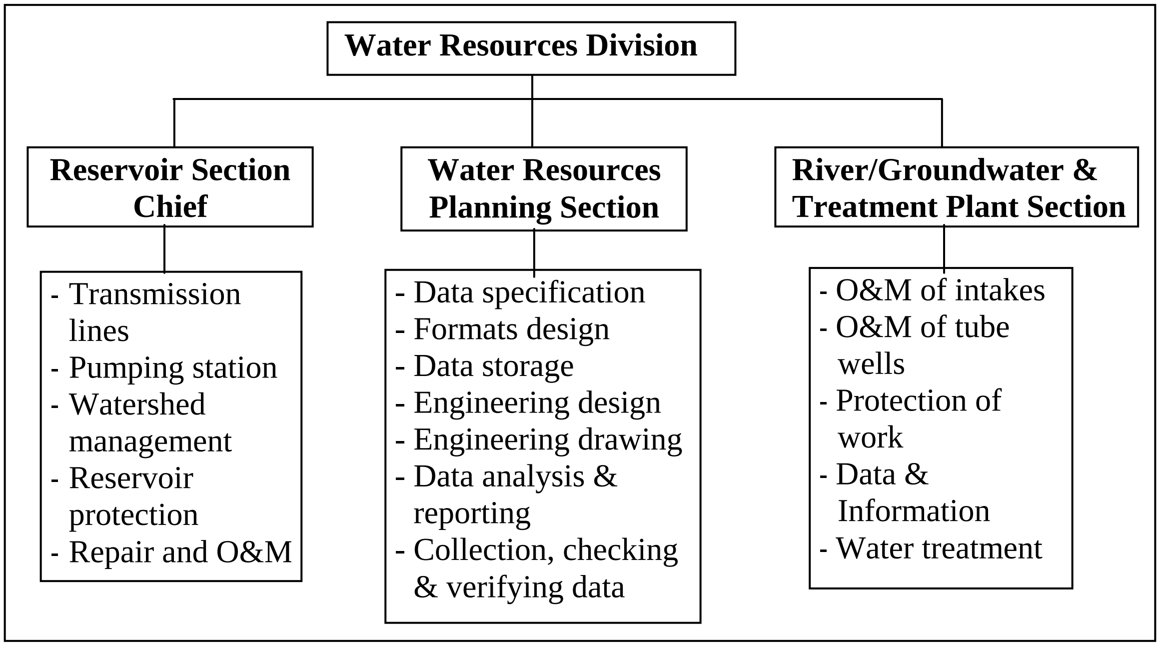


Figure 6.3: Proposed Organizational Structure of Water Resources Division and Functions

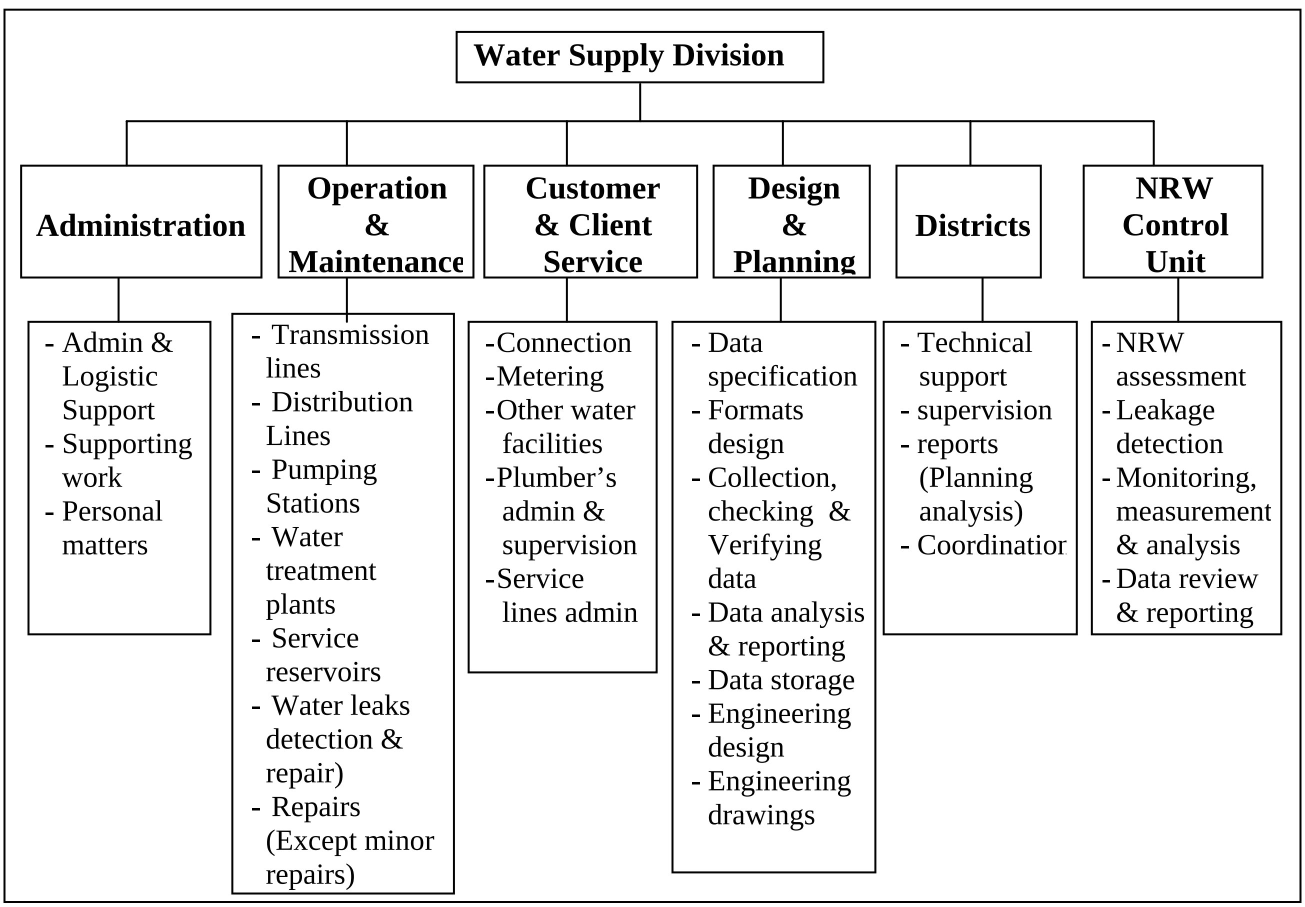
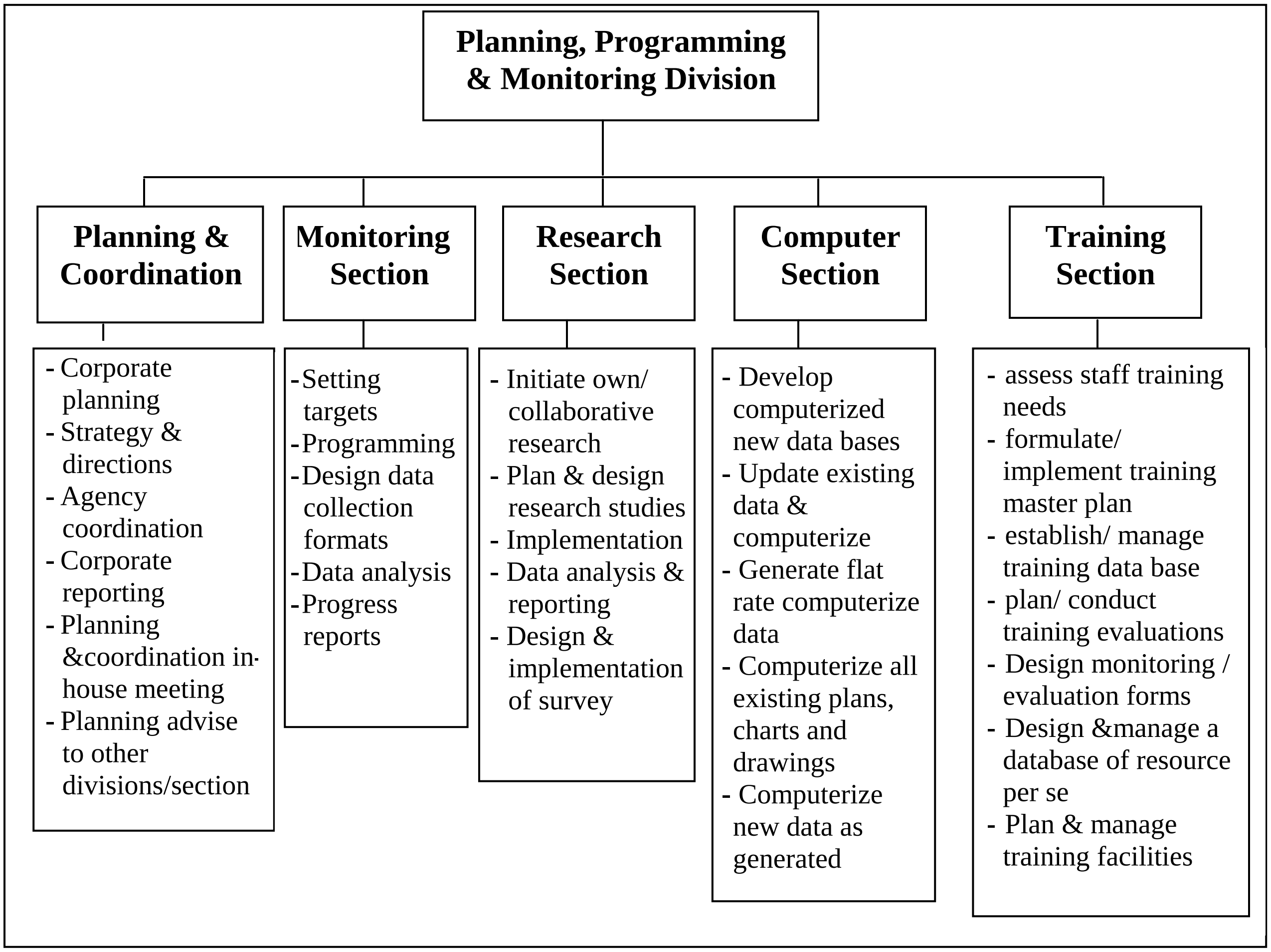


Figure 6.4: Proposed Organizational Structure of Water Supply Division and Functions



Source: JICA, 2002

Figure 6.5: Proposed Organizational Structure and Functions for Planning, Programming and Monitoring Division

Staffing: It is suggested that the new work areas proposed in the NRW control policy are assessed and arrangements as recruitment of new staff is made. In the meantime, action needs to be taken to fill all existing vacant posts and the professional posts in particular.

1. Prepare a recruitment policy and a plan to accomplish need
2. Fill all vacant positions in head office and in field offices including the township
3. Determine professionals (type and number) to carry out new functions and prepare

4. Policy for recruitment of such staff
5. Prepare details for staff placement
6. Provide any pre-service training if needed

The recruitment of some key staff from other professions becomes a necessity to implement the effective NRW control. As the department does not have a history of recruitment of non-engineers for senior management positions, it suggested that the relevant recruitment procedures are developed. Together with NRW control for new recruitments, salary review and job analysis need to be carried out.

Recommendation is that the above staff be provided with opportunities aimed at securing professional training on water supply and sanitation. Considering the number of professionally unqualified staff in-charge of townships (11 out of 33 townships at present), it would be quite possible to organize professional courses in collaboration with higher educational institutes in the country. It could be recommended that staff sharing of knowledge gathered following the completion of overseas or in country or tour and the professional staff could be encouraged to pursue their activities in professional associations wherever possible.

Training***:*** Effective training can be beneficial to organizations in many ways. From a financial perspective, it can enhance compliance with policy, specifications, and applicable legal and regulatory requirements, thereby reducing liability and costs. It can increase productivity, thereby enhancing revenue and reduction pollution control abatement cost. From a management perspective, it can empower employees to make decisions and it can provide skilled labor. Under these ways, WSS should provide training for all parties involved in the water supply management. Training subjects to be considered are public relationship, planning and implementation, waste minimization practices, conducting water leakage monitoring, technologies and techniques concerned with handling (repair and maintain) water in an environmentally sound manner, emergency repair, etc.

Training policy for efficient management of all departmental work should be adopted. The main requirement is 1) undertaking a training needs assessment and 2) formulation of a training for NRW control plan for the target period. The training needs assessment is the significant tool as the facilities available for training with the department. The proper identification of training needs including facilities is a fundamental requirement before the design of a package of training to suit staff at different levels of the department. Hence, the training needs assessment becomes a very high priority. And also some of the specific areas for training together with the approximate number of staff should be trained. Some significant training milestones to be accomplished by the current practices are:

1. Management training for corporate staff would initially focus on the development of an organizational vision and long-term goals up to 2020.
2. Each professional staff of the department should participate at least in one professional training every other year while each professional staff without such qualification should undergo training every year.
3. Professional staff without qualifications needs to acquire professional qualifications within a stipulated time period.
4. Professional staff training will include both engineering and other professional subjects (i.e. data collection & analysis, planning, monitoring, customer management, etc.) relevant to their work.

It is expected that the training for NRW control plan will address the above issues.

Technical Aspect

Metering in the whole system are required throughout the distribution network to establish the amount of water harvested, treated, imported, exported, stored, and consumed. To accurately measure, water use in a distribution system, meters should be installed by level of water distribution such as source or raw water meters, bulk flow, production or purchase meters, district meters, industrial, commercial and non-domestic meters, and domestic/residential meters. To ensure accuracy, meter selection, installation, systematic and cost effective replacement schemes, and appropriate and systematic schedules to ensure efficient information flow must be taken. These step lead to correct revenue collection. Meter calibration needs to be undertaken periodically to assess drift in accuracy. A systematic metered testing, repair, and replacement program should be established. Lack of progress towards comprehensive metering must be challenged at the policy making and operational level. Even metered customers have to maintain their meters properly. To a great extent, the government policy, as far as influencing the metering on water supply system is concerned, is already moving in the right direction. The city government needs to be consistent and persistent going ahead with carrying out their policies.

Network Inspection to Assess the Whole Water Supply System, Leakage Condition and to Stop Illegal Connection and Busting: This is a step taken to start action on this policy for the whole water supply system. A simple five steps plan will assist in the system and these steps can be undertaken immediately and as soon as possible even in drought condition in dry season. These five steps are 1) system assessment, 2) site assessment, 3) water loss assessment 4) preliminary leak survey and 5) reassessment of water loss. These steps could be conducted to confirm real loss of water in the system. On the other hand, the public will be advised to stop using and pursuing illegal connections. Incentives are given to anyone who could provide information on illegal connections. A heavy penalty should be slapped on those found to be using illegal connections. Any staff of WSS found to be associated with illegal connections will removed immediately. If any of the staff is found guilty of allowing corruption from illegal connections, a punitive action must be taken immediately such as fines and /or suspension or dismissal from their duties. As a result, the number of illegal connections will be eliminated, if any. Most of these policies and recommendations should be consistent to all customers and staff.

New Work Design and Construction: YCDC should be revised and improve its consumer files with new work design. A consumer survey should be carried out to identify the actual number of connections. The consumer files should be corrected and updated by using computerized system handling that will help tremendously in bill collection and accurate data keeping for further study and further improvement project in the water institution.

Technical Assistance: To deal with the scope of the work needed to achieve the objectives, YCDC currently lacks any of the institutional capacity required for NRW control planning and implementation, a technical assistance program will be required to support it. This assistance will take the form of a technical assistance unit, providing expertise and advice to YCDC in the establishment of an effective permanent organization in the authority and continuing advice on the detailed solutions of problems encountered during implementation. The technical assistance unit should be concerned with other functions and services covered in the form of general NRW technical management assistance, mapping survey and capture, district metered area (DMA) design and implementation, meter sizing and selection, meter testing and calibration, metering policy, bylaws and technical standards policy and implementation. YCDC must ensure that the staff assigned to the technical assistance unit has a sufficient number of suitably motivated, intelligent, and qualified “counterpart” employees to gain the necessary training and experience to take over the operation at the end of the technical assistance.

Economic Aspect

<u>Water Tariff is to Recover Cost</u>: Present water tariff structure does not reflect the cost recovery for supplying water throughout the whole city. Tariff structure should be set up with people’s willingness to pay and affordability of 24-hours clean water supply. A progressive rate structure will ensure that the poorer sector of the population can afford the services. Some proposed steps to improve the economic sustainability of the institution included the following factors:

- Water tariffs in the urban areas should be set at such a level that it should be possible to recover operating costs including depreciation, and should be gradually increased to recover the full supply cost of providing services, including debt service and a reasonable rate of return.
- Sewerage tariff covering operation and maintenance costs should be introduced, based on water consumption for the sewered areas, and also as and when sewerage services are made available in areas and introduced to new areas.
- For low-income people, appropriate life- line tariff should be available to ensure the affordability of water of sufficient quantity and quality to satisfy both basic consumption and hygienic requirements.

The final decision to increase the water tariffs is primarily a political process. The general experiences in developing countries have often been that politicians may prefer to "go slow" in terms of increasing tariffs, especially before elections. While the proposed policy is a step in the right direction, the main consideration for the future will not be the adequacy, or even the appropriateness and desirability of the policy, but its proper and timely implementation. This also means that special attention needs to be paid in terms of equity, so that the poor families are not unduly penalized by higher water and sewerage charges, which they may not be able to afford. It should at least ensure that people pay the true cost of the water they use.

Cost-benefit Analysis: NRW control is primarily an element of demand management, whereby efforts are made to reduce consumption and the need for supply-side increases in capacity. The more demand can be managed the less the need for very capital-intensive investments to build new facilities for supplying more water.

The policy points out that one of the important issues is the need for funds for capital investment for expensive rehabilitation or managing non-revenue water and new water supply and sewerage projects. Thus, NRW control has a role on the economic of operations and the extent of the role it has to play is defined by the cost-effectiveness of the measures in terms of maximizing revenue by ensuring that as much water use as possible is paid for and minimizing unit operating costs (kyat/m^3). The extent and nature of the interventions should always be justified on a cost-benefit analysis.

Social Aspect

Public Education***:*** An effective program aimed at providing better information and education for customers needs. The customer education should focus on improving water & sanitation, effective water use with reduced waste, information about the city water supply plan for improvement, and water tariffs, among many other potential subjects. The sanitation program should particularly concentrate on those customers who obtain their domestic water from communal tanks and ponds/lakes. On the other hand, the customers need information on O & M strategies, standards and procedures. They also need to be educated for the execution of quality repair work of customer's responsible lines and connections and training on modern techniques to detect repair needs. Moreover, WSS should embark on a program to educate the public on the importance of paying their water bills and aware of water consumption. This is not an easy task. However, WSS must have a lot of hard work and strong political commitment from authorities both national and city government.

Private Sector Involvement Options: In many developing countries, water shortages obstruct both the normal operation of the system and NRW control. Rationing by intermittent supply damages both the physical supply system and the credibility and esteem of the utility. Many of these problems can be traced back to inadequate revenue. Unrealistically low tariffs and poor revenue recovery lead to a progressive decline in the supply, abuse by consumers and the use of unsanitary shallow wells and the emergence of an informal, unregulated and inefficient system of water vendors, tanker supplies and private boreholes. In such cases, the terms of reference for privatization could be extended to include all or most of the major functions of the utility. The consultant would then not only assist the utility to improve its financial and technical performance but also to match the supply to the latent demand and ability to pay for water in the community it serves. A method of providing incentives to the consultant to provide the greatest supply at least cost can be developed. National governments as well as local ones should consider the form of private sector participation as a step by step strategy for comprehensive privatization of water utilities.

For instance, private sector participation by outsourcing its information technology to the private sector, the WSS can show a new form of public-private partnership, where overall services are provided by public sector, but with private sector participation in specific areas where three performances are more cost-effective. Outsourcing of additional specific activities can make the WSS increasingly more efficient.

One possible area for future outsourcing could be meter reading. The current practices of the WSS have not produced good results as in most developing countries. Meter-readers are given specific areas to cover over long periods of time. Such territorial control by meter-readers has often resulted in increasing their unauthorized incomes, since for some staff members, personal interest may override the overall public interest. Such a problem can be addressed in two ways. First, the meter reading could be outsourced to a national private company, perhaps with an incentive payment, which could be directly linked to the generation of additional income for the WSS. Second, the levels of corruption could be reduced if the meter-readers are regularly rotated in terms of areas they cover so that they do not have opportunities to establish individual fiefdoms.

It would probably be a difficult political process for the WSS to outsource meter reading to the private sector, or change the territories of the meter-readers, who are highly organized and are politically well connected. It is highly like that the meter-readers will resist such moves very strongly because of their own personal vested interests. Outsourcing of the meter reading to the private sector is likely to improve the present situation very significantly. It could significantly reduce the systemic corruption in meter reading. In addition, the overall cost of meter reading could also be reduced appreciably since not only the number of meter-readers will be less, but also the private sector is unlikely to pay the existing high salaries and fringe benefits that they currently receive.

The WSS could provide an incentive to the private sector in that they could receive a percentage of additional revenues that could be generated from the existing consumers by better practices. Such steps could improve the net income of the WSS, in terms of generating additional revenues and reducing costs. There are some other activities that the WSS could outsource to the private sector, among these possibilities are: leakage detection and repair, bill collection, new water connections, and vehicle maintenance and fleet management.

All these activities, both individually and collectively, are likely to contribute to steady advances in the sustainability of the water supply programs through better public-private partnership arrangements.

Implication for Further Study

Some suggestions are proposed for further studies in applying NRW for improving water supply system and management. Due to the limited time and resources, this study could not adequately address these issues despite their significance. This study also intends to apply for base line data and road map for further study. The recommended studies, shown below, are thus seen as logical follow-up of what this research has initiated.

1. Detail study on NRW value in the whole system including pressure management, meter reading, maintaining records, and evaluate NRW by monthly to yearly records, etc.
2. In-depth study to identify water price on consumer affordability and willingness to pay for both domestic and commercial customers in service available area and in the non-service available area of Yangon City.
3. Initiate a study for demand management of the supply water system and water conservation practices in Yangon City

These recommendations are indicative of what can be followed up but they are by no means an exhaustive list of possible directions for further research.

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