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SUSTAINABLE WATER MANAGEMENT FOR WATER SUPPLY EFFICIENCY: A CASE STUDY AT SYARIKAT AIR MELAKA BERHAD

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Abstract

Water use has been growing at more than twice than rate of population growth in last century. This level of population growth will result in increased demand for potential water from agriculture, industrial and domestic sectors of the economy. Rapidly rising demand and falling supplies of fresh water are leaving ever more nations to face chronic water shortages. The objective of this research is examined current water management systems in Syarikat Air Melaka Berhad (SAMB), assessing how far the current systems manage to keep the water sustainably. This research aimed to identify the effectiveness of programs implemented by the SAMB to sustain the water supply. Furthermore, this research aimed to formulate and propose improvements and enhancements for better water management systems. This research is beneficial for the government, university and the public. The research is been conducted at Syarikat Air Melaka Berhad (SAMB) through interviews of fifteen respondents. From there, researcher gained crucial information and point of view from the managerial perspective and also technical and technology insight regarding sustainable water management at SAMB.

Keywords: *Sustainable Water Management, Water Supply Efficiency,case study*

1.0 Introduction

According to Fogden (2009), defines "safe drinking water" as water from an improved water source, which includes household connections, public standpipes, boreholes, protected dug wells, protected springs and rainwater collections. Fogden (2009) also states that water use has been growing at more than twice than rate of population growth in last century. This level of population growth will result in increased demand for potential water from agriculture, industrial and domestic sectors of the economy. Rapidly rising demand and falling supplies of fresh water are leaving ever more nations to face chronic water shortages. By 2025, 1.8 billion people are expected to be living in countries or regions with absolute water scarcity, and two-thirds of the world population could be under stress conditions.

Fogden (2009) also states that water prices are usually higher in regions where water is scarce. As demand for potential safe drinking water increase and the total volume of available freshwater resources falls, the price of drinking water is likely to increase. Water supply costs are also determined by the infrastructure costs involved in sourcing, cleaning and transporting drinking water. As the decline in freshwater resources means that water companies have to employ ever more extreme measures to extract water. In addition, as demand increase, the water infrastructure has to be extended to serve more consumers, and the aging infrastructure needs to be maintained and replaced.

Under The Kementerian Tenaga, Teknologi Hijau dan Air (KETTHA), government has been implementing various programs and formulating strategies to maximising every energy resources including water resources. Every program aims to enhance optimisation of water management system and fully utilise water resources to the optimum. Through Rancangan Malaysia Ke-10 (RMK-10), various implementation of projects and economic incentives by the government has been arising question whether these project really give positive impact towards waters resources, did these programs and incentives really achieve their target and expectation.

Thus, research questions are constructed as stated below:

1. What are the impacts of sustainable water management towards water supply efficiency?
2. How does Syarikat Air Melaka Berhad manage the water supply sustainably?
3. What are the innovative suggestions to improve sustainable water management system towards water supply efficiency?

The objectives of this research are to examine current water management systems in Syarikat Air Melaka Berhad (SAMB), assessing how far the current systems manage to keep the water sustainably. This research also aims to identify the effectiveness of programs implemented by the SAMB to sustain the water supply. Furthermore, this research aims to formulate and propose improvements and enhancements for better water management systems. This research will be beneficial for the government, university and the public.

Thus, the objectives of the research are stated as below:

1. To assess the impact of sustainable water management towards water supply efficiency.
2. To assess the strategies of Syarikat Air Melaka Berhad (SAMB) in managing water supply sustainably.
3. To propose innovative suggestions on sustainable water management system towards water supply efficiency.

2.0 Literature Review

This paper is to discuss about the sustainable water management. Sustainable water management use in the context of planning involves ensuring there are adequate supplies of fresh water for present and future generations and for the environment. It addresses all catchment waters

from storm water, carried as surface water in rivers, creeks and held in reservoirs and dams (Cullen, 2004).

2.1 Impacts of Sustainable Water Management

Ross (2012) highlights the importance sustainable water management, where it is vital in providing the public with clean and safe water and helping to ensure the environmental, economic, and social health of the nation's communities.

With our finite water resources, there are increasing demands for our drinking supply, and also for other societal needs including energy, agriculture, industry, and water needed to support healthy nature ecosystems. Having adequate water of sufficient quality underpins the national's health, economy, security and ecology, ensuring that water resources are safe for use and can be sustained for future generations.

2.1.1 Cost-Effective Investment

According to Farley (2008), detection and control of leakage varies from company to company, and the choice of methodology is largely dependent on local conditions, which may include financial constraints on equipment and other resources. Staffing resources are relevant, as a labour intensive methodology may be suitable if manpower is plentiful and cheap. The main factor governing choice of technology, however, it is whether a particular methodology is economic for the cost savings achieved. A low activity method, such as repair of visible leaks only, may be cost-effective in supply areas where water is plentifu1 and cheap to produce. On the other hand, countries which have a high cost of production and supply can justify a much higher level of activity, like leakage monitoring, or even telemetry systems, to warn of a burst or leakage occurring.

Liemberger (2010) emphasises that sustainability of water management able to provide a number of financial benefits. Sustainable water management able to maximise the value of each investment on the water infrastructure, including:

a) Minimising costs by optimising investment choices, operating water and wastewater systems more efficiently, and pursuing cost-effective investment and management strategies, such as collaboration and partnering with neighbouring systems to leverage resources and improve efficiency.

b) Maximising results and investments to ensure a continuing source of water, treatment, and discharge capacity, as well as financing capability.

c) Improving the ability to analyse a range of alternatives, including (as appropriate) both traditional and non-traditional infrastructure alternatives, such as green infrastructure and/or decentralised systems, and selecting the option or mix of options that best meet the needs of the utility and the community it serves.

d) Engendering greater support for the utility by recognising community values and sustainability priorities.

e) Ensuring that financial and revenue strategies are adequate to finance, operate, maintain and replace essential infrastructure throughout its operational life, while appropriately considering the needs of disadvantages household.

2.1.2 Adequate Water Supply

According to Liemberger (2010), one of the major issues affecting water utilities in the developing world is the considerable difference between the amount of water put into the distribution system and the amount of water billed to consumers (also called "non-revenue water" [NRW]). High levels of NRW reflect huge volumes of water being lost through leaks, not being invoiced to customers, or both. It seriously affects the financial viability of water utilities through lost revenues and increased operational costs.

According to Farley (2008), globally, water demand is rising and resources are diminishing. Water loss from the pipe network, always the bête noire of the operations engineer, has long been a feature of operations management, even in countries with a well-developed infrastructure and good operating practices. A diagnostic approach, followed by the practical implementation of solutions which are practicable and achievable, is recommended for developing a water loss management strategy. However, practitioners working in developing countries will invariably face a slower pace, greater financial constraints, less developed infrastructure, lower levels of skills and technology, and political, cultural and social influences.

2.1.3 Safe and Clean Water Supply

According to Liemberger (2010), eighty per cent of the diseases were caused by drinking unclean water, lack of sanitation, and poor hygiene. According to Hopkins (2002), unlike genetic disease, which individuals are predisposed to, acquiring water, sanitation, and hygiene related diseases are controllable and preventable. The spread of these diseases depends on environmental conditions and behaviour in the household and community. Diarrhoea, acute respiratory infection, measles, malaria and malnutrition are the most common diseases related to water. Illnesses related to water, sanitation and hygiene include the following:

a) Water-borne diseases occur when a disease-causing agent the body through drinking.

b) Water-washed diseases occur because of inadequate hygiene conditions and practices.

c) Water-based diseases include those illnesses that are spread through a disease vector that lives in water.

Hopkins (2010) also adds that diarrhoea disease is one of major risk factor in emergency settings because it can cause sickness and death among children. Most diarrhoeal diseases including viral gastroenteritis, cholera, Shigellosis, typhoid, polio and some forms of hepatitis being spread by fecal-oral means are often called fecal-oral diseases. Fecal-oral disease transmission occurs when feces, which contain disease causing pathogens, from one person enters the mouth and is ingested by another person. Fecal-oral diseases can easily spread in overcrowded unsanitary conditions, which are typical of camps and settlements in emergencies. Factors related to fecal-oral disease spread include drinking water contaminated with fecal material which can occur at the source, during transport or in the household, poor hygiene due to a lack of water or hygienic practices and poor food hygiene.

2.2 Sustainable Water Management Strategy

Wiedeman (2012) states that disinfection of drinking water is none of the major public health advances of the 20th century. Water suppliers use a variety of treatment processes to remove contaminants from drinking water. These individual processes may be arranged in a series of processes applied in sequence. The most commonly used processes include filtration, flocculation and sedimentation. Some treatment system includes ion exchange and absorption. Water utilises select a combination of treatment processes most appropriate to treat the contaminants found in the raw water used by the system.

2.2.1 Water Treatment Systems

According to Wiedeman (2012), water treatment systems come in all shapes and sizes, and no two are exactly the same. They may be publicly or privately owned and maintained. While their design may vary, they all share the same goal: providing safe, reliable drinking water to communities they serve. The amount and type of treatment applied by a public water system varies with the source type and quality. Large-scale water supply systems tend to rely on surface water resources, while smaller systems tend to rely on ground water. However, surface water systems are exposed to direct wet weather runoff and to the atmosphere and are therefore more easily contaminated.

Types of treatment according to Wiedeman (2012):

a) Flocculation/Sedimentation/Coagulation

Flocculation refers to water treatment processes that combine or coagulate small particles into larger particles, which settle out of the water as sediment. Alum and iron salts or synthetic organic polymers are generally used to promote coagulation. Settling or sedimentation occurs naturally as flocculated particles settle out of the water (Wiedeman, 2012).

b) Filtration

Many water treatment facilities use filtration to remove all particles from the water. Those particles include clays and silts, natural organic matter, precipitates from other treatment processes in the facility, iron and manganese, and microorganisms. Filtration clarifies water and enhances the effectiveness of disinfection (Wiedeman, 2012).

c) Ion Exchange

Ion exchange processes are used to remove inorganic contaminants if they cannot be removed adequately by filtration or sedimentation. Ion exchange can be used to remove arsenic, chromium, excess fluoride, nitrates, radium, and uranium (Wiedeman, 2012).

d) Absorption

Organic contaminants, unwanted colouring, and taste-and-odour-causing compound can stick to the surface of granular or powder activated carbon and are thus removed from drinking water. Absorption allows the water produce to be more crystal clear and odourless (Wiedeman, 2012).

e) Disinfection

Water is disinfected before entering distribution system to ensure that potentially dangerous microbes are killed. Chlorine, chloramines, or chlorine dioxide are mostly often used because they are very effective disinfectants, not only at the treatment plant but also in the pipes that distribute water to our homes and business. Ozone is a powerful disinfectant, and ultraviolet radiation is an effective disinfectant and treatment for relatively clean water sources, but neither of these is effective in controlling biological contaminants in distribution pipes (Wiedeman, 2012).

Water systems monitor wide variety of contaminants to verify that the water provide to the public meets all quality standards. There are more than 83 contaminants that have been identified. The major classes of contaminants include volatile organic compound (VOCs), synthetic organic compound (SOCs), inorganic compounds (IOCs), radionuclides, and microbial organism including bacteria.

Testing for these contaminants takes place on varying schedules and at different locations throughout the water systems (Wiedeman, 2012).

2.2.2 Water Distribution Management

According to Farley (2008), water loss occurs in all distribution systems, only the volume of loss varies. This depends on the characteristics of the pipe network and other local factors, the water company's operational practice, and the level of technology and expertise applied to controlling it. The volume lost varies widely from country to country, and between regions of each country. The components of water loss, and their relative significance, also vary between countries. One of the corner stones of a water loss strategy is therefore to understand the relative significance of each of the components, ensuring that each is measured or estimated as accurately as possible, so that priorities can be set via a series of action plans. The expressions 'water loss' and 'non-revenue water' (NRW) are now internationally accepted, and have replaced expressions such as 'unaccounted-for water' (UFW) which are less consistent and which make inter-country comparisons more difficult.

2.2.2.1 Leakage Management Policies

Farley (2008) has come out with policy to identify the priorities addressed in water loss strategy. Reduction of real losses, or leakage, will, in most networks, be directly influenced by leakage monitoring, pressure management, and operation and maintenance.

2.2.2.1.1 Pressure Management

According to Farley (2008), pressure management is one of the fundamental elements of a well-organised leakage management strategy. The most cost effective schemes are those which cover a large area, and which make a significant impact on average pressures. Pressure management is best undertaken in conjunction with district metering, or when establishing supply zones. As well as the reduction in pressure, good pressure management will also result in more stable pressures, causing less strain on the pipe network, and less chance of fatigue damage at joints.

Water distribution systems convey water drawn from the water source or treatment facility, to the point where it is delivered to the users. These systems deal with water demand that varies considerably in the course of a day. Water consumption is highest during the hours that water is used for personal hygiene and cleaning, and when food preparation and clothes washing are done. Water use is lowest during the night. It is necessary to maintain sufficient pressure in the distribution system to protect it against contamination by the ingress of polluted seepage water (Trifunovic et al., 2008).

2.2.2.1.2 Leakage Monitoring

The technique of leakage monitoring is considered to be major contributor to cost-effective and efficient leakage management. Leakage monitoring is flow monitoring into zones or districts to measure leakage and to prioritize leak detection activities. This has now become one of the most cost-effective activities and the one most widely practiced for leakage management. A flow measuring system in a water distribution network should include not only measurement of total flows from source or treatment works (production), but also zone and district flows. This allows the engineer to understand and operate the system in smaller areas, and allows more precise demand prediction, leakage management and control to take place.

Leakage monitoring requires the installation of flow meters at strategic points throughout the distribution system, each meter recording flows into a discrete district which has a defined and

permanent boundary. Such a district is called a District Meter Area (DMA). Therefore, the leakage monitoring system will comprise a number of districts where flow is measured by permanently installed flow meters. In some cases the flow meter installation will incorporate a pressure reducing valve.

2.2.2.1.3 Operation and Maintenance

Operation and Maintenance (O&M) is crucial to the successful management and sustainability of water supply networks, whatever the level of technology, infrastructure, and institutional development. The O&M philosophy applies as much to boreholes and hand-pumps as it does to complex water distribution networks. 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 best practice in operating and maintaining the system. It is essential that an O&M program is built into the project from an early stage and not as an afterthought.

2.3 Theoretical Framework

Theoretical framework for this research consists of two main components, which are the strategies to achieve sustainable water management, efficient water supply phase, and the impact of efficient water supply.

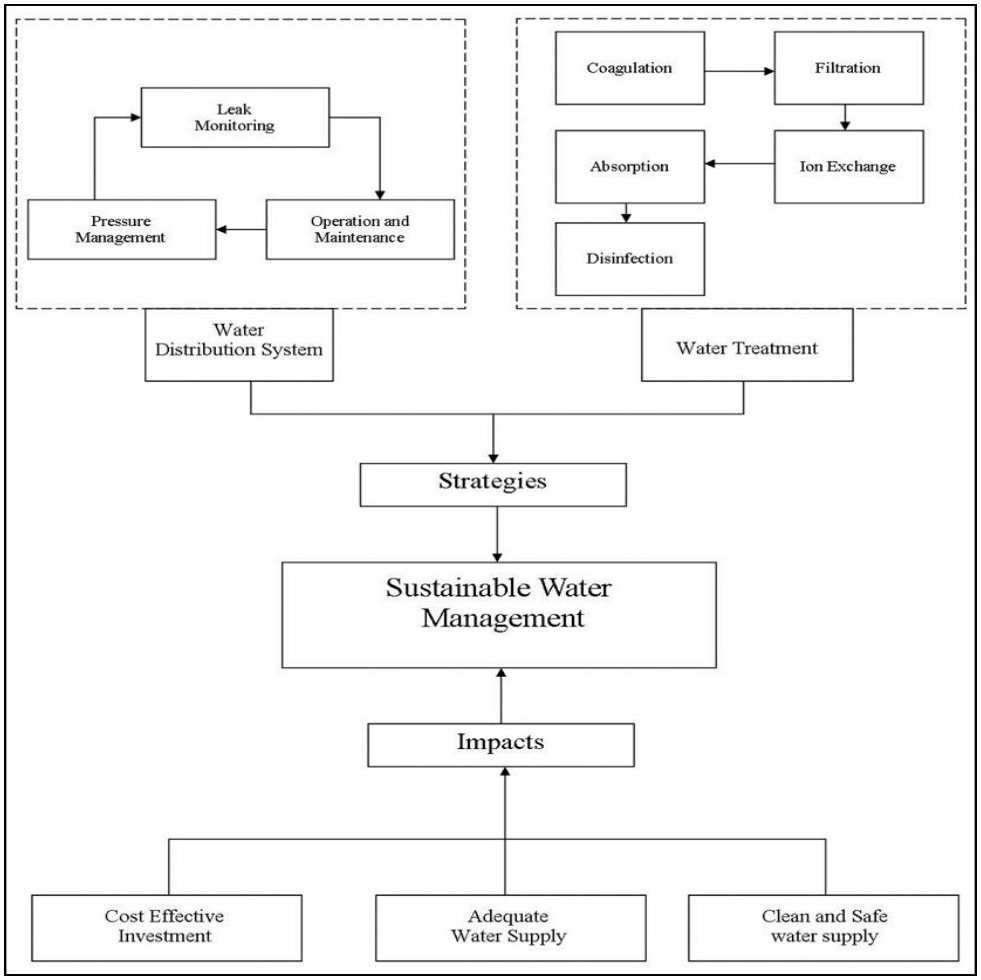

Figure 2.2 : Shows the overall picture of aspects of sustainable water management in a theoretical framework.

3.0 Method of Study

The research focused on the renewable energy resources; Sustainable Water Management for Water Supply Efficiency: A case study in Syarikat Air Melaka Berhad (SAMB). This research intended to study the importance of sustainable water management and how to achieve efficient water supply. Sustainable water management has become important issue for many developing countries, and many researches have been done to improve the sustainability of water management. According to Ghauri and Grønhaug (2005), the research methods are rules and procedures and can be seen as 'tool or ways of proceeding to solve problems'. Syarikat Air Melaka Berhad (SAMB) is chosen as a case study due to its potential capability for the implementation of sustainable water management.

For this research, qualitative approach is been used as a research design for data collections. According to Sakeran et al (2009), qualitative data can come from a wide variety of primary sources and/or secondary sources, such as individuals, company records, and the corporate websites. For that, semi-structured and in-depth interviews were the main method for this research. The research interviews involved respondents who work at SAMB with the designation as middle management in SAMB and involved with the management of water system. The respondents are divided into two categories; the first category consist minimum of five respondents from management department which are managers and executives that have been involving with sustainable water management at SAMB. From there, researcher gained crucial information and point of view from the managerial perspective. The second category consist minimum of five respondents consists of people in production and operation department which comprised of engineers and technicians. Where, this second category of respondents contributes technical and technology insight regarding sustainable water management at SAMB. Meanwhile, secondary data refer to information gathered from sources that already exist which can be acquired from secondary data such as company records or archives, industry analyses offered by the media, websites and others. The secondary data for this research are from books and journals written by scholars on the related field of knowledge. The literary works help the researcher obtained basic understanding of the research background.

4.0 Result and Discussion

4.1 Background of the Organisation

Syarikat Air Melaka Berhad (SAMB) is a statutory body company responsible in the management of water supply for Malacca state, which are responsible for the treatment and distribution of potable water in the state of Malacca. In 1993 Melaka Water Board has changed its name from Perbadanan Air Melaka (PAM) when it is incorporated on July 1, 2006 to Syarikat Air Melaka Berhad (SAMB). These measures are to improve water supply services to consumers in accordance with the aspirations of the country's federal government through privatization. Once incorporated, Syarikat Air Melaka Berhad has been given the role and wider jurisdiction without compromising the original activity of Perbadanan Air Melaka. It is the State Government's efforts to strengthen the management and distribution of water supply to the people of this country for its greater functions, objectives, role and powers of Syarikat Air Melaka Berhad. Currently, there three dams are built in order to meet Malacca water demand, which are Durian Tunggal, Jus and Asahan that can sustain maximum capacity of 75 billion cubic litres of water. Apart from the dams, Malacca has three main reservoirs Kesang Satu, Kesang Dua and Tasik Ayer Keroh and other smaller reservoirs and water facilities. Apart from the 300 million liters of raw water from Sungai Malacca, the state also receives up to 100 million liters of raw water daily from Sungai Gerisik in Muar and more than 54 million liters daily from Sungai Kesang. It has been reported that Malacca needs about 500 million liters of water daily and the current capacity could meet the demand only until 2017. Malacca has also identified another water source from Tasik Biru in Chin Chin, Jasin that could complement the water needs of the state. Apart from that, Malacca also has plans to set up a new retention pond in Sungai Jernih, Alor Gajah that would cater for the water needs in areas like Kuala Sungai Baru, Simpang Ampat, and Lubuk Cina (SAMB, 2015).

4.2 The Respondents of the Organisation

The case study was conducted by using qualitative method through an in-depth interview on fifteen respondents that are working at Syarikat Air Melaka Berhad (SAMB). Firstly, one respondent from senior manager level and two respondents from manager level of production department, and two respondents from manager level of Maintenance department were been interviewed at headquarter of SAMB situated at Wisma Air, Malacca. Secondly, five respondents which consist of managers, engineers, technologists and technicians from Non-Revenue Water (NRW) department were interviewed at SAMB branch situated at Duyong, Malacca.

4.3 Impacts of Sustainable Water Management

Ross (2012) highlights the importance sustainable water management, where it is vital in providing the public with clean and safe water and helping to ensure the environmental, economic, and social health of the nation's communities.

With our finite water resources, there are increasing demands for our drinking supply, and also for other societal needs including energy, agriculture, industry, and water needed to support healthy nature ecosystems. Having adequate water of sufficient quality underpins the national's health, economy, security and ecology, ensuring that water resources are safe for use and can be sustained for future generations.

4.3.1 Cost-Effective Investment

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b) Maximising results and investments to ensure a continuing source of water, treatment, and discharge capacity, as well as financing capability.

c) Improving the ability to analyse a range of alternatives, including (as appropriate) both traditional and non-traditional infrastructure alternatives, such as green infrastructure and/or decentralised systems, and selecting the option or mix of options that best meet the needs of the utility and the community it serves.

d) Engendering greater support for the utility by recognising community values and sustainability priorities.

e) Ensuring that financial and revenue strategies are adequate to finance, operate, maintain and replace essential infrastructure throughout its operational life, while appropriately considering the needs of disadvantages household.

According to National Audit Department Malaysia (2014), the issue of non-revenue water (NRW) losses has often drawn the attention of Members of Parliament and State Legislative Assembly as well as the mass media. The losses incurred through NRW are detrimental to both the government and the people and can have a negative impact on the economy. The roles and responsibilities of auditors in the management and control of NRW losses are crucial in ensuring accountability of the responsible parties.

Operation Manager 1 emphasised that among the benefits of Sustainable water management is it can reduce operation losses and improve revenue collection. In term of reducing operating losses, sustainable water management promotes cost-effective investment and adequate financial planning which provide cost minimisation on the water management operations and activities. Sustainable water management provides reduction of water loss allowing SAMB to reap higher revenue collection of water they produced. By comparing the cost of water being lost versus the cost of undertaking NRW reduction activities, the economic levels of NRW can de define.

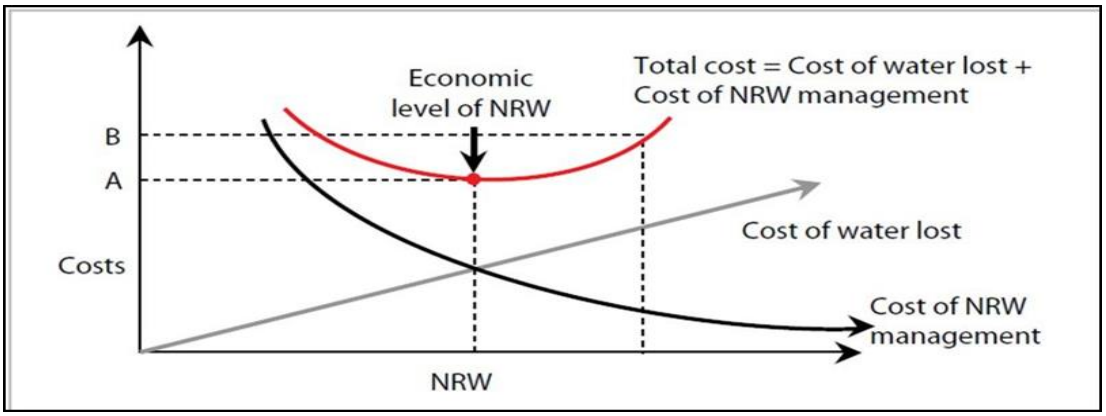

Figure 1: Shows the economic level of NRW.

Figure 3.1 highlights how the economic level of NRW is determined. The two components that must be determined are the cost of water lost and the cost of NRW management:

(a) The cost of water lost is the value of the water lost through both physical and commercial losses. The volume of physical losses should be multiplied by the variable operational costs, including manpower, chemicals, and electricity. The volume of commercial losses should be multiplied by the average customer tariff. As NRW increases, the cost of water lost increases proportionally.

(b) The cost of NRW management is the cost of reducing NRW, including staff costs, equipment, transportation, and other factors. As NRW decreases, the cost of NRW management increases.

Adding the two cost components together gives the total cost. In Figure 3.1, the intersection of the two component lines coincides with the minimum total cost (cost A), which is the economic level of NRW. The graph shows that letting NRW increase past the economic level reduces the cost of NRW management, but the total cost for the utility (cost B) will rise. Similarly, reducing NRW lower than the economic level of NRW will cost more than the potential savings.

Operation Manager 2 stated that there are some financial factors that need to be considered. In preparing a financial budgeting, managers need to identify and consider the involving costs, and to determine suitable decision in term of financial and economically wise. The involving cost consist of staffing cost which is to identify optimum numbers of hired staff for every work tasks, equipment cost which includes the cost of procurement of water equipment, leakage detection equipment, and also the installation of those equipment, and also transportation cost in maximizing the work rate of all staff in covering the entire thousand miles of supply system for undertaking NRW works.

Operation Manager 3 explained that sustainable water management allow SAMB to improve asset management, and water supply network systems and their components through the use of latest hardware and software technology. Under the Geographical Information System (GIS), SAMB able to monitor and maintain their water supply network system in better condition. Detecting poor condition of service connection pipes such as old and rusting pipes, low quality materials and poor workmanship which are the main causes of leakage in service connection pipelines, joints and fittings. Ensuring longer age of the piping network provide long-term financial benefits to SAMB in reducing cost of piping breakdown in the future.

Researcher can concludes that in order to promote adequate financial planning on managing sustainable water management practices; water agency should conduct a thorough consideration on optimizing cost of NRW management over cost of water loss. Sustainable water management should provide an economic level of NRW on the water management cost through cost-effective investment on the water management infrastructure and greater support for the utility. Sustainable water management should also focuses on effective asset management for long-term financial benefits and resources. Thus, sustainable water management provides should be able to provide solution for cost of water loss through effective cost investment.

4.3.2 Adequate Water Supply

According to Liemberger on 2010, One of the major issues affecting water utilities in the developing world is the considerable difference between the amount of water put into the distribution system and the amount of water billed to consumers (also called “non-revenue water” [NRW]). High levels of NRW reflect huge volumes of water being lost through leaks, not being invoiced to customers, or both. It seriously affects the financial viability of water utilities through lost revenues and increased operational costs.

According to Farley (2008), globally, water demand is rising and resources are diminishing. Water loss from the pipe network, always the bête noire of the operations engineer, has long been a feature of operations management, even in countries with a well-developed infrastructure and good operating practices. A diagnostic approach, followed by the practical implementation of solutions which are practicable and achievable, is recommended for developing a water loss management strategy. However, practitioners working in developing countries will invariably face a slower pace, greater financial constraints, less developed infrastructure, lower levels of skills and technology, and political, cultural and social influences.

According to Suruhanjaya Perkhidmatan Air Negara (SPAN) on their NRW report on 2014, Malacca has been reported on 2013 with 22.1% of non-revenue water with the reduction of 1.7 per cent from 2012. Malacca has been the second with lowest non-revenue water behind Pulau Pinang and followed by Labuan as the third lowest NRW.

Table 4.1: The Statistical Report Published by SPAN.

State	2012				2013			
	System Input Volume	Billed Authorised Consumption	NRW	NRW (%)	System Input Volume	Billed Authorised Consumption	NRW	NRW (%)
	(MLD)				(MLD)			
Johor	1,537	1,110	427	**27.8**	1,580	1,163	417	**26.4**
Kedah	1,292	639	653	**50.6**	1,326	651	675	**50.9**
Kelantan	407	188	219	**53.9**	430	202	228	**53.1**
Labuan	58	46	12	**20.4**	63	46	16	**25.9**
Melaka	475	362	113	**23.8**	482	375	107	**22.1**
N. Sembilan	737	439	298	**40.4**	734	468	267	**36.3**
Pulau Pinang	966	796	170	**17.6**	988	809	180	**18.2**
Pahang	1,082	496	586	**54.2**	1,065	504	561	**52.7**
Perak	1,158	809	349	**30.1**	1,200	835	365	**30.4**
Perlis	200	67	133	**66.4**	211	80	132	**62.4**
Sabah	1,057	529	528	**49.9**	1,132	530	602	**53.2**
Sarawak	1,088	768	320	**29.4**	1,150	790	359	**31.3**
Selangor	4,323	2,893	1,429	**33.1**	4,564	2,989	1,575	**34.5**
Terengganu	615	389	226	**36.8**	623	413	210	**33.8**
MALAYSIA	14,996	9,532	5,464	36.4	15,549	9,855	5,694	36.6

In researcher opinion, some state shows relatively high NRW rate compare with the others. The differences show that some state water agency possesses superior water management system compare to the other state's water agency with higher NRW rate. For example, in Pulau Pinang, the water supply is managed by Perbadanan Bekalan Air Pulau Pinang Sdn Bhd (PBAPP). Compare with the others, PBAPP is considered as one of the most successful privatized water company in Malaysia. This indicates that some state's water agency should learn from other state's water agency on how to manage water supply effectively.

NRW Manager 1 claimed that on 2014 around twenty-two per cent of the water supplies produced by SAMB are considered non-revenue water. Twenty-two per cent of non-revenue water which equal one over fourth of the water produced is wasted. Around 14 million m3 are produced within a year, which mean 3.5 million m3 of water is wasted within a year. Thus, this makes non-revenue water as one of challenges for SAMB to cope with. By reducing the impacts of Non-revenue water (NRW) through sustainable water management, SAMB will be able to provide more adequate water supply to the public.

NRW Manager 2 emphasised that in order to promote sustainable water management, all water agency in each states should have their own non-revenue water department in coping with NRW problems. This reflects how large the impact of NRW can bring towards our water supply. Even, the water agencies around the world are also focusing on minimising NRW problems. It is clearly show that NRW issues become the main focus in achieving goal of adequate water supply.

NRW Manager 3 stated that sustainable water management increases the efficiency of water supply distribution system management. Allowing the minimisation of unscheduled water supply disruption, through efficient water pressure control measures and close supervision of quality of work and materials. Which will ensure adequate water supply been supplied to public with less disruption and superior services.

In summary, to promote adequate water supply, superior water services is necessary to ensure that water supply is been fully utilise. A poor water services will lead to large waste on the water supply that has been produced due to non-revenue water problems. Well-developed infrastructure and good operating practices will be able to help water agency to cope with non-revenue water and enhancing better water supply system. Through effective water supply planning, water supply disruption can be reduced and it will lead to adequate water supply by the water agency.

4.3.3 Safe and Clean Water Supply

According to Liemberger on 2010, eighty per cent of the diseases were caused by drinking unclean water, lack of sanitation, and poor hygiene. Unlike genetic disease, which individuals are predisposed to, acquiring water, sanitation, and hygiene related diseases are controllable and preventable. The spread of these diseases depends on environmental conditions and behaviour in the household and community. Diarrhoea, acute respiratory infection, measles, malaria and malnutrition are the most common diseases related to water. Illnesses related to water, sanitation and hygiene include the following:

a) Water-borne diseases occur when a disease-causing agent the body through drinking.

b) Water-washed diseases occur because of inadequate hygiene conditions and practices.

c) Water-based diseases include those illnesses that are spread through a disease vector that lives in water.

According to water treatment Manager 1, water treatment is essential in preparing water supply for the use of society. Through water treatment, Bacteria and waterborne illnesses will be completely removed before the water can be used or consumed. Illnesses such as cholera, typhoid and dysentery can be deadly if contracted by humans. Using crucial treatment processes such as chlorination, filtration and distillation will remove such unwanted elements from our water. Some treatment system includes ion exchange and absorption for alternatives. Water utilizes select a combination of treatment processes most appropriate to treat the contaminants found in the raw water used by the system.

Zaini on 2008 suggests in water quality and resources management, a holistic water policy approach is crucial for sustainable development. In order to provide safe drinking water, several urban and rural water supply programs were implemented with an emphasis on developing and upgrading source works, storage and treatment plants as well as rehabilitating the distributions systems.

Quality Manager 1 stated that in ensuring the water deliver are safe and clean, regular piping rehabilitation must be perform. Piping rehabilitation consist of activities such piping examination and piping replacement, which to assure the piping network do not affect the quality and the cleanliness of the water distributed through the distribution network.

According to Trifunovic (2008), corrosion deposits in pipes or sediments caused by improper treatment have to be removed to prevent water quality deterioration. The technique commonly used is flushing, where it greatly help to improve the water quality that passing thru network. The efficiency of flushing can be increased by injection of compressed air into a continuous but smaller flow of water. Pushed by the air, the water will form into discrete slugs forced along the pipe at high velocities.

Quality manager 2 suggested that in order to ensure safe and clean water supply, it is essential for SAMB to carry-out flushing process. Where flushing activity consists of cleaning the piping network, ensuring the piping network is in a good condition to flow the water supply along the piping network. A good condition of water network do not affected the quality of water flow through it. In flushing activity, certain chemicals substances mixed with water are flowed along the piping system, removing dirt and molds stuck at the cavity of the pipe. A piping system is then rinsed a few times before cab is used to remove the leftover dirt from the system.

World Bank reported on 2013, 1.8 million annual deaths were attributable to unsafe water, sanitation and hygiene around the world. It involved more than 50 countries, which are mostly the third world countries. The main source of water related diseases is associated with inadequate provision of water and sanitation services.

The researcher agrees that water treatment is essential in removing bacteria and waterborne illnesses for clean and safe water supply. Not only that, In order to provide safe drinking water, several urban and rural water supply programs should be implemented with an emphasis on developing and upgrading source works storage and treatment plants as well as rehabilitating the distributions systems. Water is probably the most valuable natural resource that we have and it is absolutely vital when it comes to sustaining industries. Thus it is crucial to have clean and safe water supply for development of our country.

4.4 Sustainable Water Management Strategies

There are two strategies for sustainable water management for water supply efficiency that are water treatment system and water distribution management. Under water distribution management, consist of three components which are pressure management, leakage monitoring, and operation and maintenance.

4.4.1 Water Treatment Systems

According to Wiedeman (2012), water treatment systems come in all shapes and sizes, and no two are exactly the same. They may be publicly or privately owned and maintained. While their design may vary, they all share the same goal: providing safe, reliable drinking water to communities they serve. The amount and type of treatment applied by a public water system varies with the source type and quality. Large-scale water supply systems tend to rely on surface water resources, while smaller systems tend to rely on ground water. However, surface water systems are exposed to direct wet weather runoff and to the atmosphere and are therefore more easily contaminated.

Wiedeman (2012) also adds that disinfection of drinking water is one of the major public health advances of the 20th century. Water suppliers use a variety of treatment processes to remove contaminants from drinking water. These individual processes may be arranged in a series of processes applied in sequence. The most commonly used processes include filtration, flocculation and sedimentation. Some treatment system includes ion exchange and absorption. Water utilises select a combination of treatment processes most appropriate to treat the contaminants found in the raw water used by the system.

According to water treatment manager 1, process such as coagulation, sedimentation, Filtration and disinfection are the common and conventional processes which are important in any water treatment process. These processes are essential in producing clean and safe water supply for the use of society. There are also few new technology that have been used in SAMB for higher water quality, one of the new technology is called Dissolve Air Floatation (DAF) that have been used in Bertam water treatment plan. Dissolved air floatation (DAF) process that uses micro air bubbles to attach and float flocculated particles and suspended solids to the water surface for removal. They are a cost-effective alternative to conventional sedimentation clarification processes.

According to Kementerian Tenaga, Teknologi Hijau dan Air website, there are two water treatment plants in Malaysia with sophisticated water treatment technology. The first one is Air Bertam water treatment plant in Malacca with the technology of Dissolve Air Floatation (DAF), and the other one is Sungai Rumput water treatment plant, in Selangor with the technology of Ultra Filtration Membrane (UFM). These advance water treatment technology will ensure greater water treatment process for safe and clean water supply.

Water treatment manager 2 stated that water chlorination process also has been improved. Instead of using conventional chlorination method, SAMB has been using electro-chlorination for their disinfection process. Electro-chlorination is more safe, inexpensive and more efficient in term of productivity and water quality. The different between conventional chlorination process and electro-chlorination is the usage of different type of chlorine substance, electro-chlorination use chlorine

liquid rather than chlorine gas to enhance the use of more accurate amount of chlorine which is harmful if been used excessively.

According to water treatment manager 3, SAMB also include Aeration process into their water treatment system. Aeration process allow the treated water to have higher oxygen content and lower carbon dioxide content which will slow-down the corrosion process of the piping network. This process also prevents iron particle and manganese particle from dissolve into the water for further filtration process.

Water treatment manager 2 noted that, the water treatment processes consist of processes of coagulation, flocculation, dissolved air floatation (DAF), filtration, aeration, electro-chlorination, and ph correction.

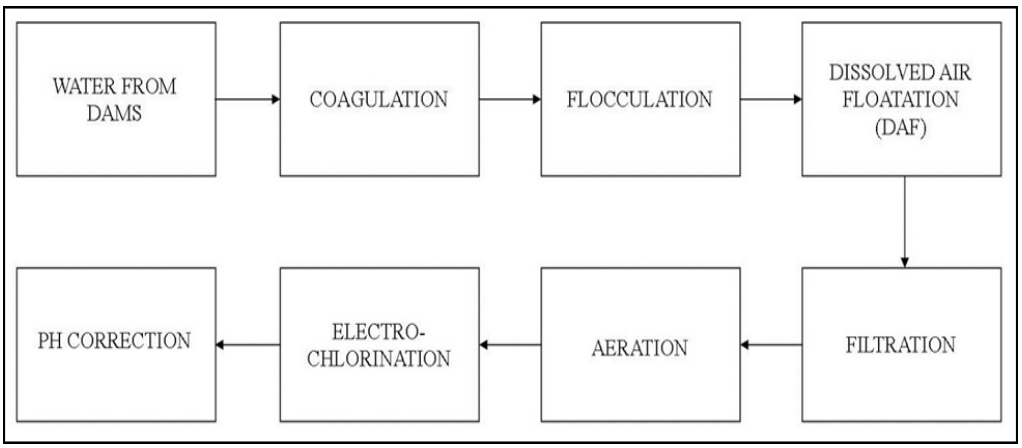

Figure 4.6 : shows the overall picture of public water treatment system of Syarikat Air Melaka Berhad.

In researcher's opinion, by adding new water treatment process through the help of advance new technology, SAMB able to enhance more effective and efficient water treatment process. SAMB will be able to implement water treatment processes that are not only able to increase the quality of water production, but also able to minimize the production cost and the efficiency of the water production for higher performance. Through effective water treatment system, SAMB able to provide its society with superior performance in term of high quality water treatment.

4.4.2 Water Distribution Management

According to Farley (2008), water loss occurs in all distribution systems, only the volume of loss varies. This depends on the characteristics of the pipe network and other local factors, the water company's operational practice, and the level of technology and expertise applied to controlling it. The volume lost varies widely from country to country, and between regions of each country. The components of water loss, and their relative significance, also vary between countries. One of the cornerstones of a water loss strategy is therefore to understand the relative significance of each of the components, ensuring that each is measured or estimated as accurately as possible, so that priorities can be set via a series of action plans. The expressions 'water loss' and 'non-revenue water' (NRW) are now internationally accepted, and have replaced expressions such as 'unaccounted-for water' (UFW) which are less consistent and which make inter-country comparisons more difficult.

4.4.2.1 Pressure Management

According to Farley (2008), pressure management is one of the fundamental elements of a well-organised leakage management strategy. The most cost effective schemes are those which cover a large area, and which make a significant impact on average pressures. Pressure management is best

undertaken in conjunction with district metering, or when establishing supply zones. As well as the reduction in pressure, good pressure management will also result in more stable pressures, causing less strain on the pipe network, and less chance of fatigue damage at joints.

Water distribution systems convey water drawn from the water source or treatment facility, to the point where it is delivered to the users. These systems deal with water demand that varies considerably in the course of a day. Water consumption is highest during the hours that water is used for personal hygiene and cleaning, and when food preparation and clothes washing are done. Water use is lowest during the night. It is necessary to maintain sufficient pressure in the distribution system to protect it against contamination by the ingress of polluted seepage water (Trifunovic et al., 2008).

Engineer 1 explained that pressure control is the simplest and most immediate method of saving water and reducing leakage. The requirement for pressure changes during the day and night, and by controlling the pressure at the peak times, huge water savings can be made. Excessive water pressure in the pipe can lead to burst pipes and leakage. High pressure in pipes will cause cracks to appear or enlarge existing cracks and subsequently increase the size of leakage. Pressure in the pipes needs to be controlled by installing pressure-reducing valves (PRV).

Technician 1 stated that the usages of water differ during day and night. Water usage is highest during the day and lowest during the night. Thus, the pressure required during the day and the night also differ, where higher pressure are required during the day and lower pressure is required during the night. Sufficient pressure is crucial in enabling the water to flow from the distribution tanks to houses and premises through distribution network. Determining and exerting the accurate pressure in the distribution network is important. Thus, to determine the accurate required pressure, a logger is use to in the distribution network. Data loggers enable SAMB to gather important information on their network performance, from the tension of the pressure exert in the network, measure leakage and also verify the performance of Pressure Reducing Valves. Data logger also allows SAMB to plan network expansion, identify pressure zones and monitor District Metered Areas. The data logger also comes with a feature that allows SAMB to access the information from the logger through smart phones and computer. By entering the serial numbers of the logger into their program, information from the logger can be access.

Technician 2 revealed that in SAMB the main component to control the pressure in the distribution network is pressure reducing valve (PRV). Pressure reducing valve is use in keeping system pressures safely below a desired upper limit to maintaining a set pressure in part of a hydraulic network system. Pressure reducing valve enables pressure into a zone to be switched between two pre-set values ("low" and "high") according to the demand (flow rate) or time of day. Restriction is necessary to produce the required pressure control, without controlling or limiting the pressure within the distribution network, the network could be damaged. Pressure reducing valve will reduce high pressure in the network to suitable water pressure. In other words, pressure reducing valve is use to ensure optimum water pressure for optimum performance of the distribution network. Pressure reducing valve also help to extend asset life and reduce burst frequency, whilst providing a more consistent service to the customer.

In researcher's opinion, effective pressure management is important to ensure the water supply network is in a good condition. Pressure in the network should always be monitored and control, to ensure that the number of pipe burst and leakage in the network can be minimising in order to reduce the water losses. With the help of technology such as pressure reducing valve (PRV) and electronic logger can enhance the effectiveness and efficiency of the pressure management in the water supply network.

4.4.2.2 Leak Monitoring

According to Farley (2008), the technique of leakage monitoring is considered to be major contributor to cost-effective and efficient leakage management. Leakage monitoring is flow monitoring into zones or districts to measure leakage and to prioritize leak detection activities. This has now become one of the most cost-effective activities and the one most widely practiced for leakage management. A flow measuring system in a water distribution network should include not only measurement of total flows from source or treatment works (production), but also zone and district flows. This allows the engineer to understand and operate the system in smaller areas, and allows more precise demand prediction, leakage management and control to take place.

Leakage monitoring requires the installation of flow meters at strategic points throughout the distribution system, each meter recording flows into a discrete district which has a defined and permanent boundary. Such a district is called a District Meter Area (DMA). Therefore, the leakage monitoring system will comprise a number of districts where flow is measured by permanently installed flow-meters. In some cases the flow-meter installation will incorporate a pressure reducing valve.

According to Trifunovic (2008), finding a precise leak location can be a difficult problem. In case of severe breaks the water may appear on the surface and the exact position of the leak can be determined by drilling test holes alongside the pipe route. If the leak is not visible on the surface, leak detection equipment has to be used. The most common devices are an acoustic (sound) detector and a leak noise correlator.

Active leakage control manager 1 stated that the fastest way of detecting leakage is through public complaint. Where network audit is only be perform on a regular basis, and if the leakage occur in-between two scheduled network audit, that leakage can be only detect on the next scheduled network audit. With the help from the public, SAMB will be able to detect the leakage as soon as it is visible.

Referred to SAMB website, public hotline has been launched to allow public to file in complaints and reporting sighted leakage occurrences for quick action measures. This is to promote public awareness among the society about the importance of reporting any sign of leakage on the ground. More water can be save, when detected leakages are been reported as soon as possible.

According to Technician 2, by designing and establishing District Metering Zone (DMZ), managing NRW can be simplified to more effective and efficient. SAMB has been dividing the water network into 170 small section and a bulk water meter is been set up at every divided section. NRW is monitored and measured in each established zone. The NRW reduction program will have a higher chance of success through the monitoring of water flow and pressure in distribution systems within established boundaries.

Maintenance manager 1 stated that, network audit allow SAMB to measure volume flows across the network to support the water balance calculation and helps to identify which part of the network having water loss. The water network is divided into 170 small districts and a bulk meter is been set-up at every divided district. The bulk meter will provide information on how much water flow at that district and allow SAMB to detect any water loss on that district. The telemetry system can be connected to the bulk meters to monitor flow and pressure data remotely. Then, devices such as sounding stick will be used to detect more specific leakage location on leaked section. If the leakage still has not been found, more sophisticated devices such as ground microphone will be used. These two devices are using the principle of sounding, where leaked pipe will produce different sound with the one not having any leakage.

Maintenance technician 1 emphasised that leakage problem not only occur at the piping network, but it can also happen at the distribution tanks. Leakage in water tanks can occur when there

are cracks or structural failure. This usually occurs in old water tanks. Leakage to these structures usually can be detected visually. SAMB did come out with program which allow SAMB to monitor all distribution tank all-over Malacca. This program called G1 allow SAMB to monitor the quantity of water in the tanks and able to detect any sign of leakage on those tanks. G1 program will not only detect leakage at the tank, will also detect overflow of water into the tank. Every reservoir or water tank has a maximum capacity according to its size. The uncontrolled inflow of water into the reservoir or water tank will lead to overflow. This is cause by malfunctions of the flow control valve in the tank system which required maintenance at regular basis.

According to maintenance technician 2, once a pipe leak has been located, repair work must be carried out promptly to prevent further water loss. The timeframe for action according to best practices is within 4 hours. Aside from speedy action, the materials used must be of high quality and certified by IKRAM QA Services Sdn Bhd (IKRAM) or Standards and Industrial Research Institute of Malaysia (SIRIM). Repairs should be done by personnel who are skilled in pipe repair work to ensure high quality workmanship and to prevent recurrence of the problem.

Through effective leakage monitoring system, researcher believes that large amount of water can be save from loss in the water supply network. With the help of effective methods such district metering zone (DMZ) will enable SAMB to have better leakage monitoring system. District metering zone will provide full monitoring works in every area of the supply network. With the help of advance technology equipment such as sounding system and sophisticated metering techniques will provide greater leakage monitoring system. With the help of G1 system, tanks and reservoir can be maintain effectively.

4.4.2.3 Operation and Maintenance

According to Farley (2008), Operation and Maintenance (O&M) is crucial to the successful management and sustainability of water supply networks, whatever the level of technology, infrastructure, and institutional development. The O&M philosophy applies as much to boreholes and hand-pumps as it does to complex water distribution networks. 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 best practice in operating and maintaining the system. It is essential that an O&M program is built into the project from an early stage and not as an afterthought.

According to Technologist 1, in order for SAMB to manage and sustain their water supply networks, SAMB has been using the help from various systems to monitor their water supply networks. These various systems are controlled by the telemetry system, which is an information /data delivery system used for the remote monitoring of parameters such as water flow, pressure, depth and control valves, and pumps. This whole system is called Supervisory Control and Data Acquisition (SCADA).

According to technologist 2, the reservoir/water tank, District meter zones (DMZ|), and Pressure Reducing Valve (PRV) provide data such as flow, pressure, water level, pump operation and water quality parameters which can be controlled and monitored by both the SCADA and telemetry systems. By using a SIM card, information from a remote terminal unit (RTU) can be sent to the centralized database on a daily basis. The information can also be sent to mobile phones and alarm systems. Furthermore, the data can be managed and displayed on a website using a web server. Other than the web server, a LAN network can also be used to display the relevant information.

In researcher opinion, with the help of Supervisory Control and Data Acquisition (SCADA), every water operations and maintenance can be perform systematically and efficient. SCADA allow SAMB to receive real time information on any problems that occur on-site which allows proactive

action to be taken to address the problem. Moreover, the system is equipped with the facility to store records and information on an on-going basis, which can be used as reference materials. The telemetry system makes monitoring and delivery of NRW data simple and cost-effective.

4.5 Innovative Suggestions on Sustainable Water Management

This part discussed the researcher' innovative suggestions on sustainable water management for water supply efficiency based on responds and feedbacks from interviewed manager and technicians.

4.5.1 Centralised Information and Communication Technology (ICT) System

According to Technologist 1, sustainable water management can be improved by implementing the standardisation of the water management of water agency in each state. Currently, every state has its own different procedures of operation in managing water supply. Which it leads to different outcomes and result in term of non-revenue water and cost of production. Some of the state water agencies have been reported with higher non-revenue water rate and some of the water agencies have been reported with a relatively low non-revenue water rate. This problem happen when the knowledge and information is not been disclosed between water agencies.

Researcher agrees that it is important for the information and knowledge regarding the sustainable water management is been centralised and can be access by every water agency. Thus, creating a medium for every water agency to disclosed information and knowledge to one-another will allow greater sustainable water management practices among the water agencies. Managers from each states water agency can sit together, proposing the best water management practices and provides the best guidelines of best water management practices in a complete, effective and prudence manner.

4.5.2 Technology and Knowledge Transfer

According to World Bank on 2007, Singapore has been recorded with only five per cent of non-revenue water in their water supply system, following by Denmark and Netherlands with six per cent of non-revenue water, and Japan with seven per cent of non-revenue water.

According to Operation Manager 1, in present, Malaysia water management system even-though we have a good water management system, but we still can learn a lot from other developed country. Other countries posses' far more superior water management system, that we can learn in-order to improve our water management system. There more sophisticated technology to manage water sustainably and high-knowledge techniques and methods for managing efficient water supply.

In researcher's opinion, technology and knowledge transfer can improve out water management system, allowing greater sustainable water practices in optimising our water supply resources. By transferring technology from other countries, it will promote new and advance water management technology for better water management practices. Knowledge transfer will allow enhancement to our people minds with better understanding and gain greater information and in-sight in managing sustainable water management system.

4.5.3 Promoting Public Awareness

According to Production Executive 1, it is important to sensitise and generate a greater degree of awareness to the strategic importance of water conservation. Water conservation activities, such as water loss reduction programs and public awareness campaigns for rational water use could result insignificant water savings. The saved water could then be made available to the underprivileged

people who lack sustainable access to water supply services, while new And expensive projects for developing additional water supply sources could be Cancelled or postponed for at least several years.

Researcher agrees that public awareness and education is a critical water conservation priority. A multi stakeholder and participatory approach involving water users and service providers, governmental agencies and non-governmental organizations needs to be encouraged. Raising awareness of water issues at all levels is deemed critical in the successful implementation of water conservation programs and activities. Without public awareness in water conservation, the implementation of sustainable water management in water supply system will be wasted. Thus, it is crucial to promote public awareness in water conservation, while improving our water management system for efficient water supply.

5.0 Conclusion

Sustainable water management is crucial for any country to advance ahead, water resources plays an important roles in the development of every sectors in Malaysia. Plenty water resources allow a country to have rapid development on sectors such as agriculture and industrial sectors. Country with advance development of its sectors will have a strong economy. It is the government role to create an effective and appropriate institutions and management which enhance sustainability on the water resources handling. Implementing a proper system, that keeps the balance of human needs with the needs of the natural environment. To do so, sustainable water management system need to be applied, which not only it will optimise the usage of water resources but also ensure the environmental sustainability.

This study allows the researcher to gain deeper understanding on how to achieve sustainable water management. The research also allow the researcher to take part in finding ways, generating and producing ideas and alternative in helping to sustain the water resources. The research will allow the university and the government to share same mutual interests in improving the sustainable water management system in Malaysia. The purpose of this research is to help the authority to measure the impacts of the current water management system. Where, the research focuses on the sustainable water system, and enhance efficient water supply which are critical to the interests of all humans, nations and governments.

References

Farley, M., (2003). Non-Revenue Water–International Best Practice for Assessment, Monitoring and Control. In 12th Annual CWWA Water, Wastewater & Solid Waste Conference.

Farley, M., & Liemberger, R. (2005). Developing a non-revenue water reduction strategy: planning and implementing the strategy. Water Science & Technology: Water Supply, 5(1), 41-50.

Farley, M., & Trow, S. (Eds.). (2003). Losses in water distribution networks: a practitioner's guide to assessment, monitoring and control. IWA Publishing.

Farley, M., Wyeth, G., Ghazali, Z. B. M., Istandar, A., & Sigh, S. (2008). The Manager's Non-Revenue Water Handbook. A Guide to Understanding Water Losses, Ranhill Utilities Berhad and USAID, Malaysia.

Frauendorfer, R., & Liemberger, R. (2010). The issues and challenges of reducing non-revenue water.

Ghauri, P. N., & Grønhaug, K. (2005). Research methods in business studies: A practical guide. Pearson Education.

Khairol, A. B., & Jaafar, D. K. Commisioner of Nattional Water Service (Suruhanjaya Perkhidmatan Air Negara): Function and Effectiveness on Water Management In Malaysia.

Lawler, J. J. (2009). Climate change adaptation strategies for resource management and conservation planning. Annals of the New York Academy of Sciences, 1162(1), 79-98.

Liemberger, R., & Marin, P. (2006). The Challenge of Reducing Non-Revenue Water in Developing Countries--How the Private Sector Can Help: A Look at Performance-Based Service Contracting.

Mara, D., & Horan, N. J. (Eds.). (2003). Handbook of water and wastewater microbiology. Academic press.

National Audit Department Malaysia. (2007). Audit Guidelines: Non-Revenue Water. Malaysia National Audit Department.

Phang, W. L., Ngai Weng, C. H. A. N., & Lai, C. H. (2011). Domestic Water Saving Practices as a Water Demand Management Strategy in Penang, Malaysia.

Reed, M., & Johnsen, S. (Eds.). (2012). Produced water 2: Environmental issues and mitigation technologies (Vol. 52). Springer Science & Business Media.

Saunders, M. N., Saunders, M., Lewis, P., & Thornhill, A. (2011). Research methods for business students, 5/e. Pearson Education India.

Sekaran, U., & Bougie, J. R. G. (2009). Research Methods for Business: A Skill Building Approach.

Ujang, Z., & Henze, M. (Eds.). (2006). Municipal wastewater management in developing countries: Principles and engineering. IWA Publishing.

Wiedeman, A. (1996). Regulation of produced water by the US Environmental Protection Agency. In Produced Water 2 (pp. 27-41). Springer US.