WATER RETICULATION MODEL FOR TAMAN MAJU, PARIT RAJA

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ABSTRAK

Satu model numerikal telah dihasilkan untuk menilai kuantiti kehilangan turus tenaga dalam jaringan pengagihan air di Taman Maju, Parit Raja, Johor. Sebuah pengiraan numerikal mempunyai kelebihan berbanding sebuah pengiraan manual apabila menganalisa sebuah jaringan pengagihan yang kompleks. Bahasa pengaturcaraan yang digunakan dalam kajian ini ialah Microsoft Visual Basic 6.0. Kaedah Hardy-Cross dipilih untuk mengira jumlah kehilangan turus tenaga yang berlaku dalam jaringan pengagihan air gelung Taman Maju. Jenis paip yang digunapakai dalam jaringan pengagihan air Taman Maju ialah jenis *unplasticised polyvinyl chloride* (uPVC) dengan pemalar kekasaran k = 0.0015 mm. Oleh kerana Taman Maju meliputi perumahan teres, permintaan air ialah 1360 liter/unit/hari. Tiga gelung rangkaian telah dipertimbangkan, iaitu gelung A, B dan C untuk sistem retikulasi Taman Maju. Kadar alir akhir dalam setiap paip telah diperolehi. Model ini berguna untuk mengurangkan tempoh masa yang digunakan dalam pengiraan kadar alir yang telah didapati berada dalam keperluan rekabentuk. Jika perbandingan dibuat di antara pengiraan manual, akan terdapat sedikit perbezaan. Hasil akhir adalah berbeza kerana bilangan tempat perpuluhan yang ditetapkan dalam pengiraan manual dan model adalah berbeza.

ABSTRACT

A numerical model is developed to quantify energy head losses occurred in the water distribution network of Taman Maju, Parit Raja, Johor. A numerical computation has the advantage over a manual computation when analyzing a complex distribution network. The programming language used in this study is the Microsoft Visual Basic 6.0. Hardy-Cross method is selected to calculate the total energy head loss incurred in the looped water distribution network of Taman Maju. The type of pipe used in the water distribution network of Taman Maju is the unplasticised polyvinyl chloride (uPVC) type with the roughness coefficient k = 0.0015 mm. Since Taman Maju consists of terrace houses, the water demand is 1360 litres/unit/day. Three loop networks are considered, namely loop A, B and C for Taman Maju reticulation system. The final flow rate in each pipe has been obtained. This model is helpful in reducing the period of time to calculate the flow rate which is found to be within the piping system design requirement. If comparison is made between the manual calculation, it will definitely shows some difference. The final result will be different because the decimal places fixed are different in manual and model.

CONTENTS

LIST OF SYMBOLS AND ABBREVIATIONS

a	acceleration of fluid flow
A	cross-sectional area of fluid flow
C	Hazen-Williams coefficient
D	diameter of pipe
δQ	correction for assumed flow rate
e	surface roughness of pipe
f	friction factor
F	inertial force
g	gravitational acceleration
h_f	frictional head loss
K	Hardy Cross coefficient or head loss coefficient
L	length of pipe
m	mass of fluid
υ	kinematic viscosity of fluid
Q	flow rate
Q_a	assumed flow rate
Q'	corrected flow rate
Re	Reynolds number
ρ	density of fluid
V	velocity of flow

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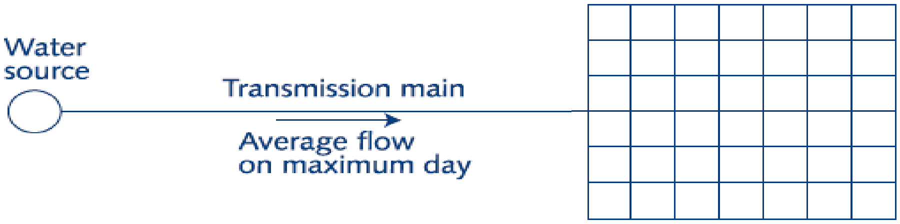
CHAPTER 1

INTRODUCTION

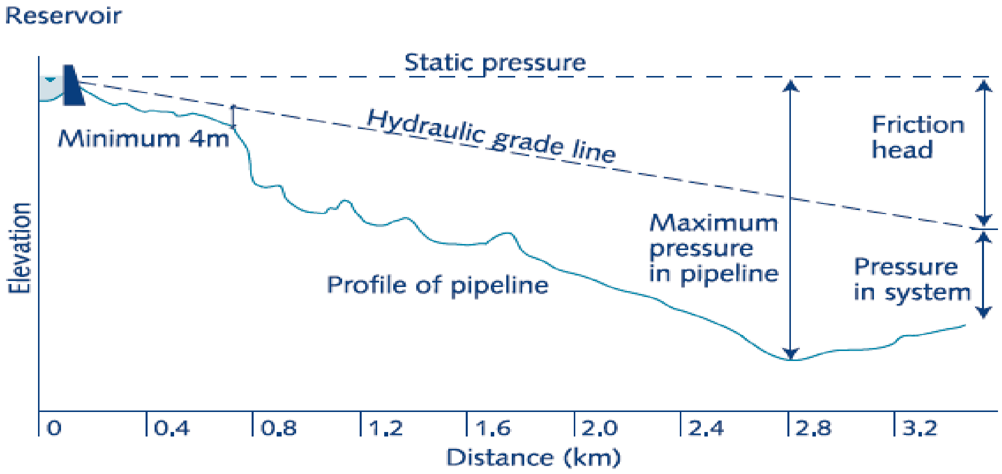
1.0 Research Background

Renewable sources of fresh water on the earth's surface are limited and irregularly distributed in space and time. There are about 1360 million km^3 of water on the surface of the earth. More than 97% of this volume comes from the oceans or seas. The remainder of about 37 million km^3 is fresh water (Eisenberg and Kauzmann, 1969). However, most of the fresh water on the earth is of little use because it is in the forms of ice-caps and glaciers. Approximately 8 million km^3 of the water is stored in relatively inaccessible groundwater and about 0.126 million km^3 are contained in lakes, reservoirs and streams (Franks, 1972). In recent years, the ever-increasing growth in the population of urban areas and the desire for security and a higher standard of living have attracted the attention on problems related to water economy. Such attention brought and will continue to bring about a surge in water-management work on a global scale. Thus, engineers, agriculturists, environmentalists, irrigation specialists, meteorologists, and hydrologists will have unparalleled opportunities to put their knowledge and skill to work for humanity.

Humans have contained water supply in one location by collecting it and creating a more reliable and constant supply despite its natural variation. Reservoirs are replenished by many sources including streamflow, groundwater, snow, and/or rainfall. They are diminished by multiple losses including consumption and friction losses. Water storage is designed to meet multiple objectives such as hydropower, irrigation, potable supplies, fishing and recreation, and to reduce the risk of floods and droughts (UNESCO, 2006).



(a) plan view



(b) cross sectional view

Figure 1.1: Head losses incurred in the distribution pipeline reduces the pressure in the System.

In hydraulic engineering practices, it is often necessary to estimate the head loss incurred by fluid as it flows through a pipeline and it is one of the most important problems in water distribution system. Friction loss refers to the difference in pressure needed to overcome the pressure drop during flow through pipe. Friction loss occurs as a result of dynamic movement caused by flow. Therefore, the pressure difference associated with this process is referred to as the dynamic differential pressure. Friction losses can only occur when flow actually takes place. Once a fluid begins to flow through a pipe it will therefore be necessary to overcome the extra difference in pressure caused by friction losses. This will have to be provided by the pump, in addition to it overcoming the stationary differential pressure. The pump’s differential pressure will always be made up of the sum total of the stationary and dynamic differences in pressure.

Loss of head is incurred by fluid mixing which occurs at fittings such as bends or valves, and by frictional resistance at the pipe wall. Where there are numerous fittings and the pipe is short, the major part of the head loss will be due to the local mixing near the fittings. For a long pipeline, on the other hand, skin friction at the pipe wall will predominate.

Head losses are generally the result of two mechanisms, friction along the pipe walls and the turbulence due to changes in streamlines is through fittings and appurtenances. Head losses along the pipe wall are called friction losses or head losses due to friction, while losses due to turbulence within the bulk fluid are called minor losses (Ibrahim, 2005). Estimation of head losses due to friction in pipes is an important task in optimization studies and hydraulic analysis of pipelines and water distribution systems.

Using a distribution system model, we can have a better view of the flow in the water supply system and it is convenient to study for friction loss. Such numerical simulations save a lot of time and can be performed without actually doing the laboratory experiment.

1.2 Problem Statement

A water supply system is considered successful if it could supply water at the required quantity and quality with minor loss. In order to supply water to meet the demand, the water pressure has to adequate at all locations.

There is no network of pipes that is able to deliver water in fully accordance to the designed system. It is important for the engineers to maximize the delivery of adequate water supplies while reducing the head loss in the pipe network. Other than the loss due to water leakage or theft, head loss in water supply is also due to the friction loss in the piping system (Donald, Bruce and Theodore, 2000).

Complex network of pipes that has a lot of connections will increase head loss in the water distribution system. This factor has to be accounted for while analyzing the head loss in the flow. Manual method is not only time consuming, but may cause errors in analysis. Therefore, a pipe network model will be developed using the Microsoft Visual Basic to obtain an accurate and faster computations.

1.3 Objectives of Study

The objectives of this study are:

1. To develop a numerical model to calculate the head loss occurs in water distribution pipe system due to frictional resistance and other minor losses,
2. To determine the required head needed to supply water to Taman Maju, Parit Raja, Johor, and
3. To determine the total head losses involved in the water distribution system of Taman Maju, Parit Raja, Johor. This requires identification of the sources of head losses and its quantification.

1.4 Scopes of Work

The water distribution network system to be studied is of the residential area of Taman Maju, Parit Raja, Johor as shown in Figure 1.2. The pipe network layout and the characteristics such as the length, diameter, type of pipe as well as the number of consumers (or demand) are obtained from the Syarikat Air Johor Holdings (SAJH) Malaysia. The details are also available on the layout.

In this study, the head losses considered are due to friction, valve and pipe fittings. Hardy-Cross method is used to determine the total head loss in the pipe distribution network. The head loss due to friction is determined using Darcy-Weisbach equation along with the tabulated Moody chart. The advantage of Darcy-Weisbach method is that it can be used to calculate frictional losses for all types of fluids.

The programming language used in the study is the Microsoft Visual Basic 6.0. Microsoft Visual Basic 6.0 is chosen as the programming language as it is user-friendly and it is known for its graphical interface. The result of analysis can be projected on its form. Even the Microsoft Office programs utilize Visual Basic in their system development.

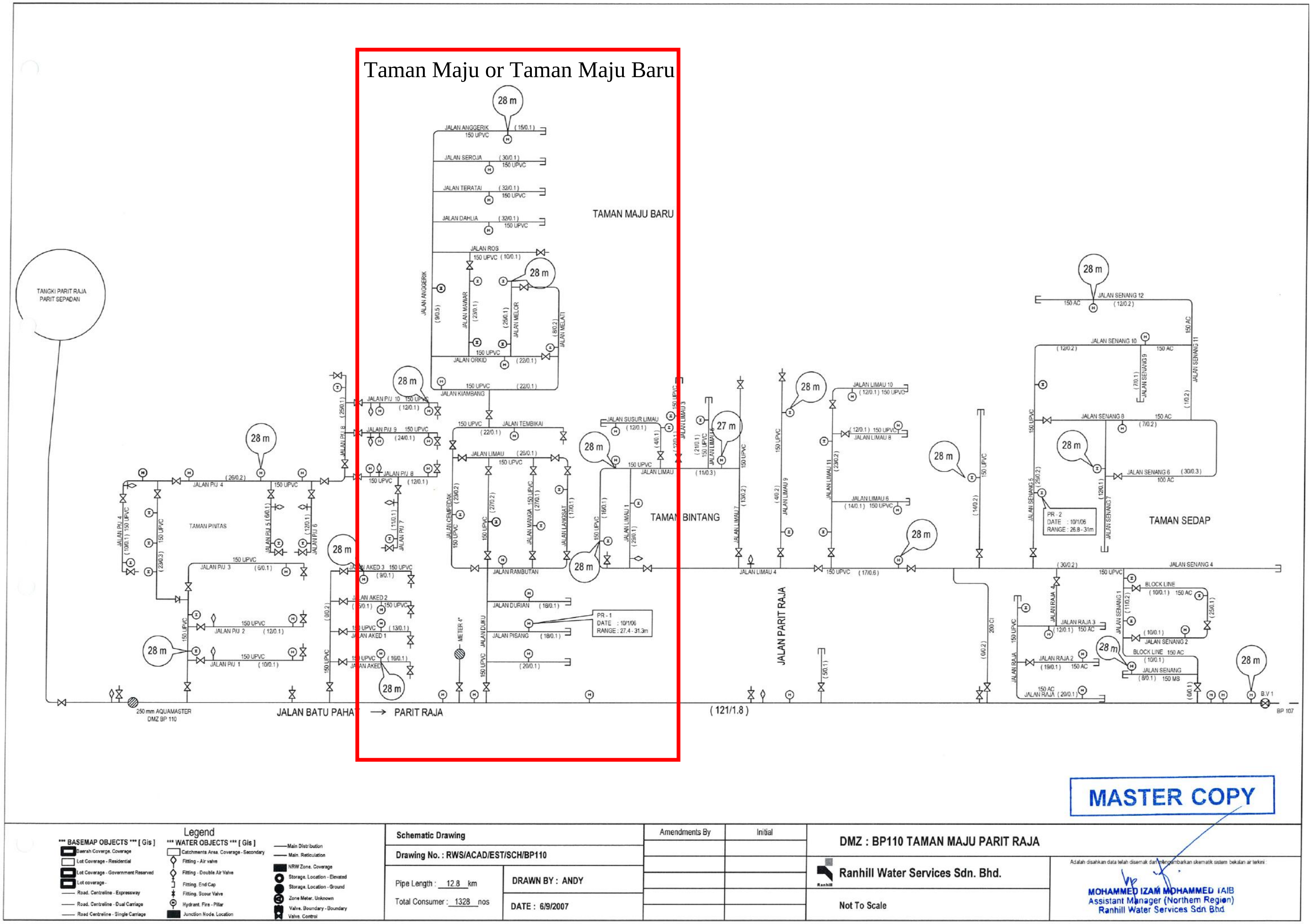


Figure 1.2: Layout of water reticulation system of Taman Maju, Parit Raja

CHAPTER 2

LITERATURE REVIEW

2.1 History of Water Supply and Distribution

The tap water in most of the world today is safe to drink and the source of water, for example river flow and groundwater are guarded against pollution. In the early 1900s, safe drinking water did not exist in the world and deadly waterborne disease such as cholera, typhoid fever, and dysentery were a constant threat. Table 2.1 shows the history of the development of water supply and its distribution since 1900.

Table 2.1. General timeline of water supply and its distribution (Constable and Somerville, 2011)

Year	Development
1900	**Sanitary and ship canal opens in Chicago** In Chicago, the main channel of the sanitary and ship canal opens, reversing the flow of the Chicago river. The 28-mile, 24-foot-wide drainage canal, built between Chicago and the town of Lockport, Illinois, is designed to bring in water from Lake Michigan to dilute sewage dumped into the river from houses, farms, stockyards, and other industries. Directed by Rudolph Hering, chief engineer of the Commission on Drainage and Water Supply, the project is the largest municipal earth-moving project of the time.

1913	**Los Angeles-Owens River Aqueduct** The Los Angeles-Owens River Aqueduct is completed, bringing water 238 miles from the Owens Valley of the Sierra Nevada Mountains into the Los Angeles basin. The project was proposed and designed by William Mulholland, an immigrant from Ireland who taught himself geology, hydraulics, and mathematics and worked his way up from a ditch tender on the Los Angeles River to become the superintendent of the Los Angeles Water Department. Mulholland devised a system to transport the water entirely by gravity flow and supervised 5000 construction workers over 5 years to deliver the aqueduct within original time and cost estimates.
1913	**Activated sludge process** In Birmingham, England, chemists experiment with the biosolids in sewage sludge by bubbling air through wastewater and then letting the mixture settle; once solids had settled out, the water was purified. Three years later, in 1916, this activated sludge process is put into operation in Worcester, England, and in 1923 construction begins on the world’s first large-scale activated sludge plant, at Jones Island, on the shore of Lake Michigan.
1914	**Sewerage Practice, Volume I: Design of Sewers** Boston engineers Leonard Metcalf and Harrison P. Eddy publish American Sewerage Practice, Volume I: Design of Sewers, which declares that working for “the best interests of the public health” is the key professional obligation of sanitary engineers. The book becomes a standard reference in the field for decades.
1915	**New Catskill Aqueduct is completed** In December, the new Catskill Aqueduct is completed. The 92-mile long aqueduct joins the Old Croton Aqueduct system and brings mountain water from west of the Hudson River to the water distribution system of Manhattan. Flowing at a speed of 4 feet per second, it delivers 500 million gallons of water daily.

1919	**Formula for the chlorination of urban water** Civil engineer Abel Wolman and chemist Linn H. Enslow of the Maryland Department of Health in Baltimore develop a rigorous scientific formula for the chlorination of urban water supplies. In 1908 Jersey City Water Works, New Jersey, became the first facility to chlorinate, using sodium hypochlorite, but there was uncertainty as to the amount of chlorine to add and no regulation of standards. To determine the correct dose, Wolman and Enslow analyze the bacteria, acidity, and factors related to taste and purity. Wolman overcomes strong opposition to convince local governments that adding the correct amounts of otherwise poisonous chemicals to the water supply is beneficial – and crucial – to public health. By the 1930s chlorination and filtration of public water supplies eliminates waterborne diseases such as cholera, typhoid, hepatitis A, and dysentery. The formula is still used today by water treatment plants around the world.
1930	**Hardy Cross method** Hardy Cross, civil and structural engineer and educator, develops a method for the analysis and design of water flow in simple pipe distribution systems, ensuring consistent water pressure. Cross employs the same principles for the water system problem that he devised for the "Hardy Cross method" of structural analysis, a technique that enables engineers – without benefit of computers – to make the thousands of mathematical calculations necessary to distribute loads and moments in building complex structures such as multi-bent highway bridges and multistorey buildings.
1935	**Hoover Dam** In September, President Franklin D. Roosevelt speaks at the dedication of Hoover dam, which sits astride the Colorado river in Black Canyon, Nevada. Five years in construction, the dam ends destructive flooding in the lower canyon; provides water for irrigation and municipal water supplies for Nevada, Arizona, and California; and generates electricity for Las Vegas and most of Southern California.

1937	**Delaware Aqueduct System** Construction begins on the 115 mile long Delaware Aqueduct System. Water for the system is impounded in three upstate reservoir systems, including 19 reservoirs and three controlled lakes with a total storage capacity of approximately 580 billion gallons. The deep, gravity flow construction of the aqueduct allows water to flow from Roundout Reservoir in Sullivan County into New York City’s water system at Hillview Reservoir in Westchester County, supplying more than half the city’s water. Approximately 95 percent of the total water supply is delivered by gravity with about 5 percent pumped to maintain the desired pressure. As a result, operating costs are relatively insensitive to fluctuations in the cost of power.
1938-1957	**Colorado-Big Thompson Project** The Colorado-Big Thompson Project (C-BT), the first trans-mountain diversion of water in Colorado, is undertaken during a period of drought and economic depression. The C-BT brings water through the 13 mile Alva B. Adams Tunnel, under the Continental Divide, from a series of reservoirs on the Western Slope of the Rocky Mountains to the East Slope, delivering 230000 acre-feet of water annually to help irrigate more than 600000 acres of farmland in northeastern Colorado and to provide municipal water supplies and generate electricity for Colorado’s Front Range.
1951	**First hard rock tunnel-boring machine built** Mining engineer James S. Robbins builds the first hard rock tunnel-boring machine (TBM). Robbins discovers that if a sharp-edged metal wheel is pressed on a rock surface with the correct amount of pressure, the rock shatters. If the wheel, or an array of wheels, continually rolls around on the rock and the pressure is constant, the machine digs deeper with each turn. The engineering industry is at first reluctant to switch from the commonly used drill-and-blast method because Robbins’s machine has a $10 million price tag. Today, TBMs are used to excavate circular cross-section tunnels through a wide variety of geology, from soils to hard rock.

1955	**Ductile cast-iron pipe becomes the industry standard** Ductile cast-iron pipe, developed in 1948, is used in water distribution systems. It becomes the industry standard for metal due to its superior strength, durability, and reliability over cast iron. The pipe is used to transport potable water, sewage, and fuel, and is also used in fire-fighting systems.
1960s	**Kuwait begins using seawater desalination technology** Kuwait is the first state in the Middle East to begin using seawater desalination technology, providing the dual benefits of fresh water and electric power. Kuwait produces fresh water from seawater with the technology known as multistage flash (MSF) evaporation. The MSF process begins with heating saltwater, which occurs as a byproduct of producing steam for generating electricity, and ends with condensing potable water. Between the heater and condenser stages are multiple evaporator-heat exchanger subunits, with heat supplied from the power plant external heat source. During repeated distillation cycles cold seawater is used as a heat sink in the condenser.
1970s	**Aswan High Dam** The Aswan High Dam construction is completed, about 5 kilometers upstream from the original Aswan Dam (1902). Known as Saad el Aali in Arabic, it impounds the waters of the Nile to form Lake Nasser, the world’s third largest reservoir, with a capacity of 5.97 trillion cubic feet. The project requires the relocation of thousands of people and floods some of Egypt’s monuments and temples, which are later raised. But the new dam controls annual floods along the Nile, supplies water for municipalities and irrigation, and provides Egypt with more than 10 billion kilowatt-hours of electric power every year.
1980s	**Bardenpho process** James Barnard, a South African engineer, develops a wastewater treatment process that removes nitrates and phosphates from wastewater

	without the use of chemicals. Known as the Bardenpho process, it converts nitrates in activated sludge into nitrogen gas, which is released into the air, removing a high percentage of suspended solids and organic material.
1996	**UV Waterworks** Ashok Gadgil, a scientist at the Lawrence Berkeley National Laboratory in California, invents an effective and inexpensive device for purifying water. UV Waterworks, a portable, low-maintenance, energy-efficient water purifier, uses ultraviolet light to render viruses and bacteria harmless. Operating with hand-pumped or hand-poured water, a single unit can disinfect 4 gallons of water a minute, enough to provide safe drinking water for up to 1500 people, at a cost of only one cent for every 60 gallons of water – making safe drinking water economically feasible for populations in poor and rural areas all over the world.

2.2 Water Supply in Malaysia

Over the past 200 years, Malaysia has started to provide water supply to agriculture, industries and homes. The foundation of piped water supply was laid down by the British, once they arrived in Penang. Table 2.2 provides a glimpse of the history of water supply system in Malaysia.

Table 2.2. History of Malaysia water supply system (Jabatan Bekalan Air, 2009)

Year	Development
1804	First formal arrangement for a water supply system was drawn when the population in Penang breached 10000. An aqueduct made of brick was constructed to transport clear stream water from hills to town. Earthen pipes were laid under the streets and water was transported through tin pipes to homes.

1877	Bricks in the aqueduct were often dislodged and the aqueduct was eventually replaced with a cast iron main. First water main in Malaysia and traces of it can still be found in the Penang water supply network.
1887	Sarawak was the next British colony to have water mains in Kuching to provide water to 8000 households. Kuala Lumpur was next to receive the tap water services.
1889	Melaka was provided with water supply and followed by the rest of the Federated Malay States. Piped water was soon available to urban households and from standpipes throughout the country.
1900s	Water was treated before distribution to homes. This came as a result of an International movement in developed nations that required the treatment of drinking water to prevent the outbreak of water-borne diseases such as chorela, typhoid, and dysentery. This paved the way for water treatment engineers to design and construct filtration and water treatment plants.
1906	Slow sand filter of Ampang intake was built for Kuala Lumpur.
1915	Disinfection technology using hypochlorite and later, gaseous chlorine made its appearance.
1934	Rapid gravity filter was built in Ayer Hitam. It was Penang’s first treatment plant and is still in service today.
1939	Households in major towns of Malaya were well-served with piped water. Many water installations, however, deteriorated from neglect during the war years of the Japanese Occupation (1941-45).
1950	Malaya had 100 treatment plants producing 195 million litres of water per day to supply a population of 1.15 million.

1957	Demand for water increased sharply in the years after Independence, especially in the capital city in Kuala Lumpur.
1959	Klang Gates dam and the Bukit Nanas treatment plant was commissioned to cope with the rising demand, ending a long period of water shortage and water rationing.
1976-1980	During colonial period, focus was mainly on urban and suburban water supplies. It was under the 3rd Malaysia Plan, that rural water supply received much needed boost. The state of Sarawak received an allocation of RM4139876.00 to convey piped water to remote areas.
1980s	There was a high demand for water when the country embarked on a programme of industrialisation. Water demand for industrial and domestic use rose from 0.8 billion cubic metres in 1980 to 3.5 billion cubic metres in 2000. This is a 437% increase. In comparison, water for irrigation remained the same at 7.4 billion cubic metres each year throughout the 20-year period.
1990	The success of the water supply plan under the 3rd Malaysian plan was reflected in the number of households in Peninsular Malaysia receiving treated water in both urban and rural areas. The figure rose sharply from 23% of all household in 1950 to 85% in 1990.
1990s	Interstate water transfers including the transfer from Sungai Muar, Johor to the Durian Tunggal dam, Melaka.
1999	There were a total of 69 dams in operation in Malaysia. 35 dams were developed for water supply, 16 are multi-purpose while the remaining are for irrigation and hydro-power generation. The large dams include the Temenggor dam in Perak, the Kenyir dam in Terengganu and the Pedu dam in Kedah, whose combined storage capacity exceeds 20000 million cubic metres.

2001-2005	The 8th Malaysia Plan projected water demand to increase by 5.4% per annum from 2001 to 2005. To ensure there is ample water supply to meet the nation’s needs, the Federal Government has allocated RM4 billion for water supply projects under the 8th Malaysia Plan, which is double the allocation under the 7th Malaysia Plan. Existing asbestos pipes will be replaced to reduce water loss which is currently averaged at about 38% of production.
2006-2010	According to the 9th Malaysia Plan, under the Ministry of Energy, Water and Communications, a total of RM8.1 billion will be spent on water supply related projects and of which RM2.7 billion will be focused on new water projects.

In 1994, the Malaysian Water Association has published a MWA Design Guidelines for Water Supply Systems which is an adaptation of the Public Works Department (JKR) Design Criteria and Standards for Water Supply System (Malaysian Water Association, 1994). The MWA design guidelines serve as a reference to water engineers and professionals in the design of water supply systems.

Figure 2.1 shows the Malaysian water authorities hierarchy.

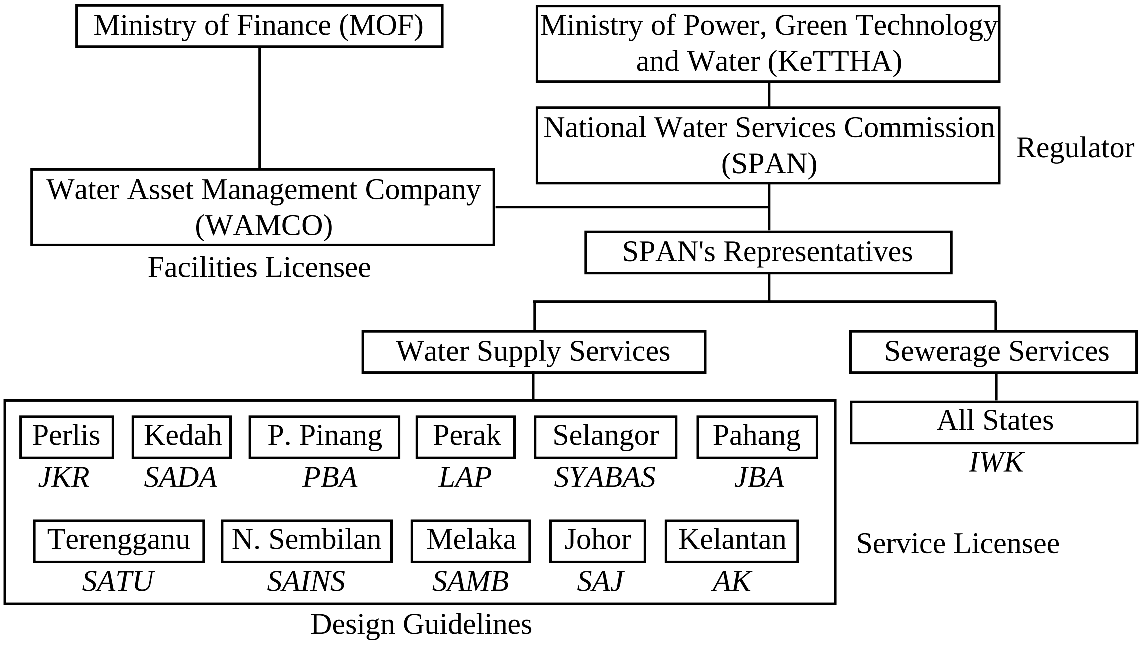


Figure 2.1: Malaysian water authorities

2.3 Water Supply in Johor

In Malaysia, the design guidelines and standards are outlined by individual state water authority. The general design guidelines and standards are outlined by Malaysian Water Association (MWA).

Since 2000, a private company Ranhill Utilities via its subsidiary SAJ Holdings has been responsible for the entire water supply services providing drinking water needs to the 3.1 million population of Johor, Malaysia. SAJ Holdings is an integrated water supply company involved in the full cycle of a drinking water supply system from sourcing of raw water, treatment and distribution of treated water to consumers, right up to billing and collection (Ranhill Berhad, 2011).

2.4 Water Distribution System

A water supply distribution system may be classified into three typical types:

i. gravity system,
ii. pumped system, and
iii. combined gravity and pumped system.

Figure 2.2 shows the difference between the three types of water supply distribution system. The choice of type of water supply distribution system depends on the topography, location and extent of the distribution area, elevation and site conditions.

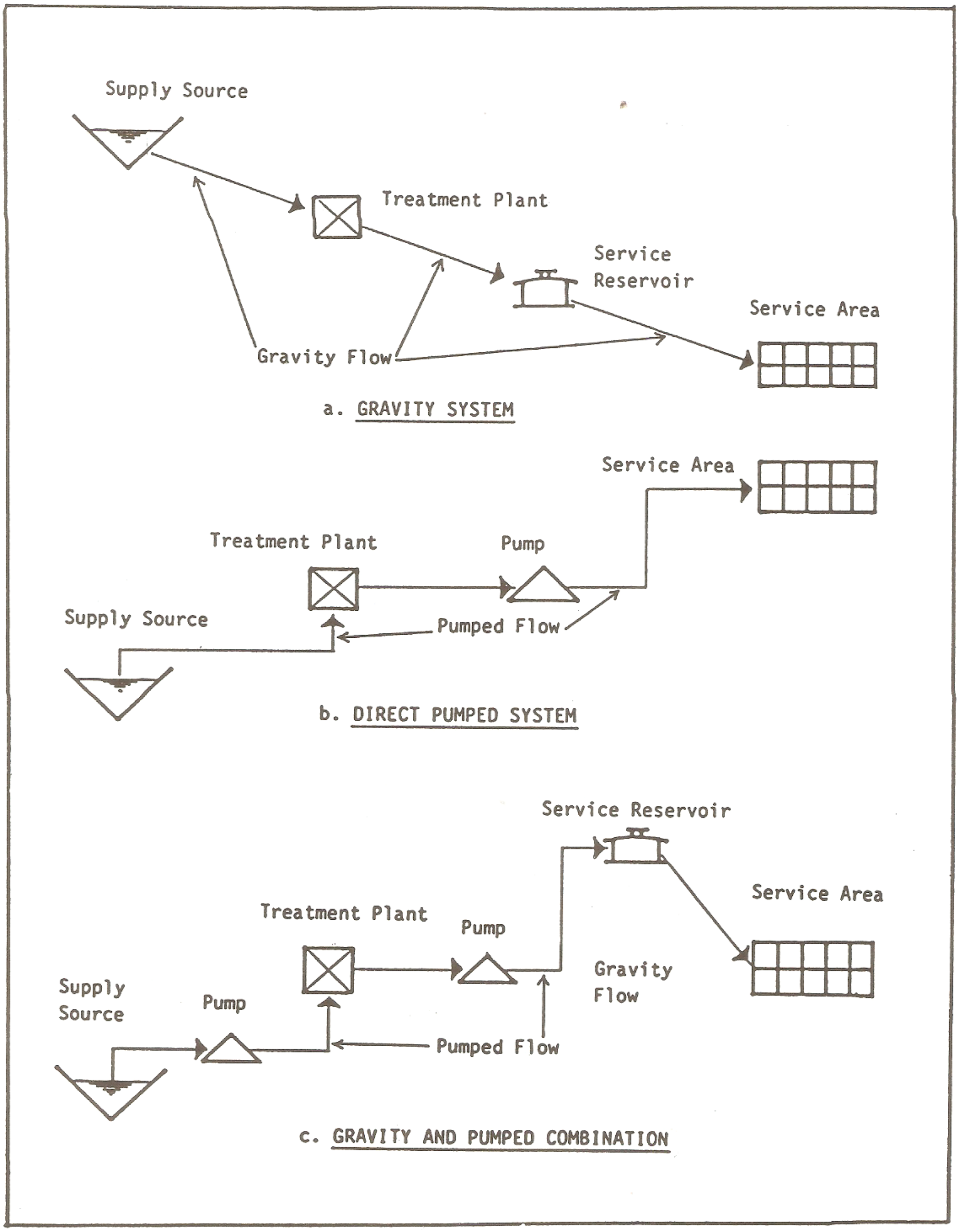


Figure 2.2: Three types of water supply distribution systems

The gravity system is the most preferred type of water distribution where adequate elevation of the supply is available. Only when the gravity type is not feasible, the combined gravity and pumped system is used. The pumped system is the least preferred as it involved higher operation cost. Table 2.3 summarizes the advantages and disadvantages of the three types of water supply distribution systems.

Table 2.3: Advantages and disadvantages of types of water supply distribution system (Malaysian Water Association, 1994)

Distribution system	Advantages	Disadvantages
Gravity	a. Most reliable b. Low operational costs	
Combined pumped and gravity	a. Least cost option under certain topographical conditions	a. Problems associated with operation and maintenance of pumping systems
Direct pumped	a. Pressure and flow can be easily regulated b. Remedial action can be speedily taken	a. Problems associated with operation and maintenance of pumping systems

2.5 Water Reticulation System

The scopes of work in water reticulation system are:

i. Determination of the location of elevated water tank and suction tank,

ii. Propose the type of pipe for water reticulation and fire hydrant, and

iii. Propose the connection to existing pipe.

There are various types of systems used in water distribution network, such as dead end system, the ring system, basic system, grid system and radial system.

i. Dead-end system or tree system

In this system, one main pipeline runs through the center of the populated area and sub mains take off from this to both the sides. It is suitable for towns that have one several road and by lanes without regularity. The main is a larger diameter at the beginning and it becomes smaller as it goes further from the sources of water supply. The pipe, which connects house within main pipe in the streets, is known as services pipe having 100 to 200 mm or even 300 mm diameter. Here less numbers of valves are required, but if there is case of repairs to any sections, the supply of the branch has to be cut off giving inconvenience to the majority. The discharge available for fire fighting in the streets will be limited.

ii. Grid-iron system or reticulation system

If the dead ends of the precious system are inter-connected, water can be made to circulate continuously through the whole of the distribution system. This system is therefore also known as the interlaced system. Here, the main supply pipe runs through the center of the rectangular area and sub mains take off from these in perpendicular directions. This system is ideal for cities laid out on rectangular plan. There is free circulation of water, without any stagnation. In case of repairs, only very small area of distribution system is affected, but here large numbers of cut off required. The systems require longer pipes lengths and bigger diameters. The cost of laying water pipe is more.

iii. Circular system or ring system

This system is most suitable for the town or area having well planned streets and roads. In this system, the supply main forms a ring around the distribution district. In case of fire, a large quantity of water is available.

iv. Radial system

This system is just the reverse of the circular system. In this system, whole area is divided in to a number of distribution districts. Each district has a centrally located distribution reservoir from where distribution pipes run radials towards the periphery of the distribution district. This system gives quick service, without much loss of head.

The following are the characteristics and considerations for the planning and design of water supply distribution and reticulation systems summarized from Twort et al. (2000) and the Malaysian Water Association (1994):

i. The service reservoir shall be as near and central as possible to the water demand area (Figure 2.3a). Because the service reservoir evens out the peak demands for water, the further the service reservoir is from the distribution area, the longer must be the lengths of main designed for peak hourly flow rates of flow and, the more costly is the system. A service reservoir close to the distribution area provides advantages when maintaining supplies under emergency conditions and for fire-fighting. It also helps to reduce pressure fluctuations in the distribution system and aids economic development of the system. Nevertheless there are occasions where the configuration of the land makes it impossible to comply with this arrangement (Figure 2.3b).

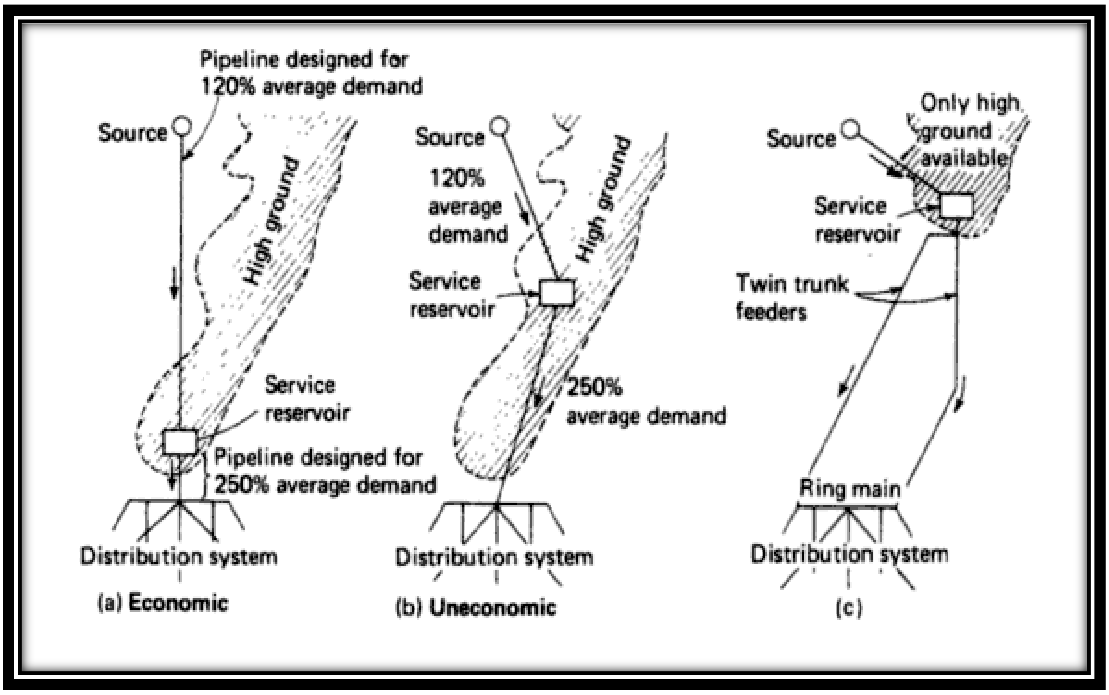


Figure 2.3: Distribution system feeds: (a)-(b) single main feed, and (c) use of ring main

ii. Where the service reservoir cannot be sited close to the demand area, a twin pipeline layout shall be considered. More than one pipeline connected together at their extremities to form a ring main (Figure 2.3c) through the distribution area will be able to cope more effectively with peak rates of flow but, in addition, should a repair be necessary on one main, at least some flow can be maintained to the distribution system.

iii. The reticulation pipes shall be laid so as to form a network system. Consistent water quality must be maintained through the system by establishing discrete hydraulic and source water quality areas. Wherever possible, dead ends, long retention times, mixing of different waters within the distribution system, and diurnal reversals of flow in the main pipe should be avoided.

iv. Minimum pressures at peak demand times on 24-hour supply systems need to be not less than 15 to 20 m in the main pipe at the highest supply point a system can serve. Higher pressures may be necessary in some areas where there are a significant number of dwellings exceeding three-storey height, but high rise blocks will normally be required to have their own booster.

v. Static pressures under low night-time demand should be as low as practicable to minimise leakage. For flat areas, a maximum static pressure in the range of 40 to 50 m is desirable. For undulating areas, a higher static pressure may be unavoidable. Where extreme topographical conditions prevail in demand areas, such as greater than 40 metres difference in elevation, pressure zoning of service areas according to ground elevations may be necessary. This can be achieved by using pressure reducing valves or break pressure tanks. Pressure reducing valves can be adopted to reduce pressures in low lying areas, but they must be regularly maintained if they are to operate reliably. To guard against mishaps, the low level system must be strong enough to resist the maximum possible static pressure if the valve fails or needs to be by-passed for operational reasons.

vi. Pipelines shall preferably be laid adjacent to roads so as to provide easy access for maintenance.

v. In the United Kingdom, the ideal fire demand requirements range from 8 L/s from a single hydrant in a one- or two-storey housing development to up to 75

L/s from pipework infrastructure to an industrial estate. This value also applies in Malaysia. Owners of property requiring supplies for sprinklers or hydrants on their premises may need to enter special arrangements with water supplier. In the United States, higher fire flows are required.

vi. Spare flow capacity must exist in the system sufficient to meet foreseeable rises of demand over the next few years.

2.6 Water Demand

There are different demand of water based on the type and purpose of buildings. The daily demand varies slightly due to the weather and festive seasons. In most states in Malaysia, daily water demand increases slightly in the months of January and February. During festive seasons, experience (Malaysian Water Association, 1994) has shown that in some urban areas, there is a change in demand due to shutting down of factories while there is an increase in demand in rural areas and smaller urban centres due to people leaving the big urban centres for their home towns or villages.

2.6.1 Industries

Estimation of demand should be made of individual industries especially of heavy industries such as breweries, soft drink manufacturers, paper mills and textile mills. The following is a guideline provided by the Malaysian Water Association (1994) for estimating industrial demand:

Table 2.4: Industrial water demand guideline by the Malaysian Water Association (1994)

Type of industries	Water demand (litres/hectare/day)
Light	22000
Heavy	45000

2.6.2 Residential

Water demand in residential area is based on the number and type of housing units set out in the housing structural plan submitted by the housing developer. For planning purposes, the following water demand (Table 2.5) has been provided by the State Water Authorities in Malaysia.

Table 2.5: Residential water demand by the Malaysian Water Association (1994)

Types of building	Water demand
Low cost houses	910 litres/unit/day
Single storey terrace houses	1360 litres/unit/day
Semi-detached / double storey terrace houses	1590 litres/unit/day
Shophouses (2 storey)	2730 litres/unit/day
Shophouses (3 storey)	4090 litres/unit/day
Shophouses (4 storey)	4550 litres/unit/day
Bungalows / shophouses (single storey)	2270 litres/unit/day
Light industrial workshop	1590 litres/unit/day
Schools	45 litres/head/day

2.7 Types of Waterworks Pipe

Pipes, lining materials and joints used in water supply system works must not cause a water quality hazard. Types of pipes commonly used in waterworks are generally of the following materials:

i. asbestos cement (A.C.)
ii. cast iron (C.I.) or grey iron pipes
iii. copper Cu
iv. ductile iron (D.I.)
v. glass fibre reinforced plastic (GRP)
vi. polyethylene (MDPE / HDPE)
vii. prestressed concrete (PSC)
viii. steel
ix. unplasticized polyvinyl chloride (uPVC)

Table 2.6 outline the advantages and disadvantages of each type of pipes.

Table 2.6: Advantages and disadvantages of water supply pipe materials

Pipe material	Advantages	Disadvantages
Asbestos cement (no longer produced)	a. Strength and rigidity b. Corrosion resistant to most soils and water c. Ease of jointing d. Flexible joints tolerate some deflection	a. Susceptible to impact damage b. Low beam strength for diameter < 200 mm c. Susceptible to certain organic contaminants when dry d. Relatively high number of joints per unit length e. Retrospective installation of fittings / repair complicated f. Need for precautions against asbestos dust risk during machining

REFERENCES

Can, I. (2005). Simplified equations calculate head losses in commercial pipes. *The Journal of American Science*, 1 (1).

Chin, D.A. (2007). *Water Resources Engineering*. U.S.: Prentice Hall.

Constable, G. and Somerville, B. (2011). Water supply and distribution. *A Century of Innovation*, National Academy of Engineering.

Eisenberg, D. and Kauzmann, W. (1969). *The Structure and Properties of Water*, Oxford University Press, New York.

Featherstone, R.E. and Nalluri, C. (1985). *Civil Engineering Hydraulics: Essential Theory with Worked Examples*. London: ELBS/Collins Professional and Technical Books.

Franks, F. (ed.) (1972). *Water - A Comprehensive Treatise*, Vol. 1, Plenum Press, New York.

Haktanir, T. and Ardiclioglu, M. (2004). Numerical modeling of Darcy-Weisbach friction factor and branching pipes problem. *Advances in Engineering Sofware*, Vol. 35, No. 12, pp.: 773-779.

Jabatan Bekalan Air (2009). Water Supply Industry in Peninsular Malaysia.

Malaysian Water Association (1994). *MWA Design Guidelines for Water Supply Systems*. The Malaysian Water Association, Malaysia.

Marsalek, J., Watt, W. E., Lefrancois, L., Boots, B. F., and Woods, S. (2004). *Municipal Water Supply and Urban Development*. Environment Canada, National Water Research Institute, Burlington, Ontario.

Microsoft Corporation (2010). *Visual Studio 6.0 Programmers Guide*.

Mohd. Noor, F., Jaffar Sidek, F. and Goh, G.K. (2000). *Mekanik Bendalir untuk Kejuruteraan Awam*. Malaysia: Universiti Teknologi Malaysia.

Petrousos, E. (1998). *Mastering Visual Basic 6.0*. San Francisco: Sybex Inc.

Ranhill Berhad (2011). *Johor Water Supply Privatisation Scheme: Environment*. Ranhill Berhad.

Rodenhuis, D., Bennett, K., Werner, A., Murdock, T., and Bronaugh, D. (2007). *Hydroclimatology and Future Climate impacts in British Columbia*. Pacific Climate Impacts Consortium, University of Victoria.

Streeter, V.L., Wylie, E.B. and Bedford, K.W. (1998). *Fluid Mechanics*. Singapore: McGraw-Hill.

Trifunovic, N. (2002). *Small Community Water Supplies/IRC Technical Paper Series* 40. Smet, J. and van Wijk, C. (eds.) Chapter 20: Water Transmission, 21 p. International Water and Research Centre (IRC), 585 p., Delft, The Netherlands.

Twort, A.C., Ratnayaka, D.D. and Brandt, M.J. (2000). *Water Supply*. 5th ed. Arnold Publishers and IWA Publishing, London.

UNESCO (2006). Water: A shared responsibility. *The United Nations World Water Development Report 2*. United Nations Educational, Scientific and Cultural Organization (UNESCO) and Berghahn books, New York, USA.

Whitfield, P. H., and Taylor, E. (2002). Apparent recent changes in hydrology and climate of coastal british columbia. In: Y. Alila (ed.), Mountains to Sea: Human Interaction with the Hydrologic Cycle. *51st Annual Canadian Water Resources Conference*: 22-29.

Young, D., Munson, B.R., Okiishi, T.H. and Huebsch, W.W. (2007). *A Brief Introduction to Fluid Mechanics*. John Wiley & Sons.