MODELLING AND FORECASTING OF FLOW RATE, WATER LEVEL AND WATER QUALITY OF MUDA RIVER AND BERIS DAM AT SUNGAI MUDA CATCHMENT, KEDAH DARUL AMAN, MALAYSIA

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By

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LIST OF SYMBOLS AND ABBREVIATIONS

%	Percent
°C	Degree Celcius
AR	Auto Regressive
ARIMA	Auto Regressive Integrated Moving Average
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
Conc.	Concentration
CV	Coefficient of Variation
DO	Dissolved Oxygen
EL	Elevation
EPA	Environmental Protection Agency
EU	European Union
FDA	Food and Drug Administration
INWQS	Interim National Water Quality Standards
MA	Moving Average
mg	Milligram
mgL	1 - Miligram Per Liter
µg	Microgram
ppt	Parts Per Trillion
ppb	Parts Per Billion
TDS	Total Dissolved Solids
USDA	U.S. Department of Agriculture
USEPA	United States Environmental Protection Agency

UNEP	United Nations Environment Program.
WHO	World health Organization

List of Publications

1. **Md. Azmal Hossain**, Abbas F. M. Al Karkhi, Nik Norulaini N. A. Statistical and trend analysis of water quality data for Beris Dam of Kedah Darul Aman, Malaysia. International Conference on Environmental Research and Technology (ICERT 2008). 568-572.
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4. F. M. Abbas Al-Karkhi, **Md. Azmal Hossain**, A. K. Mohd Omar. Assessment water quality of Beris dam using principal component analysis. Ecological and Environmental Modelling (ECOMOD 2007).

PEMODELAN DAN PERAMALAN KADAR ALIRAN, ARAS DAN KUALITI AIR SUNGAI MUDA DAN EMPANGAN BERIS DI KAWASAN TADAHAN SUNGAI MUDA, KEDAH DARUL AMAN, MALAYSIA

ABSTRAK

Laporan tesis ini sama ada variasi bermusim mempunyai apa-apa kesan terhadap kualiti air sungai di kawasan tadahan air Muda Sungai, faktor-faktor yang bertanggungjawab variasi besar dalam kualiti air di kawasan tadahan air Sungai Muda, pemodelan dan ramalan kadar aliran bulanan di kawasan tadahan air Sungai Muda, paras air empangan Beris dan kajian kemungkinan saluran lain untuk mengekalkan air bagi mengurangkan banjir dan beban empangan utama. Data kualiti air yang dikumpul dari tahun 2001 hingga 2004 daripada enam stesen persampelan di kawasan tadahan Sungai Muda. Aliran air bulanan Sg. Jeniang cabang Sg. Muda bagi tahun 1947-2001 dan data ketinggian takungan Empangan Beris dari Januari 2006 hingga Mac 2009 telah dianalisis. Analisis varian multivariat menunjukkan bahawa kualiti air di kawasan tadahan air Sungai Muda berbeza lebih musim ketara. Analisis faktor menunjukkan bahawa pengaruh faktor kualiti air adalah Faktor 1 (pH, konduktiviti dan E.coli), Faktor 2 (suhu dan kekeruhan), Faktor 3 (COD dan TSS), Faktor 4 (N_Nitrogen), Faktor 5 (BOD) dan faktor 6 (Jumlah Fosfat dan DO). Faktor-faktor ini adalah bertanggungjawab bagi 80% perubahan variasi jumlah kualiti air di kawasan tadahan Sungai Muda. ARIMA (1 0 1) model menunjukkan bahawa terdapat jumlah yang mencukupi (122 MCM) air yang dipelihara dalam empangan. Takungan itu didapati mempunyai jumlah yang mencukupi air, lebih tinggi daripada 84 meter yang berada di atas 97% daripada simpanan langsung empangan. Model ARIMA dan model regresi lelurus telah

digunakan untuk meramal aliran air bulanan untuk tahun 2002 hingga 2015 di Jeniang dalam kawasan tadahan Sungai Muda. Model ARIMA untuk aliran air bulanan Sungai Muda mendedahkan bahawa aliran air kenaikan Sungai Muda selepas bulan Julai dan aliran air adalah paling tinggi pada bulan Oktober. Rekod aliran air yang lepas menunjukkan bilangan puncak aliran air yang lebih tinggi pada bulan Oktober. Data yang diramalkan juga menunjukkan jumlah aliran air yang lebih tinggi dalam tempoh ini. Hujan yang berterusan akan mempercepatkan aliran air dan akan memburukkan lagi kemusnahan banjir. Membina saluran alternatif atau menyimpan air di empangan yang dicadangkan (empangan Naok dan empangan merebut kembali) akan mengurangkan kemusnahan banjir dan air simpanan boleh digunakan untuk tujuan pertanian, industri dan perbandaran.

MODELLING AND FORECASTING OF FLOWRATE, WATER LEVEL AND WATER QUALITY OF MUDA RIVER AND BERIS DAM AT SUNGAI MUDA CATCHMENT, KEDAH DARUL AMAN, MALAYSIA

ABSTRACT

This thesis reports whether seasonal variation has any impact on water quality of Sungai Muda catchment, the factors responsible of large variation in water quality in Sungai Muda catchment, the modeling and forecasting of monthly flow rate of Sungai Muda catchment, water elevation of Beris dam and feasibility study of another channel to retain water to alleviate flood and loading of main dam. Water quality data was collected from the year 2001 to 2004 from six sampling stations in Sungai Muda catchment. Monthly water flow of Jeniang of Sungai Muda from the year 1947 to 2001 and reservoir elevation data of Beris Dam from January 2006 to March 2009 were analyzed. Multivariate Analysis of Variance showed that water quality of Sungai Muda catchment varies over season significantly. Factor Analysis showed that the influential water quality factors were Factor 1 (pH, Conductivity and E.coli), Factor 2 (Temperature and Turbidity), Factor 3 (COD and TSS), Factor 4 (N_Nitrogen), Factor 5 (BOD) and Factor 6 (Total Phosphate and DO). These Factors were responsible for 80% variation of the total variation of water quality in Sungai Muda catchment. ARIMA (1 0 1) model showed that there was adequate amount (122 MCM) of water preserved in the dam. The reservoir was found to have sufficient amount of water, higher than 84 Meters which was above 97% of live storage of dam. ARIMA model and Linear Regression model were used to forecast monthly water flow of 2002 to 2015 at Jeniang in Sungai Muda catchment. ARIMA model for monthly water flow of Sungai Muda revealed that the

water flow of Sungai Muda increase after July and the water flow is highest in the month of October. The past record of water flow showed the number of higher peaks of water flow were during October. Forecasted figures also indicate higher amount of water flow during this period. Continuous rain will accelerate the water flow and will aggravate the destruction of flood. So making an alternative channel or reserve the water in proposed two dams (Naok dam and Reman dam) will alleviate the flood destruction and the reserved water can be used for agricultural, industrial and municipal purposes.

CHAPTER 1

INTRODUCTION

1.0 Introduction

Surface water quality in most part of Malaysia can be considered as fair conditions, while some rivers flowing in large communities are adversely affected. Water quality problems are affected by domestic and industrial waste water discharges, agricultural point and non-point source discharges, deforestation, and development project. The polluted surface water severely affects aquatic animals as well as human health. In Malaysia, the Interim National Water Quality Standard is adopted by the Department of Environment and used to assess the river water quality and to classify the river into a number of categories.

Throughout history dams and reservoirs have been used successfully for storing and managing water needed to sustain civilization. Dams and reservoirs are an integral part of our infrastructure and they can be compatible with the social and natural environment. The challenge for the future will be the utilization of dams and land use for the efficient management of the world's water resources.

Earth has approximately 97% of the world water as sea water and the balance 3% is fresh water. The 3% of fresh water, 68.7% is frozen as ice caps and glaciers, 30.1% is ground water, 0.9% of other origins (clouds) and 0.3% is surface water (rivers, lakes and springs). The surface water is 87% in lakes, 11% in fresh water swamps, and only 2% of the water comes from rivers. Malaysia totally relies on river water supply to be used for drinking water processing (Gleick, 1996).

Water Management is becoming comprehensive and complicated due to large concentrations of population, commercial activities and industries around the cities, increasing water consumption, increasing water pollution, increasing land use conflicts and climate change. Malaysia has a long history of flooding, the monsoon winds and heavy conventional rainfall throughout the year rendering the country being flood-prone.

Floods are a natural part of the hydrological cycle. It is reported that flood disasters account for third of all natural disasters by number and economic losses. There is the trend of an increasing number of deaths being due to floods. Increasing urbanization and land development in flood-prone parts has significantly raised the risk of flash floods during last decades. Therefore, flood management is becoming very important issue to the society.

Floods are part of the dynamic variation of the hydrological cycle, the basic causes of which are climatological. To this must be coupled the nature of the terrain which generates the runoff (e.g. geology, soil type and vegetation cover), and the antecedent conditions as well as the characteristics of the stream networks characteristics (e.g. storage capacity, channel length); and channel characteristics (e.g. channel roughness and shape) (Ward, 1978). Heavy monsoon rainfall, intense convection rain storms, poor drainage and other local factors, floods have become common feature in Malaysia. Many of the catastrophic floods are associated with the intense rainfalls. Floods have a number of measurable characteristics, including magnitude, frequency and seasonality.

Efficient water management, and sound reservoir planning management are hindered by inadequate knowledge of storage volumes. Although, in most arid areas, small reservoirs store large amounts of water and have significant effect on downstream flows, rarely they considered as part of water resources systems of a river basin and/ or catchment. In addition, available water in most catchments rarely matches the demand during drought periods. The absence of adequate knowledge on small reservoir storage capacities is a constraint in decision-making process regarding planning and management of existing water resources. Water and energy are two components that are highly important for the developing world. In certain situations a solution to one problem can lead to the other. For example, construction of dams can help to reduce the water and energy scarcity of many regions.

Beris Dam is situated in the district of Sik, about 65KM southeast of Alor Setar, capital of the northern state of Kedah, Malaysia. The construction work of Beris Dam started on August 2000 and major milestone of reservoir filling completed in January 2004. Beris dam project is to fulfill the demand of irrigation and potable water in the south Kedah and Penang. The dam will cover total area of about 1600 hectares. The reservoir operation of Beris dam is based on maximum demands of 17 million cubic meter downstream irrigation, domestic and industrial water supply during dry periods of February to April as recommended by Japan International Cooperation Agency (JICA), 'Beris Dam Feasibility Study' March 1985.

This is a concrete faced rockfill dam located in a narrow valley of Sg.Beris 1.6km upstream of the confluence between Sg.Muda in the district of Sik, in the state of Kedah. Completed in 2004 at a cost of RM360,000,000.00 it is used to regulate flows in Sg. Muda basin to augment water available for irrigation of paddy/upland crops, domestic and industrial water supply and other uses. The reservoir at its normal pool level covers an area of 13.7km^2 whilst at maximum pool level inundates an area of 16.1km^2. It has a gross storage capacity of 122.4 MCM (Million Cubic Meter) with an effective storage of 144 MCM (Ministry of Natural Resources and Environment. www.water.gov.my).

The dam would supply water to 97,000ha of padi fields under the Muda irrigation scheme in Kedah and Perlis, and to 13,000ha under the Seberang Prai Irrigation Scheme. Water would also be channeled to more than 4,800ha of padi fields in Kulim, Bandar Baharu and areas near Alor Setar and Pendang which were outside the rice bowl areas in Kedah. The dam would help alleviate drought problems in the northern states which affected padi fields. It could also help ease flood problems like the one which badly affect the northern States of Kedah and Penang almost every year (DID: Environmental Management Plan for Proposed Beris Dam Project Final Report Vol 1, March 1999).

1.1 Water Problems and Issues in Malaysia

In Malaysia, the two most significant natural hazards in terms of economic losses are water related and these are flood and drought. Floods are due to excess water from heavy rainfall, whilst drought is associated with too little rainfall. The water problems are also associated with the fragmented nature of water resources development and traditional water resources management (Keizrul, 2002).

1.2 Problem Statement

Pollutants can be classified into two types - point and non-point, depending on their source. Generally non-point sources are more complex than dealing with point sources pollution. Now a days, chemicals, fertilizers, illegal logging, unplanned land use deteriorating the water quality of Sungai Muda catchment. One of the basic problems for river studies are lack of reliable data. Statistics published by the Department of Environment (DOE) for the year 2004 revealed that 8% of rivers are polluted, 44% slightly polluted and remaining 48% clean (DOE, 2004). This is a clear indication that river basins in Malaysia are facing serious environmental problems. People living in arid areas with highly variable rainfall, experience droughts and floods and often have insecure livelihoods (Stevenson, 2000). Small reservoirs have often brought positive changes in people's lives and found to be important sources of water for communities (Liebe, 2002), but planning and management of these small reservoirs has been hindered by inadequate investigation on catchments water distribution and storage capacities.

Flood disasters are among the world's most frequent and damaging types of disaster (IFRCRS: International Federation of Red Cross and Red Crescent Societies) 1998: 147). During the latter half of the twentieth century floods were the most common type of geophysical disaster, generating over thirty per cent of all disasters between 1945 and 1986 (Glickman *et al.*, 1992). Glickman *et al.* (1992) indicate that globally, flood disasters are about the third most harmful form of geophysical disaster in terms of loss of life. Earthquakes and tropical cyclones kill more people than any other geophysical disaster type, but in the 1986-1995 period floods appear to have caused more deaths than any other geophysical disaster type (Munich, 1997).

1.3 Research Objectives

The objectives of this study are

- To determine whether seasonal variation has any impact on water quality of Sungau Muda catchment
- To determine the factors responsible of large variation in water quality in Sungai Muda catchment
- To model and forecast of the water level of Beris dam and monthly water flow of Sungai Muda
- Conduct feasibility study of another channel to retain water to alleviate flood and loading of main dam

In order to study these in details previous hydro meteorological information have been updated based on the data of river discharges and rainfall, which were collected from Hydrology Division of Irrigation and Drainage Department as well as Malaysian Meteorological Services (MMS).

CHAPTER II

LITERATURE REVIEW

2.0 Introduction

The water resources research literature addressing the problem of developing and testing reservoir operating rules for flood regulation involves the use of mathematical simulation and optimization models. A simulation model is a mathematical representation of a system that is able to predict the behavior of the system under a given set of conditions (Wurbs, 1993). Simulation models allow for a detailed and realistic representation of the complex physical and hydrologic characteristics of a river/reservoir system. In general, a river/reservoir simulation model computes storage levels and discharges at pertinent locations for a given set of hydrologic inputs, system demands, and operating rules. Simulation models have been routinely applied for many years by water resources development agencies responsible for planning, construction, and operation of reservoir projects (Wurbs, 1993).

Optimization is a mathematical formulation in which a formal algorithm computes a set of decision variable values that minimize or maximize an objective function subject to constraints (Wurbs, 1996). Most optimization applications to reservoir system analysis involve linear, non-linear or some variation of these techniques. Each technique can be applied using deterministic or stochastic hydrologic inputs. A deterministic model implicitly assumes that future stream-flows are known with certainty, and thus it can compute the decision variable optimum values for all periods simultaneously. Implicit stochastic optimization methods, also known as Monte Carlo optimization, optimize over long continuous series of historical or synthetically generated inflow time series, or several shorter equally likely sequences. This allows the stochastic nature of the problem to be implicitly included and deterministic methods can be directly applied. Alternatively, explicit stochastic optimization procedures attempt to operate directly on probabilistic descriptions of random streamflow processes rather than deterministic hydrologic sequences. Optimization is thus performed without perfect knowledge of future events.

2 .1 Monitoring River Water Quality

Water quality monitoring is defined as a systematic, regular and continuous (long term) observation and measurement with the purpose to describe and qualify variability in space and time of water quality. It can also be viewed as both the beginning point of water quality management efforts. Data are collected to compare with those in the past and in the future (Nader and Tate, 1998). The type of information sought depends on the objectives of the network. Objectives range from detecting stream standard violations to determining temporal water quality trends (Sanders *et al.*, 1987).

Through proper monitoring rational decisions to be made on the following:

- Describing water resources and identifying actual and emerging problems of water pollution.
- Formulating plans and setting priorities of water quality management
- Developing and implementing water quality management programmes
- Evaluating the effectiveness of management actions

Once sufficient data have been gathered, it is possible to describe the average conditions, the variations from average and the extremes of water quality, expressed in terms of measurable physical, chemical and biological variables (Nader and Tate, 1998).

The purpose of monitoring is generally guided by laws and other regulatory actions (directives, water quality standards, action plans) and aim at assessing the environmental state and detecting trends. The regulatory actions set up water quality goals or standards (e.g. a 50 percent reduction of nitrogen loading to surface waters, no pesticides in drinking water, etc), and the purpose of monitoring is to supply data and information on the water quality (Kriestensen and Bogestrand, 1996).

In general the scope of water quality monitoring was focused on hydrological monitoring. The Water Quality Index (WQI) used to evaluate the status of the river water quality consists of parameters such as Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Ammoniacal Nitrogen (NH3-N), Suspended Solids (SS), Turbidity, Conductivity, and pH. The Water Quality Index serves as a basis for environmental assessment of a watercourse in relation to pollution load categorization and designation of classes of beneficial uses as provided for under the National Water Quality Standards for Malaysia (NWQS).

2.2 Malaysian River Water Quality Scenario

The Department of Environment (DOE) used Water Quality Index (WQI) to evaluate the status of the river water quality. In the year 2006 among 146 river basins 1064 water quality stations were monitored. Out of these stations 58% were found to be clean, 34% slightly polluted and 8% polluted. In terms of river basin water quality, 55%

were clean, 40% were slightly polluted and 5% were polluted. The major pollutants were Biochemical Oxygen Demand (BOD), Ammoniacal Nitrogen (NH3-N) and Suspended Solids (SS). High BOD was contributed by untreated or partially treated sewage and discharges from agro-based and manufacturing industries. The main sources of NH3-N were domestic sewage and livestock farming and the sources of Suspended Solids (SS) were mostly earthworks and land clearing activities (DOE, 2006). River basins water quality trend given in Figure 2.1 and National water quality standards of Malaysia with water quality parameters shared in Table 2.1.

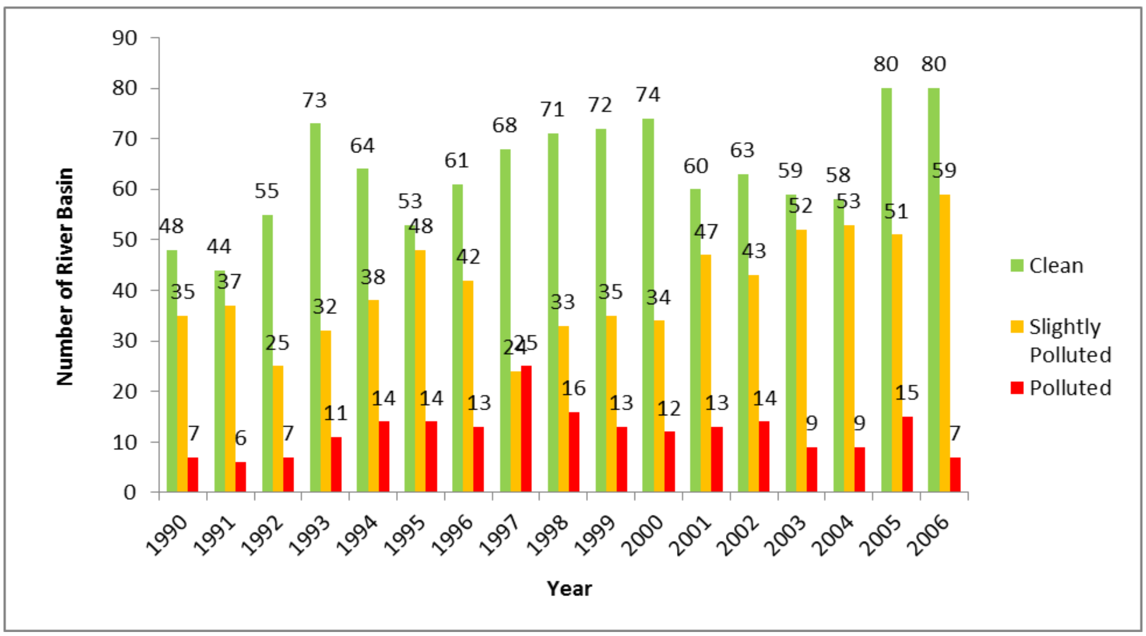

Figure 2.1: River Basins Water Quality Trend, 1990-2006 (Source: EQR 2006)

Table 2.1: National Water Quality Standards for Malaysia

PARAMETERS				CLASSES			
	UNIT	I	IIA	IIB	III	IV	V
Temperature	°C	-	Normal +2°C	Normal +2°C	Normal +2°C	Normal +2°C	Normal +2°C
pH		6.5-8.5	6-9	6-9	5-9	5-9	-
Elec. Conductivity	Umhos/cm	1000	1000	-	-	6000	-
BOD	mg/l	1	3	3	6	12	>12
COD	mg/l	10	25	25	50	100	>100
Total Suspended Solid	mg/l	25	50	50	150	300	300
Turbidity	NTU	5	50	50	-	-	-
Ammoniacal Niltrogen	mg/l	0.1	0.3	0.3	0.9	2.7	>2.7
Fecal Coliform	counts/100 ml	10	100	400	5000	5000	-
DO	mg/l	7	5-7	5-7	3-5	>3	>1

Source: DOE, Environmental Quality Report 2006

2.3 Human Activities Deteriorate Water Quality

Poor water quality can be the result of natural processes but is more often associated with human activities and is closely linked to industrial development. During the industrial revolution of the 19th century, contaminated surface waters resulted in serious human health problems, including typhoid and cholera outbreaks. Eutrophic ecosystem is often manifested as excessive growth of algae and the depletion of oxygen, which can result in the death of fish and other animals. Eutrophication can lead to changes in the composition of aquatic fauna, particularly the disappearance of species with high oxygen requirements; thus, biodiversity of aquatic communities is often compromised in nutrient-enriched environments (Boatman *et al.*,, 1999). Increased water temperature due to climate change or thermal pollution may lead to higher levels of toxic nitrogen species, particularly in high pH waters.

To mitigate these problems, large urban centers' began developing sewage networks and water treatment facilities. These facilities continue to be installed and expanded to accommodate increases in human population. However, the rapid growth in some urban areas, particularly in Asia and Latin America, has outpaced the ability of some governments to develop and maintain treatment facilities (FWR, 2004). Water quality monitoring for the detection of trends, impacts, and improvements is further complicated because the issues of concern and available resources are constantly changing (Hirsch *et al.*, 2006).

2.4 Climatic Characteristics

The main climatic feature in Malaysia is the regular distinctive two dry seasons. The first dry season occurs during the period from December to March (Niewolt, 1982). Its duration may reach four months in the northern areas, decreasing to 1 to 2 months in the southern part of the region. In more interior locations, the dry season may last 3-4 months. The frequency of occurrence of at least one dry month (with an agricultural Rainfall Index below 40) between December and March is over 90 per cent of all the years on record. A second dry season occurs around June in the extreme north and south of the region. These dry seasons are usually associated with more sunshine, higher day and lower night temperatures and a lower relative humidity than during the rest of the year. The long term annual rainfall mean in Peninsular Malaysia generally exceeds 1,600 mm, and is well over 2,500 mm in many areas (Dale, 1959).

The climatic condition with seasonal variation considering rainfall amount of Beris dam area shared in Table 2.2.

Table 2.2: Climatic condition of Beris Dam area considering the rainfall

Month	Season	Rainfall
December January February March	Dry Season	25 mm – 120 mm/month
April May August September October November	Rainy Season	250 mm – 380 mm/month
June July	Moderate	170 mm – 240 mm/month

Source: DID, ‘Beris Dam Project, June 1994.

2.5 Water Resources

Rainfall generally occurs throughout the year, but there is some concentration due to the North-East and South-West monsoons. The mean annual rainfall averages about 2,300 mm, while the annual potential evaporation averages about 1,500 mm. The total annual surface water resource is estimated to be 566,000 million m^3 per year and of this 26 % is in Peninsular Malaysia, 54 % in Sarawak, and the remaining 20 % in Sabah. Groundwater resource is estimated to have a safe yield of 14,700 million m^3 per year in Peninsular Malaysia, 5,500 million m^3 per year in Sarawak, and 3,300 million m^3 per year in Sabah (DID, 2009).

The present annual total consumptive use of water is estimated to total 10,400 million m^3 for irrigation and 4,900 million m^3 for domestic and industrial water supply. On the whole, Malaysia has sufficient water resources for development to meet all the demand provided there is proper water resources development, conservation and management. Ground water resources account for more than 90% of the national fresh water resources (Keizrul and Azuhan, 1998).

2.6 Occurrence of Flood Events

Flooding is the most significant natural hazard in Malaysia in terms of population affected, frequency, area extent, flood duration and social economic damage. Having 189 river basins throughout Malaysia, including Sabah and Sarawak, the rivers and their corridors of flood plains fulfill a variety of functions both for human use and for the natural ecosystem, i.e. they are fundamental parts of the natural, economic, and social system wherever they occur. At the same time, rivers might be the largest threat to entire corridor areas (DID, 2007).

Since 1920, the country has experienced major floods in the years of 1926, 1963, 1965, 1967, 1969, 1971, 1973, 1979, 1983, 1988, 1993, 1998, 2005 and most recently in December 2006 and January 2007 which occurred in Johor. The January 1971 flood that hit Kuala Lumpur and many other states had resulted in a loss of more than RM 200 million then and the death of 61 persons. In fact, during the recent Johor 2006-07 flood due to a couple of “abnormally” heavy rainfall events which caused massive floods, the estimated total cost of these flood disasters is RM 1.5 billion, considered as the most costly flood events in Malaysian history. Recent urbanization amplifies the cost of damage in infrastructures, bridges, roads, agriculture and private commercial and residential properties. At the peak of that recent Johor flood, around 110,000 people were evacuated and sheltering in relief centers and the death toll was 18 persons (DID, 2007).

The basic cause of river flooding is the incidence of heavy rainfall (monsoon or convective) and the resultant large concentration of runoff, which exceeds river capacity. However, in recent years, rapid development within river catchment has resulted in higher runoff and deteriorated river capacity; this has in turn resulted in an increase in the flood frequency and magnitude. With 60% of the Malaysian population now residing in urban areas, flash flooding in urban areas are perceived to be the most critical flood type (surpassing the monsoon flood) since the mid 1990's. This is reflected in the flood frequency and magnitude, social-economic disruption, public outcry, media coverage and the government's escalating allocation to mitigate them (DID, 2007).

In the coastal areas, flooding could be attributed to high tides and occasionally aggravated by heavy rains or strong wind. In the last decade, also of great concern is the increased occurrence of other flood-related disasters such as debris flood flow, mud flow and land slides in mountain streams and hill slopes, not to mention the new threat of tsunami-induced coastal flood disasters. Flood management aims to reduce the likelihood and the impact of floods (DID, 2007).

2.6.1 Flash Floods

Flash floods occur as a result of the rapid accumulation and release of runoff waters from upstream mountainous areas, which can be caused by very heavy rainfall, cloud bursts, landslides, the sudden break-up of an ice jam or failure of flood control works. They are characterized by a sharp rise followed by relatively rapid recession causing high flow velocities. Discharges quickly reach a maximum and diminish almost as rapidly (WMO, 2008).

2.6.2 Method for Flood Forecasting

The methods for formulating the flood forecast may be categorized under two groups:

i) statistical methods and

ii) deterministic methods (Singh, 2008).

2.6.2.1 Statistical Methods

The methods by which statistical data are analyzed called statistical methods. Statistical methods used to organize, present, analyze and interpret the information effectively. Statistics present facts in a precise and definite form and thus help proper comprehension of what is stated. Statistical methods present meaningful overall information from the mass of data (CWC, 1989).

2.6.2.2 Deterministic methods

One of the important areas in hydrology pertains to the study of the transformation of the time distribution of rainfall on the catchment to the time distribution of runoff. This transformation is studied by first relating the volume of rainfall to the volume of direct surface runoff, thus determining the time distribution of rainfall excess (the component responsible for direct surface runoff on the catchment) and then transforming it to the time distribution of direct runoff though a discrete or continuous mathematical model. The first step decides the volume of the input to the catchment and therefore any error in its determination is directly transmitted through the second step to the time distribution of direct runoff. A number of watershed conceptual models find this component for each time step through a number of stores representing various processes on the catchment. The parameters of these models including those in the functional relationship are determined from the historical record and their performance is tested by simulating some of the rainfall-runoff events which have not been used in the parameter estimating process. The models need to be run continuously so that the status of various stores is available at all times. One of the operational uses of these models is in the area of real time flood forecasting required for real time operation of the reservoir. In such a situation these models are run by inputting the rainfall and forecasts are issued assuming no rainfall beyond the time of forecast value of the rainfall in the future (Singh, 2008).

2.6.2.3 Stochastic Models for Real Time Flood Forecasting

Several stochastic/time series models have been proposed for modeling hydrological time series and generating synthetic stream flows. These include Box-Jenkins class of models (Box and Jenkins, 1970; Salas *et.al.*, 1980). The time series models are considered to be most suited for real time forecasting as on-line updating of model forecasts and parameters can be achieved using various updating algorithm. It has been observed that the dynamic stochastic time series models are most suitable for online forecasting of floods (Kalman, 1960; Sage and Husa, 1969; Eykhoff, 1974; Kashyap and Rao, 1975; Kumar, 1980; O'Connell, 1980; Chander *et al.*, 1980, 81, 84). These models also provide a means for the quantification of the forecast error, which may be used to calculate the risks involved in the decisions based upon these forecasts. Further, these models can be operated even with interrupted sequences of data and easy to implement on computer and other computing devices.

2.7 Increasing Flood Risk in Malaysia

Heavy monsoonal and convectional rainfall, flat topography on both coasts, heavy siltation of rivers, and human activities have all contributed to high flood risk. Risk is increasing because flood characteristics are changing due to rapid urbanization of catchments. Deforestation and other environmentally damaging human land uses have also significantly altered hydrological parameters. Research has revealed that significant water yield increases occur after deforestation, and that commercial logging resulted in significant increases in storm flow volume and initial discharge (Abdul Rahim *et al.*, 1988, 1990). Other human activities such as tin mining have also contributed to flooding. Climatic change inducing sea level rise may also be an important flood inducing mechanism which can increase future flood risk (Parry *et al.*, 1992). Flood reports for the period 1925 to 1996 also suggest that flooding has become progressively more frequent, with flash floods mainly affecting the federal capital and Pulau Pinang. Flooding magnitudes have also appeared to have increased since the 1970s (a period of rapid economic development) in the east coast states.

In Malaysia, flood hazards and disasters continue to escalate in frequency and magnitude mainly because humans choose to occupy flood plains, ignore the dangers of such hazard zones, mismanage flood hazards, overdevelop land and deplete natural resources (e.g. forests and hill slopes) at rates of change which natural systems can neither cope with nor adapt to. While east coast inhabitants who are largely dependent on agricultural and traditional coping mechanisms are well adapted to seasonal monsoon floods, west coast inhabitants whose livelihood is largely based on an urban way of life are not so well adapted (Ngai, 1997).

2.7.1 Flood Management Options (a) Structural Measures

After the disastrous flood of 1971, beside the Natural Disaster Relief Committee (1972), the Government has also established the Permanent Flood Control Commission in December 1971 to implement flood control measures with a view to reduce flood occurrence and to minimize flood damage. This commission is presently chaired by the Minister of Natural Resources and Environment (previously chaired by the Minister of Agriculture) and DID acting as the secretariat.

Since 1971, the Department of Irrigation and Drainage (DID) has been designated with the task of implementing both structural and non-structural flood mitigation measures. Flood mitigation plans have been developed for 17 major river basins and 27 towns. Based on these plans, various structural and non-structural measures have been proposed and implemented in stages. The structural measures include improving river channel sections, building of flood protection bunds, perimeter bunds, by-pass flood ways, use of former mining ponds for flood attenuation and construction of flood retention dams to regulate flood flows and minimize flood occurrence (DID, 2007).

For the periods from 1971 to 2000 (30 years) and 2001 to 2005 (5 years), a total of RM 1.642 billion and RM 1.790 billion respectively had been spent on structural flood mitigation measures. However, under the Ninth Malaysia Plan (2006-2010), the allocation for structural flood control works has escalated to RM 3.834 billion. It is estimated that the cost of future river improvement and flood mitigation works for the next 15 years will amount to more than RM 17 billion (DID, 2007)

2.7.2 Flood Management Option (b) Non-Structural Measures

In the past, local government and developers relied upon engineering solutions to move stormwater as quickly as possible into concrete channels toward discharge locations. As a result, the overload of stormwater entering waterways created significant flood damages. Today, in the current emphasis of peak discharge control at source, a new Urban Stormwater Management Manual (MSMA) has been published by DID in 2000 which has superseded the Urban Drainage Planning and Design Procedure No.1 (1975). In January 2001, it has been approved by the Cabinet to be implemented and complied by all local authorities, public and private development projects as well (DID, 2007)

Urban storm-water runoff is water from precipitation and landscape surface flows which do not infiltrate into the soil. Under natural and undeveloped conditions, surface runoff can range from 10 to 30 percent of the total annual precipitation. Depending on the level of development and the site planning methods used, the alteration of physical conditions can result in a significant increase of surface runoff to over 50 percent of the overall precipitation. In addition, enhancement of the site drainage to eliminate potential on-site detention can also result in increases in surface runoff (DID, 2007).

Alteration in site runoff characteristics can cause an increase in the volume and frequency of runoff flows (discharge) and velocities that cause flooding, accelerated erosion, and reduced groundwater recharge and contributed to degradation of natural rivers and streams. It flows over roadways and other hard surfaces in our urban landscape, picking up rubbish and sediments and flows into culverts, channels, and into rivers. As we cover more land surface areas, less water can be absorbed by the soil. Thus, the volume of urban stormwater is increasing. This escalating volume of urban runoff not only increases siltation and blockage in rivers, it also elevates the risk and severity of flooding.

However, this Urban Storm-water Management Manual procedure provides control at-source measures and recommendations on flood control by means of detention and retention, infiltration and purification process, including erosion and sedimentation controls. The quality and quantity of the runoff from developing areas can be maintained to be the same as pre-development condition (DID, 2001)

In order to achieve the MSMA guideline objective, DID have implemented the following:

i. To review previous drainage master plans using the new urban stormwater management approach.

ii. To upgrade old drainage systems in stages.

iii. To network cooperation and support from other government agencies such as Local Authorities, Town and Country Planning Department, Forestry Department, Malaysia Highway Authority, Public Works Department, Department of Environment, CIDB, etc.

iv. To organize training courses for engineers with the Institution of Engineers, Malaysia (IEM) for enhancing the practicing engineers' expertise.

v. To impose Erosion and Sedimentation Control Plan as mandatory approval for earth works development plan.

To date, some public development projects have implemented the new urban stormwater management approach. At the Federal Government Administrative Center, Putrajaya, it has been applied by incorporating the lake and wetlands as storage and purifier of stormwater. In addition, there are some private housing projects utilizing this new approach too (DID, 2007).

2.7.3 Flood Control and Defense

There was a strong emphasis on building flood embankments designed and constructed to engineering standards, constructing flood relief channels and sometimes constructing a series of flood control dams. The emphasis in this approach was to control the river and to prevent floodwater entering communities located in flood-prone areas. The language used reflects this struggle to make rivers efficient servants of human purposes: floods were to be 'controlled' and 'defences' to be prepared against floods.

Much of the history of flood mitigation in the United States during the nineteenth and twentieth centuries (until the late-1960s) was based upon this strategy as the US Corps of Engineers struggled to control great rivers such as the Mississippi. The benefits of such strategies have been large during particular periods. For example, the modernization of the lagging economies of the Tennessee river basin during the middle part of the twentieth century was driven by a strategy to control river flooding and soil erosion by building a series of large dams which had other benefits such as generating electricity for rural electrification programmes.

Unfortunately, structural approaches have a number of disadvantages, including that flood control structures may encourage further floodplain development; flood embankments may be only partly effective in exceptional floods (i.e. they may be overtopped or breached); structural approaches may have adverse or damaging environmental consequences (Brookes, 1988; Purseglove, 1988); perverse impacts on downstream areas (making their flood problems worse); and flood control may only address a part of the problems which cause flood disasters (i.e. flood control does not address people's vulnerability to flood hazards).

2.7.4 The role of dams in flood management

In the appropriate circumstances, the storage provided behind dams can result in a substantial reduction in flood losses. The California Flood Emergency Action Team (Berga, 1999) reported on the 1997 floods claimed that on a number of major river systems, flood control dams reduced flood flows by half; the US Army Corps of Engineers annual reports to the US Congress routinely claim very substantial reductions in flood losses as a result of the storage provided in dams. Storage in soil or in surface waters will reduce total flood flows and controlled storage reduces the peak flood flow, the latter being particularly helpful in flood management. The forms of storage those are possible, if any, are determined by local conditions. Positioning the storage in relation to the areas at risk and the timing of storage uptake and release are both important to the choice of the form of storage to adopt and the impact of the storage on the flood (WCD, 2000).

But, to reiterate, the choice of flood management strategy must be made on a comparative basis, the advantages and disadvantages of each available option being compared.

According to Green *et al.*, (2000) a dam is most likely to form part of the appropriate management strategy when:

- the major part of the runoff comes from a small, steep catchment immediately above the area at risk;
- the time to concentration is short;
- multiple tributaries contribute to the local flood problem and it is important to prevent the flood crests from the different tributaries being synchronized;
- the ratio of flow in an extreme flood to the flow of the annual flood is high; and
- the floodplain is heavily developed.

Where the reservoir created can also be used for other purposes, such as irrigation or power generation, the case for a dam is strengthened.

- Small scale ‘warping’ and ‘catch dams’ can frequently form a useful component of a strategy to control soil erosion and sediment movement in areas where the sediment loads generated would otherwise be considerable

2.8 Urban Water Supply Management

It is inevitable that the current shortfall of water to meet the existing and future needs in large cities must be met by increasing supply. Cities with limited water resources, such as in Singapore and Penang, have tackled their long-term water needs in innovative ways, but at huge costs, and, of course, long-term agreements with neighbouring states. In Singapore, this is in addition to impoundments in the hilly interior parts of the island; also, urban storm runoff is harnessed through the construction of drains that lead to large collection ponds and reservoirs. The installation of rainwater in urban dwellings to increase water supply for washing, watering of gardens and other users (Latham and Schiller, 1987) has, for example, been translated into building requirements for new housing estates in Selangor, Malaysia. This measure recognizes two important benefits; making use of water available in the locality throughout the year, given the climate regime, and the reduction of surface runoff, hence decreasing flood potential, particularly flash flooding which urban development seems to cause in Malaysia.

In most cities in Southeast Asia, domestic consumption accounts for the largest proportion, for example, more than 75 percent in Penang and about 70 percent in Singapore (Goh, 1992), through consumption by industries and business is likely to increase in the future. Reduction in consumption can occur by reducing per capita consumption reinforced through education and campaigns, and installing water-saving devices and pricing mechanisms; using alternative sources of water, such as industry obtaining its own supply or relocating high water consuming establishments elsewhere; recycling used water, especially by industry.

The El Nino-induced drought in 1998 brought home this reality when many parts of Kuala Lumpur were without water for several months, with serious social and economic costs (Hamirdin, 1998). In general, the major constraints preventing integrated management approaches include a lack of inter-sectoral coordination, conflicting national, provincial and local water allocation priorities, and continued focus on creating