

RESERVOIR STORAGE SIMULATION AND FORECASTING MODELS
FOR MUDA IRRIGATION SCHEME, MALAYSIA

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A project report submitted in partial
fulfillment of the requirements for the award
of the Master of Engineering (Civil-Hydraulics and Hydrology)

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APRIL 2010

I declare that this thesis entitled “RESERVOIR STORAGE SIMULATION AND FORECASTING MODELS FOR MUDA IRRIGATION SCHEME, MALAYSIA” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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ABSTRACT

Reservoir operation policies aim at deriving maximum benefits from water that can be stored in it and allocated to crops. Water shortage is the main constraint in establishing stable irrigation water management in Muda Irrigation Scheme, Kedah, Malaysia. Thus, the objective of this study is to develop a reservoir simulation model and to consider stochastic models and Log-Pearson Type III distribution to generate storage to compare with the observed storage, and to forecast future storage to examine the performance of the reservoir with reliability under changing conditions. The reservoir simulation model storage amounts were calculated for 1998-2008 using measured values of rainfall and evaporation (reservoir station no. 61), reservoir inflow, release, seepage, spill, and Muda reservoir inflow. The developed reservoir simulation model results simulated well with the mean monthly observed long-term storage amounts (1998-2008), except for a few months where the model storages are found relatively higher than the observed storage amounts. A stage-storage curve is plotted using the monthly observed values of storage and water level from 1998-2008 to convert water level into storage and vice versa. The first order Markov model with periodicity and Log-Pearson Type III distribution are considered to generate storage amounts to compare with the mean monthly observed storages, and hence to forecast future storage with reliability. The first order Markov model generated and observed mean storage amounts were compared for each month. The comparison results imply that the monthly statistical parameters of the historic record, except the lag1 serial correlation between December and January months (i.e., over-year monthly correlations), are preserved satisfactorily. The storage amounts are forecasted for year 2009-2015 to be used in future reservoir operation, using first order Markov model. The expected mean and minimum storage amounts for different return periods are estimated, using Log-Pearson Type III distribution and trendlines with equations and R^2 values are shown, to help decision makers to estimate future storage with corresponding return period under any changing weather conditions and or demand.

ABSTRAK

Polisi pengoperasian empangan yang mensasarkan keuntungan maksimum dari air yang disimpan atau bagi tujuan penanaman. Masalah kekurangan air menjadi masalah utama dalam memastikan pembangunan pertanian yang seimbang di Muda Irrigation Scheme, Malaysia. Oleh yang demikian, tujuan kajian ini dijalankan adalah untuk membina model simulasi yang menitikberatkan stokastik model dan juga kaedah pengagihan Log-Pearson type III untuk mendapatkan jumlah simpanan empangan dan membandingkan simpanan sediaada dengan hasil daripada kiraan model tersebut. Data dari tahun 1998-2008 digunakan untuk mengukur jumlah curahan dan cairupan (bagi empangan stesen 61), kadar alir masuk, pelepasan, penyerapan, limpahan, dan Kadar alir dari empangan Muda. Model simulasi bagi empangan yang diperolehi agak baik dengan purata bulanan jangka masa panjang (1998-2008), kecuali untuk beberapa bulan di mana model simpanan didapati agak tinggi daripada jumlah sebenar. Lengkungan simpanan-langkah telah diplotkan untuk menukarkan paras air kepada simpanan. First Order Markov Model dan Log Pearson Type III dipertimbangkan untuk mendapatkan jumlah simpanan dan dibandingkan dengan purata bulanan simpanan sebenar, dan juga untuk meramalkan simpanan dengan kemungkinan tertentu. Setiap model yang diperolehi dibandingkan bagi setiap bulan. Hasil perbandingan tersebut membayangkan statistical parameter bagi data-data yang direkodkan, kecuali bagi lag1 hubungan diantara bulan Januari dan Disember adalah dijangkakan selamat. Jumlah simpanan yang diramalkan dari tahun 2009-2015 akan digunakan untuk operasi empangan pada masa akan datang. Purata dan jumlah simpanan minimum yang dijangkakan bagi tempah kalaan yang berbeza dijangkakan, menggunakan Log Pearson Type III dan didapati trendlines, R2 ditunjukkan untuk membantu membuat keputusan bagi pengurusan empangan pada masa akan datang dengan sebarang perubahan cuaca.

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LIST OF ABBREVIATIONS

A	Cross-sectional area
$A_r(t)$	Reservoir surface area
$A_w(t)$	Watershed area during period t
$E(t)$	Evaporation rate at the reservoir surface area
ET_p	Potential evapotranspiration
$ET_p(t, t + \Delta t)$	Evapotranspiration between t and $t + \Delta t$
$IG(t)$	Any other gain
GCM	General Circulation Model
GIS	Geographic Information System
$I(t, t + \Delta t)$	Infiltration/percolation between t and $t + \Delta t$
$IL(t)$	Any other loss
LP	Linear Programming
MADA	Muda Agricultural Development Authority
$P(t)$	Precipitation falling on the reservoir surface area
$P(t, t + \Delta t)$	Precipitation between t and $t + \Delta t$
$Q_i(t)$	Inflow to the reservoir per unit watershed area during period t
Q^{j+1}	Water delivered by conveyance system to the field (outflow)
$Q_s(t)$	Uncontrolled releases downstream or spills from the reservoir
$R(t)$	Required reservoir release rate
$R(t, t + \Delta t)$	Runoff between t and $t + \Delta t$
SP	Seepage and percolation losses
X_i	Measured value of storage at time i
X_{i+1}	Generated streamflow

y	Average of the absolute values of deviations from the mean
Y_i	Measured transformed value of storage at time i
Y_{i+1}	Transformed generated streamflow
$Y(t)$	Reservoir yield
ε_{i+1}	Random component with mean zero and variance σ_ε^2
μ_x	Mean of X
$\rho_x(1)$	First order serial correlation
Δt	Time step

CHAPTER I

INTRODUCTION

1.1 Background

Allocation and management of water for agricultural purposes is a complex issue affected by social, environmental and political factors. Reservoirs are very useful choices for storage of irrigation water to use in drought periods. Optimal operation of reservoir systems is important for effective and efficient management of available water resources for maximum system net benefit (Consoli et al. 2008; Nandalal and Sakthivadivel 2002; Raju and Kumar 1999; Suiadee and Tingsanchali, 2007; Shrestha et al., 1996).

In water resources development, reservoirs play a major role in modifying uneven distribution of water both in space and time. To make the best use of the available water, the optimal operation of reservoirs in a system is undoubtedly very important though it is a very complicated task. During the last several decades many attempts have been made towards solving this problem by various mathematical means (Wurbs, 2005).

Irrigation projects which receive water from a reservoir can be challenging to manage, since annual fluctuations in runoff from the reservoir's catchments area can have considerable impact on the irrigation management strategy. (Shrestha et al., 1996) mentioned that there is a general realization that many irrigation networks are failing in their fundamental function of delivering water, where and when it is needed, and in the right quantity. Irrigation departments, particularly in developing countries, have been suffering financial setbacks and therefore implementing improved techniques for operational management of these systems receives inadequate attention.

Irrigation reservoir operation policies are aimed at deriving maximum benefits from the water that can be stored in it and allocated to crops. Water releases from reservoirs have to be conveyed through a hierarchical distribution system of canals, branch canals, distributaries and field turnouts or outlets before they reach the cropped fields. The operations are complex but substantial increases in benefits can be derived even from relatively small increases in operating efficiency (Maidment and Chow, 1981). Water management basically consists of determining when to irrigate the amount to be applied during each state of plant growth, and the operation and maintenance of the system. Water distribution systems and management strategies that enable users to apply water uniformly and accurately require large capital investments. All the three stages of the irrigation operation problems, namely, determining the reservoir releases, transferring them to the field level, and allocating the field supplies to crops are important components of operation of large irrigation systems. Missing any one of these components can lead to low agricultural productivities and operating efficiencies.

1.2 Statement of the Problem

Malaysia has mostly arid and semiarid climate, and spatial and temporal distribution of rainfalls is irregular. Food demand is rapidly increasing with increasing population. Water resources system of Malaysia has a complex structure and financial opportunities to construct new dams are very restricted depends on the purposes of construction, economical value and etc. Water resources managers and decision makers paid a significant attention on optimum operation of reservoirs during the last decade. Mathematical programming methods were the most widely applied methods of optimization.

Water is main component for living beings on earth to continue their lives. But, now-a-days the problem related to water such water shortage is very crucial. This can be happened due to improper water management. The proper management is very important in order to sustain the water resources with high water quality and can reduce the problem on water shortage.

Reservoir is one of the sources of surface water. It can reserve the water and supply water to the people. Reservoir will regulate inflows and provide outflows at more regular rate, which is determined by water demand, temporarily storing the surplus when inflows exceed outflows. These days reservoir has been facing a lot of problems such as low water quality and water release not following an energy-efficient schedule. It gives tendency of occurrence of water shortage.

According to previous studies, the water volume of Pedu and Muda dams experience frequent deficit due to shortage of water supply from catchment. Thus, the plan is needed to be modified periodically during real-time operation based on

current season data and climate change. The Muda irrigation scheme is highly dependent on rainfall, fulfilling about 51% of the irrigation requirements. Two dams (Pedu and Muda) contribute about 29%, while the uncontrolled river flow and recycling supply contribute about 15 and 5%, respectively (Ali et al., 2000; MADA, 1987). In fact, the reservoirs were so depleted that irrigation for the 1978 dry season crop was impossible, and again in 1983 and 1984, only half of the area could be irrigated (Kitamura, 1990).

The shortage of reservoir water remains the most serious constraints on the establishment of stable double cropping of rice. The efficient utilization of water resources needs information, such as, annual effective rainfall, runoff, consumptive use, and reservoir release, etc., thus, a reservoir simulation model often used to predict the response of the system under a given set of conditions. On the other hand, forecasting are used for warning of extreme events (e.g., floods and droughts), for operation of water resources systems such as reservoir, hydropower generation projects and etc. In addition, the models can be used to predict the future performance of reservoirs.

1.3 Justification of the Study

Water management generally means the supply, conveyance, distribution, and application of the right amount of water at the right time to the right place so that the plants would thrive and produce good yield.

The shortage of reservoir water still remains the most serious constraints on the establishment of stable double cropping of rice. Thus, a reservoir simulation

model needs to be developed to estimate the reservoir yield precisely. Long-range water supply forecasting is an integral part of drought management and of water supply management itself. Stochastic data generation aims to provide alternative hydrologic data sequences that are likely to occur in future to assess the reliability of alternative systems designs and policies, and to understand the variability in future system performances. It is also very important to develop a stochastic hydrologic model to generate the monthly streamflows and thus to estimate the future streamflows with reliability.

1.4 Objectives of the Study

The main objectives to be carried out in this study are:

- (i) To develop a reservoir simulation model to simulate model storages with the long-term observed storage amounts,
- (ii) To use stochastic models to generate storage and to compare with the observed storage, and hence to forecast future storage with reliability.

1.5 Scope of the Study

The main scope of this study will be confined to the development of reservoir simulation model, and utilization of stochastic models to generate and forecast storage. The scopes of work that will be covered in this study are:

- i. Collection of various relevant historical data from MADA.
- ii. Development of various mandatory modules of reservoir systems.

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