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ANALYSIS OF LOW FLOWS IN RANTAU PANJANG, SG. JOHOR

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ABSTRACT

This study reviews the probability distribution functions suitable for low flow in Rantau Panjang, Sg. Johor. The daily discharge data was collected from the Department of Irrigation and Drainage. The proposed probability distribution functions are Gumbel distribution, Weibull distribution, Log-Pearson III distribution and Log-Normal distribution. The data obtained ranges from year 1975 to year 2014, 40 years of records. The Kolmogorov-Smirnov test and Chi-Squared test were used as the goodness of fit test to choose the best fit probability distribution.

Keywords: Low Flow, Probabilty Distribution Function, Goodness of Fit Test, Frequency Analysis

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CHAPTER 1 INTRODUCTION

1.1 Background of Study

Low flow is the lowest sustaining flow during base runoff conditions of a river. Definition of low flow is given as ''flow of water in a stream during prolonged dry weather'' by the World Meteorological Organization (WMO, 1974). Many have mistaken low flow is the same as drought but in fact they are different. Drought is a condition when there is deficiency in water supply either in meteorological, agricultural and hydrological. The significant difference between both of them is low flow is a seasonal phenomena while drought is a general phenomena that precipitation is below average for an extended of period. Low flow happens in drought but a seasonal low flow that occurs continuously is not obliged to be a drought.

The understanding of low flow statistic is important for the development and management of water resources. It is essential in forecasting seasonal low flows and as a reference for maintaining water quality standards. Analysis of low flow should aim to indicate the impact caused by low flow in order to manage the drought and low flow in drought-prone regions effectively. Water is one of the most vital resources in our earth and every living thing on this world need to consume water for survival and thus shortage of water consumption will cause a big problem and even fatal cases. Low flows are affected by urbanization, construction of dams and reservoirs, illegal logging and the list goes on.

The low flow analysis that has been carried out in many areas around the world is insufficient to solve the impacts brought by drought such as depleted water flows and scarcity of water in some areas. This will lead to difficulties to be faced in agricultural and electricity generation that can make a hit impact on our economics. It will also increase the water pollution and also salinity in the water. Furthermore, it restraints people from boating. According to the last month Borneo newspaper, water level dropped in the Baram River which low flow occurred had depleted the water sources at Lepong Dam and water supply from Simunjan. Besides, one of the biggest dam in the world, Hoover Dam was once shutdown due to the low flow in Lake Mead, the reservoir behind the dam. This is because of the bubbles that were formed due to the low flow had burst and exploded which caused the turbine blades to be scoured.

1.2 Problem Statement

Many researchers have been carried out on flood analysis to improve flood management and precautions. However there are not many hydrologists who carry out research on low flow or droughts analysis compared to the flood analysis. Flood is a phenomenon that occurs more frequent compared to drought which can bring big impacts too. Extra attention should be focused on low flow and drought analysis in order to improve water resources and drought management in the future. Malaysia is now under rapid economic development and population growth in order to achieve the goal to be a fully developed country by 2020 under the vision 2020 which is introduced by Malaysia former Prime Minister, Tun Dr. Mahathir. The development of oil palm plantation which is going on rapidly has caused the river to undergo reduction in water flow over the years and slowly drying up. The clearing of forest tress had made the situation worse by causing the river catchment area to lose water especially during the dry season. Water resources demands are increased due to the population growth thus study has to be carried out to assess methods for low flow analysis that can aid in improving water resources and drought management in the future.

1.3 Aim

- To carry out low flow analysis that can help to improve water resources and drought management in the future.

1.4 Objective

- To study different types of probability distribution and choose the most suitable probability distribution to perform analysis of low flows in selected river catchments in Malaysia.
- To determine the low flow for desired periods of occurrence.

1.5 Scope of Work

This research work covers the Johor River which is located at Johor state, the south part of peninsular Malaysia. Data will be collected from the department of irrigation and drainage (DID) and the most suitable method will be chosen to carry out the analysis of low flow in selected river catchments.

There are many probability methods that have been used by hydrologists for the low flow analysis. Gumbel distribution, Weibull distribution, Log-Pearson type III distribution and Log-normal distribution are few of the most commonly used among all the probability distribution. All the probability distributions will be compared by using the goodness of fit test in order to determine the most suitable probability distribution. There are few comparison methods that are available such as Chi-square test and Kolmogrov-Smirnov test.

CHAPTER 2 LITERATURE REVIEW

2.1 Low-flow

Low flow is a seasonal phenomenon and is the lowest sustaining flow during base runoff conditions of a river. Low flow analysis is about the study of the minimum flow in a river during the dry periods of the year. The low-flow regime of a river may be described in terms of various characteristics (indices). These characteristics may have multiple uses in different areas of water-related research and practice and uncertainty often exists as to which low-flow characteristic is the most suitable for a specific purpose (VY Smakhtin, M Toulouse 1998). Low flow has to be fully understand in various aspects of water resources management and engineering such as hydropower planning, determining allowable water transfers and withdrawals, and decisions regarding environmental flows. Besides, low flow statistics also can be used in ecological research. Low-flow conditions can disturb ecosystems and create biological responses and changes in habitat such as reduced populations of aquatic species and shifts in the relative distribution of species (Miller and Golladay, 1996).

Furthermore, knowledge of the magnitude and frequency of low flows for streams is fundamental for water-supply planning and design, reservoir storage design, maintenance and quantity and quality of water for irrigation, recreation, and wildlife conservation. Low-flow statistics indicate the probable availability of water in streams during times when conflicts between water supply and demand are most prevalent. Because of this, low-flow statistics are needed by Federal, State, and local agencies for water-quality regulatory activities and water-supply planning and management (Kernell & Paul). These statistics can be used as thresholds when setting wastewater-treatment plant effluent limits and allowable pollutant loads to meet water-quality regulations. Low-flow statistics can be used by commercial, industrial, and hydroelectric facilities to determine availability of water for water supply, waste discharge, and power generation (Eash, D.A., Barnes, K.K, 2012).

Where significant amounts of systematically observed flow data exist low flow frequency analysis should be employed in decision-making because of potential economic impacts. A high economic value is associated with the activities of prediction and analysis of low-flows and the resulting long-term droughts. It should be mentioned that droughts have more severe consequences and are often more costly than flood events. Damage accounting to approximately US 40 billion occurred during the USA droughts of 1988-1989, while the financial cost of the floods in the Missisippi area in 1993 was in the range US 18-28 million(Demuth, 1974). On the other hand, where the amount of available local observed streamflow records is meager, regional estimation techniques can be utilized.

The prediction magnitude of streamflow with a series of desrired retun periods is needed for specific periods of the year in order to calculate the maximum allowable load of a pollutant in a stream. Estimates of expected streamflow are especially important for low-flow periods when agencies need to determine waste-load allocations (WLAs) for National Pollution Discharge Elimination System (NPDES) discharge permits for municipalities, industries, and other entities with facilities that release treated wastewater into a stream. A WLA is the loading capacity or maximum quantity of a pollutant each point-source discharger is allowed to release into a particular stream. WLAs are used to establish water-quality-based limits for point-source discharges.

2.2 Low Flow Index

Low flow index is used predominantly to define particular values obtained from any low-flow measures. Some of the commonly used low-flow indices are annual minimum mean daily flow (mdf), annual minimum m-day sustained low-flow (m-day SLF), annual minimum m-day moving average flow (m-day MAF) and 95%ile flow. The most widely used low-flow indices (particularly in USA) are 7-day 10-year low flow (7Q10) and 7-day 2-year low flow (7Q2), which are defined as the lowest average flows that occur for a consecutive 7-day period at the recurrence intervals of 10 and 2-years, respectively. The average of the annual series of minimum 7-day average flows know as Dry Weather Flow (DWF) is used in the UK for water abstraction licensing. 1-day and 30-day summer and winter low-flows are the most commonly used in those countries that having four seasons such as Russia and Eastern Europe. The most widely used low-flow indices in Ireland are 95%ile flow (Q95), Dry Weather Flow (DWF) which has been defined by the Environmental Protection Agency (EPA) as the minimum daily meanflow rate with a return period of 50 years, 7-day 15-year sustained low-flow. EPA uses DWF & 7-day 15-year SLF for stream water quality management purposes. Q95 is generally used to assess the stream waste-load assimilative capacity assessment (Mandal & Cunnane, 2009)

2.2.1 Base Flow Indices

The Base Flow Index (BFI) is used as a measure of the base flow characteristics of catchments. It was created throughout the research which is carried out at United Kingdom to assist in measuring the qualities of low flow for the streams. It provides a systematic way of assessing the proportion of base flow in the total runoff of a catchment. It shows the impacts on stream flows which is brought by soil and geology and thus it is essential. Nowadays extreme low flow events are more diligently analysed and given focus in the emerging field of eco-hydrology.

The BFI has been computed using the archived record of gauged daily mean flows. In deriving the relationship between catchment characteristics and base flow index, various variables are employed. These include the catchment size (A), stream density (Dd), climate index or aridity (humidity) index (AI), hypsometric integral (I), normalized digital vegetation index (NDVI) extracted from satellite images and geologic features.

Base Flow Index (BFI) is been utilized in order to identify the consequences regarding geology upon the low flows while using the ratio of base flow in the stream to prevent a new profusion involving the relationship concerning low flow indices and catchment characteristics. BFI is not applied specifically as an essential variable to connect the catchment characteristics and the low flow statistics. Rather, the Base Flow Index was applied as an essential variable in conveying the hydrological response of catchments. Besides, BFI may be utilized when sufficient periods of flow data are provided to measure the low flow statistics.

To calculate for the annual base flow index, there are 2 ways. The first method is to compute the particular record separately and then calculate the each year of BFI. The other way is to run the particular splitting up system on first year and then second year subsequently by assuming each year as a solely new record.

The definition of BFI is given as the proportion of V_B/V_A where V_A is the average flow beneath the hydrograph while V_B is the volume beneath the base flow separation line. The average magnitude of base flow index can be determined from a series of annual BFIs, however there will be slightly difference from a particular value determined from the period or record.

An analysis had been performed to estimate the effect of the missing data on calculated values of BFI. It was shown that the base flow index is sensitive towards the missing data when numerous of days of data are omitted from the base flow separation due to the result of one day missing from the data of the gauged station. It can be said in other words that the calculation of BFI shown some improvements when interpolation is done within 5 missing days of data.

Base Flow Index (BFI) is defined as the non-dimensional ratio of the volume of base flow divided by the volume of total stream flow. In catchments with high groundwater contribution to stream flow, BFI may be close to 1, but it is equal to zero for ephemeral streams. BFI was found to be a good indicator of the effects of geology on low-flows and for that reason is widely used in many regional low-flow studies (IH, 1980).

2.2.2 7Q10 flow

Low flows are associated with low dissolved oxygen and high contaminant concentrations, with negative consequences for aquatic habitat. Thus, the state and local municipalities establish regulatory limits on the basis of estimated low-flow characteristics, such as $Q_{7,10}$ (Riggs, 1980). $Q_{7,10}$ is defined as the estimated annual minimum 7-day average flow that is expected to be exceeded on average in 9 out of 10 years(Ken and Milly, 2007). The low flow index that is most frequently and widely been used is 7Q10. According to Singh, the relevant department of States used 7Q10 as an indicator for the water quality standards of the rivers to regulate the stream pollution (Singh, 1974). The water quality of any stream can be accepted unless the flow was below the minimum 7-day 10 year low flow (7Q10). According to Chiang and Johnson's research during year 1976, it is said that the water quality of the stream over the limit could be degraded if any diversion is made exceed the limit of 7Q10.

The table below shows the purposes of applying 7Q10. From the beginning, the 7Q10 flow is used to identify the water quality standards of the stream flow for pollution purposes; however later on it has been widely used by many organisations for their other interests. There are considerations regarding the 7Q10 flow whether it is suitable to be used as the index flow or not. The U.S. Fish and Wildlife Service (1981) argued that the 7Q10 flow had been used within the past as a minimum flow for protection of the aquatic community, but it is not an appropriate way. This is because the application of 7Q10 is to determine the volume for dilution to line the limits for wastewater discharge, which it does not aid in the protection of aquatic life and thus it is not suitable. Caissie and El-Jabi (1995) had give out some warnings that the application of the 7Q10 flow might somehow underestimate the flows, and it might bring the consequences of harmful biological effects. The State of Massachusetts (2004) stated that a flow with higher magnitude is required although 7Q10 flow statistic had been clarified to be the guideline for maintaining a healthy ecosystem for stream flow.