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Identifying the Correlation of Rainfall and Water Level and Rainfall with Stream Flow In Sungai Johor by using Pearson Correlation Coefficient

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ABSTRACT

Stream or river plays a critical role in maintaining hydrologic cycle. The flow trend is usually from an upstream to a downstream. This re-search is conducted to produce a map of study area by using ArcMap software and to determine the correlation of rainfall with water level and the correlation of rainfall with stream flow in the Johor River by using Pearson Correlation Coefficient. The study area involved are in Kota Tinggi, Johor. The coordinates of this research site are 1°43'07.6'' N 103°52'06.7'' E, 1°44'54.0'' N 103°53'11.6'' E, 1°41'05.04'' N 103°55'11.0''E, 1°42'09.2'' N 103°57'00.2'' E. All the importants data obtained from the Department can be concluded that, there were no correlation between rainfall with water level and it was found that rainfall and stream flow has slightly positive correlation.

Key words : ArcMap, correlation, Pearson Correlation Coefficient, Kota Tinggi, Department of Drainage and Irrigation (DID).

1. INTRODUCTION

River plays an important role towards the society. It is where fresh natural water flowing through a channel or a passage that will flow from an upstream to a downstream. There are few parameters that influence the flow pattern and one of them is rainfall intensity. The study area chosen are in Kota Tinggi, Johor. In this study, the researcher uses ArcGIS software to produce maps of the study area and to store data as a backup. The software used to produce maps is ArcMap. Next, the correlation between rainfall and water level and correlation between rainfall and stream flow are determined. The research aimed to see the correlation between all parameters which is rainfall with water level and rainfall with stream flow. The correlation method used is Pearson Correlation Coefficient (PCC) where it gives a range of correlation -1.00 to 1.00.

Raw data are obtained from the Department of Irrigation and Drainage (DID). This data are called as primary data. Data provided were rainfall data, water level data and stream flow data. This data have not gone through any analysis [1]. While the existed data collected through the reading of journals, books, thesis, and the internet [2]. Data that had been collected and gathered were processed and analyzed. In literature review the introduction to ArcGIS, Pearson Correlation Coefficient, rainfall pattern, rainfall analysis, water level analysis and stream flow analysis were explained.

2. ARCGIS

ArcGIS is one of the GIS software that used to produce maps. It is a computer-based system involving mapping and geographic information. In addition, rainfall data and stream flow data were added into the map of the study area as a backup data.

2.1 Rainfall Pattern

Factors and effect of rainfall towards water level and river flow were determined and identified and those factors are also related to climate change effect, topography effect which included the shape, the depth of the river bed, and also may cause by the land use effect. Theoretically, if the rainfall intensity is high, the water level will be increased and if the rainfall increase, the stream flow will increase. However, in recent years, it was reported that several drought events had occurred [3] due to seasonal monsoon. On the other hand, there also flood event occurred after an intense amount of rainfall in a short period of time especially in 2006 and 2007. So, in order to identify the relationship between these parameters, Pearson Correlation Coefficient were used.

2.2 Factor affecting rainfall pattern

There are several factors that causing the alteration in rainfall pattern. The most significant factors are seasoned and climate changes. Generally, the rainfall received throughout Malaysia both monthly and annually is influenced by monsoon factor [4]. When the temperature are increasing, the evaporation rate will be increased too. Other than that, the factor that affecting rainfall pattern is geographical location [5].

2.3 Water level

Water level is defined as the height of the water surface in lake, river, etc. In this research, the water level of the Johor River at Sg. Johor, the Rantau Panjang station obtained from the

Department of Drainage and Irrigation were analysed. The same technique was used to import all the data into Microsoft excel. The data used to create the water level graph is the maximum data for the years 2002 until 2017.

2.4 Stream flow

Stream flow also known as channel runoff is where water flow in either stream or any other channels which is a main element in water cycle systems. The discharge of water flow can be estimated by using Manning equation. The record of flow against period is called as hydrograph. There are many sources of stream flow, such as channel precipitation, groundwater, inter flow and overland flow.

3. RESEARCH METHODOLOGY

Planning is an important stage. During this phase, the study location and the software to be used were determined. In this study, the ArcGIS software and Microsoft Excel were used. Data collected from the Department of Irrigation and Drainage (DID) is classified as primary data came from verified station with raw data and has not gone through any analysis process.

3.1 Map processing

Map of study area was produced with ArcMap. To use ArcMap, the researcher needs to have a strong internet connection. Table 1 shows the steps involved to create a map of the study area using ArcMap.

Table 1 : The steps involved to create a study area map using ArcMap.

Title	Description
Explore study area	Key in the coordinates of the study area and explore its geography
Compute the data	Create shape file and store the data into the point

3.2 Data Analysis

The study area are based on four coordinate stated at Table 2, from the DID station located at the area we search for raw data such as rainfall (RF), stream flow (SF) and water level (WL) that match with our objectives. Once the raw data has collected clean dataset need to be done first to eliminate error data before map and graph can be produced using ArcGIS and PCC (Fig. 1).

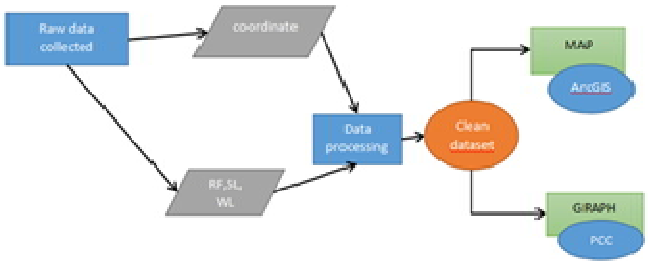

Figure 1: Flow chart of data analysing

3.3 Data processing

Rainfall data, water level data and stream flow data were exported and converted into Microsoft excel for each year (2002 until 2017). This process was to make it easier for these data to be analysed. Graphs were produced based on the data and the trend and pattern can be identified. Graphs can be easily created when the data converted to excel data. All the data were changed into graph in order for visualizing the data to ease the analysis process.

Correlate between the Rainfall and Water Level data (Table 2) using Pearson Correlation Coefficient (PCC) formula below;

$$r=\frac{N\sum XY-(\sum X)(\sum Y)}{\sqrt{(N\sum X^2-(\sum X)^2)(N\sum Y^2-(\sum Y)^2)}} \quad \text{..... (1)}$$

Where;
X= rainfall
Y= water level

Table 2 : Processing data for Pearson Correlation Coefficient (PCC) formula

Years	Rainfall (m) (X)	Water level (m) (Y)	(XY) m2	(X^2) m2	(Y^2) m2
2002	0.629	4.41	2.774	0.396	19.448
2003	2.420	7.31	17.690	5.856	53.436
2004	2.174	9.68	21.044	4.726	93.702
2005	1.911	7.51	14.352	3.652	56.400
2006	1.119	10.94	12.242	1.252	119.684
2007	1.824	11.87	21.651	3.327	140.897
2008	2.403	6.07	14.586	5.774	36.845
2009	1.579	6.14	9.695	2.493	37.670
2010	1.111	5.14	5.711	1.234	26.420
2011	2.573	10.04	25.833	6.620	100.802
2012	2.226	6.16	13.712	4.955	37.946
2013	2.542	7.06	17.947	6.462	49.844
2014	2.019	6.45	13.023	4.076	41.603
2015	1.911	5.15	9.842	3.652	26.523
2016	2.004	4.95	9.920	4.016	24.503
2017	2.578	7.13	18.381	6.646	50.837
TOTAL	31.023	116.01	228.403	65.137	916.56

4. RESULTS AND DISCUSSION

4.1 Study Area Maps

By referring to the coordinate obtained, the map of the study area was created and utilized by using ArcMap. Fig.2 show the study area location in a map form.

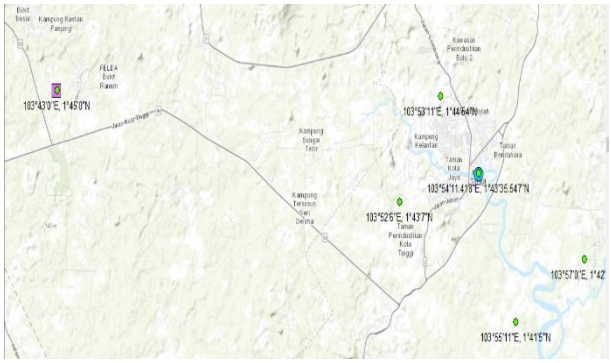

Figure 2: Map of study area

4.2 Rainfall Analysis

To analyze the rainfall data, researcher first need to convert the rainfall data obtained from the Department of Drainage and Irrigation (DID) Ampang into Microsoft Excel. Data was computed by days and months from year 2002 until 2017.

From Fig.3. for the last 7 years (2011-2017) the rainfall intensity become more scattered compared to in 2002 until 2010. This is due to the climate change occurred globally, where based on the study conducted the rate of evatranspiration increase, the rainfall volume will be increased [6].

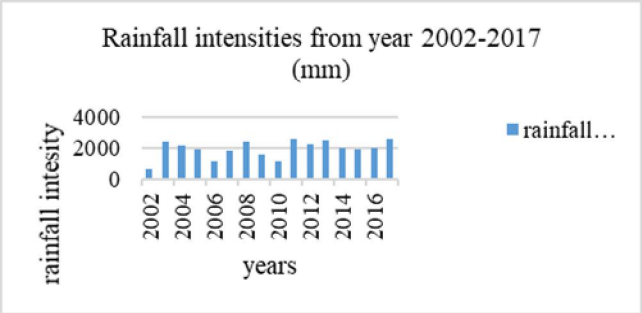

Figure 3: Rainfall intensities graph from year 2002-2017

4.3 Rainfall Pattern

Fig.3. show a graph that had been produced from year 2002 until 2017 period, the highest intensities of rainfall recorded was in 2017 which is 2578 mm. While the lowest rainfall intensity was recorded in the year 2002 which is 629 mm. This is due to the climatic change that had influenced the rate of evatranspiration [6]. We can see the amount of rainfall in the last 7 years from 2011 until 2017 were slightly increased from the past year especially compared to 2009 and 2010. It is due to climate change that had occurred throughout the globe. One study concludes that as the atmosphere become warmer, the evaporation rate is increasing [6]. [2] had stated that " Rainfall were lead to serious flooding issues and expected to keep increasing due to climate changes".

4.4 Water Level Analysis

From Fig.4., water level recorded in 2006 and 2007 was very high where the highest was in 2007 where the water reading was 11.87 m. This is during flood occurrence in Kota Tinggi. Based on Malaysia Meteorological Department, due to cold surges of the northeast monsoon, abnormally heavy rainfall occurred in the southern part of several days in late December 2006 and in the middle of January 2007 cause massive floods. The series of flooding events occurred in Kota Tinggi for the past 16 years were in 2004, 2006,2007 and 2011 [5]. Where from the statistics, water level recorded for all four years were higher compared to the rest 12 years, which were 9.68 m, 10.94 m, 11.87 m, and 10.04 m with the average of 10.63 m.

We can see that from the statistics in Fig.4., the level of water in 2008 and 2012 drop drastically as based on report of the Review of the National Water Resources Study (2000-2050) and Formulation of National Water Resources Policy [8], the study of the flood mitigation master plan and its common structural flood mitigation measures was conducted in Sg. Johor.

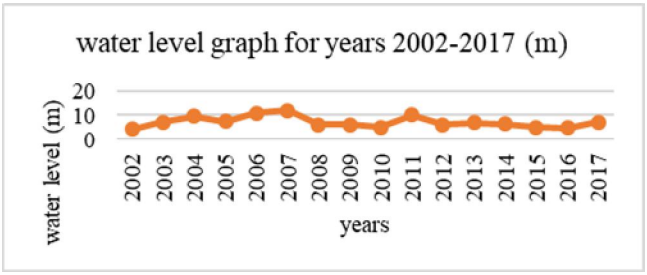

Figure 4: Water level graph for years 2002-2017

4.5 Stream flow Analysis

Stream flow also known as channel runoff is where water flow in either stream, river or any other channels which is a main element in water cycle systems. From Figure 4.10, the peak stream flow occurs in 2007 which is shockingly 554.93 m3/s followed by 364.23 m3/s in 2006 prior to catastrophic flood events in Kota Tinggi. High flow also recorded in 2011 where the flow was 320.43 m3/s. Based on the Fig.4 and Fig.5, when water level increase, the stream flow will increased. Table 4.4 shows the data of maximum flow in 2002 until 2017. This is also including the tides effect that affecting the river flow current speed and volume [7]. The tidal effect plus high precipitation contribute to the flood [5].

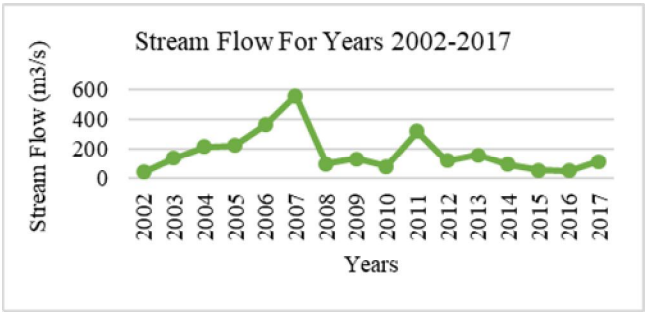

Figure 5: Graph of maximum stream flow from years 2002-2017.

4.6 Correlation between Rainfall and Water Level

Based on the rainfall and water level data available, relationship between two types of data can be identified. From the graph, the rainfall intensity is become more scattered in 2011 until 2017. To see the strength between both variables, Pearson Correlation Coefficient method was used. Where Pearson, R test was utilized. There are five (5) steps for conducting the Pearson Correlation Coefficient value. Fig.6, shows the correlation graph between rainfall and water level in 2002-2017. Table 3 shows the PCC table of rainfall and water level.

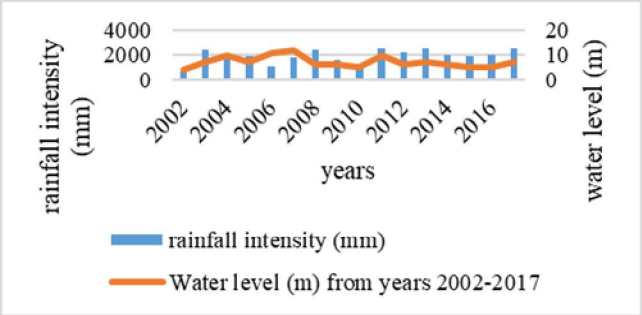

Figure 6:. Correlation graph between rainfall intensities and water level in 2002-2017.

Table 3: Pearson Correlation Coefficient table of rainfall and water level.

Years	Rainfall (X) (m)	Water level (Y) (m)	(XY) m^2	(X^2) m^2	(Y^2) m^2
Total	31.023	116.01	228.403	65.137	916.56

$$r = \frac{3654.448 - 3598.98}{\sqrt{(67885.3 - 962.43)(14664.96 - 13458.32)}}$$

$$r = +0.00617$$

So, since the value of r is 0.00617, thus the value indicates to 0. There is no linear relation between rainfall and water level as it relations might need some other parameters such as river profile. However, the value from Excel is slightly different from the value obtained from the equations. This is due to the rounding different used in software and in the manual calculation.

4.7 Correlation between Rainfall and Stream Flow

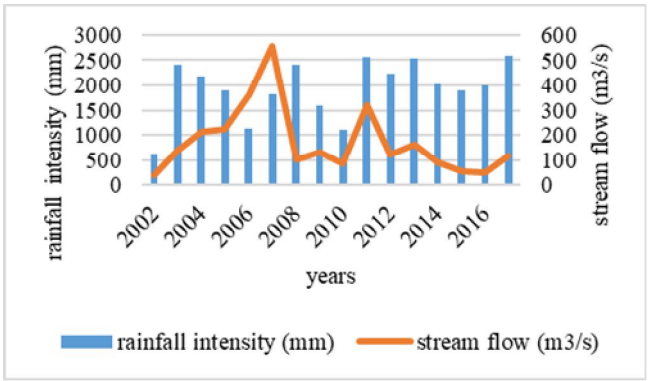

Figure 7: Correlation between rainfall and stream flow in 2002-2017.

In this study, the trends of annual rainfall and stream flow were identified between 2002 and 2017. In general, the results show that increased in rainfall amount will increase the stream flow values and vice versa. So, the Pearson Correlation Coefficient method was used to see the correlation of both variables. Fig.7 and Table 4 shows the correlation between rainfall intensities and stream flow from years 2002-2017.

Table 4: Pearson Correlation Coefficient table of rainfall and stream flow

Years	Rainfall (m) (X)	Stream flow (m^3/s) (Y)	(XY) m^4/s	(X^2) m^2	(Y^2) m^3/s
Total	31	2778.9	5430.4	65.1	764420.4

$$r = \frac{677.560}{4154.416}$$

$$r = +0.163$$

So, since the r value is +0.163 which is positive, so the rainfall and stream flow were positively correlated. However, the correlation is very weak. But, the correlation using Excel give the negative correlation. This is due to the rounding affect in software (Excel) version.

5. CONCLUSION

In this research, the correlation of rainfall and water level and stream flow can be known by analysing the data and graph using Pearson Correlation Coefficient and also producing study area maps using ArcGIS. In addition, this research has achieved both objectives based on summary stated from the previous sub-topics. Rainfall and water level data, rainfall and stream flow data were correlate to see the relationship of the data either as it is positively or negatively correlated.

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