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NEW METHOD FOR FLOODS EARLY DETECTION USING SOME SENSORS BASED ON IOT TECHNOLOGY

Agung W. Biantoro[1], SI Wahyudi[2] and Moh. Faiqun Niam[2]
[1]Department of Engineering, Universitas Mercu Buana, Jakarta, Indonesia
[2]Department of Engineering, Sultan Agung Islamic University, Semarang, Indonesia
E-Mail: agung_wahyudi@mercubuana.ac.id

ABSTRACT

This research is motivated by flood conditions that often occur in low-lying areas in big cities such as Jakarta and Semarang. Notification and early detection of floods are often delayed and carried out manually, and are not integrated with hydroclimatological data, and disaster mitigation, so that they are often delayed and cannot be anticipated by upstream areas. Therefore, it is very important to be able to develop early warning tools so that floods can be detected early and can be anticipated in upstream areas. This research method uses quantitative data analysis of flood prediction studies and the design of the FEDS prototype that uses several sensors for IoT-based flood early detection. The study was conducted along the Ciliwung River from Katulampa, Bogor to the MT Haryono area, Jakarta, Indonesia, using secondary and primary data. Secondary data in the form of water level, river discharge, flood discharge plan, length of the river, rainfall and the area of the watershed. This study uses quantitative data analysis by performing simple and multivariate regression calculations, hydrograph analysis and the curve is the intensity duration frequency (IDF) curve. The results show that flood discharge in Jakarta will increase due to various reasons, one of which is a higher intensity of rainfall in the future and a lower area that can absorb excess water. By comparing the measurement of water level using HEC RAS with data on the floodgates. MT. Haryono, it can be seen that the results are not too different. The Flood Early Detection System (FEDS) is a tool to provide accurate and real time flood early information, so that people living in areas around rivers can prepare early if there is a possibility of flooding. This tool uses an environmentally friendly 20 WP solar power supply, can detect water level, rainfall, humidity and ambient air temperature. This tool uses Ultrasonic Sensor, Flow Sensor, rain sensor and the IoT-based Blynk application, which is expected to be able to provide early information on flood hazard predictions in downstream locations in a practical, accurate and real time manner.

Keywords: FEDS (floods early detection system), ultrasonic sensor, flow sensor, rain sensor, blynk.

INTRODUCTION

Rapid development, especially in urban areas, has reduced open land. The construction of office buildings, shopping centres, housing estates, and parking lots which all use concrete as a building material reduces the infiltration of rainwater into the ground. The lack of green open space makes water absorption in the area worse. The amount of garbage in the watercourse is also a factor that aggravates the flow of water. With reduced rainwater that is absorbed into the ground and the obstruction of water flow causes flooding. Floods in Indonesia may have been considered an ordinary disaster; people are no longer surprised by the occurrence of floods, especially in densely populated urban areas.

Floods can also occur due to bridge construction. Construction of bridge buildings can affect the flow of water in rivers, causing water overflow (Han *et al.*, 2018) The flood control management plan must be reviewed from various aspects, simultaneously and comprehensively. This is due to the very complex nature of the problem. The watershed area in order to realize optimal planning and can be used as a reference for various interested and important parties is supported and based on local regulations, but with consideration of limited funds in its development (Wahyudi SI, 2007).

Flood Early Warning Systems (FEWS) are implemented in many parts of the world, but early warning does not always translate to an emergency response of all individuals at risk. Global online survey results, and experiential knowledge help identify cross-cutting issues such as failure to use a participatory approach to engage communities and address their concerns in warning, inadequate levels of preparedness and response from FEWS, inadequate translation of disaster risk reduction policies (DRR) into action at the community level, lack of knowledge and practice of DRR among key stakeholders (Perera *et al.*, 2020).

A monitoring system that can be accessed easily, quickly, anywhere, and anytime is needed by the community. As well as the need for early warning that can inform the public that the water level rise has reached a level that is dangerous for the community. So that people can prepare themselves for the upcoming flood (Prasetyo and Setyawan, 2018).

Floods have become one of the fastest growing types of natural disasters that have spread all over the world. Critical criteria for flood risk assessment will be identified and the second step will involve the development of a relative flood risk measurement model using Geographic Information Systems (GIS), Multi Attribute Decision Making (MADM) and data mining techniques. In the third objective, a holistic architectural design is developed to include communication (Omar *et al.*, 2020)

Indonesia as a tropical country has the potential to experience heavy rains in several periods due to global warming due to erratic weather resulting in extreme weather. With high rainfall intensity and minimal land

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infiltration, the volume of water in the dam can exceed capacity and overflow. Figure-1 below is a map of flood-prone areas in DKI Jakarta (Jakarta, 2019)

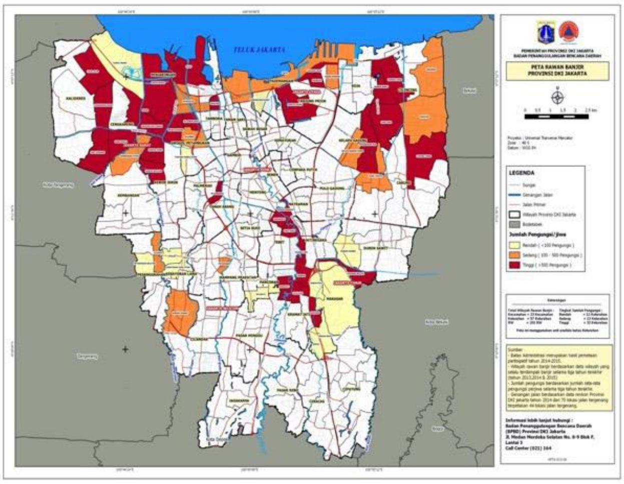

Figure-1. Flood Map Condition in Jakarta.

One of the current problems, the early detection system developed is only related to altitude sensors, only uses one door and is not integrated with hydrological data, climatological data and low access to disaster mitigation (Syamsul and Widianti, 2016).

Floods - the most destructive natural hazard in Poland - include flooding from rivers and mountain eruptions, as well as flooding from ocean waves in coastal areas, and overflows in sewer systems (Kundzewicz, 2014). For this reason, it is necessary to develop a tool to get good, integrated, reliable results, it is necessary to provide various other variables, for example with variables related to hydrology and climatology and access related to disaster and flood mitigation.

Mitigation of flood disasters in Imotsko-Bekijsko Polje has been carried out since the mid-20th century to protect the area from floods. Polje is a typical karst with very complex hydrological and hydrogeological relationships. The results showed that flooding in Imotsko-Bekijsko Polje was mostly influenced by water management objects (reservoir, retention, tunnel) and only indirectly by rainfall (Ljubenkov, 2015).

The results of this study inform that the third-order polynomial function shows the best relationship between the magnitude of the water depth and the degree of loss for structural and architectural conditions. RMSE estimates the accuracy of the model, and it shows reliable results. As defined in the distribution requirements, vulnerability increases significantly as the intensity of the process increases (Azmeri *et al.*, 2020).

The flood resistant solutions described in the article are intended to identify potential alternatives to climate change adaptation strategies. The solutions described in the article are essential for the disciplines of architecture and urban planning, civil engineering and transportation (Wojnowska-Heciak, Heciak and Kłak, 2020).

Rational Method

The rational method is used for small watershed. For urban flood planning and building facilities (such as culverts, open drains, etc.) the rational method also shows the parameters used by other flood forecasting methods, namely: runoff coefficient, rainfall intensity and area of watershed). The intensity - duration frequency curve (frequency I - t) is used for the calculation of runoff with rational formulas and for the calculation of peak discharge. The rational method is used for urban areas with a DPS area of less than 200 hectares or ± 81 ha (Subarkah, 1980; Grigg 1996), with the equation:

$$Q = 0{,}278CIA \tag{1}$$

Where:

C = Runoff coefficient (from table or by formula)

I = Maximum intensity during concentration time (mm/hour)

A = flow area (km^2)

Q = maximum discharge (m^3/second)

Frequency Analysis

Frequency analysis is an analysis of hydrological data using statistics that aim to predict the quantity of rain or discharge with a certain return period.

Parameter Statistik

Analysis of statistical parameters used in hydrological data analysis, namely: central tendency, standard deviation, coefficient of variation, slope and peak coefficient.

a. Central Tendency is a measurement that seeks the average value of a set of variables (mean).

$$X = \frac{1}{n}\sum_{i=1}^{n} Xi \tag{2}$$

For log calculations, the equation is as follows:

$$LogX = \frac{1}{n}\sum_{i=1}^{n} Xi \tag{3}$$

b. Standard Deviation is the measurement value of the dispersion of the collected data.

$$S = \sqrt{\frac{\sum_{i=1}^{n}(xi-x)^2}{n-1}} \tag{4}$$

$$SLog = \sqrt{\frac{\sum_{i=1}^{n}(logxi-logx)^2}{n-1}} \tag{5}$$

c. The slope coefficient is a value that indicates the degree of asymmetry of a distribution form.

$$Cs = \frac{n}{(n-1)(n-2)S^3}\sum_{i=1}^{n}(xi-x)^3 \tag{6}$$

$$Cslog = \frac{n}{(n-1)(n-2)S^3}\sum_{i=1}^{n}(logxi - logx)^3 \qquad (7)$$

d. Coefficient of Variation is the comparison value between the standard deviation and the mean value calculated from a distribution.

$$Cv = \frac{s}{x} \qquad (8)$$

e. Kurtosis Coefficient (peak)

$$Ck = \frac{n^2}{(n-1)(n-2)S^3}\sum_{i-1}^{n}(xi - x)^4 \qquad (9)$$

HEC-RAS Software

The application that can be used to model the flow in the river is the HEC-RAS application. HEC-RAS contains three components of a one-dimensional hydrological analysis for Calculation of uniform flow water level profil, Simulation of non-uniform flow and Calculation of sediment transport with limits of motion (Suadnya, Sumarauw and Mananoma, 2017).

Flood Control Method

Basically flood control activities are activities that include the following activities: Recognize the magnitude of the flood discharge, Isolation of flood inundation areas. And Reducing flood water levels. In the face of the climate crisis, amphibious architecture is becoming an increasingly attractive alternative to expensive flood control infrastructure. The research presented focuses on the spatial and technical aspects related to reducing the vulnerability of various types of buildings and land development in areas affected by fluvial flooding (Januchta-Szostak and Karaśkiewicz, 2020).

Multiple flooding can result from the interaction of two or more contributing processes, which may not be extreme on their own, but in combination cause extreme impacts. Statistical models used to predict the occurrence of floods include vine-copulas and conditional extreme value models, to test the sensitivity of the results to the choice of data pre-processing steps, statistical model setup, and outliers. (Santos *et al.*, 2021).

An efficient and integrated system for river management facilities is needed so that operations can take into account observational data. The completed canal extension allows a reduction in the volume of water flowing through urban areas (Kawasaki *et al.*, 2017).

METHODOLOGY

The study was conducted along the Ciliwung River from Katulampa, Bogor to the MT Haryono area, Jakarta, Indonesia, using secondary and primary data. Secondary data in the form of water level, river discharge, flood discharge plan, length of the river, rainfall and the area of the watershed. This study uses quantitative data analysis by performing simple and multivariate regression calculations, hydrograph analysis and the curve is the intensity duration frequency (IDF) curve. The IDF curve is a graphical analysis used to calculate flood discharge for the location of the Ciliwung river, Jakarta. The results of secondary data processing are then compared with prediction calculations using the HEC RAS application. The scope of the research analysis results includes the Ciliwung River in Katulampa, Bogor, Depok, to MT Haryono, East Jakarta, with a river length of 79.2 km, with a maximum slope of 3.8%, with eye observations as high as 77.98 km from the mainland. Satellite imagery using Google Earth can be seen in Figure-2 below.

Figure-2. The stretch of the Ciliwung River from Katulampa, Depok to MT Haryono, East Jakarta, with a river length of 79.2 km, with a maximum slope of 3.8%.

11 years of daily rainfall data from 2010 to 2020, to analyze the average maximum rainfall intensity. Other data were also collected to assess the condition of the river so that it could estimate the value of the Manning roughness coefficient, water level, which was collected through direct observations in the field.

This study also mentions the importance of early detection tools for flood information in Jakarta. This tool can work by using a power supply that comes from an energy-efficient solar cell. Sensors detect river water level and rainfall, then send this information to the microcontroller. The system then sends this information immediately to mobile phones using the Blynk app, so residents can anticipate possible flooding. The research data collected are:

a) Primary Data : Water level (m), River discharge (m^3/s), Design flood discharge (m^3/s), Rainfall (mm),
b) Secondary data: watershed area, rainfall, RH, river length, river slope.

FEDS Tool Design

The prototype design of the FEDS tool is as follows:

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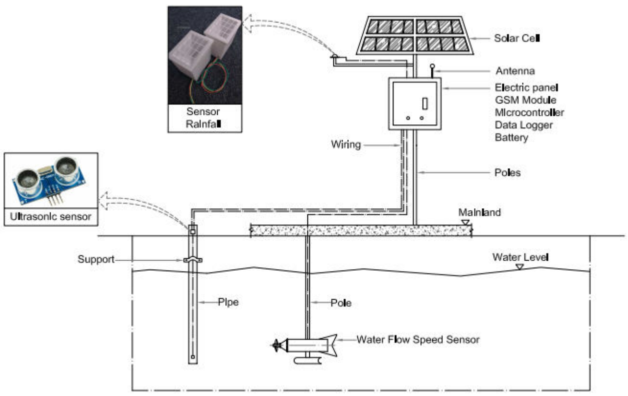


Figure-3. FEDS Tool Design.

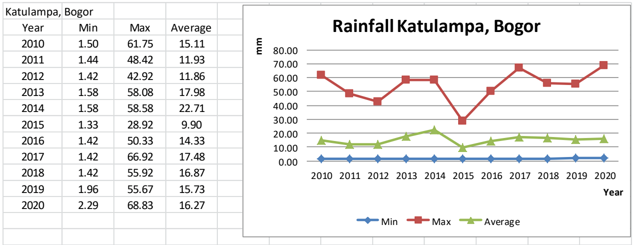
Based on Figure-3 above, it can be seen that the Flood Early Detection System (FEDS) is designed by utilizing solar cells as its power source. This FEDS tool is equipped with a rainfall gauge, water flow velocity meter, water level meter, temperature gauge and humidity indicator. This tool is also equipped with an LED screen that displays the sensor readings.

FEDS tools are also equipped with antennas, GSM modules, microcontrollers and data loggers. These tools are used to complement the FEDS tool so that it can provide information via the cellular network to parties who are integrated with the tool. The application used to present the data received by the sensor on the FEDS tool is the Blynk application. The data receiver can see in real time the rainfall that falls, the speed of the water flow, the water level and the temperature and humidity that comes from where the FEDS is placed.

RESULTS

Secondary Data

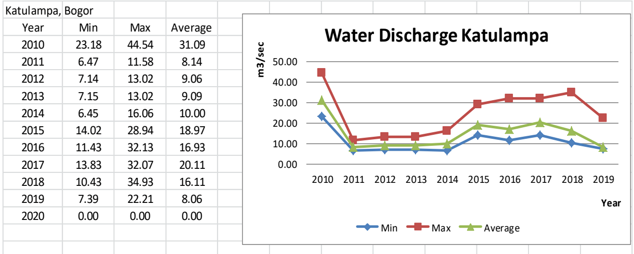
Secondary data was obtained from the Cilicis River Basin Center (BBWS), Ministry of PUPR, Jakarta, in the form of daily, monthly and yearly average rainfall, water discharge and water level. Data in the form of annual average rainfall and water discharge from the Ciliwung Katulampa River, Bogor during the period 2010 to 2020. The water level data used is located on the Ciliwung River near Jalan MT Haryono, Jakarta.



Katulampa, Bogor

Year	Min	Max	Average
2010	1.50	61.75	15.11
2011	1.44	48.42	11.93
2012	1.42	42.92	11.86
2013	1.58	58.08	17.98
2014	1.58	58.58	22.71
2015	1.33	28.92	9.90
2016	1.42	50.33	14.33
2017	1.42	66.92	17.48
2018	1.42	55.92	16.87
2019	1.96	55.67	15.73
2020	2.29	68.83	16.27

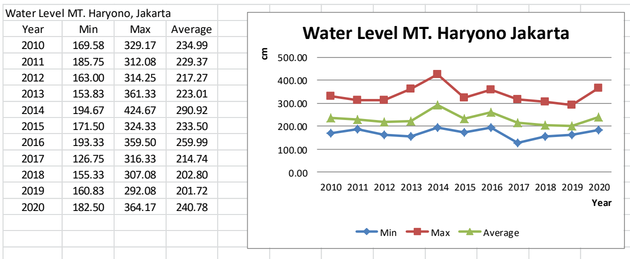
Figure-4. Ciliwung River Rainfall in Katulampa, Bogor in 2010-2020 period.



Katulampa, Bogor

Year	Min	Max	Average
2010	23.18	44.54	31.09
2011	6.47	11.58	8.14
2012	7.14	13.02	9.06
2013	7.15	13.02	9.09
2014	6.45	16.06	10.00
2015	14.02	28.94	18.97
2016	11.43	32.13	16.93
2017	13.83	32.07	20.11
2018	10.43	34.93	16.11
2019	7.39	22.21	8.06
2020	0.00	0.00	0.00

Figure-5. Ciliwung River Water Discharge, Katulampa, Bogor



Water Level MT. Haryono, Jakarta

Year	Min	Max	Average
2010	169.58	329.17	234.99
2011	185.75	312.08	229.37
2012	163.00	314.25	217.27
2013	153.83	361.33	223.01
2014	194.67	424.67	290.92
2015	171.50	324.33	233.50
2016	193.33	359.50	259.99
2017	126.75	316.33	214.74
2018	155.33	307.08	202.80
2019	160.83	292.08	201.72
2020	182.50	364.17	240.78

Figure-6. Water level in Ciliwung River, MT. Haryono road, Jakarta.

The data from Figures 3, 4 and 5 were then processed to obtain the results of whether there is an influence between rainfall and water discharge in Katulampa on the water level in MT Haryono, Jakarta. The results are in Table-1 below.

Table-1. Effect of Rainfall and Water Discharge in Katulampa on Water Level in Jakarta.

Variable	Coefficient	t value	Sig	Result
Constanta	152.156	11.709	0.000	
Rainfall	0.289	4.295	0.000	Significant
Water Discharge	2.286	4.135	0.000	Significant
R^2	0.274			
F value		22.102	0.000	Ha accepted

The results of the regression test shown in Table-1 show that there is a significant effect between rainfall and Katulampa water discharge on the water level at the MT location. Haryono Jakarta.

Calculation of Jakarta Flood Discharge

Calculation of flood discharge using Rainfall data from Kemayoran Climatology Station, Kemayoran Jakarta, from 2006 to 2020 (Table-2).

Table-2. Rainfall Data from Kemayoran Climatology Station.

Year	Rainfall(X) mm
2006	72.0
2007	234.7
2008	192.7
2009	122.5
2010	93.0
2011	119.2
2012	105.2
2013	193.4
2014	147.9
2015	277.5
2016	125.0
2017	180.0
2018	121.65
2019	130.225
2020	235.95

Furthermore, rainfall analysis was carried out using the Pearson Type III Log Method. The results can be seen in Table-3 below.

Table-3. Results of Rainfall Analysis Method Log Pearson Type III.

Return Period	R (mm)
2	61.265
5	71.166
10	81.822
20	100.095
50	117.517
100	138.605

Taking into account the rainfall data in Table-2 and the planned rainfall in Table-3, an estimate of the intensity of rainfall to the return period (RP) for the next 100 years is made. The results are shown in Figure-6 below:

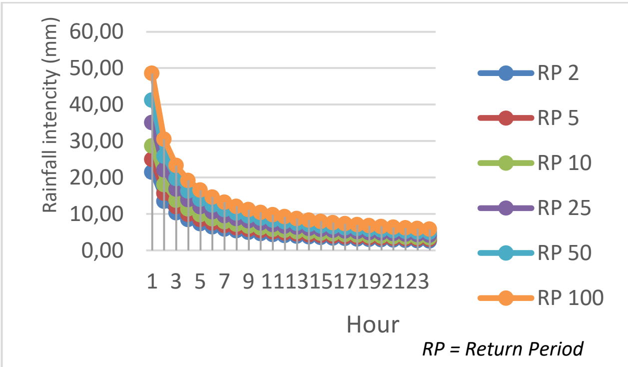


Figure-7. IDF curve with return period of 2-100 years.

The IDF curve shows the intensity of rainfall in 24 hours according to a certain return period. This calculation is used to calculate the magnitude of the planned flood discharge at a certain return period.

Table-4. Results of Calculation of the Jakarta Flood Plan Discharge (Year 2020).

Return Period	Coefficient	C Value	I	A	Q
2	0.278	0.422	4.392	257.84	132.71
5			5.101	257.84	154.16
10			5.865	257.84	177.24
25			7.175	257.84	216.82
50			8.424	257.84	254.56
100			9.936	257.84	300.24

Calculations using the rational method show that flood discharge in Jakarta will increase for various reasons, one of which is a higher rainfall intensity in the future and a lower area that can absorb excess water.

HEC-RAS is an application program for flow modelin rivers, the River Analysis System (RAS) created by the Hydrologic Engineering Center (HEC) which is a work unit under the US Army Corps of Engineers (USACE). The HEC RAS used is HECRAS 6.0.

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Figure-8. Location of the Depok city, showing a flooded area (Q25).

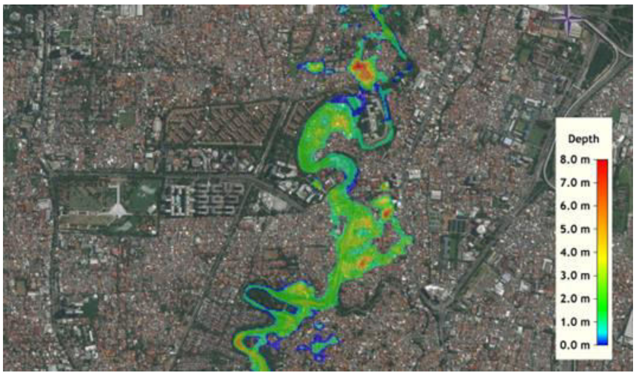

Figure-9. Location of the Crossing MTHaryono, Jakarta showing a flooded area (Q25)

Figures 8 and 9 show the results of the HEC RAS simulation of areas experiencing inundation and depth around rivers in Depok City and Crossing MT. Haryono street, Jakarta, return period Q25.Analysis using Hec Ras also shows the prediction of the area of inundation on the riverbanks of Depok City, at the return period Q 25 is 0.185 km^2. while the predicted inundation of MT Haryono, Jakarta is 0.456 km^2

The results of this calculation indicate that the potential for flooding at the MT Haryono crossing location is high. This result is in line with the calculation of the planned flood discharge using the rational method which shows that in the future Jakarta has the opportunity to face wider inundation due to higher water discharge in the future.

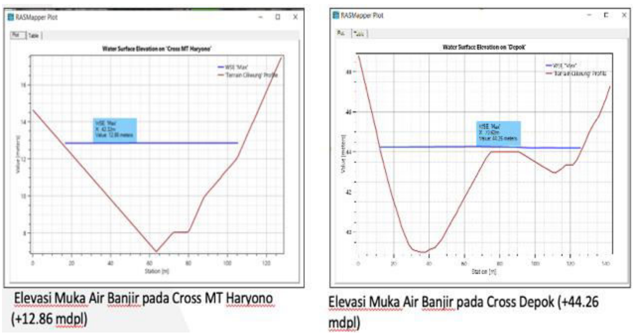

Figure-10. Floodwater Level Crossing MT. Haryono (Q10).

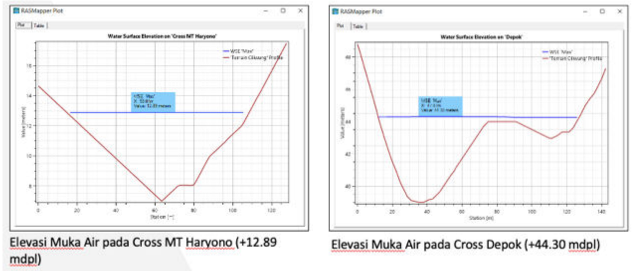

Figure-11. Floodwater Level Crossing MT. Haryono (Q20).

HEC RAS value at the location of the River near the MT road. Haryono shows a value of +12.86 m above the sea level (masl) at Q10 and 12.89 masl at Q20 (Figures 10 and 11). While the maximum water level is at the MT floodgate. Haryono (2020) is 364.17 cm with an average height of 240.78 cm. HEC RAS data is measured based on the water level above sea level, while the water level at the sluice gate is measured based on the water level from the bottom of the sluice gate. The DKI Jakarta area as a whole is a low-lying area, which is between 1-8 meters above sea level.

By comparing the measurement of water level using HEC RAS with secondary data obtained from MT. Haryono floodgates, it can be seen that the data obtained are not much different (HEC RAS = 12.89 meters above sea level/masl, MT. Haryono = 8 m + 364.17 cm = 11.64 masl), and there is no significant difference in the data.

At the Depok crossing location, the HEC RAS data shows a value of 44.30 masl (meter above sea level). Depok area is a lowland area with low hills. The Depok area has an altitude between 50 - 140 meters above sea level with a slope of 15%. In addition, the area of rivers and lakes in the Depok area has a depth of between 4-6 meters and is experiencing land degradation, resulting in a decrease in water level. At the Depok crossing location, the HEC RAS data shows a value of 44.30 masl, which means that at that location there is land degradation which causes a decrease in the water level to read.

DISCUSSIONS

Several previous studies have shown the importance of analyzing flood early detection. This is intended to reduce the negative impact of floods such as property losses and even to save lives.

Renima, *et al* (2018) research shows that flood regime modeling has been made based on threshold current quantiles derived from statistical adjustments compared, taking into account the characteristics of watershed flood regimes (QIXA10 and D), with different comparisons. quantile of Flow-Duration-Frequen (Renima *et al.*, 2018).

Ly, *et al* (2018) demonstrated the integration between HEC RAS and ArcGIS in providing facilities for creating flood mapping. The flood maps from 2000-2013 and the inundation maps of the 10 year return period are good examples of this collaboration. The maps generated by this model are very useful for development planning as well as disaster management. All results can conclude that HEC-RAS is a good hydraulic tool for primary flooding of the Mekong River in future studies (Ly *et al.*, 2018).

The availability of water is decreasing and even tends to be increasingly scarce, mainly due to the decline in quality and environmental quality due to pollution due to climate change. Potential flood hazard increases every decade (Dunggio, Wayan Sutapa and Gede Tunas, 2021). Research by Almazan, *et al* (2021) monitors the river environment using a UPS-based tool equipped with sensors to measure river water levels (Almazan, Eleria and Selibio, 2021). The results of the calculation of the planned flood discharge using the rational method and the calculation using the HEC RAS have similarities regarding the condition of puddles that occur in Jakarta, especially in areas that are traversed by rivers.

Figure-8 shows the increasing extent of the standing water running off from the Depok area to MT Haryono, Jakarta. With this flood prediction, of course, a tool for early flood detection is needed, which is useful for early flood information for communities around the upstream and downstream of the river. The high potential for flooding in Jakarta is one of the reasons why the use of an Early Warning System (EWS) such as the Flood Early Detection System (FEDS) is very important to provide accurate and real time information, so that people living in the area around the river. This tool uses a solar power supply that is environmentally friendly, can detect water level, rainfall, humidity and ambient air temperature. By using the IoT-based Blynk application, this tool is able to provide flood hazard prediction information in downstream locations of rivers. The regression results in Table 1 show that an increase in rainfall and water discharge at the Katulampa dam (upstream) will result in an increase in the water level at the MT. Haryono sluice gate, Jakarta.

CONCLUSIONS

This study shows the concept of early flood detection by utilizing FEDS has good results. The existence of a system that can provide information quickly and accurately in a short time can help people in flood-prone areas to prepare themselves so as to minimize negative impacts that may arise. On the other hand, an early flood detection system can also help interested parties to take evacuation actions and prepare for the needs of flood victims. The HEC RAS results show 12.89 masl and the detection of the water level sensor at the MT sluice gate. Haryono shows 11.64 masl. Flood Early Detection System (FEDS) is very important to provide accurate and real time information, so that people live in areas around rivers. This tool uses an environmentally friendly solar power supply, can detect water level, rainfall, humidity and ambient air temperature.

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