Study of flood discharge due to land use and population change of Way Pisang watershed

Lilik Ariyanto1*, Agustinus Purna Irawan2
1Department of Civil Engineering, Universitas Tarumanagara, Indonesia
2Faculty of Engineering, Universitas Tarumanagara, Indonesia

*slilikaryanto@saburai.ac.id

Abstract. In some areas in Indonesia, especially those around rivers that develop into urban areas are always faced with the problem of flooding in each rainy season. Soil surface characteristics can affect surface runoff in some areas. In general, human activities will increase along with the rate of population growth which results in increased land conversion activities to meet the economic needs of an area. This study will examine the level of population growth around the Way Pisang watershed in South Lampung Regency in 2007 and 2019, which is expected to influence land use change as a result of activities to meet economic needs, which in turn will have an impact on changes in the drainage coefficient resulting in an increase flood discharge in the watershed. The results of this study can be concluded that from 2007 to 2019, population growth in the Way Pisang Watershed increased by an average of 9.62%. With population growth accompanied by changes in land use where forest area has decreased 81.39%, paddy fields 52.90% and shrubs 85.54%. While the area of settlements increased by 56.10% and dry agricultural land/gardens increased to 147.62%. This resulted in an increase in drainage coefficient of 102.18% which in turn resulted in an increase in flood discharge on average by 28.82%. Keywords: flooding, flow coefficient, population growth.

1. Introduction
In every region in Indonesia, especially those around rivers that develop into urban areas are always faced with the problem of flooding in each rainy season. The condition of land cover will affect the surface flow from rainfall that falls in a watershed in a certain time and eventually flows into the natural drainage channel / river. To be able to anticipate flood events, one of them needs to know the magnitude of drainage coefficient based on land use. The Way Pisang River hydrologically located in the Seputih-Sekampung River Region which is a national strategic River Region. While administratively crossing South Lampung Regency [1-5].

Every year in the rainy season at certain points the Way Pisang River experiences floods with low to moderate intensity and with varying inundation impacts at each flood location. To find out the amount of surface runoff in a watershed (DAS), it is necessary to observe and analyze activities on land use as land cover in a watershed [4], [6-10]. Each type of land cover has a surface runoff coefficient value which states the estimated amount of rain that will flow on the surface of the land leading to a larger drainage channel. Land cover that has a high level of infiltration will help reduce the surface flow that occurs, and vice versa if the land cover has a low infiltration, then the surface flow that occurs will be even greater.

Flood events in the Way Pisang River Basin are floods that occur every year, on the other hand the growth rate of the population who live in the surrounding areas is increasingly dense, this
is evident from the increasing number of houses and buildings erected around the Way Pisang River.

![Figure 1. Location of Potential Floods in the Way Pisang Watershed](image)

The objectives to be achieved in this study are knowing the growth rate of the population that affects changes in land use in the Way Pisang Watershed, knowing the changes in the value of the runoff coefficient in the Way Pisang watershed as a result of changes in land cover and knowing changes in flood discharge in the Way Pisang Watershed from 2007 to 2019 [11-14].

2. Method
In carrying out this research will be divided into several stages of activities as follows:
a. Analyzing the distribution of the locations of Rainfall Observation Posts around the Way Pisang Watershed;
b. Conduct an analysis of the Regional Maximum Rain (Rainfall Area) on the Way Pisang Watershed using the Polygon Thiesen method;
c. Calculate the flood discharge of the Way Pisang Watershed design;
d. Compile research conclusions on changes in design flood discharge from 2007 to 2019 as a result of changes in land use caused by population growth that is expanding its activities with land conversion activities in the Way Pisang River Basin [11-12].

3. Result and Discussion
a. Long of Way Pisang River
   Based on the results of data collection on the measurement of the Way Pisang River it is known that the Way Pisang River Length is 27.32 km.

b. Area of Way Pisang Watershed
   Based on the results of data collection and measurements on the Way Pisang watershed map has an area of 155.34 km².

c. Land Use of Way Pisang Watershed
   Based on the map of the Way Pisang watershed in 2007 and 2019, the following types of land use can be identified:
Table 1. Way Pisang Watershed Land Use in 2007

| No | Land Use                        | Area (km²) | %   |
|----|---------------------------------|------------|-----|
| 1  | Forest                          | 74.03      | 47.66|
| 2  | Residential                      | 3.44       | 2.21 |
| 3  | Rice fields                      | 19.85      | 12.78|
| 4  | Dry land agriculture /gardens    | 50.8       | 32.70|
| 5  | Thicket                         | 7.22       | 4.65 |
|    | **Total**                        | **155.34** | **100**|

Table 2. Way Pisang Watershed Land Use in 2019

| No | Land Use                        | Area (km²) | %   |
|----|---------------------------------|------------|-----|
| 1  | Forest                          | 13.78      | 8.87 |
| 2  | Residential                      | 5.37       | 3.46 |
| 3  | Rice fields                      | 9.35       | 6.02 |
| 4  | Dry land agriculture /gardens    | 125.79     | 80.98|
| 5  | Thicket                         | 1.04       | 0.67 |
|    | **Total**                        | **155.34** | **100**|

d. Population in Way Pisang Watershed

Based on data obtained from the Central Statistics Agency (BPS) in South Lampung Regency, it can be seen data on population in the Way Pisang Watershed as follows:

Table 3. Way Pisang Watershed Population in 2007

| No | sub-district | Area (km²) | Area in Watershed (km²) | Population |
|----|--------------|------------|-------------------------|------------|
| 1  | Bakauheni    | 57.13      | 7.20                    | 806        |
| 2  | Kalianda     | 226.06     | 10.37                   | 5321       |
| 3  | Ketapang     | 180.93     | 4.02                    | 1178       |
| 4  | Palas        | 173.56     | 34.92                   | 12243      |
| 5  | Penengahan   | 97.59      | 97.59                   | 25450      |
| 6  | Sragi        | 93.44      | 1.24                    | 262        |
|    | **Total**    | **155.34** |                        | **45260**  |

Table 4. Way Pisang Watershed Population in 2019

| No | sub-district | Area (km²) | Area in Watershed (km²) | Population |
|----|--------------|------------|-------------------------|------------|
| 1  | Bakauheni    | 57.13      | 7.20                    | 1133       |
| 2  | Kalianda     | 226.06     | 10.37                   | 6346       |
| 3  | Ketapang     | 180.93     | 4.02                    | 1385       |
| 4  | Palas        | 173.56     | 34.92                   | 13814      |
| 5  | Penengahan   | 97.59      | 97.59                   | 26648      |
| 6  | Sragi        | 93.44      | 1.24                    | 289        |
|    | **Total**    | **155.34** |                        | **49615**  |

e. Rainfall Observation Post around the Way Pisang Watershed

Based on the results of data collection and analysis there are 4 (four) Rainfall Observation Posts around the Way Pisang Watershed as can be seen in Table 5 below.
Table 5. Rainfall Observation Post around the Way Pisang Watershed

| No | Name of Post | LS             | BT             | Data Availability |
|----|--------------|----------------|----------------|-------------------|
| 1  | PH030 - Klaten | 5°44'4.5562"   | 105°41'33.0431" | 2008 - 2019       |
| 2  | PH 031 - Purwodadi | 5°40'58.700"   | 105°40'28.4000" | 2008 - 2019       |
| 3  | R 021 - Pasuruhan | 5°44'42.500" | 105°40'35.3000" | 2008 - 2019       |
| 4  | R 233 - Palas | 5°36'4.1000"   | 105°41'44.8000" | 2008 - 2019       |

f. Distribution of Rain Observation Posts in the Way Pisang Watershed

Based on the results of GIS analysis data, it can be seen the distribution of Rainfall Observation Post locations in the Way Pisang Watershed as can be seen in Figure 2.

g. Extent of Effect of Rain Observation Post on Way Pisang Watershed

Based on the results of GIS analysis data collection, the area of influence of each Rainfall Observation Post in the Way Pisang Watershed is as follows:

Table 6. Extent of Effect of Rain Observation Post on Way Pisang Watershed

| No | Name of Post | Area (km²) | % Area |
|----|--------------|------------|--------|
| 1  | PH030 - Klaten | 33.5       | 21.566 |
| 2  | PH 031 - Purwodadi | 35.9     | 23.111 |
| 3  | R 021 - Pasuruhan | 75.39     | 48.532 |
| 4  | R 233 - Palas | 10.55      | 6.792  |
| Total |          | 155.34     | 100    |

h. Way Pisang Surface runoff coefficient

Based on the type of land cover in Way Pisang River Basin, it can be seen that the drainage coefficient values in the Way Pisang River Basin are as follows:
Table 7. Runoff Coefficient of Way Pisang Watershed in 2007

| No | Land Use                  | Area (km²) | %     | C    | L.C  |
|----|----------------------------|------------|-------|------|------|
| 1  | Forest                     | 74.03      | 47.66 | 0.02 | 1.48 |
| 2  | Residential                | 3.44       | 2.21  | 0.6  | 2.06 |
| 3  | Rice fields                | 19.85      | 12.78 | 0.15 | 2.98 |
| 4  | Dry land agriculture / gardens | 50.8      | 32.70 | 0.4  | 20.32|
| 5  | Thicket                    | 7.22       | 4.65  | 0.07 | 0.505|
|    | **Total**                  | **155.34** | **100** | **27.35** |     |
|    | **C Average**              |            |       | **0.18** |     |

Table 8. Average Flow Coefficient Based on the Way Pisang Land Use Land Use in 2007

| Period | Runoff coefficient (C) | 2 | 5 | 10 | 20 | 25 | 50 | 100 | Average |
|--------|------------------------|---|---|----|----|----|----|-----|--------|
| Rain   |                        | 0.83 | 0.66 | 0.58 | 0.52 | 0.51 | 0.47 | 0.43 |
| TGL    |                        | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 |
| Average|                        | 0.50 | 0.42 | 0.38 | 0.35 | 0.34 | 0.32 | 0.30 | 0.37 |

Table 9. Runoff Coefficient of Way Pisang Watershed in 2019

| No | Land Use                  | Area (km²) | %     | C    | L.C  |
|----|----------------------------|------------|-------|------|------|
| 1  | Forest                     | 13.78      | 8.87  | 0.02 | 0.28 |
| 2  | Residential                | 5.37       | 3.46  | 0.6  | 3.22 |
| 3  | Rice fields                | 9.35       | 602   | 0.15 | 1.40 |
| 4  | Dry land agriculture / gardens | 125.79  | 80.98 | 0.4  | 50.32|
| 5  | Thicket                    | 1.04       | 0.67  | 0.07 | 0.073|
|    | **Total**                  | **155.34** | **100** | **55.29** |     |
|    | **C rata-rata**            |            |       | **0.36** |     |

Table 10. Average Flow Coefficient Based on the Way Pisang Land Use Land Use in 2019

| Period | Runoff coefficient (C) | 2 | 5 | 10 | 20 | 25 | 50 | 100 | Average |
|--------|------------------------|---|---|----|----|----|----|-----|--------|
| Rain   |                        | 0.74 | 0.62 | 0.56 | 0.51 | 0.5 | 0.47 | 0.44 |
| TGL    |                        | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 |
| Average|                        | 0.55 | 0.49 | 0.46 | 0.43 | 0.43 | 0.41 | 0.40 | 0.45 |

i. Design Flood of the Way Pisang Watershed

By using the Nakayasu unit hydrograph, it can be seen that the Way Pisang River Design Flood according to the time of return is as follows:

Table 11. Way Pisang Watershed Design Flood in 2007

| Period     | Design Flood in 2007 (m³/s) |
|------------|----------------------------|
| KU – 2 year| 123.65                     |
| KU – 5 year| 193.58                     |
| KU – 10 year| 245.48                    |
| KU – 20 year| 303.72                    |
| KU – 25 year| 316.93                     |
| KU – 50 year| 374.22                    |
| KU – 100 year| 434.98                    |
Table 12. Way Pisang Watershed Design Flood in 2019

| Period   | Design Flood in 2019 (m³/s) |
|----------|-----------------------------|
| KU – 2 year | 185.34                      |
| KU – 5 year | 264.35                      |
| KU – 10 year | 319.61                      |
| KU – 20 year | 379.22                      |
| KU – 25 year | 392.41                      |
| KU – 50 year | 448.70                      |
| KU – 100 year | 506.91                     |

Figure 3. Way Pisang Watershed Design Flood in 2007 and 2019

4. Conclusion

Based on the results of the analysis and calculations that have been carried out in this study, the following conclusions can be obtained: The population in the Way Pisang Watershed from 2007 to 2019 increased by 4,355 inhabitants (9.62%), while the type of land cover experienced a significant change where forest area decreased 81.39%, settlement area increased 56.10%, paddy area experienced 52.90% decrease, dry land/garden area increased 147.62% and shrub land decreased by 85.54%, with the land cover condition causing drainage coefficient to increase by 102.18% so that it affected the amount of design flood discharge which experienced an average increase of 28.82%.

References

[1] Balai Besar Wilayah Sungai Mesuji Sekampung, 2018, Way Pisang River Border Study.
[2] Triatmodjo, B., 2013, Hidrologi Terapan. (Beta Offset: Yogyakarta)
[3] Balai Besar Wilayah Sungai Mesuji Sekampung, 2015, Search and Audit of the Way Pisang, (PT. Prana Kurnia Pratama).
[4] Anggun Citra Putrinda, 2012, Surface Flow Coefficient in Sekampung watershed in Lampung Province in 1995-2010: Lampung
[5] Balai Besar Wilayah Sungai Mesuji Sekampung, 2015, Pattern of Water Resources Management for the Seputih Sekampung River Basin.
[6] Indarto, 2016, Hidrologi. (Bumi Aksara: Jakarta).
[7] M. Ridhwan, 2012, Modeling of Flood Areas in Jambi City: Jambi
[8] Iin Widiatni Widyaningsih, 2008, Influence of Land Use Change in the Keduang Sub-Watershed in Hydrological Aspects: Wonogiri
[9] Hartono Himawan, 2015, *Alternative Management of Deli River Flood Using the Water Tunnel Model: Medan*

[10] Dessy Rosliani, dkk, 2013, *Study of Channel Design Optimization in the Context of Flood Control in Upper Citarum: West Java*

[11] M. Rogger, M. Agnoletti, G. Bloschl, 2017, *Land use change impacts on floods at the catchment scale: Challenges and opportunities for future research.* (AGU Publications).

[12] P. M. Kundu, L. O. Olang, 2011, *The impact of land use change on runoff and peak flood discharges for the Nyando River in Lake Victoria drainage basin, Kenya.* (WIT Transactions on Ecology and The Environment, Vol 153, © 2011 WIT Press).

[13] Suyono, T., Pranoto, W.A., Irawan, A.P. 2019 *IOP Conference Series: Materials Science and Engineering* **508**-1-012035

[14] Benjamin Rabb, 2011, *Integrated modelling of climate and land use change impacts on groundwater flooding risk in a Chalk catchment.* (UMI U516908 Published by ProQuest LLC 2013. Copyright in the Dissertation held by the Author. Microform Edition © ProQuest LLC)