The assessment of Sei Petani Sub Watershed health based on hydrology indicator

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Abstract. Deli watershed is one of three most critical watersheds in North Sumatera. Sei Petani Sub Watershed is upstream area of Deli Watershed which must be paid attention in Deli watershed management. There are some indicators in watershed management that have given attention such as hydrology, erosion, and sedimentation. This study aims to assess Sei Petani Sub watershed health on hydrology indicators (specific maximum discharge, specific minimum discharge, river regime coefficient, runoff coefficient and water yield). The result of this study shown that specific maximum discharge value is 0.234 m$^3$/s/km$^2$, specific minimum discharge value is 0.095 m$^3$/s/km$^2$, river regime coefficient is 2.34, and coefficient runoff is 0.142 whereas discharge value and water yield is shown by the time series data. The result shown that Sei Petani Sub Watershed categorized in a good condition.

1. Introduction

Watershed is a whole ecosystem unit from upstream to downstream. The downstream area of the watershed is generally use to agricultural cultivation area, residential (urban), industrial, and reservoir for power plants electricity, fisheries and others. The upstream area of the watershed is usually intended for water catchment areas. Thus the success of the downstream watershed management depends on the success of the upstream watershed management.

Sub-watershed is part of the watershed area that receives rainwater and flows it through tributaries to the main river. Sub-watershed have an important role in watershed management as a natural resource management unit. Problems with the sub-watershed areas include inappropriate land use, lack of vegetation in the ground cover around the sub-watershed area, lack of surface water catchment, erosion and increased sedimentation in river basins.[1]

Deli watershed is one of three most critical watersheds in North Sumatra. Deli river flows from the upstream part which is Namorambe Village Deli Tua District Deli Serdang Regency and flows across Medan city, and down to the downstream part in Labuhan Deli Village, Deli Serdang Regency. Sei Petani sub-watershed is the upstream part of the Deli Watershed [2]

In order to watershed management, there are some indicators that show watershed health condition. There are three main aspects that are always concern in watershed management, they hydrology condition (maximum discharge, minimum debit, river regime coefficient, water yield,and Runoff Coefficient), erosion, and sedimentation. Hydrology is a very significant indicator of knowing the
existence of watershed degradation. Poor watershed conditions are characterized by various indicators such as high rates erosion on land, high sedimentation rates in the river flow, and value river regime coefficient which indicates the lack of water availability. Phenomenon the other is that during the rainy season the color of the river becomes brown. Sediment comes from soil eroded on the land. The high rate of erosion on the land caused by the increase in open land and the high rate of conversion land becomes a settlement.

The health condition of a watershed is very much influenced by watershed internal conditions. Human who occupants the watershed contribute to the health of the watershed ecosystem Watershed health analysis is very necessary in an effort to avoid excessive watershed degradation which resulting in deterioration in quality of life. Good and sustainable watershed management will maintain watershed health so that it can be said success and efficient for the community.

This study aims to assess Sei Petani Watershed Health based on its hydrological condition, the are discharge value, maximum and minimum discharge, river regime coefficient, runoff coefficient, water yield, and sedimentation.

2. Material and Methods

The research was conducted in the upstream area of deli Watershed, Sei Petane Sub watershed, located at $3^\circ12'\ 52,81''\ s/d\ 3^\circ47'0,611''\ L U$ dan $98^\circ29'23,32''\ s/d\ 98^\circ42'\ 49,79''\ B T$ Karo Regency Sumatera Utara Province dengan luas area 1191 Ha. Observation of Rainfall and climate was done by using the rainfall and climate data of Tuntungan Rainfall Station and Climate Station for year 1999-2018 which obtained from Badan Meteorologi, Klimatologi, dan Geofisika.

2.1. Analysis of Hydrological Indicators

a. Rainfall analysis. The average of rainfall in this area was calculated by rainfall data of Tuntungan rainfall station for year 1999-2018

b. Potential evapotranspiration is calculated using Penmann – Monteith Methods by analyzing climatology data (temperature, wind velocity, relative humidity, long exposure of sunshine)

c. Measurement of water level was done at Doulu River Water observation station by Hatta dkk (2018) to calculate discharge values.

d. Calculation of discharge value was done by analyzing water level data and then calculate the discharge using the equation of relationship between water level and discharge in dry season

$$Q = 37.58(h)^2 - 8.019(h) + 0.869$$

And the equation for wet season is

$$Q = 18.79h^2 + 1.372h - 0.190$$

Where Q is discharge value (m$^3$/s) and H is water level (m)

e. Maximum discharge is the highest discharge in a year (m$^3$/s) while minimum discharge is the lowest discharge in a year (m$^3$/s)

f. River Regime Coefficient is the ratio of maximum discharge and minimum discharge

g. Runoff coefficient is the ratio between the amount of runoff and rainfall in the region by calculates the thickness of region’s rainfall which is the amount of monthly rainfall multiplied by the area of watershed (A). The rain is in mm and the area of watershed in km$^2$. The thickness of runoff is calculating with the amount of water yield in a year

The calculation of runoff coefficient is comparison between runoff and the thickness of rainfall

h. Water yield is total of water discharge flowing at the outlet point of watershed in certain period.

$$\text{Water yield} = \sum_{n=1}^{12} \text{discharge result of model simulation}$$
3. Results and discussion

3.1. Climatic Condition of Sei Petani Sub Watershed

The climatic conditions of an area can be determined by measurable climate factors. These climate factors include temperature, relative humidity (RH), sunlight, and evaporation. The average of relative humidity in this area is 84%, where the average of temperature is 24.85°C with the maximum temperature is 32.6°C and the minimum temperature is 22.1°C. The average of wind velocity is 4.34 m/s and the average of sunlight is 78.01%. Climatic condition of Sei Petani watershed generally can be seen in Figure 1.

![Figure 1. Climatic condition of Sei Petani Sub Watershed](image)

Furthermore, climatic conditions of Sei Petani Watershed determined using the climate classification by Schmidt Ferguson. Schmidt Ferguson Climate Classification classify based on rainfall data which are grouped by ratio of wet month and dry month based on the following condition:

1. Wet Month > 100mm, rainfall > evaporation
2. Dry month < 60 mm, rainfall < evaporation
3. Moist month 60 -100 mm, rainfall = evaporation

The result of analyzing rainfall data of Sei Petani Sub watershed in year 1999 – 2019, then it shown that the average of wet month in a year is 11 months and the average of dry month is 1 month, so that the ratio of dry month and wet month is 0.09. This value is classify as very wet climate condition based on Schmidt Ferguson climate classification which is said that if the ratio of dry month and wet month 0 to 0.143 it is classify as very wet condition.

3.2. The average of Rainfall

The description about distribution of rainfall in watershed can be found by any rain gauge that scattered in that watershed. Sei Petani Sub Watershed is categorized as very small watershed that just 1911 ha areas. The nearest rain gauge is Tuntungan rainfall station. Rainfall data used year 1999 – 2018, from the result of analyzing rain data, the average of annual rainfall is about 2965.8 and the average of monthly rainfall is about 243.47 which can be categorized as moderate rain. The average of rainfall mid-month can be seen in figure 2 below.
3.3 Potential Evapotranspiration
Potential evaporatortranspiration is calculated with Penmann – Monteith Methods. Based on the analysis of climatology data which includes temperature data, humidity data, evaporation, solar radiation, wind velocity, half monthly evapotranspiration values can be calculated. The average of daily potential evapotranspiration is 4.73 mm. The average of half monthly evapotranspiration is presented in the figure 3 below

![Figure 3. Evapotranspiration of Sei Petani Sub Watershed](image)

3.4 Analysis of Hydrological indicators in Watershed
3.4.1 Analysis of Water Availability. One of hydrology characteristics for study of watershed health is the magnitude of discharge measured at the outlet point. The observation of measured discharge in area of Sei Petani Sub Watershed was done in Water Level Observation Station Doulu by using Automatic Water Level Recorder. The water level recorded in the automatic water level recorder will be converted to a discharge value based on rating curve equation that relation of water level and discharge. In this study, rating curve equation about relation of water level and discharge is obtained from research of Setiawan for rainy season, and research of hatta for dry season. The average of half monthly discharge of Sei Petani Sub Watershed can be seen in figure 4 below

![Figure 4. Average discharge of Sei Petani Sub Watershed](image)
3.4.2. Specific Maximum Discharge, Specific Minimum Discharge, River Regime Coefficient. The value of specific maximum discharge, specific minimum discharge, and river regime coefficient is analyzed by discharge value that shown in Figure 3. The value of specific maximum discharge, specific minimum discharge, and river regime coefficient are important hydrologic indicators that indicate watershed health. The category of specific maximum discharge, specific minimum discharge, and river regime coefficient can be seen in Table 1 below that indicate the condition of watershed health.

| Parameter               | Unit          | Quantitative value | Qualitative Value |
|-------------------------|---------------|--------------------|-------------------|
| Specific Maximum Discharge | m$^3$/s/km$^2$ | $>$0.58            | Good              |
|                         |               | 0.58 – 1.5         | Moderate          |
|                         |               | $>$1.5             | Bad               |
| Specific Minimum Discharge | m$^3$/s/km$^2$ | $>$0.035           | Good              |
|                         |               | 0.001 – 0.035      | Moderate          |
|                         |               | $<$0.001           | Bad               |
| River Regime Coefficient | -             | $<$50              | Good              |
|                         |               | 50 – 120           | Moderate          |
|                         |               | $>$120             | Bad               |

Source : Elkagian [5]

Based on analysis of discharge measured that can be seen at Figure 3, maximum discharge occurs in the last middle month of December which values is 2.788 m$^3$/s and minimum discharge occurs in first middle month of February which values is 1.137 m$^3$/s. The value of maximum discharge and minimum discharge when compared to the area of watershed, the value is 0.234 m$^3$/s/km$^2$ for specific maximum discharge and 0.095 m$^3$/s/km$^2$ for specific minimum discharge. Based on Table 1 above, this value is categorized as a good condition. The value of river regime coefficient is calculated by a comparison between the value of maximum discharge and the minimum discharge. As a maximum discharge and minimum discharge, the river regime coefficient is also one of indicator in assessing the health of watershed. It’s also one of the main concerns in the consideration of watershed management. The value of river regime coefficient is 2.45 and it categorized in a good condition based on Tabel 1. Based on the value of specific maximum discharge, specific minimum discharge, and river regime coefficient, Sei Petani Sub Watershed is in a good condition where the range value of maximum discharge and minimum discharge is not too high. That means the flow rate in Sei Petani Sub Watershed is not too extreme.
3.4.3. Runoff Coefficient. Runoff coefficient (C) is a dimensionless coefficient relating to the amount of runoff to the amount of precipitation received. The value of runoff coefficient is one indicator to determine whether a watershed is physically impaired. The high value of it, show that there are more rainfall becomes runoff. The value of C ranges from 0 – 1. The value 0 shows that all precipitation is distributed into interception and infiltration, whereas the value 1 shows that all precipitation flows as runoff. The assessment of runoff value is based on Table 2 below.

| Score | C       | Criteria    |
|-------|---------|-------------|
| 3     | < 0.5   | Good        |
| 2     | 0.5 – 0.75 | Moderate    |
| 1     | >0.75   | Bad         |

Source: [6]

The average value of runoff coefficient of Sei Petani Sub Watershed is 0.142. This value is analyzed by precipitation and discharge value in 2018. The value of runoff coefficient is categorized in a good condition based on the table classification of runoff assessment. The relation of precipitation and discharge volume can be seen at Figure below. The value 0.142 means that about 14.2% of the rain falls into a stream. The small coefficient runoff value shown that the rain is absorbed well into soil as infiltration and interception. This is influenced by local landuse. The main factors influencing runoff coefficient value are the infiltration rate of soil, cover crops, and rainfall intensity. Runoff coefficient is a combination of three factors, they are topography, landuse, and soil texture.

3.4.4. Water Yield. The hydrological response of a watershed can be shown by water production which assessed by the contribution of direct flow to total flow. It depends on the character of rain and physical characteristics of watershed/sub watershed. The expected watershed output have to guarantee equitable water distribution throughout the year with fairly high water yield. Water yield of Sei Petani Sub Watershed can be seen at Figure below. The trend of water yield is as same as discharge value.
Figure 6. Water yield of Sei Petani Sub Watershed

Whereas the accumulation of water yield can be seen at Figure 6 below

Figure 7. Accumulation of water yield of Sei Petani Sub Watershed

Figure 6 and Figure 7 illustrate the condition of water available at Sei petani Watershed. From the figure, water production in this watershed is good enough.

4. Conclusion

In watershed management, there are some indicators that shown the health of a watershed. They are hydrology, erosion, and sedimentation indicators. The assessment of hydrology indicators are Spesific maximum discharge, specific minimum discharge, river regime coefficient, runoff coefficient, and water yield. The assessment of that shown the water avibility in this watershed. The assessment shown that Sei Petani Sub Watershed is in a good condition which can be seen from the discharge data time series, the specific maximum discharge is 0.234 m³/s/km² and 0.095 for specific minimum discharge and river regime coefficient is 2.45. The value of runoff coefficient is 0.142.

5. References

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