A rating-curve method for determining debit for dry season in micro-scale watersheds

E Susanto, N Hatta and Sumono
Department of Agricultural Engineering, Universitas Sumatera Utara, Prof. A. Sofyan No. 3 Kampus USU, Medan, Indonesia Republic-20155

email: edi.susanto@usu.ac.id

Abstract. A rating curve discharge are equations which are functions of water level surface with river debit. This equation is needed to determine the river debit if the known data is only the water level surface. There are several methods that could be used to determine the equation including linear, exponential, logarithmic, polynomial of second degree and power-law method. The purpose of this study was to obtain the rating curve equation of relationship between the river water level surface with the debit at the research location. From the research results obtained that the most suitable equation was the second degree polynomial equation, namely: \( Q = 49.761H^2 - 13.663H + 1.5112 \) due to its satisfying \( R^2 = 0.818, r = 0.905 \) and \( NS = 0.995 \).

1. Introduction
Watershed is an area bounded by mountain ridges where the rainwater that falls on the area will be accommodated by the ridges and will be channeled through small rivers to the main river or watershed that is a geographical area drained by a watercourse [1]. Debit is the rate of water flow that passes through a cross section of a river per unit of time. The availability of long and complete flow debit data is very supportive in the water resources planning and management program in a watershed area. Debit data from rivers that represent watershed areas are important data that can be used for certain purposes such as to determine the availability of irrigation water, domestic and industrial purposes, but the debit data is not always easily obtained, especially for areas on Sumatera island. Debit can be obtained by several methods such as using the empirical formula, including the water flow velocity (v) calculation and the wet cross section channel (A) calculation, by using the rating curve equation between the water level Surface and debit and using Cippoletti weir[2][3]. To facilitate the calculation or measurement of debits in the river, it can use the rating curve equation between water level surface and the debit can be obtained from the water level data by using the rating curve equation that has been set for the location point measurement, then the debit amount of each measured water level value will be known[4]. The aim of the research was to obtain the rating curve equation of the relationship between river water level and debit at the research location.
2. Material and Methods

2.1 Location

The study was conducted in March - June 2018 in the upstream part of the Deli Watershed located in Sei Petani Sub-watershed at latitude of 03° 12' 00" to 03° 16' 30" North and longitude 98° 29' 00" up to 98° 32' 30" East (Figure 1). The materials used in this study were spatial data such as soil type map, Digital Elevation Mode (DEM) map, land use map and climate data series. Other supporting materials were the river debit data, physical and chemical soil characteristics data. The equipment used were a set of computer with ArcGIS software, Microsoft Office, water level logger (global water fp 111).

2.2 Research Procedure

Research data collection stages consist of primary and secondary data collection. Primary data was obtained directly by observation at the River Flow Measuring Station (SPAS). The velocity of river flows also measured at SPAS station using current meters and river water level surface. Measurement of river water level was conducted every 30 minutes using water level loggers (automatic water level recorder). Other primary data taken were soil samples from each type of soil in the study location to analyze the characteristics in the form of soil texture class, soil particle density, and available water. Secondary data included 1) climate data such as: daily rainfall, air temperature, wind velocity, air humidity and solar radiation 2) land cover data, 3) soil type data, 4) DEM map. The data was obtained from several related agencies.

![Research Location](image)

**Figure 1.** Research Location
2.3 Stage of rating curve debit and model evaluation
At this stage, the graph of the relationship between water level surface and debit observed at SPAS was conducted by curve fitting (goodness of fit) using a rating curve equation model such as linear, exponential, logarithmic, polynomial second degree and power-law method, then to find out the performance of the equation model compare to the observation data, the model was evaluated using parameters such as coefficient of determination \( R^2 \), correlation coefficient \( r \) and Nash-Sutcliffe Efficiency (NS) which is recommended by The American of Civil Engineers [5][6]. The coefficient of determination \( R^2 \) is an indicator of the relationship between observation value and simulation value strength [7], \( R^2 \) has a range of 0-1, \( R^2 \) value is satisfactory if the value is above 0.6, NS is an indicator of the goodness of fit between observation values with simulation on line 1:1, NS value can be at \(-\infty \) to 1, NS value is good if NS value is \( \geq 0.75 \); satisfying if \( 0.74 \geq NS \geq 0.36 \); and less satisfying if NS <0.36 [8].

3. Results and Discussion

3.1 General condition of watershed
Sei Petani sub-watershed has an area of 1191 ha, elevation interval of 1276 m - 2064 m, land cover in the form of dry land forests, shrubs, open land and was dominated by 95% food crop land, two soil types namely andosol and podsol soil.

3.2 Rating curve discharge
Figure 2 showed a graph of relationship between water level surface and debit observed during study, and from Figure 2, the smallest debit occurred on March 30, 2018 at 0.62 m\(^3\)/s and the largest occurred on June 26, 2018 at 1.54 m\(^3\)/s could be seen. The occurred debit in March was the smallest because it was still in the dry season while in June it had entered the rainy season so that the debit was quite large.

Figure 3 showed the results of fitting-curve from the river water level surface data with observational debit data using linear, exponential, logarithmic, polynomial second degree and power-law method. The fitting-curve matching results obtained from the equation of each method used and the equation of each method used was also obtained by constants of \( a \), \( b \) and \( c \). Table 1 showed the results of the model evaluation using \( R^2 \), \( r \) and NS Efficiency. When viewed from the model evaluation using \( R^2 \) and \( r \) it turned out that the value was above 0.6 which meant that the the relationship strength between the observation data with the model results showed a strong closeness (satisfactory) or in other word the equation using the five models could be used to determine the debit at the study location using only data river water level surface, whereas from the NS value the study results for the five methods also showed satisfying, this because the NS value of the five models was \( >0.75 \) [8]. From Table 1 also showed that the polynomial second degree equation could be used as the best rating-curve equation which could then be used to calculate the occurred debit at the research location, this polynomial second degree equation was also used in some watersheds in determining the amount of debit [9].
Table 1. Result of model evaluation of each rating-curve method

| No | Method              | Equation                     | R²  | r   | NS  |
|----|---------------------|------------------------------|-----|-----|-----|
| 1  | Linier              | \( Q = 8.8844H - 1.0208 \)  | 0.7993 | 0.894 | 0.799 |
| 2  | Exponential         | \( Q = 0.1275e^{0.9905H} \) | 0.7982 | 0.894 | 0.995 |
| 3  | Logarithmic         | \( Q = 1.9715 \ln(H) + 3.924 \) | 0.7828 | 0.887 | 0.994 |
| 4  | Polynomial second degree | \( Q = 49.781H^2 - 13.663H + 1.5112 \) | 0.8185 | 0.905 | 0.995 |
| 5  | Power-law           | \( Q = 19.604H^{2.0158} \)   | 0.7982 | 0.893 | 0.995 |

Note: \( R^2 \) = coefficient determination; \( R \) = coefficient correlation; \( NS \) = Nash Sutcliffe efficiency

Figure 2. Graph of the relationship between river water level surface and debit at research location
Figure 3. Rating-curve for several method

4. Conclusion

The occurred highest debit at the research location was 0.62 m$^3$/s and the lowest was 1.54 m$^3$/s. The best method for determining rating-curve between water level surface and debit at the research location was the second degree polynomial equation, that was $Q = 49.761H^2 - 13.663H + 1.5112$ because it has the greatest $R^2 = 0.818$, $r = 0.905$ and $NS = 0.995$ values, so this equation could be used to determine the debit amount only by using the river water level surface data at the research location.

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