II －12 **Hysteresis Analysis of Storm Runoff Quality in the Forested Catchment Considering the Characteristics of Catchment Area**

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1. Introduction

Relationships of stream water quality and discharge (C-Q relationship) were commonly reported as clockwise (positive) hysteresis during storm events (Williams, 1989; Steegen et al., 2000; Picouet et al., 2001). These studies showed the rising period of the hydrograph was more important than the falling period when analyzing the water quality changes, because the peak of concentration occurred earlier than discharge. In order to analyze this phenomenon in the forested catchment, a field survey was conducted during the period of typhoon No.11 on August 22nd-23rd at two streams that concentrated to point 8 and 9 in the Mae tributary of the Kamafusa Lake catchment, Kawasaki town, Miyagi Prefecture(**Fig.1**). The hourly runoff discharges and water quality data in the rising period of discharge and the bi-hourly ones in falling (recession) period were measured at points 8 and 9 respectively. The field survey results showed different positive or negative (counter-clockwise) hysteresis (**Fig.5**) The possible causes were analyzed considering the characteristics of these two small sub-areas, such as land use/land cover, soil type and topographic data.

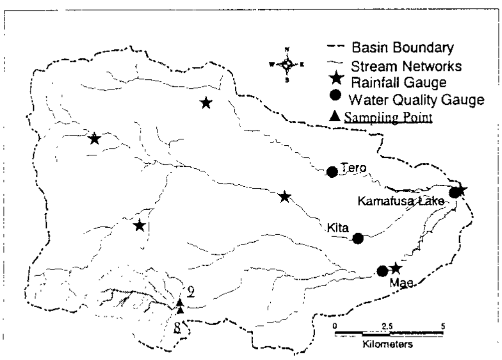

Fig.1 Study Area and Location of Sampling Points

2. Methods and Materials

The measured storm discharges and water quality data of suspended solids (SS), total nitrogen (TN) and total phosphorus (TP) were used in this analysis. The topographic data and sub-areas corresponding to sampling points 8 and 9 were derived from 50m digital elevation model (DEM) data set. The land use, and soil type data were extracted for each sub-area based on Geographical Survey Institute (GSI) database (**Tables 1** and **2**). The vegetation cover (NDVI) data specific to each sub-catchment were statistically calculated based on a NDVI database derived from Landsat TM data.

3. Results and Discussion

C-Q relationships were influenced by many factors, such as: 1) precipitation intensity and areal distribution, 2) runoff amount and rate, 3) floodwater travel rates and travel distances, 4) spatial and temporal storage-mobilization-depletion processes of available sediment source, and 5) the sediment travel rates and distances (Williams, 1989). In one hand, the most possible cause that contributes to positive hysteresis is a depletion of available pollutant sources before the water discharge has peaked. On the other hand, at least two causes would lead to negative hysteresis. One possible cause is the relative travel time of the flood wave and the pollutant flux, especially in the view of the downstream distance between the flood source and the measuring station. Changes in water discharge tend to travel with wave velocity. This velocity generally is somewhat faster than the mean flow velocity. Since suspended sediment tends to travel in a velocity closer to the mean flow velocity, the sediment flux tends to lag behind the flood wave. The lag time increases with distance downstream. The second possible cause is high soil erodibility in conjunction with prolonged erosion during the flood.

Sub-areas 8 and 9 did not show quite difference in land use/vegetation cover (**Tables 1 & 2**). Both of sub-areas 8 and 9 were predominantly covered by dense forest of high NDVI values, and had similar NDVI distribution pattern (**Fig.2**). The flood water travel distances showed difference between these two sub-areas (**Table 1**), however, the observed hydrograph showed that the discharge peaked earlier at the point 8 than at the point 9 (**Fig.4**). This is due to the larger travel rate of discharge in the sub-area 8. These seemed that the differences in travel rate and in travel distance had no significant effect on the hysteresis phenomena in these two sub-areas. Furthermore, the field survey was conducted in the same storm event and almost simultaneously, and the sub-catchment areas were small and neighbored, therefore, the precipitation intensity and spatial distribution were considered as similar between these two sub-areas. Then the remained differences probably lie in soil types and topographic feature (**Tables 1&2**). On the one hand, the different soil types may have different available pollutant sources, which can be exported to stream water during the rising or falling period of hydrograph. On the other hand, the different topographic feature (slope) may cause different depletion rate of available pollutants during the storm period.

The study results of soil chemistry showed that podzolized soil contained a little more nitrogen and organic substances than brown forest soil (日本林業技術協会,1983). This means that the available nitrogen or organic substance source of unit area in sub-area 8 is a little larger than that in sub-area 9. However, the statistic slope data showed that the mean slope of sub-area 9 is larger than that of sub-area 8 (**Table 2**), and the more flat areas were located in the sub-area 8, and more steeper areas were located in the sub-area 9 (**Fig.3**). We deduced that the steeper slope would cause faster depletion of available pollutants during the rising period of hydrograph. Therefore, the difference in topographic feature is the most important factor to cause the different positive or negative hysteresis phenomena during the observed storm period.

4. Summary

Our analysis showed that when the available pollutant sources and rainfall intensity are similar, the runoff amount and rate, and floodwater travel rate and travel distances are not important. We deduced that the topographic feature (slope) would be the most important factor that affected the hysteresis phenomenon, i.e., the steeper the slope, the faster depletion of available pollutant source during the rising limb of hydrograph.

Table 1 Land use, soil type and geological data and area of sub-catchment

Sampling Point	Pt. 8	Pt. 9
	Land Use (%)	
Paddy field	0.09	0
Cropland	0.05	0.1
Forests	98.7	99.9
Residential area	0.67	0
Other land uses	0.49	0
	Soil Type (%)	
Stony soil	1.3	0
Black-boku soil	8.7	0
Brown forest soil	54.2	84.6
Dry podzolized soil	35.8	15.4
Sub-catchment area(km^2)	8.80	1.56
Max distance to outlet (km)	5.0	2.4

Table 2 Vegetation cover and topographic data

	NDVI		Slope (degree)	
	Pt.8	Pt.9	Pt.8	Pt.9
Minimum	0.40	0.50	0	1
Maximum	0.87	0.86	48	46
Mean	0.75	0.76	22.7	24.3
Std.Dev.	0.08	0.05	9.7	9.8

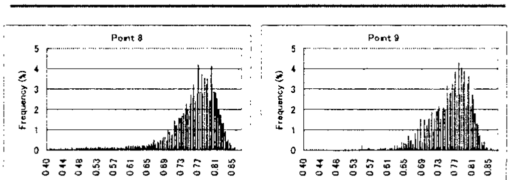

Fig. 2 Frequency of NDVI in sub-areas 8 and 9

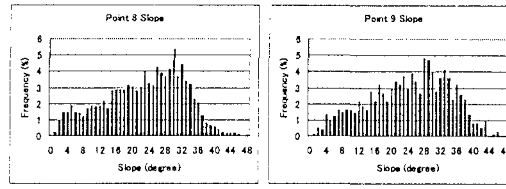

Fig. 3 Frequency of slope in sub-areas 8 and 9

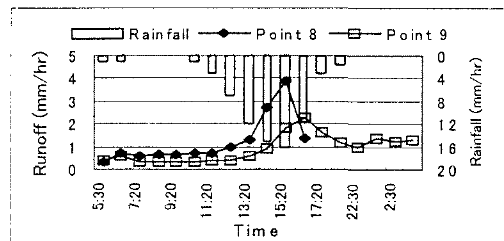

Fig. 4 Runoff depth at points 8 and 9

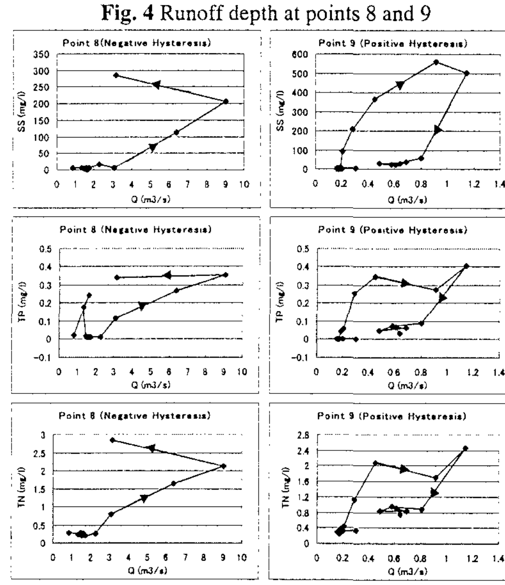

Fig. 5 C-Q relationships of SS, TN or TP at point 8 (negative hysteresis) and point 9 (positive hysteresis)

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