On the turbidity-discharge response in the upstream region of the Hitotsuse River watershed

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1. Introduction

The Hitotsuse River watershed has been perceived to be in a critical problem of turbid water propagation, after the dams construction. In the past years, several efforts had been conducted to reduce the turbidity in the stored water of reservoir. In this manner, concerning the reducing of high turbid water generation problem in the river should not only be focused in the reservoir, but it is also very important to manage and control the turbidity generation in the upstream region of watershed. Since it is essential to obtain a better understanding of the generation of turbid water in the upstream region, this paper will focus on analyzing the turbidity response to discharge in the river stream in the upstream region of the watershed.

2. Characteristics of study area

This study will focus on the upstream region of the Hitotsuse River watershed, which has a drainage area of 209.3km^2 and 25.6km of river length (**Fig.1)**. The geology of the study area is dominated by sandstone mudstone which cover approximately 33.4% of study area. Major parts of the study area are mainly dominated by brown forest soil which covers 54.2% of the total study area. Forestry working passages and collapsed areas were recognized as the major source of high turbidity generation in the study area where analyses resulted from SPOT images showed that within period 2004 to 2006, there was a significant increase of about 14% in total collapsed area.

3. Turbid water generation

(1) Sources of turbid water generation

The sources of turbid water generation in response to hydrological events in the study area were presumed to be from 3 types, as shown in the following explanations.

A. Type 1 (Collapsed of mountainside)

Type 1 expresses to the generation of turbid water due to the collapsed of mountainside (**Fig.2**). In certain circumstances where the collapsed soils from mountainside fall down into river channel, it will be transported by stream flow. Type 1 usually occur during the heavy rainfall occurrence where there was a possibility that a considerable amount of collapsed soil which contain a high percentage of fine particles (silt and clay), were eroded and routed down from the mountainside to the river channel.

B. Type 2 (Outflow of collapsed soil)

Type 2 expresses the generation of turbid water due to the outflow of collapsed soil (**Fig.3**). The primary causal factor of source of turbid water in Type 2 is overland flow. In the case of numerous amounts of collapsed soil from the mountainside, some parts of the collapsed soil will be deposited somewhere on hillslope toe on their way before entering the river stream. These deposited of collapsed soil will become a potential source of turbid water in the high rainfall event, where overland flow which comes from the surface of collapsed areas will run across the deposited soils and transport fine particles to the river stream. The rill and gully channel resulting from erosion process on the mountain hillslope will give a route for overland flow.

C. Type 3 (Waterside erosion)

Type 3 expresses the generation of turbid water due to waterside erosion (**Fig.4**). In this Type, stream flow becomes the driving factor of turbid water generation in the river. In Type 1, the collapsed soil transported by stream flow will be accumulated in somewhere in the downstream part. These accumulated soils, subsequently, will be transported again by stream flow to other parts in the downstream. These transportation and accumulation processes of fine particles in the river stream will take place continually.

4. Change of turbidity

(1) Definition of Turbidity Discharge Ratio

Fig.5 shows two turbidity-discharge events in different period, where **Fig.5 (a)** was characterized by a higher of turbidity value than discharge on August 12 - 14, 1994, while **Fig.5 (b)** shows a similar value of turbidity and discharge on June 13 - 14, 1998. Both figures indicate an occurrence of the different response between turbidity and discharge. In order to express these different response phenomena, the Turbidity

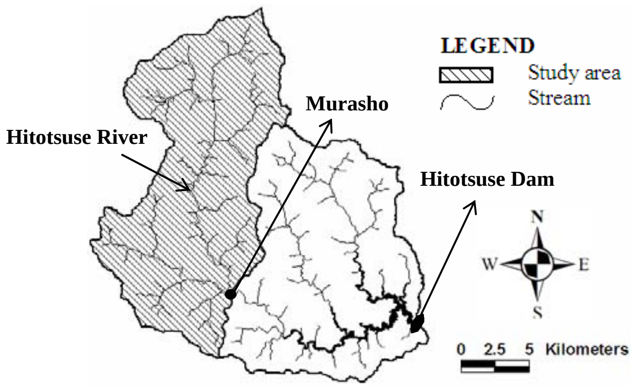

Fig.1 Study area.

Fig.2 Collapsed area of mountainside (Type 1).

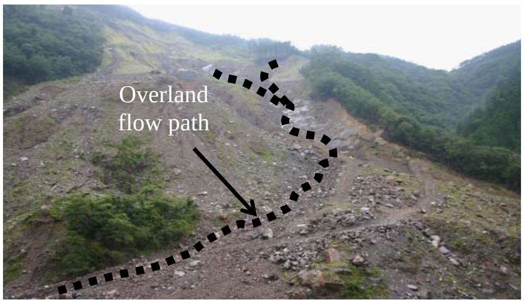

Fig.3 Source of turbid water from outflow of collapsed soil (Type 2).

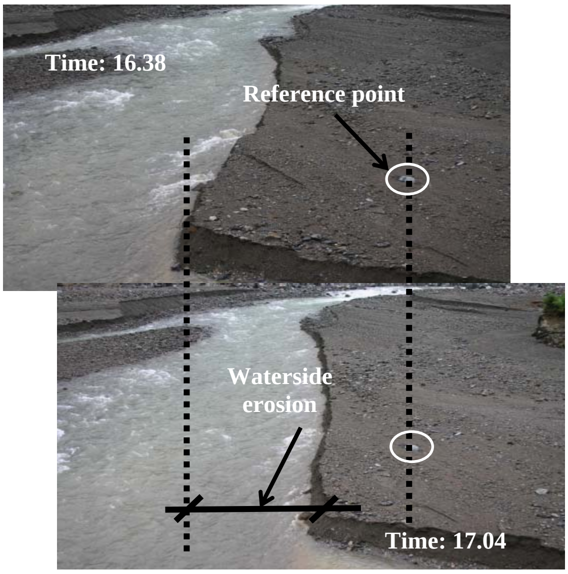

Fig.4 Source of turbid water from waterside erosion (Type 3).

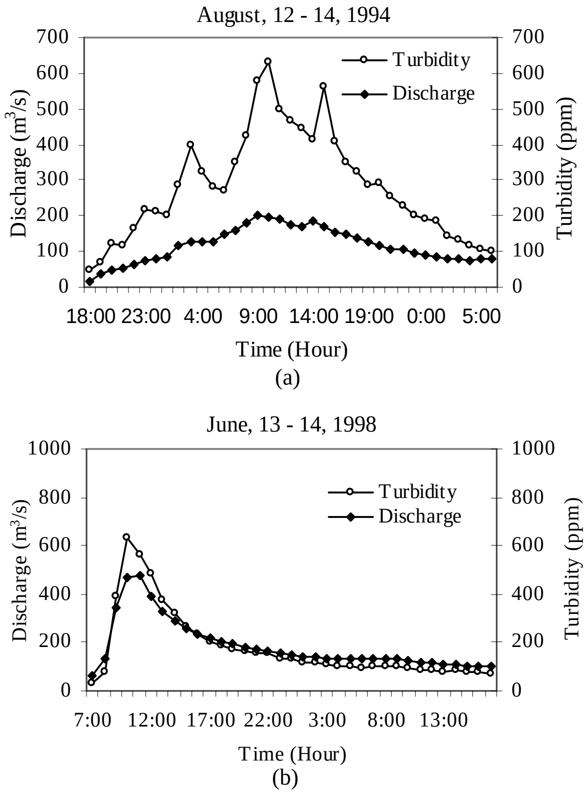

Fig.5 Turbidity-discharge events for selected periods

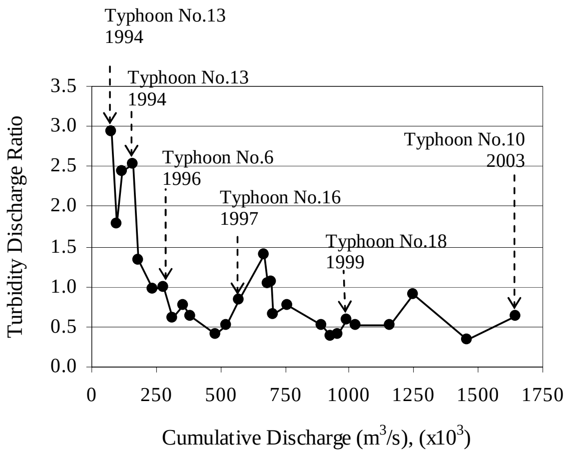

Fig.6 Result of Turbidity Discharge Ratio 1994 – 2003.

Discharge Ratio was proposed and defined as the ratio between the total amount of turbidity and total amount of discharge in a specific period of observation. This description clearly shows the change of turbidity in response to hydrological events.

(2) Calculation of Turbidity Discharge Ratio

The 27 turbidity-discharge event records were selected during 1994 – 2003 to analyze the Turbidity Discharge Ratio due to the collapsed areas in September 2 – 4, 1993 (Type 1). From these serial data of turbidity and discharge, a selection of specific measurement periods was carried out by selecting only periods when the turbidity were higher than 100ppm. Afterward, the calculation of the summation of each turbidity and discharge in that period can be done, followed by the calculation of the Turbidity Discharge Ratio.

(3) Discussion

Fig.6 depict the result of the Turbidity Discharge Ratio in the study area over the period 1994 – 2003. Turbidity Discharge Ratio was very high in the beginning of the selected period (1994) which indicated the generation of high turbid water in the river stream. The height of the Turbidity Discharge Ratio in this period was caused by a lot of transportation of fine particles from collapsed areas to the river stream. The period of relatively high of Turbidity Discharge Ratios were occurred until $180\text{x}10^3\text{m}^3/\text{s}$ of cumulative discharge (June, 1995) which indicated the generation of high turbid water in the river stream. Within the period of cumulative discharge $230\text{x}10^3\text{m}^3/\text{s}$ to $1640\text{x}10^3\text{m}^3/\text{s}$ (July, 1995 to August, 2003), the fluctuation of Turbidity Discharge Ratio values are relatively stable, averaging 0.70. Therefore, a cumulative discharge about $200\text{x}10^3\text{m}^3/\text{s}$ is required to reduce the Turbidity Discharge Ratio below 1. The Type 2 and Type 3 play an important role in the fluctuation of turbidity in river stream in this period.

5. Conclusion

The following results were obtained in this study:

1. There were 3 types of sources of turbid water in the upstream region of the Hitotsuse River watershed, namely: Type 1 (Collapsed of mountainside), Type 2 (Outflow of collapsed soil), and Type 3 (Waterside erosion).
2. In period of 1995 – 2003, the Turbidity Discharge Ratio tended to decrease due to the lesser amounts of fine particles transported to the river by overland flow.
3. The cumulative discharge about $200\text{x}10^3\text{m}^3/\text{s}$ is required to reduce the Turbidity Discharge Ratio below 1.

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