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Suspended Sediment Load Process of Volcanic Ash Deposition at Kurikara and Nishidake Rivers in Mt. Aso

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Research on "Suspended Sediment Load" (SSL) was conducted at the downstream site of Kurikara and Nishidake rivers in Mt. Aso. This SSL originated from the volcanic ash deposition at the upstream site of Mt. Nakadake. Using the vertical stage sampling apparatus equipped with some *500 cc* plastic bottles. Samples were filtered, dried, weighed and sorted at the laboratory. Afterwards, the relation between SSL and water level, and the particle size distribution were analyzed.

The results of SSL concentration varies, especially in relation to the height section from the river bed to its surface on the cross section of each single streamflow. The variation decreases from the river bed to its surface, which was also influenced by time (duration of the capture of SSL). The dominant characteristic in the particle size distribution indicates medium to very coarse sand near the river bed, very fine to fine sand in the middle part and clay to silt near the surface. Both SSL variation and particle size distribution were influenced by some factors i.e. streamflow velocity associated with turbulence, tractive force and gravity wave.

Both Kurikara and Nishidake rivers should be considered based on the sedimentation characteristics, also its relation to the geomorphological process on the rivers and the upperland surface.

INTRODUCTION

Mt. Aso is included as an active volcano in Japan. Most volcanic ash felldown and accumulated on the peripheral crater five years ago. Besides that, volcanic ash is as fine granule. It can fall and deposit on the slope becoming a good source of fine soil supply.

In 1990, there was a disaster on the Furue river (one of the rivers in Mt. Aso). Erosive phenomenon of volcanic ash deposition caused this disaster, which flowed into this river. As a consequence, the river was heavily damaged which led to a big problem at present.

Characteristic of the runoff process of volcanic ash in Mt. Aso is the deposition of volcanic ash on the peripheral crater. It becomes the main source area of volcanic ash. Most its fine particles transported downward, while diffused into a river as suspended sediment load. Moreover, this fact can also lead to a low level of degradation, which has been going on for long period.

The objective of this research is to determine the "Suspended Sediment Load" (SSL) at Kurikara river (southern slope of Mt. Aso) and Nishidake river (northern slope of Mt. Aso). Especially in relation to the source area of volcanic ash deposition and its transport process carried by a streamflow.

RESEARCH AREA

Location of Mt. Aso at Kumamoto Prefecture, central Kyushu, Western Japan. There is an enormous caldera, which has 18 km wide in east -west and 25 km long in north-south). The central cones formation clustered near the center of caldera (Japan Saba Assoc., 1988), i.e. Mt. Nekodake (1437m), Mt. Takadake (1592m), Mt. Nakadake (1500m, actually the volcanic crater is 1280m), Mt. Eboshidake (1337m) and Mt. Kishimadake (1270m) from east to west, respectively. The caldera floor divided into two valleys i.e. the northern valley is Aso Dani and the southern one is Nango Dani (Forest work of Kumamoto Pref., 1991).

The study was conducted at the downstream sites of Kurikara and Nishidake rivers. The watershed area of Kurikara and Nishidake are 6.70 km^2 and 10.36 km^2, respectively. Kurikara river empties into the Shira river and Nishidake river empties into Kura river. Both the upstream of those watersheds united on the peak of Mt.

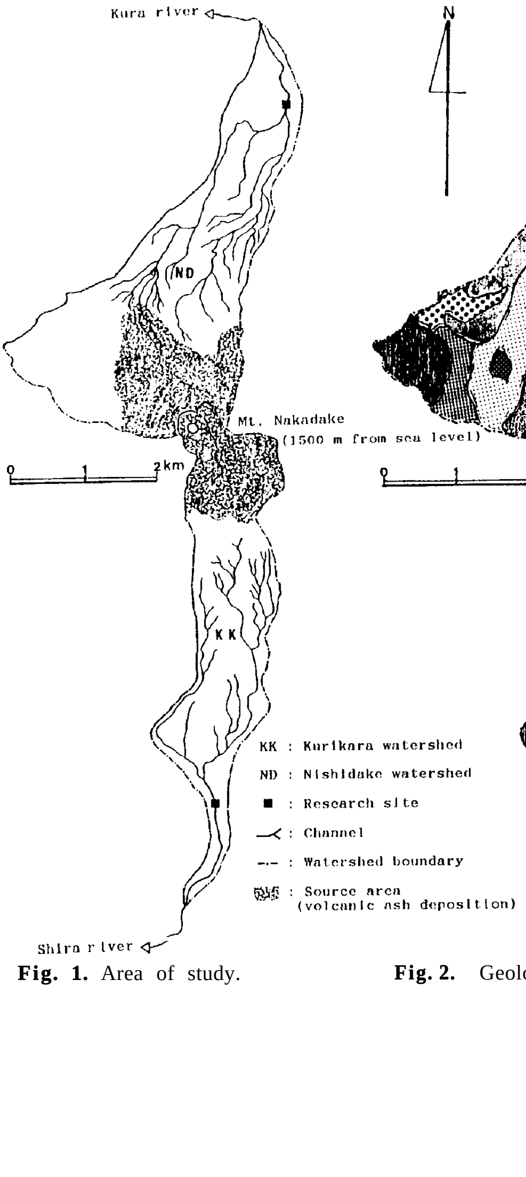

Fig. 1. Area of study.

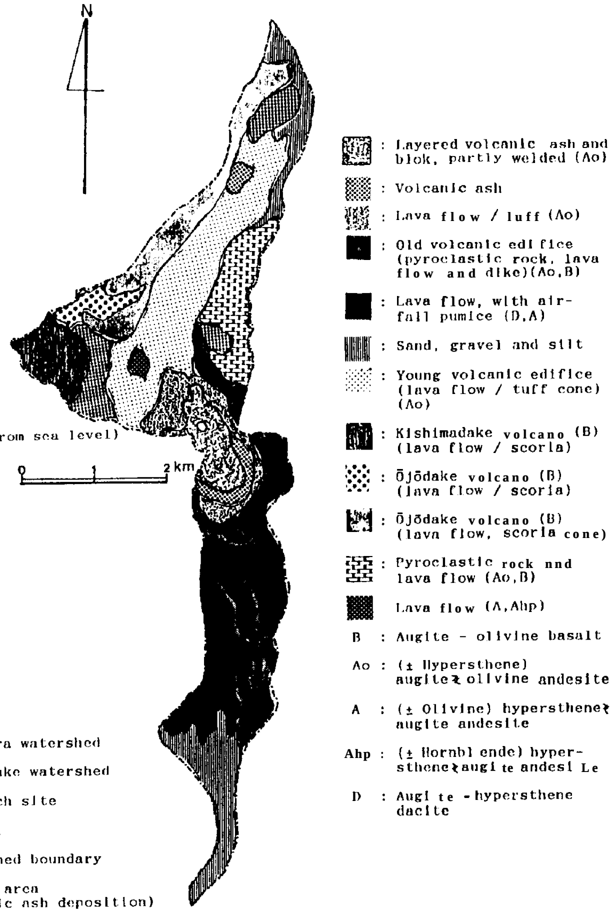

Fig. 2. Geology of Kurikara and Nishidake watersheds.

Nakadake (Fig. 1).

During heavy rainfall, the volcanic ash deposited on the peripheral crater of Mt. Nakadake is able to flow into the rivers leading through the gullies as SSL.

The geological Mt. Nakadake (Ono et *al.,* 1985) is a composite volcano of basic andesite to basalt. The active crater of Mt. Nakadake is at the top of the youngest pyroclastic cone. It consists of agglutinate, ash and accessory ejecta layers. The active crater of Mt. Nakadake emits only volcanic gas or steam in a quiescent period. During the active period is characterized by discharge of black, fine essential ash of basaltic andesite and ejection of red hot scoriae or driblets.

The geological Kurikara watershed consists of old volcanic edifice mainly, i. e. pyroclastic rock, lava flow and dike. The others are fan deposit (sand, gravel and silt),

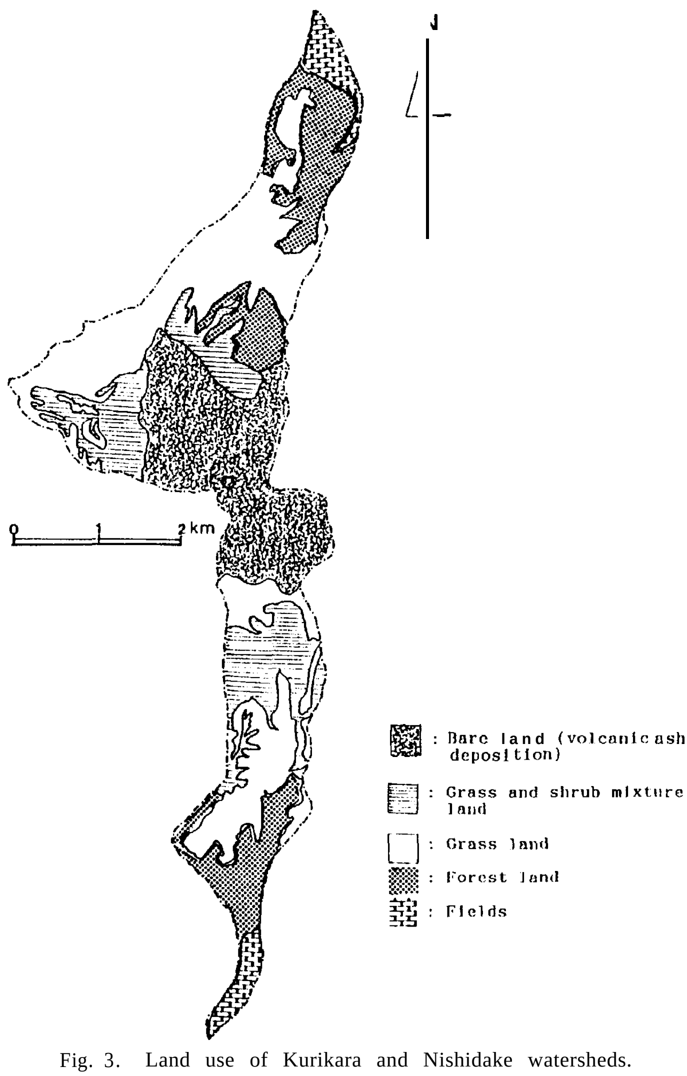

Fig. 3. Land use of Kurikara and Nishidake watersheds.

lava flow with air -fall pumice, youngest pyroclastic cone (volcanic ash and block layer), and air-fall volcanic ash. On the other hand, the Nishidake watershed consists of young volcanic edifice (lava flow/tuff) mainly. The others are pyroclastic rock and lava flow, air-fall volcanic ash, lava flow/scoria, fan deposit, youngest pyroclastic cone and pumice cone (Fig. 2).

The general land use of Kurikara and Nishidake watersheds are as follows: bare land, grass shrub mixture land, grass land, forest land and fields (Fig. 3). The percentage area of land use on Kurikara watershed includes of bare land (29%), grass land (7%), grass shrub mixture land (21%), grass land (18%), forest land (19%) and fields (6%). The percentage area of land use on Nishidake watershed includes of bare land (25%), grass shrub mixture land (15%), grass land (35%), forest land ('21%) and fields (4%). Most surface land of both Kurikara and Nishidake watersheds are still covered by plants. Except the upper land which is certainly bare land.

RUNOFF AND VOLCANIC ASH DEPOSITION

The Runoff Process

Runoff is a summary term used to refer to the various processes which produces streamflow (Hewlett et *al.*, 1969). Obviously, all the precipitation that fall does not immediately flow out of a basin. Some water flows out quickly. Some stored in various ways and for various lengths of time. Some never flows out via the stream channels, because it evaporates back to the atmosphere or percolates to deep ground water aquifers.

Classification of the components of main runoff process is as follows: surface runoff (overland flow), interflow (subsurface flow), direct runoff (channel precipitation, surface runoff and interflow), and baseflow (ground water outflow).

Runoff process has a connection with the storage components and infiltration. The storage components and infiltration can influence the stream flow into the river. If rainwater or snowmelt fail to pass into the mineral soil surface, the water can run quickly into streams as overland flow. Also infiltration is greatly impeded, the overland flow is the dominant source of stormflow. On the contrary, the higher infiltration capacity can contribute to the subsurface flow and percolation.

Transported Volcanic Ash Deposition in River

Usually, in order to estimate rates of landform change, the only data available are sediment loads transported by river.

There are three components of the total sediment load of a river i.e. dissolved load, suspended load and bedload (Chorley et *al.,* 1984). Dissolved load is materials in solution. Suspended load is the sediment held in the water by its turbulence. Bed load is the sediment moving on or near the bed. The particles moved in suspension depend on the flow velocity and turbulence, especially the larger particles quickly return to the bed.

River system has a connection with the activity of Mt. Aso, especially on the volcanic ash fallout mechanism. The volcanic ash falldown as deposition on the peripheral crater mainly, the other one on the mountain slopes. These sites become a material source area of suspended load. If there is a stormflow, the volcanic ash flows as a suspended load through the gully into the river.

Coinciding with the flowstorm, a volcanic ash deposition can eroded and transported as wash load. It also contributes to bed material transport. These flows fuse into surface flow and interflow. Both wash load and bed material transport are able to lead to suspended load. Especially on the bed material transport, besides leads to suspended load, it also lead to bed load. The mechanism of sediment transport can divided into suspended load and bed load. Suspended load is the particles movement floating in the river. Bed load is the particles movement in rolling, jumping and friction ways.

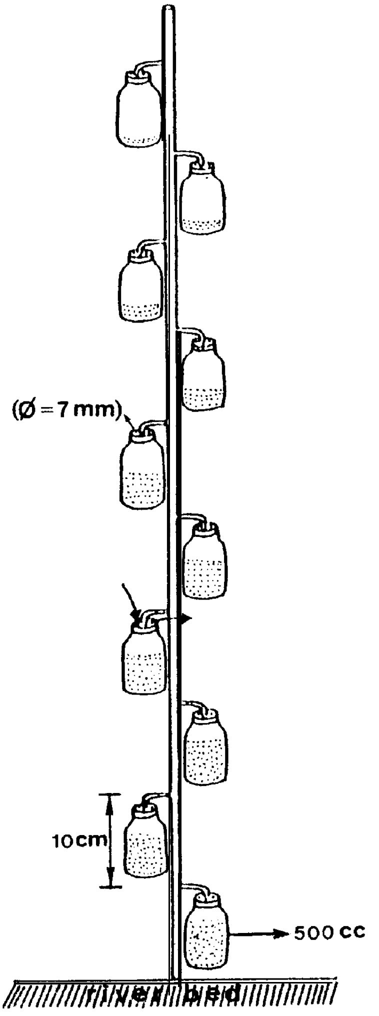

Fig. 4. Apparatus of SSL sampler.

METHODS

Suspended Sediment Load (SSL)

Study on the "Watershed Hydrological System" can be approached by hydrological analysis, among other things sediment content in a river, including suspended load and bed load.

In this research, the measurement of the runoff process of volcanic ash focused on SSL. The sites for collecting SSL were at the downstream of Kurikara and Nishidake rivers. To trapped the SSL samples by using an apparatus equipped with plastic bottles (Fig. 4). The plastic bottle has 500 cc volume with 4 holes of 7 mm diameter on the bottle cap. To arranged ten plastic bottles vertically, and to connected to a plastic pipe (31 mm diameter) at 10 cm interval. Then, to placed a metal pipe (14 mm diameter) inside the plastic pipe to install on the river bed. Using these bottles to trapped a SSL which carried by streamflow. Afterwards, to filtered the SSL samples by using filter paper. The filter paper separates water from samples. To dried the samples in the oven until 105°C for 24 hours, then to weighed the samples by using the balance. To counted the SSL content by the following formula (Chow, 1964):

$$Cs = \frac{g_2 - g_1}{V}$$

where: Cs = SSL content (g/l) ; g_2 = weight of SSL + filter paper in dried condition (g) ; g_1 = weight of filter paper (g); v=volume of samplers.

In addition, to installed the Automatic Water Level Recorder and Rain Gauge at Kurikara river. These apparatuses record the fluctuation of river water level and rainfall around this river. Data from these apparatuses completed in the SSL analysis.

Particle Size and Sorting

Using the 7 stages sieve-mesh, to sorted each dried SSL samples. The 7 stages sieve-mesh with the diameters of 5mm, 2mm, 0.85mm, 0.4mm, 0.25mm, 0.11mm and 0.074mm, respectively. It meant to determine the particle size distribution. From the size distribution curve, the following parameters express their size characteristics (Takayama, 1974) :

(i) The central diameter (d50) is the size for which 50% by weight. It also mentions the median phi (Md ϕ) for phi scale.

(ii) The average diameter (mean diameter), it also mentions the mean phi (M ϕ) for phi scale. To calculate M ϕ by using "Inman formula" as follows, $M\phi = 0.5(\phi 84 + \phi 16)$

where: ϕ 84 = the size for which 84% by weight;

ϕ16 = the size for which 16% by weight.

(iii) The coefficient class diameter (So) is to express the range of sizes by using "Trask formula" as follows, $So = \sqrt{Q1/Q3}$. It also mentions the quartile deviation of phi (Qd ϕ) for phi scale. This formula becomes:

$Qd\phi = 0.5\ (\phi 75 - \phi 25)$

where: Q1 = ϕ 75 = the size for which 75% by weight;

Q3 = ϕ25 = the size for which 25% by weight.

Correlation between ϕ (phi scale) and particle size diameter d (mm) of sediment distribution is pointed out by "Krumbein, W.C. formula" as follows: $-\phi = \log_2 d$

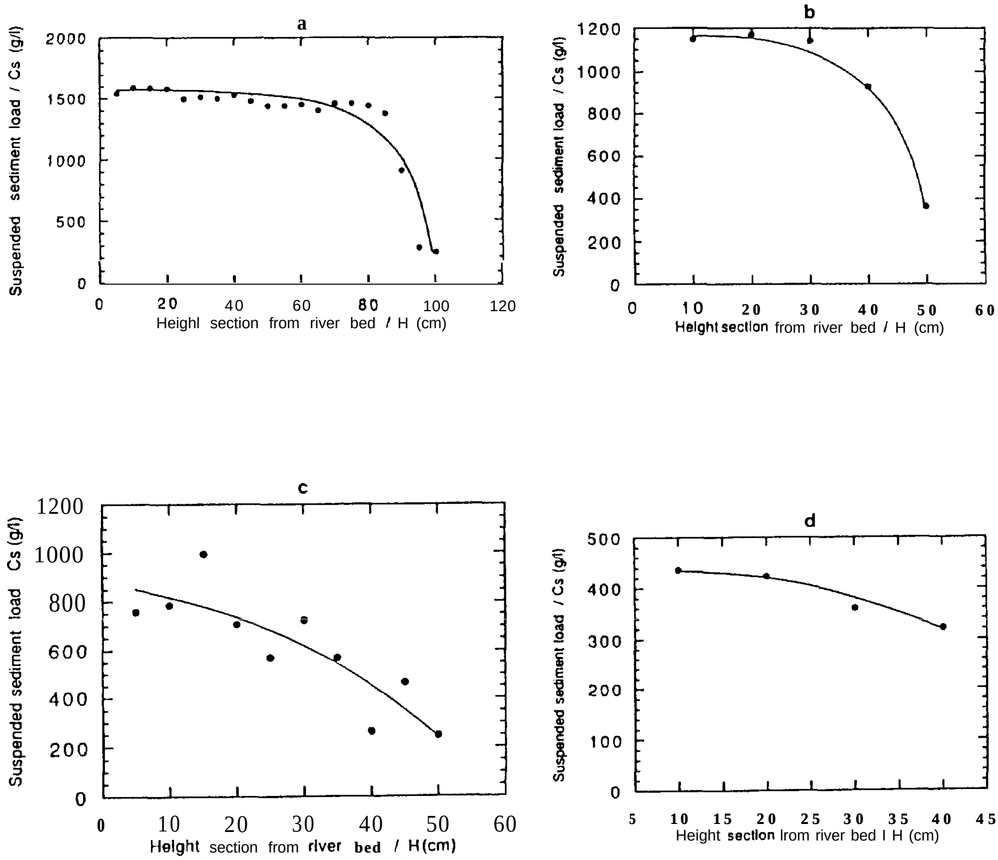

Fig. 5. Relation between the height section from the river bed and SSL.
a. Kurikara river on August 6, 1992
b. Nishidake river on August 6, 1992
c. Kurikara river on August 21, 1992
d. Nishidake river on August 21, 1992

RESULTS AND DISCUSSION

Relation between SSL, Water Level and Time

Measurement of SSL in river has formed the base for most of the estimate of land surface degradation rates by erosion generally. It also includes the land surface by the volcanic ash deposition, which is vulnerable on erosion (Buch, 1988).

Measurements of the SSL concentration (Cs) and the height section from river bed (H) were carried on August 6 and 21, 1992. Fig. 5 shows the variation of Cs and H on each streamflow at single vertical profile of Kurikara and Nishidake rivers. Result of Fig. 5 reveals that during the passage of a single streameflow, the SSL concentration varies, decreasing from the bed of river to its surface. The SSL concentration varied between 236 - 1588 g/l at Kurikara river, but 321 - 1170 g/l at Nishidake river.

Time (duration of the capture of SSL) can influence a variation of SSL

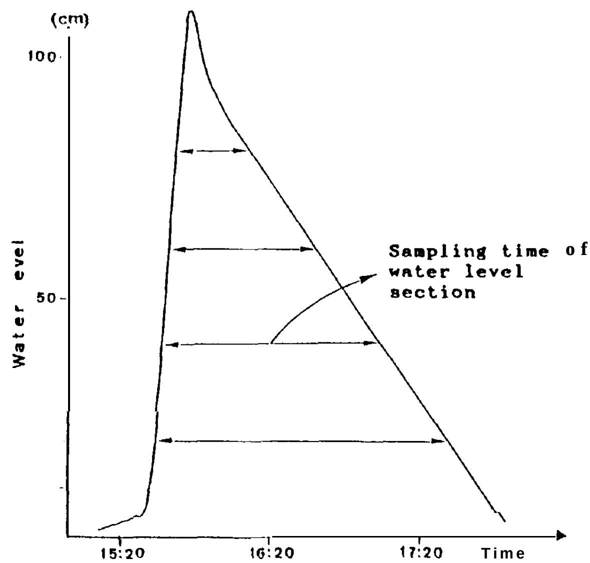

Fig. 6. Hydrograph on August 6, 1992.

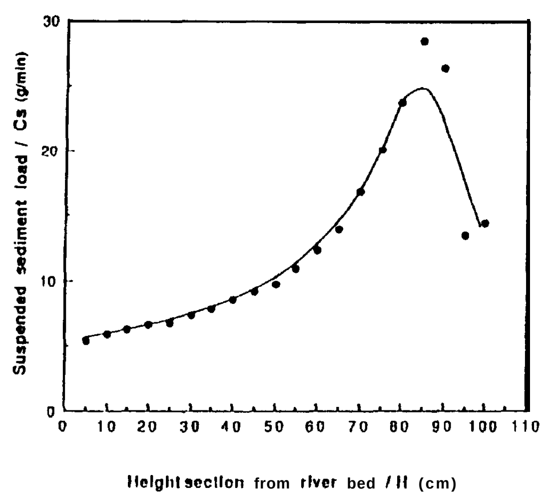

Fig. 7. SSL concentration per minute.

concentration. Duration of the capture of SSL on each height section became shorter from the bed of river to its surface. Furthermore, to obtain the sampling time of water level section by the hydrograph of automatic water level recorder on August 6, 1992 (Fig. 6).

The graphic curve of SSL concentration per minute at each height section from the river bed in Fig. 7. This graphic curve based on Figs. 5.a and 6. Fig. 7 explains that the single stream flow with the maximal water level of 100 cm. It also resulted an increased concentration of SSL from the height section near river bed to 85 cm. Afterwards, steep decrease occurred until 100 m. This means that the cross-sectional

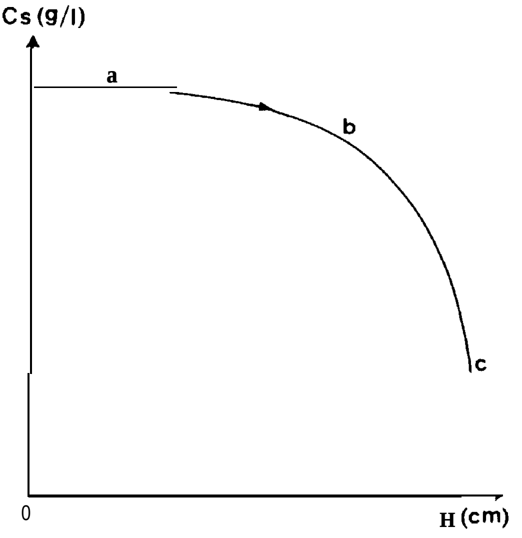

Fig. 8. Pattern of relation between the height section from the river bed and SSL.

velocity distribution of flowing water has the maximal velocity at about 85% of the maximal height of water level. The mean velocity was at 40% and the slow velocity near the bed river and its surface. Especially, the velocity near the bed river is usually associated with the tractive force and the influence of gravity wave. The tractive force has also a response to bed load transport.

In addition, summary of the transport process of SSL is rain fall eroded the volcanic ash deposition on the upper land. The mixture of water and volcanic ash become wash load. The wash load through the gully. Furthermore, it united with the bed material flow together into the river. The main factors influence its transport i.e. rainfall, slope, velocity of flowing water, turbulence, tractive force, gravity wave, etc..

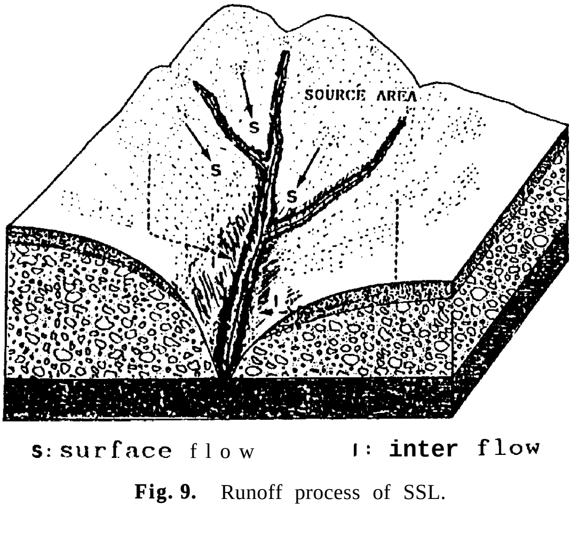

Fig. 9. Runoff process of SSL.

Consequence of these factors cause a concentration of SSL varied on the each height section from the river bed. These various concentrations can indicate its distribution on the single of the vertical wetted profile of streamflow.

All of the graphic curves resulted to a similar pattern i.e. a convex curve in Fig. 5. Fig.8 point out that the process of passage SSL concentration in the convex curve. The greater concentration i.e. near the river bed (a). It continued to gradually decrease till the center of the vertical wetted profile (b). Further decreased steep to a few part of concentration near the surface (c).

Surface flow seemed to be able to contribute more SSL than interflow into a river. Which may be directly caused by factors such as rainstorm, erosion and wash load. On the other hand, interflow depends mostly on the capacity of infiltration and its influence on the weather factors indirectly.

Illustration of the runoff process of SSL in the location of this research in Fig. 9. Fig. 9 describes that when a rainstrom falls down on the surface of volcanic ash deposition (source area>. It will together transported by the runoff process as surface flow (S) and inter flow (I). Afterwards, it flows through the gully and continued into the river.

Particle Size of SSL

Distribution of SSL particle size based on weight (%) of class diameter (mm) at a single wetted profile (Fig. 10). Fig. 10 points out that class diameter <0.074-<0.25 mm (clay, silt and fine sand) of SSL samples dominated on the height sections about 60 - 100 cm from the river bed. Whereas, class diameter 0.25 -<5 mm (dominated by sand) were SSL samples on the height sections <60 cm from the river bed. Particularly, silt and clay between 80 - 100 cm of the height sections from river bed. On the other hand, very fine and fine sands between 40 -<80 cm, and sand about <40 cm. Fig. 10 also describes that clay and silt particles most found in suspension at the upper part of the single of vertical wetted profile. While, very fine and fine sand particles at the middle part, then medium to very coarse sand particles at the lower part. Naturally, particle weight of clay and silt are lighter than sand. The lighter particles occupies on the upper part, but velocity, turbulence and tractive force of streamflow also influence to its distribution.

Analysis of the particle size of SSL samples by three parameters. Each parameters are the central diameter (d50) /median phi (Md ϕ), the average diameter/mean phi (M ϕ), and the coefficient class diameter (So) /Quartile deviation phi (Qd ϕ). These parameters express their size characteristics. The graphic curve of the result of these calculations in Fig. 11. Fig. 11 points out that the central diameter (Md ϕ) was between 1.43 - 2.55 (fine and medium sand). The average diameter (M ϕ) was between 1.49 - 2.46 (fine and medium sand). The quartile deviation phi (Qd ϕ) was between -0.5 - -0.8 (very coarse sand). It expresses that the average of each SSL sample most contains fine and medium particles. Furthermore, the deviation was very coarse sand. Fig. 11 also explains that the trend of the curves of central diameter (Md ϕ) and average diameter (M ϕ) towards smaller particle coinciding with the increasing height section. In spite of the small quantity of very coarse sand particle limited as a deviation, it can distributed evenly from the bed of river to its surface. Because the increase in velocity, turbulence and tractive force of streamflow can influence this movement.

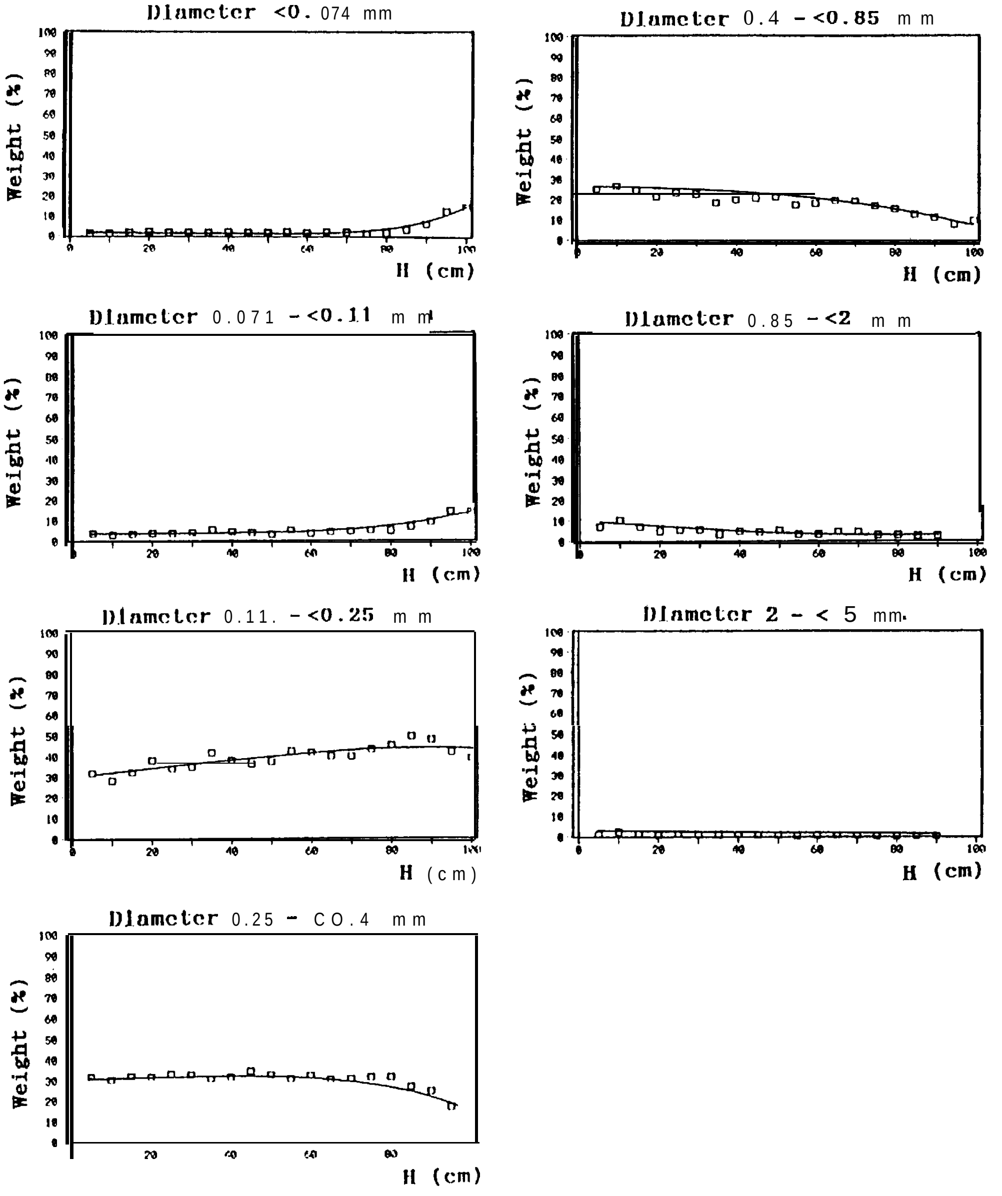

Fig. 10. Particle size distribution of SSL.

The important problem of Kurikara and Nishidake rivers is a sedimentation rate, and its relation to the geomorphological process on the rivers and the upperland surface.

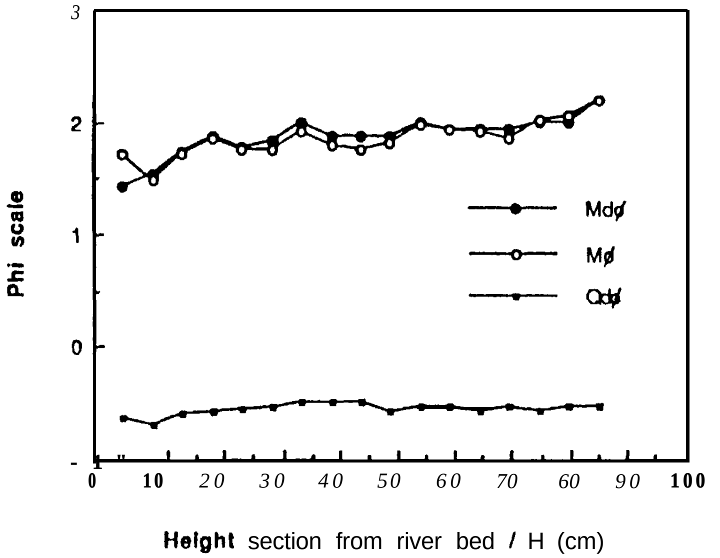

Fig. 11. Particle size characteristic of SSL.

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