INVESTIGATION OF COMPLEX DISASTER OF DEBRIS FLOW AND FLOOD IN HIGASHI RIVER, SHIMATA RIVER SYSTEM

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ABSTRACT

The heavy rain in July 2018 caused debris flow and river flooding in the Higashi River in the Shimata River Basin in the Osogoe district of Iwakuni City, Yamaguchi Prefecture. In this study, we conducted a record of the disaster situation and field survey using the UAV after the disaster in the Osogoe district. In addition, we conducted the ortho-images production, runoff analysis, and inundation analysis. As a result, the causes of the inundation in the Osogoe district were 1) the significant rise in the riverbed due to the flowing of sediments and driftwoods carried by the debris flow and 2) the driftwoods blocking up the river flows at the bridge. In addition, the inundation did not happen without outbreaking the debris flow from the situation of the inundation analysis. The area where the debris flow occurred was included in the landslide prone area. Therefore, the management strategy for the afflicted area like the Osogoe district needs to predict the direct inflow of the debris flow with a lot of sediment and driftwoods to the river segments.

Keywords: heavy rain in July 2018, complex disaster, flood, debris flow, unmanned aerial vehicle

1. INTRODUCTION

From June 28 to July 8 in 2018, the stagnant rainy season front and Typhoon No. 7 caused record breaking heavy rains in a wide area from west Japan to the Tokai region. Over 230 lives were lost or missed, and enormous damage was caused to houses, roads, railways and public facilities. In the Osogoe area, one of the affected areas in Iwakuni City, a large amount of sediment and driftwoods flowed from the side into the Higashi River, which flows through the Osogoe area. The sediments and driftwoods were caught by a bridge near the inflow point and the Higashi River was flooded. As a study on past river disasters, Hashimoto et al. (2018) has investigated flood influencing factors by field survey and numerical simulation in Sumiyo Town in Amami City affected by Amami heavy rain in 2010. Komuro et al. (2018) has conducted teproduction simulation and the estimation of sediment deposition from river inundation by surveying UAV (Unmanned Aerial vehicle) equipped with LP (Laser Profiler) in the Sozu River damaged by a complex disaster in northern Kyushu in 2017. Based on these studies, a lot of knowledges for sediment flooding, river flooding, debris flow, and complex disasters have been obtained. However, there are few studies on complex disasters with sediment-related disasters and river flooding in mountainous areas. Therefore, in this study, we conducted a reconnaissance survey and a UAV-based field survey for the complex disaster with debris flow and river flooding in the Osogoe district of Iwakuni City in Yamaguchi Prefecture in order to clarify the actual situation of the complex disaster.

2. FIELD SURVEY

2.1 Survey area

The Osogoe district in Shuto Town in Iwakuni City, Yamaguchi Prefecture is a V – shaped valley located in the upstream of the Higashi River in eastern Yamaguchi Prefecture (Figure 1). The Higashi River is a second-class river with a length of about 14.6 km and is a tributary of the Shimata River (basin area 269.5 km2, length 34.5 km). In the Shimata River Basin, flood damage occurred in the 1950s due to the Makurazaki Typhoon, the Kiziya Typhoon, the rainy season front with a total rainfall of 598 mm, and the Loose Typhoon. Thus, Yamaguchi Prefecture has released the information on the landslide prone areas and the possible inundation areas in the Shimata River Basin. However, Osogoe district was out of the range of the possible inundation area.

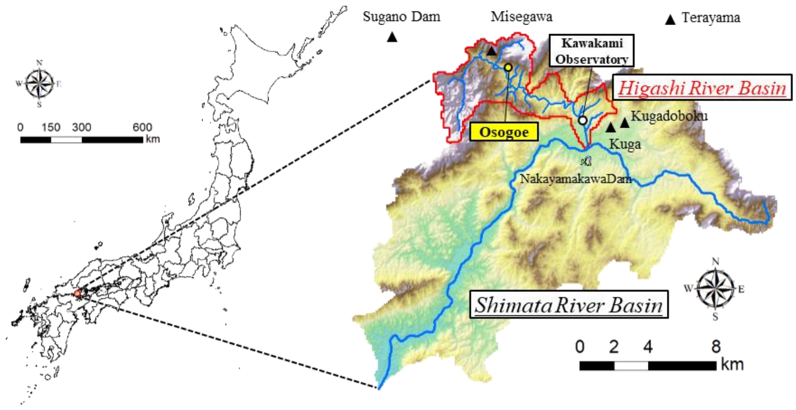


Figure 1 Higashi River in eastern Yamaguchi Prefecture

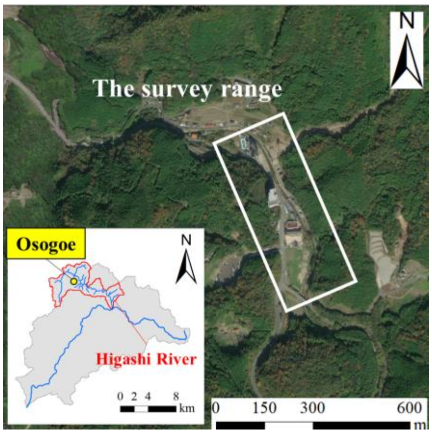


Figure 2 The survey range

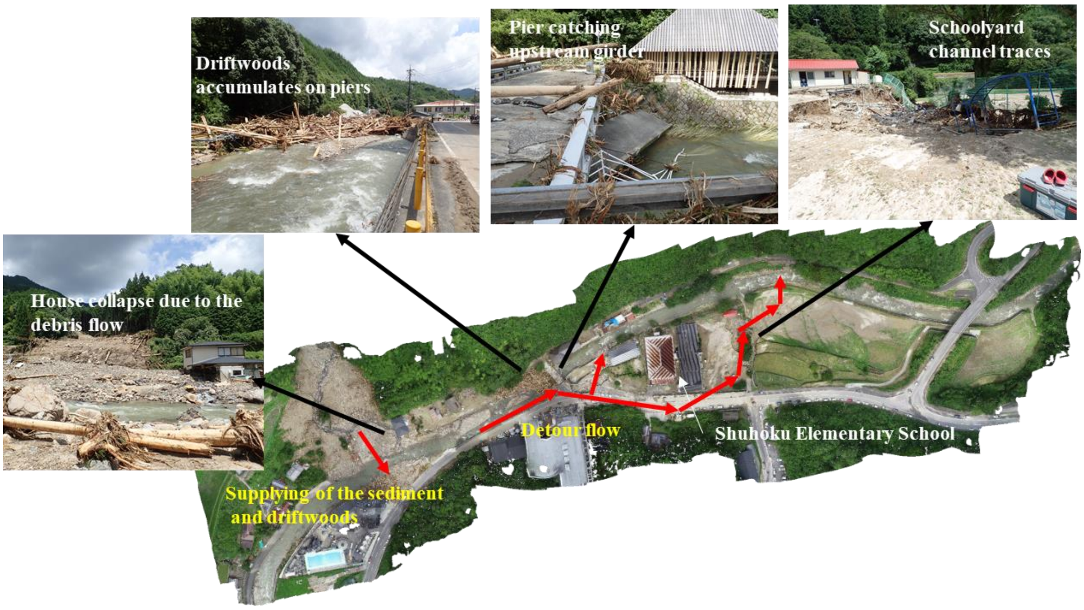


Figure 3 The ortho-images around the afflicted area and the damage situation

2.2 Field survey method

The field survey was conducted on July 9 and July 11 in 2018 immediately after the disaster occurred, and on October 20 in 2018 approximately three months after the disaster occurred (the survey range was shown in Figure2). In the survey, we recorded the damage situation by field investigation and photographed the target area using UAV (DJI Phantom4 Pro and Mavic Pro). In addition, using GNSS (Global Navigation Satellite System), we obtained the geocoordinate (latitude, longitude, and altitude) of the fixed points such as huge rocks. We also measured the cross sections of the river channels. SfM-MVS (Structure from Motion-Multi-Video Stereo) is conducted by reflecting the survey results as GCP (Ground Control Point) and using images taken by UAV. Moreover, DSM (Digital Surface Model) and ortho-images were created to grasp the situation of afflicted area and the amount of sediment deposited due to the disaster.

2.3 Field survey results and discussion

Figure 3 shows the ortho-images around the afflicted area and the damage situation. Sediment and driftwoods have been deposited in the river channel, and a lot of driftwoods have been caught between the bridge piers. In addition, sediments and wood fragments, which have been carried by the flood, have been deposited on the road. From the situation of the afflicted area, it is confirmed that after a lot of driftwoods have been supplied into the Higashi River channel, the driftwoods have become a dam and a detour flow has occurred on the road due to the driftwoods caught by the downstream bridge pier. The detour flow has eroded the Shuhoku Elementary School yard and re-entered the Higashi River. This situation indicates two things. First, during the disaster, river inundation has occurred because of the remarkable rise of the riverbed. Second, the significant rise in the riverbed could be 1) sediment and driftwood carried into the Higashi River by the debris flow and 2) river clogging caused by the driftwoods caught between the bridge piers.

3. ANALYSIS OF OSOGOE DISTRICT

3.1 Analysis method

Table 1 The parameter

Manning's roughness coefficient	**0.035**	**Unsaturated effective porosity**	**0.12**
Roughness on slope	**0.6**	**Hydraulic conductivity rate**	**4**
Soil depth(m)	**1.0**	S_w	**0.995**
Saturated effective porosity	**0.3**	S_d	**0.41**
Saturated hydraulic conductivity	**0.01**	C_d	**0.6**
		C_w	**1.1**

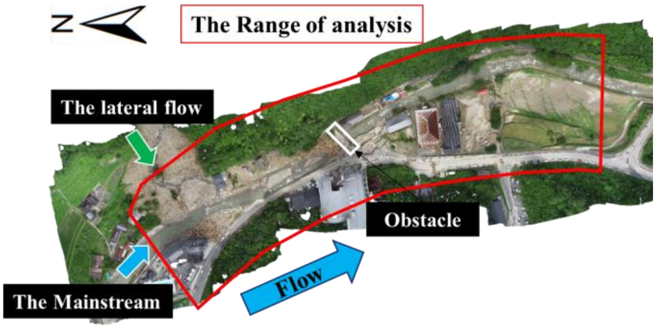


Figure 4 The range of the inundation analysis

3.1.1 Runoff analysis of the Higashi River

Because the measured data of water level and discharge did not exist in the survey area, we had conducted the runoff analysis by using the RRI (Rainfall-Runoff-Inundation) Model (Sayama et al., 2014) to estimate the discharge that flowed into the Osogoe district at the disaster.

The target area of the analysis is the Higashi River Basin (Figure 1) and the rainfall data were obtained at the rain observatories (Kuga, Kugadoboku, Terayama, Misegawa, and Sugano Dam). The Thiessen polygons were made by the observed data of the rain per hour. It is confirmed that there were the strong hourly rainfalls more than 40mm at July 5, 2018 at 4:00 and July 7, 2018 at 2:00. In addition, the residence's testimony that the debris flow was occurred around July 7, 2018 at 3:00 was obtained. The analysis period has set from June 28, 2018 at 0:00 to July 9, 2018 at 0:00. For the inundation analysis, we have created terrain data from the digital surface model (5m mesh and 10m mesh) published by the Geospatial Information Authority of Japan. A 30m mesh computation grid has been set in the analytical range. The slope calculation time interval has been set 60 second, and the river calculation time interval has been set 20 second. Incidentally, we need to surmise the river width W (m) and river depth D (m) as first approximation as shown in Eq. (1) and (2) in RRI if we could not get the detail information of river cross section

$$W = C_W A^{S_W} \tag{1}$$

$$D = C_d A^{S_d} \tag{2}$$

About Eq. (1) and (2), A is intake area (km) and S_w, C_w, S_d, and C_d are river parameters estimated from the available information of the cross section. In the analysis, S_w, C_w, S_d, and C_d are estimated from the available information of the cross section of 3 sites in the Higashi River Basin to match the measured river width and depth. The parameter values are shown in Table 1.

3.1.2 Inundation analysis in the Osogoe district

We have conducted inundation analysis on two cases to clarify the effect of the inflow of the sediment and driftwoods. In case 1, the sediment was deposited on the riverbed, and driftwoods were clogged on the pier of bridge immediately after the disaster in July. In case 2, the sediment and driftwoods were removed after the disaster in October. We have used the Nays2DH-Flood solver of iRIC (iRIC institute, 2019) for the inundation analysis. The position of the confluence of debris flow, ortho image of the Osogoe district, and the range of the inundation analysis are shown in Figure 4. The terrain data of case 1 have been created by using the digital surface model (DSM) data in July, and the terrain data of case 2 have been created by using the DSM data in October. The terrain data have been created by extracting DSM data of the field survey area. The calculation time interval has been set 0.01 second. A 1m mesh computation grid has been set in the analysis range. In each case, Manning's roughness coefficient has been set 0.01 at the road and 0.03 at the river and other land use area. The discharge time series obtained by the runoff analysis of the Higashi River were set to the upstream boundary condition. The downstream boundary condition was free outflow. In addition, the obstacle polygon was set in the analytical range of the bridge in case 1 in order to set the effect of driftwoods blocking up the river flows.

3.2 Analysis method

3.2.1 Runoff analysis

The time series variation of the discharge that flowed into the Osogoe district was obtained by the runoff analysis (Figure 5). In the Osogoe district, there were two inflows from the mainstem of the Higashi River and the valley where the debris flow occurred. Therefore, the discharge time series for each inflow were estimated. The peak value was 68.52 m^3/s and the discharge has increased rapidly in July/7, 2018 at 0:00 (20 hours after the starting of the inflow on July 6, 2018 at 4:00).

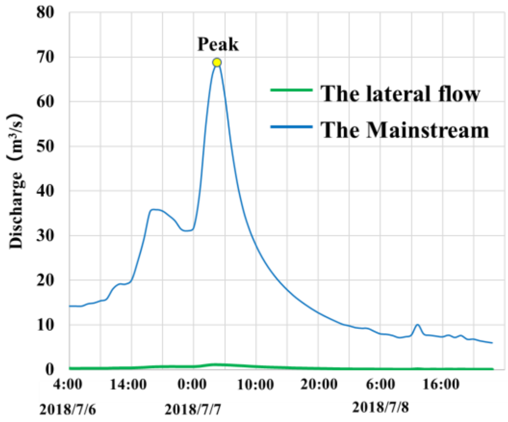
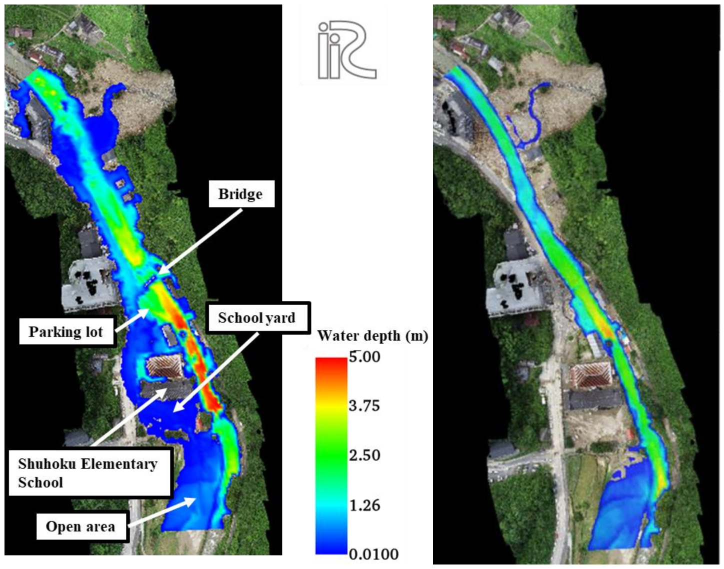


Figure 5 The discharge time series of the Osogoe district



(a) Case1 (b) Case2

Figure 6 The discharge time series of the Osogoe district

3.2.2 Inundation analysis

The discharge of the upstream boundary and the lateral flow set for inundation analysis were estimated by the runoff analysis in the Higashi River Basin. The downstream boundary was free outflow. The contour diagrams of water depth (m) at the time of the flood peak runoff (July 7, 2018 at 4:00) of case 1 and case 2 are shown in Figure 6 (a) and Figure 6 (b), respectively. In the case 1, the flow has reached to the schoolyard of the Shuhoku Elementary School after 12 hours and 10 minutes (July 6, 2018 at 4:10) from the starting of the calculation because of the detour caused by the driftwood. It was indicated that the entire Shuhoku Elementary School (including the road section) was inundated at the peak. Moreover, it was confirmed that the water depth has been over 5m. The inundation area of case 1 matched the flow trace in the ortho image. On the other hand, in the case 2, Shuhoku Elementary School was not inundated, and the flood flow reached up to a range of parking lot and the open area under the Shuhoku Elementary School even at the peak. Moreover, the maximum water depth was under 5m in the calculated area. Our results indicated 1) the inundation in the Osogoe district would not have occurred without the debris flow and 2) it is necessary to make a countermeasure for the inundation in the river where a debris flow may flow directly into the river even the outside of the possible inundation area.

4. CONCLUTION

The causes of the flood in the Osogoe district were 1) the significant rise in the riverbed due to the flowing of sediments and driftwoods carried by the debris flow and 2) the driftwoods blocking up the river flows at the bridge. In addition, the inundation did not happen without outbreaking the debris flow from the situation of the inundation analysis. The area where the debris flow occurred was included in the landslide prone area. Therefore, the management strategy for the afflicted area like the Osogoe district needs to predict the direct inflow of the debris flow with a lot of sediment and driftwoods to the river segments.

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