LAHAR IMPACT TO THE LANDUSE ALONG KONTO RIVER AFTER KELUD ERUPTION 2014

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As an impact of secondary hazard after Kelud eruption in 2014, lahar flowing along Konto River located in the northern flank. Lahar flood caused many destruction to the element at risk mainly in agricultural and infrastructure. The aims of these study are to identification which elements that have a most damage impact due to the disaster. We try to compare the map of Konto river before and after Kelud's eruption. So this study can determine which is the most destructed one. Satellite imagery was helpful for this study, because they can record same area periodically. This Study using very high resolution satellite to conduct this research, i.e. GeoEye-1 for pre disaster analysis and WorldView-2 for post disaster analysis (2 m for both).
From the result can know that two regencies surrounding Kelud as the most affected by lahar, that is Malang and Kediri. About 679646, 63 m^2 and 19935,04 m^2 of lahar befall on it respectively. Actually lahar only occur inside the riverbank, but at the same time local farmer also plant many crop in the middle of the river. So that, when lahar occur on the river, it swept out the agricultural area. As a consequences, they cannot take the harvest time and they need to change their occupation because the land was losses.

Key words: lahar, Kelud Volcano, landuse, Konto river

INTRODUCTION

Java island located in the subduction zone of Australian and Eurasian tectonic plate. As a results of this collisional, many volcanoes were arise along the island from the west part to the east part. One of the most

dangerous volcano on this main island of Indonesia is Kelud. Located in the east side of Java. Kelud has a lot of deadly history to the humanity related with its type of eruptions.

Since 1000 AD, earliest data of Kelud eruption has been collected by many researcher from various country. With its unique characteristics, Kelud was being natural laboratory for those who want to take a research related with geoscience and social aspect.

In 2014, Kelud erupted once more after seven years become a dorman volcano. It was a huge eruption by only two hours of its danger level alert from "Siaga" to "Awas". Produce a lot of ashfall that disturb human activities on the island. Almost the island has been covered and about six to seven airports need to reschedule their flight due to the thickness of the ash which is very dangerous for airplane machine.

The aim of this research is to determine damage areas for current of lahar, especially on geomorphology aspect, settlement aspect, and agriculture land. This research also describe those areas and to predict of loss damage areas. Hopefully this study will useful for expertise and practitioner. By at expertise, we hope the knowledge is concerned with current of lahar can increase from this research. Then, the community can increase the capacity for minimalizing damage of lahar flood.

Literature Review

Secondary dangers Volcano (Lahar)

The hazard of volcanic divided into two, namely primary and secondary hazard. Secondary hazards that occur after volcanic eruption is lahar flow which is commonly referred as *lahar dingin* (Indonesian term). The potential for large lahar after the eruption of volcanoes can expand or widen the river body which through by lahar flow because the material transported by the discharge of rainwater that fell along the river. Potential lahar also damage the environment around the river, such as settlements, agricultural land, and infrastructure that has been built.

Lahar has a definition of etymology, the flow of waste material from the eruption were accumulated by heavy rainfall from the upstream to the downstream to be deposited (Lavigne, et al: 2006). Similar with that definition, lahar can be interpreted as sedimentary material that has erupted which flow along the river that have sediment material in the upstream. The material sediment carried by the river flow that triggered rains upstream.

Land use

Land use is closely related to the carrying capacity of the land in the ability of the land to be used. The ability of the land has a different carrying capacity, especially in any areas that become the object of

research studies. If further elaborated, then the use of land used for the fulfillment of human needs with regard to agricultural land and settlements. The capacity of agricultural land can be changed at any time according to the conditions at the time of the study. It can be influenced by several factors, such as changes in technology that affect the productivity of the land, the culture that affects the needs of each individual life, and natural disasters also affect the productivity of agricultural land. Therefore, the data collected to determine how big the impact of natural disasters that are the focus of this research study is needed to determine the actual state of the area.

Availability of Remote Sensing Imagery

The ability of remote sensing data to perform repeated recording on a same location gives a distinct advantage in monitoring due to catastrophic events. Environmental conditions at the time of the pre to post-disaster can be seen well without having observers present at the scene. Especially for volcanic disasters, when eruptive activity has gradually decreased to return to normal, it still needs a long time to get closer to the center of the eruption. This is due to the area subjected to various types of material bursts is still fragile and contains gases that are harmful to the body. Steep slopes at the volcano also be a challenge in the post-disaster assessment, for those circumstances remote sensing imagery plays an important role (Davilla-Hernandez, 2011).

Several remote sensing satellites that record Kelud Volcano area used in this study. The satellites include Landsat 8, Hyperion EO-1, WorldView-2, GeoEye-1, and FORMOSAT-2. In particular, the five satellites can be divided into two categories, based on spectral composition (Hyperspectral-Multispectral) and based on the spatial resolution (High-Medium). Satellites are included in the category Hyperspectral is Hyperion EO-1 and the rest is a multispectral satellite. Whereas if divided based on spatial abilities, the Hyperion EO-1 and Landsat 8 is classified in the group of moderate spatial resolution and the rest in the group of high spatial resolution. Table 1 and diagram 1 illustrates the availability of satellite remote sensing data in the study.

Table 2.1 Specifications Satellite Remote Sensing Capabilities

Name	Resolutions				Image Acquisition
	Spatial (m)	Spectral (Band)	Temporal (days)	Radiometric (Bit)	
Hyperion EO-1	30	242	16		March 2014
Landsat 8	30 MS 15 Pankromatik	12	16	12	Maret 2014
WorldView-2	2 MS 0,50 Pankromatik	8	1-3	11	May 2014
GeoEye-1	1,65 MS 0,41 Pankromatik	4	< 3	11	Des 2012
FORMOSAT-2	8 MS 2 Pankromatik	4	1-3	16	Des 2014

Research Framework

Volcano has a primary and secondary hazard. The primary danger occurs when volcanic eruptions or almost simultaneously with the ongoing eruption time. The primary danger can be anticipated by the volcanic eruption in radius away from the center that are considered safe. Secondary volcanic disasters occur because of the trigger (triggering factor). One of the triggering factors that could cause secondary disasters volcano is rainwater. Rainwater can change the post-eruption pyroclastic material deposition into lahar. Identification damage risk elements (land use) using analyses the condition before and after the disaster. The ability of temporal remote sensing imagery is very reliable at this stage. Calculation of the area existing before the disaster occurrence compared to the area after the disaster occurred. Result analyses of the affected area can be displayed in nominal grade, up to ratio. Figure 2.1. display our framework.

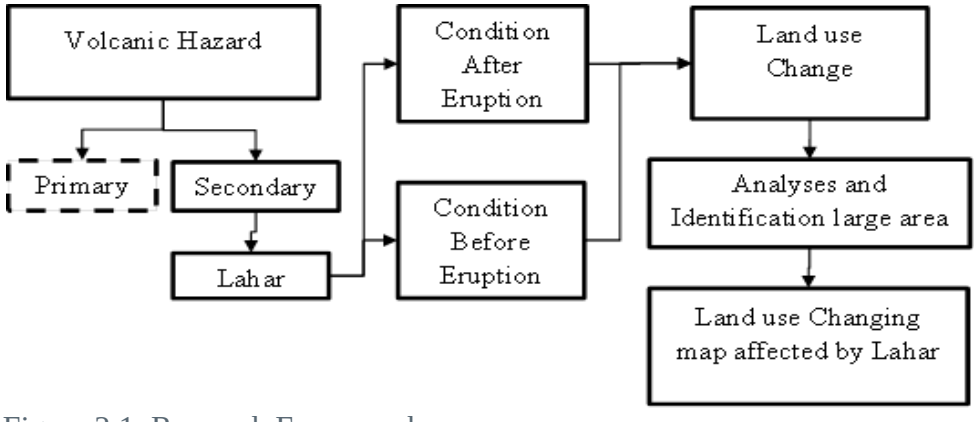

Figure 2.1. Research Framework

Research Method

The study area is Konto River, located on the northern slopes of Kelud Volcano. Konto River is one of the worst affected rivers of lahar after the eruption of Kelud 2014. Lahar flood has ruined settlements, livelihoods, casualties and broke Kediri-Malang transportation lines and lahar was still flowing when the rainy season arrives.

Tools and Materials

Tools and material that used in this research are:

1. ArcGIS 10.1, for computation GIS
2. ENVI 5, for image processing and remote sensing
3. Google Earth, for decision attribute table

Materials that used in this research are:

1. RBI Map Scale 1:25000 around Kelud's Mountain
2. WorldView-2 Imagery resolution 2 m
3. GeoEye-1 resolution Imagery 2 m

Research Stage

3.2.1 Preparation Stage

The main materials are prepared in this study is a remote sensing image data that WorldView-2 (WV-2) and GeoEye-1 (GE-1). The second image is corrected at the level 2A has a second sense the image no longer require geometric correction because it had been corrected by the data provider and already have a projection image of the WGS-84. Radiometric correction is not performed on the image because the interpretation will be done merely based on the visual interpretation of the key instead of the value of the spectral image.

3.2.2 Processing Data Stage

Data analysis methods used to use the land use classification of high resolution satellite images before and after the eruption. Classification of land before and after can be seen lava flood affected areas in the Kali Konto. Results of the affected areas further analyzed to determine the amount of area affected by the lava flood events Konto River. For more details can be seen in Figure 3.2.

Key interpretations that can be used to determine the distribution of material Kelud Volcano eruption bursts results include color, hue, and the association's website. The color associated with the appearance of the eruption are different from the surrounding environment. Rona shows the gray level. While sites and associations describe the relative position of the material from the eruption towards the center of the eruption. Based on the purpose of research that seeks to identify the impact of the volcanic eruption of Kelud then sampling focused on the three main elements of risk that land use, settlement and geomorphology. The

samples were carried out by observing the morphology and also the access to risk elements are affected. Each morphology Volcano Kelud has a different kind of damage. Figure 4.3. draws sampling field.

Figure 3.1. Ilustration of sample point. Figure (A) Keluds envirinment; (B) and (C) Condition in the field after eruption.

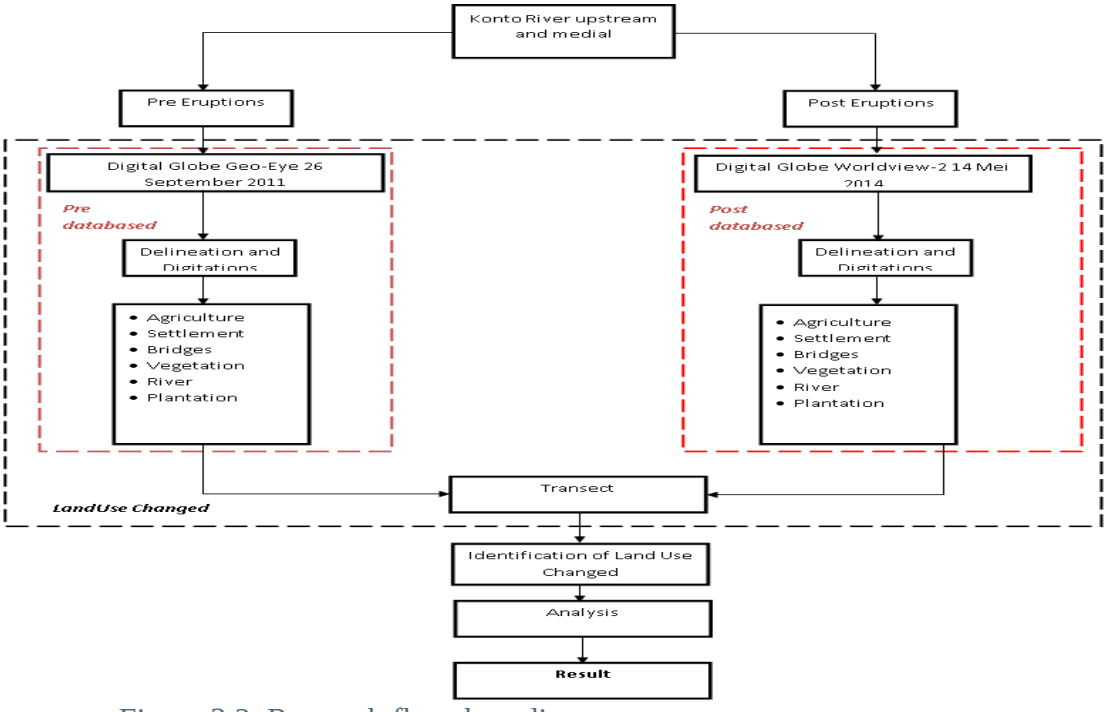

Figure 3.2. Research flowchart diagram

RESULTS AND DISCUSSION

Land use along Konto river

Before the eruption of Volcano Kelud, assumed land use and land cover around Konto River in stable condition and not damaged. Here are the results of delineation and digitization of land use around the River Konto before lahar flood in 2014. Maps of land use along the Konto from upstream and the middle part shows that there are 12 classifications of land use (Figure 4.1.). Land use is dominated by agriculture such as rice fields, orchards, and barren land. It shows that most of the population around the river Konto livelihood as farmers and will increase the risk of loss in the event of flooding lava potentially damaging agricultural land.

Figure 4.1. Existing Land use around Konto River (before eruption)

The second category that dominates around Konto River is a settlement. Most of the settlements are located in the central part Konto River located some distance from the river banks, but there remains the possibility affected given the potential for a large lahar flood events. Land use that dominates the third form of vegetation that can be either a plant or mixed forests are numerous in the area upstream Volcano Kelud. The existence of infrastructure such as bridges and reservoirs also have affected the risk of flooding lahar. The bridge is located on the river infrastructure and serves to connect transportation between villages, so that in case lahar flood that destroyed the bridge it will be cutting off transportation between villages. Results of classification and land use in the area around the River Konto presented in Table 4.1. following:

Table 4.1 Types and extensive use of land around the River Konto

No	Land Use and Land Cover	Area (m^2)
1	Settlement	991.607,29
2	Rice Field	1.828.160,98
3	Plantation	242.661,08
4	Ladang	105.537,49
5	Open Field	1.424,60
6	Tegalan	6.456,51
7	Warehouse	2.108,88
8	Bridges	1.940,254
9	Pond	2.882,58
10	Reservoir	127.068,93
11	Irrigation	2.556,40
12	Vegetation	656.068,59

Source: Analysis Result, 2015

Landuse around Konto River (2014, May 14)

Based on the analysis of Worldview imagery of the area around Kali Konto after the eruption of Volcano Kelud, there has been a change in land use both the extent and type. This is caused by the eruption of the volcano Kelud material cause potential damage to the surrounding land use and infrastructure facilities such as roads and bridges. Land use after the lahar flood unchanged. However, some areas affected by the lahar flow which can then be viewed on a map of the area affected by the lahar flow (Figure 4.2. And 4.3.).

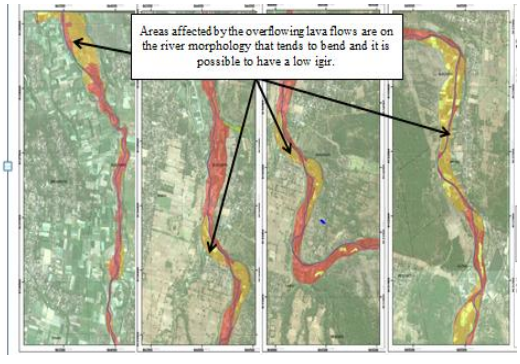

Figure 4.2 Damage area by lahar flood map (medial area)

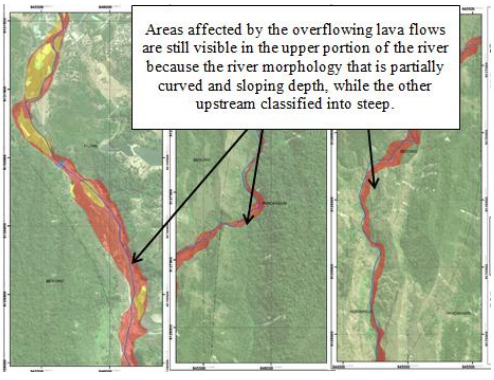

Figure 4.3 Damage area by lahar flood map (Upstream area)

Analysis Areas affected Around Konto River

There are two districts were affected in the two regency, namely Kasembon in Malang and Kepung sub district in Kediri as below.

Table 4.2 The area affected by the floods of lahar

Regency	District	Sub-district	The Wide of Affected Area (m^2)				
			Rice Field	Plantation	Vegetation	Bridges	Warehouse
Malang	KASEMBON	BAYEM	126.460,59	5.962,71	0	0	0
		HUTAN	172.464,03	24.185,07	0	1.700,27	0
		SUKOSARI	301.944,28	32.741,01	14.163,83	0	24,84
Kediri	KEPUNG	BRUMBUNG	19.211,30	0	723,74	0	0

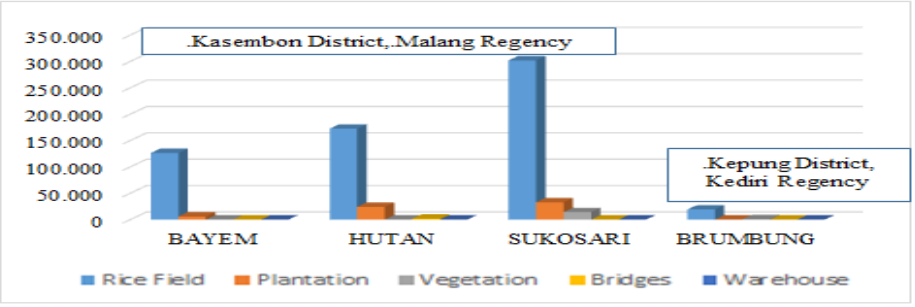

Figure 4.4 The area that damage by lahar flood

The use of paddy fields most affected by the lahar flood that is an area of 620,080.21 m2 followed by the use of agricultural lands (62888.8 m 2). There are also facilities such as bridges and warehouses awoke with each affected area 1700.27 m2 and 24.84 m2. Based on the area affected by the lahar in the middle of Kali Konto (Figure 4.2) it can be seen that there are some land use affected, namely agricultural land and infrastructure. For residential areas is still relatively safe the impact of lava flows in this area. This happens because there are several factors that affect the overflowing lahar flood along the Kali Konto medial area. The first factor is the high rainfall, the second factor is the river morphology, and the third factor is the material that is taken from the upstream toward the middle of the river.

The first factor, namely precipitation of interrelated factors such as river morphology as the second factor and the third factor related to waste material carried by the river from the eruption. Increasingly heavy rainfall, the potential lahar overflows that occur are also increasingly towards the use of land around the river. The second factor in the form of river morphology have curve channel and low ridge can trigger a flood of lahar as well. It is in line with the opinion of Maritimo, et al (2014) which states that the lahar flow in the river overflow can occur because

of the morphology have curve channel with ridge is low. If morphology as these circumstances, the lahar flows suddenly turn direction, so that the flow of lahar flowing from the upper reaches of the river colliding with low ridge, causing overflow of lava may occur. This results in damage to the use of land around the river morphology are grooved and low ridge. The third factor is the amount of material that is carried by the lahar flow, so that the material can be deposited while in parts of certain morphology, for example on the edge of the river that has the shape morphology that have curve channel with high ridge. This does not apply if the river morphology notched with a low ridge.

Based on the map of the affected area in the upstream of Konto show that the morphology of the river in the upstream area still has a high ridge and do not have a bend in the river which is quite steep, so that the flowing lava flow is still on the river flow. However, in some bends upstream areas that are steep enough overflow of lava flows. That is because the lahar flow suddenly hit the riverbank when the the river morphology suddenly changed from slope slightly to a steep curve. The flow of heavy and bend the sudden steep make the overflow of lahar in some areas. In addition, the morphology of the river in the upstream have shallow depth, so the overflow of lahar can occur.

If seen from the characteristics of the population in the area around Kali Konto, most have a livelihood as farmers. From the table analysis results affected areas, fields and gardens have a proportion of the most widely affected by lava flood is about 682,969.00 m2 or 98% of the total area affected (Figure 4.5).

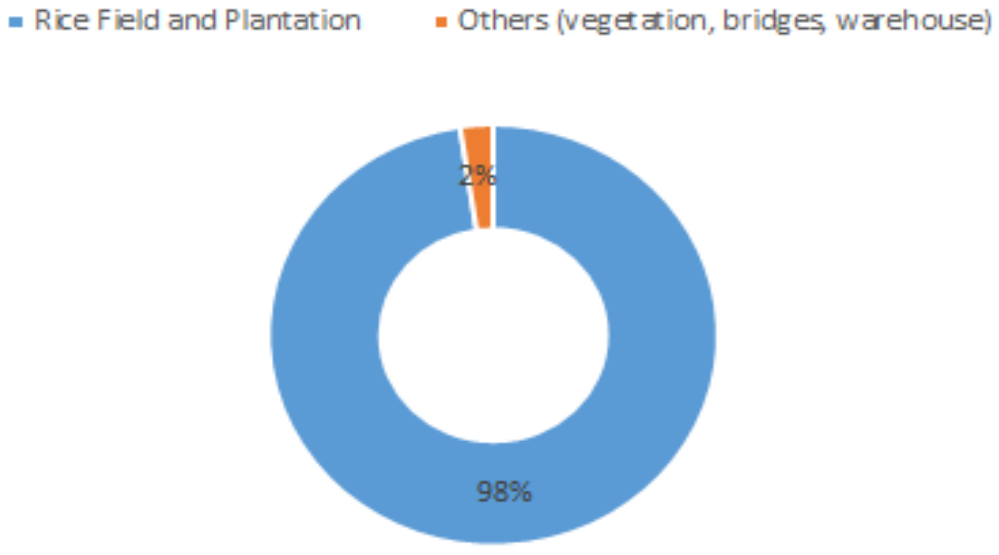

Figure 4.5 Damage proportion of agriculture

Infrastructure Damage

Tunnel Damage in The Top Area of Kelud's Volcano

Tunnel at the top of Kelud main function is to reduce the amount of water in the volcano crater lake. This is part of efforts to prevent the spilling of water crater lake can be a trigger factor of lava. Tunnel graded (7 levels) that construction is carried out by the Netherlands circa 1926-1928. Tunnel made in the Netherlands capable of removing water crater lake 4.3 million m3.

The addition of tunnel made by the Government of the Republic of Indonesia (RI) and completed in 1967. The tunnel is named 'Ampera' scheme 1.2 km long, has a crater lake water discharge outlet to Kali Rhinos and located at an altitude of 1,110 meters above sea level. This tunnel was closed due to the eruption of pyroclastic material in 1990, normalization is done and completed in 1994. In 2007 the eruption of events does not run with the function of the tunnel should, because at the eruption in the crater lake Kelud appear Kelud child with a diameter of 469 m and a volume of 16.2 million m3. Crater lake water remaining only slightly in the southern area. Another tunnel was at the top of Kelud is tunnel 'Ganesha' which has a length of 200 m and serves for connecting tourists to the crater of Kelud. After the eruption of 2014, the inlet and outlet of the two main tunnels covered entirely by material from the eruption so that water is expected to replenish the crater lake at the summit Kelud certainly will not be able to flow past the Ampera and tourists cannot access Ganesha. Figure 4.6. Left: Ganesha tunnel inlet, Right: inlet tunnel Ampera

Figure 4.6. Left: inlet tunnel Ganesha, Kanan: inlet tunnel Ampera

Damage Lahar Control Dam (SABO DAM)

Kelud has 16 rivers / creeks that Konto, Batan, Serinjing, Ngobo, Toyoaning, Dermo, Sukorejo, Gedog, Rhino, New Termas, Termas Old, White, Loding, Lekso, Jari and Ants. Of these only 10 rivers/tributaries has control structures that lahar Lekso, Ants, Fingers, White, Rhinoceros,

Gedog, Sukorejo, Toyoaning, Serinjing and Konto. SABO number DAM list in Table 4.3.

Table 4.4. List of existing DAM SABO

No	Name of River	Total SABO DAM
1	Konto	13
2	Batan	0
3	Serinjing	14
4	Ngobo	0
5	Toyoaning	30
6	Dermo	0
7	Sukorejo	10
8	Gedog	6
9	Badak	37
10	Termas Baru	0
11	Termas Lama	0
12	Putih	32
13	Loding	0
14	Lekso	9
15	Jari	3
16	Semut	15
	Total	**169**

Source: PP Kelud, 2002

Kelud eruptions in 2014 produce secondary disasters in the form of lahar that flow Konto River on the northern slopes Kelud. Lahar flow damage to the DAM SABO along Konto such as levee, a bag full of lahar, consolidation DAM damaged and destroyed bridges in 6 major locations namely Badas, Oro-oro Ombo, Siman, Brumbung, Sambong, and Damarwulan. Figure 4.8 below shows the damage SABO DAM and Table 4.4 is an inventory of the damage.

Table 4.4. List of DAM SABO damage due to the eruption of Volcano Kelud 2014

No	Name of River	Lokasi	Kerusakan
1	Serinjing	Desa Puncu, Puncu, Kediri	Dike cracked 1 x 6 m
2	Konto	Oro-oro Ombo, Badas, Kediri	Dike broke down 100 m
		Karang Tengah, Kandangan, Kediri	Dike broke down 300 m
		Badas, Badas, Kediri	Lahar pocket full
		Siman, Selodono, Kediri	SABO DAM broke down
		Brumbung, Kesamben	SABO DAM cracked
		Pandansari, Ngantang, Malang	Bridges broke down
3	Badak	Badas, Badas	Dike cracked 1,50 m
		Kedawung, Nglegok, Blitar	Dike cracked,50 x 500 m
4	Termas Lama	Sumbersari, Udanawu, Blitar	Dike cracked 2 x 500 m
		Demangan, Udanawu, Blitar	Dike cracked 1,50 x 300 m

Source: PP Kelud, 2014

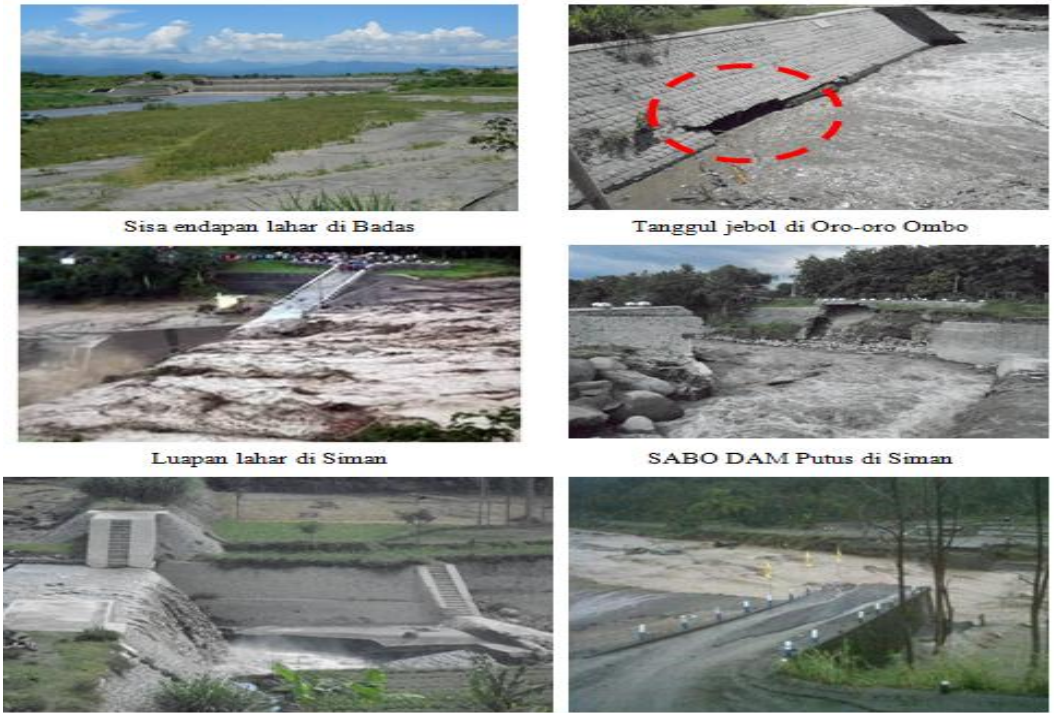

Figure 4.7 Damage DAM SABO

CONCLUSION

Based on research that has been done on the identification of changes in land use caused by the disaster volcano lava flow Kelud 2014 Konto River, it can be concluded some of the following:

1. The area affected by the lava flow contained in the two districts of Malang and Kediri. The most severely affected areas are in Malang, precisely in the Village Sukosari. The most widely affected land in the area is farmland.
2. There are no changes of land use settlement. Land use changes occur on agricultural land and infrastructure. Land use change much affected due to the lava flow in the middle of Kali Konto.
3. Impact of lava flows are loss in the population are farmers. Damage to agricultural land make decrease of agricultural productivity.

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