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The Study of Infrastructures and Riparian Area at Krasak Watershed, Indonesia

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Abstract. Debris flows due to the eruption of Mt. Merapi in 2010 caused damage at some infrastructure on the Krasak River. Some areas had been impacted by debris flow. It resulted in the severe damage at the streets which become an important access connecting Yogyakarta and Magelang. Krasak River is one of the rivers that has upstream on the Mt. Merapi slope and also got impact of debris flow in 2010. This research is aimed to figure out condition of infrastructure and edge of river at the Krasak River had been impacted by the debris flow. This research used survey method that directly observed the object of research to figure out the condition of the infrastructure and edges river with survey form 123. The result of the research showed some infrastructures on the river were damaged caused by the cold lava. Debris flow had happened in the past. Therefore, some of infrastructure had been repaired. However, there are some infrastructures which still has few damages. However, the function of this infrastructure showed good condition. Condition of river edges are still secured, it happens because the Krasak River had passed through regions plantation. However, there are some locations of the settlement in the riparian area or debris prone area.

Keywords: Debris Flow, River Infrastructure, Riparian Area, Krasak River.

INTRODUCTION

The geographical location of Java Island which lies on the ring of fire makes the island experience seismic events that trigger volcanic activity. One of the active volcanoes on the island of Java is Mount Merapi located in the Special Region of Yogyakarta and Central Java. Mount Merapi, which is located at an altitude of 2930 meters above sea level and is one of the most active volcanoes in the world, erupted in 2010. With a big eruption, Mount Merapi can eject volcanic material as high as approximately 1.5 km. One of the disasters caused by the eruption of Mount Merapi was debris flow that occurred because of volcanic material spreading across several rivers that were upstream on the slopes of Mount Merapi.

Before 2010, the condition of riparian and infrastructures along the rivers in Mount Merapi is in stable condition. At that time, there are no debris flows that damage the infrastructure and riparian. However, after Merapi eruption in 2010, debris flows often occurred in all rivers in Mount Merapi. This situation disturbed the stability of the existing infrastructures in the rivers and caused damage to the riparian. One of the rivers affected is the Krasak River which is on the border between Sleman Regency and Magelang Regency and has a length of approximately 27 km and runs on the Progo River. The debris flow that flows in the Krasak River carries a number of volcanic materials in the form of mountain ash and rock frigates which can flow more swiftly when compared with ordinary water flow. Because of that, debris flows can potentially damage infrastructure along the Krasak River, and can endanger the area on the left and right of the Krasak River.

The Minister of Public Works and Public Housing Regulation No. 28 of 2015 concerning the determination of riparian area and lake border lines, stipulates that river banks are the space between the edge of the riverbed and the bottom embankment legs located to the left and / right of the river trough. The riparian area is the virtual line on the left and right of the riverbed which are designated as the river protection boundary. However, the increasing population growth has resulted in the transfer of land functions, so that more buildings and population are on either side of the river so that the risk of debris flow increases.

According to Central Bureau of Statistics [1, 2], the population of Tempel sub-districts, one of the sub-districts crossed by the Krasak River, the total population in 2007 and 2010 were 49,310 and 51,815, respectively. Population density in 2007 was 1,564person/km^2 and in 2010 was 1,595person/km^2. With an increase in population, of course, it will be followed by an increase in the number of supporting infrastructures. Given the potential caused by debris flows that can damage infrastructure along the Krasak River and endanger the community around the border area of the Krasak River, a study of infrastructure and riparian area along the Krasak River was conducted. This research is intended to minimize the impact of debris flows, especially in the Krasak River.

LITERATURE REVIEWS

According to Ekacrudh (in [3]), the riparian area is an area that is limited by the outer border of the river which limits the establishment of buildings on the banks of the river and is designated as river protection. The distance can be different in each river, depending on the depth of the river, the presence of dikes, the position of the river, and the influence of sea water. River border is functioning for flood control and can also be used for the benefit of the surrounding community with the conditions and procedures that have been set. In order to realize the benefits of the river and control river damage, it is necessary to establish a riparian area, which is the boundary line for river protection. This riparian area line will then become the main reference in the activities of river utilization and protection as well as the settlement boundaries in the area along the river [4].

The width of the border set in Sukoharjo Regency is divided into two categories, namely absolute border and buffer border. The width of the border itself is the cumulative result of the absolute border of land use at a distance of 0 (zero) meters to a certain extent. Whereas the buffer border is based on land capability and has been implemented with the development of the riparian area [5]. Total population and the rapid pace of development have resulted in higher intensity of land use change. This change has an impact on the border of the river, which is a non-artificial area on the right and left along the river that serves to preserve and safeguard the river environment.The threat of eruption hazards coupled with the increasing number of vulnerable populations in disaster-prone areas causes the risk of disasters due to eruptions is still relatively high in the future. This condition indicates that disaster management activities carried out so far need to be improved from time to time [6]. Changes in land use that are increasing around the Krasak River have resulted in more housing and public facilities such as factories, office buildings, highways, etc. According to [7], the volume and inundation area will increase with increasing urbanization.

THEORETICAL BASIS

River

According to the Republic of Indonesia Minister of Public Works and Housing Regulation No. 28 / PRT / M / 2015 [8], rivers are natural and/or artificial waterways in the form of water drainage networks and water in them, starting from upstream to estuary, limited by right and left by border line. Based on the gradient analysis, there is a structure in the form of a fault which indicates by the maximum value on the horizontal gradient and the value of zero on the second vertical derivative. And this type of fault is a normal fault which is indicated by SVDmax greater than SVDmin. The possibility of this fault forming a basin that causes the direction of eruption of Mount Merapi often leads to the Southwest through this basin to Mount Patuk Alap Alap and Krasak River [9].

River Infrastructure

River infrastructure is very important in the process of controlling the river or water treatment in the river area. The shape and size of the river infrastructure adjusts the functions and needs of the infrastructure. Some examples of infrastructure in the river:

1. Bridges are buildings that allow a road to cross rivers / waterways and valleys or to cross other roads that are not of the same height [10].

2. Groundsill is a river infrastructure construction built transversely as a threshold that serves to control sediment and water flow velocity. The building placed 94 crosses the river and serves to keep the riverbed from descending [11]
3. Dam is one of the water buildings that functions to raise the water level so that it can be flowed to where it is needed. Dam is a construction used to hold the flow of water, and ensure that water is distributed evenly [12].
4. Check dam adalah a water building that functions to control sediment carried by the water flow and improve the riverbed so that the slope on the riverbed is better.
5. Shear wall is a construction that is built to hold land that has a slope / slope where the stability of the land cannot be guaranteed by the land itself. The building of retaining walls is used to withstand lateral soil pressure caused by landfill or unstable native land due to the topographical conditions [13].

Debris Flow

According to Wood dan Soulard (in[14]), debris flow is one of the volcanic hazards that can occur during the eruption period and there is a compilation of mixed volcanic materials with rainwater. Debris flow is dangerous when the volume of material is enlarged that flows in rivers that are upstream in volcanoes and hit settlements and infrastructure in the downstream region.

Volcanic eruption will produce volumes of lava with a large volume and will result in prochemical flow (sedimentary material). The volume of this sediment settles around the mountain slopes, especially in river. The sediment can be carried downstream into a high concentration of sediment transport, hereinafter referred to as debris flow [15]. The debris flow flood disaster can be more dangerous than the eruption of the volcano itself. Due to the threat of debris flow not only along the river on the slopes of the volcano, at the foot of the mountain is even more dangerous because it is a free gliding zone.

Riparian Area

According to [16], Riparian area is a very important area, because the border is an area that gives floods to the right and left. Therefore, the speed of water to the downstream can be reduced, and energy can be reduced. The erosion on river banks and on the river bed decreases. According to [17], a riparian is area as a thin band-shaped area that flanks a water channel in riparians, including areas where living things that are fused or affected by a water body live. Riparian area width, can be determined based on the count of flood plan and based on physical study of the ecology, hydraulics and morphology of the river directly in the field. Determination of the width of the river border using the flood plan method generally has difficulty in implementing it in the community, because the community has difficulty understanding the meaning of the flood count plan. A fertile border ecosystem makes the water conversion along the river flow maintained, because the vegetation component that functions as a supplier of nutrients to the fauna in the river [18].

In Minister of Public Works Regulation No. 63 of 1993 as shown in **TABLE 1**, states that the determination of riparian area lines are an effort so that the activities of protection, use and control of natural resources in rivers including lakes or reservoirs can be carried out in accordance with its objectives, namely:

1. The function of rivers or lakes or reservoirs is not disturbed by existing activities in the vicinity.
2. Utilization and efforts to increase the value of existing natural resources can provide optimal results and can maintain the function of rivers or reservoirs or lakes.
3. Damage caused by activities in rivers or lakes or reservoirs can be limited.

TABLE 1. Criteria for determining riparian area

No.	Types of River	Outside Urban Area		Inside Urban Area		Article
		Criteria	Min. Riparian Area Width	Criteria	Min. Riparian Area Width	
1	Reinforced River Embankment	-	5 m	-	3 m	7 & 8
2	Unreinforced River Embankment	Large river (Watershed area> 500 km^2)	100 m	Depth ≤ 3 m	10 m	5& 6
			50 m	Depth 3 -20 m	15 m	5& 6

		Small river (Watershed area< 500 km²)		Depth>20 m	30 m	5& 6
4	Watersprings	-	200 m	-	200 m	11
5	Tidal-affected rivers	Riparian area determinations are as same as non tidal-affected rivers				10

Source: The Minister of Public Works and Public Housing Regulation No. 28 of 2015 [8]

Geographic Information System (GIS)

Geographic Information System or in the Indonesian Geographic Information System is a technology in the geographical field that can analyze and disseminate information on the location or natural resources that exist in an area. Geographic Information System is a computer-based system used to enter, store, manage, analyze and reactivate data that has a lack of references for various purposes related [19]. According to [4], the advantage of GIS technology compared to conventional databases lies in the possibility of interrelated data and can also make structured analysis.

RESEARCH METHODOLOGY

The steps in this research are data collection, data processing with ArcGIS and data analysis. Data collection was performed by using two methods: primary and secondary data collection. Secondary data included RBI maps and Google Earth of research location. Both data were used as a basic for creating watersheds and river riparian. Primary data collection was conducted by using the form survey123 application, which can be used online. The data recorded is the condition of the river border, public facilities, river infrastructure, riverbank reinforcement, riverbed material and river cross-section data, including photographs of the data.

This infrastructure and riparian area study was conducted on the Krasak River with a length of 27 km that has the upstream slope of Mount Merapi in Ngablak Village, Magelang Regency and Ngargomulyo Village, Sleman Regency and has downstream in Bligo Village, Magelang Regency and Banyurejo Village, Sleman Regency that connects to the Progo River.

Data Collecting Methods

In collecting research data, the study of infrastructure and riparian used primary data and secondary data. Tools and materials used to conduct surveys included smart phones, length measuring devices and GPS.

a. Primary data obtained from data collection using online 123 survey form were connected directly to ArcGIS online.
b. Secondary data obtained from satellite maps / google earth were used to determine the location / coordinates of the infrastructure located along the Krasak River, and the RBI Map was used in the creation of Watershed Areas (DAS) and mapping of the Krasak River border area.

Research Implementation

This research began by determining the location of the study to be reviewed and then conducted a literature study and observe the problems that existed in the location of the research and research objectives.

1. Data collection by using Survey123
   The data collection was carried out in the location of study in the Krasak River which is the border between Sleman Regency and Magelang Regency. The data collection in the field used digital forms made through XLForm which is supported to connect with Survey123 is a survey. Survey123 has two types: Survey123 which is connected to ArcGIS and Survey123 For ArcGIS [20]. The first step in collecting the data is to create a survey form with any reference that is reviewed, and use google erth to determine the location of the study.
2. Analysis of research results
   The results of field surveys that are entered into the survey form will automatically be analyzed in the form of graphs, diagrams and maps. However, for population density in border areas it is necessary to

match the results of the width of settlements that are in the border of argics with the total population obtained from disdukcapil.

3. Making watershed and border lines
The administrative regions of Sleman Regency and Magelang Regency obtained from the Tanahairindonesia.co.id site are then processed in ArcGIS to find out the areas included in the Krasak River Watershed, and the areas included in the specified border line.

RESULTS AND DISCUSSION

The Krasak River has a watershed area of 32,715 km^2 and has a river length of 27 km whose upper reaches is located on the slopes of Mount Merapi precisely in Ngablak Village, Magelang Regency and Ngargomulyo Village, Sleman Regency. Its downstream are in Bligo Village, Magelang Regency and Banyurejo Village, Sleman Regency is a confluence with the Progo River (figure 2). Krasak River is one of several rivers that are passed by debris flows.

For the Sleman regency, which is included in the Krasak River watershed of 3 sub-districts and 9 villages, the population is shown in Table 2 and Table 3, as follows.

TABLE 2. Population and area each administrasion region of Sleman Regency

Sub-District	Total Population (individual)	Area (Ha)	Population Density (individual /Ha)
Turi	37,192	2,537.72	15
Tempel	54,407	2,015.53	27
Pakem	37,537	4,240.63	9
Total	**129,136**	**8,794**	**51**

TABLE 3. Population and area each administrasion region of Magelang Regency

Sub-District	Total Population (individual)	Area (Ha)	Population Density (individual /Ha)
Srumbung	48,339	1,888.25	26
Ngluwar	32,415	1,074.34	30
Dukun	46,730	1,777.36	26
Ngablak	41,569	1,125.66	37
Salam	47,605	558.42	85
Total	**216,658**	**6,424**	**204**

In 2018, Sleman Regency has an area of 57,480 hectares with a population of 1,063,938 people, and an area that includes the Krasak River watershed covering an area with a population of 129,136 inhabitants. For Magelang Regency the area included in the Krasak River Watershed is 5 sub-districts and 11 villages. In 2017 the area was 108,573 ha with a population of 1,278,624 people, and the area including Sungai Krasak watershed was 6,424 hectares with a population of 216,658 inhabitants. From these data, it can be used to assume the total of residents in the Krasak River watershed (Table 4 and Table 5). This analysis uses ArcGIS 10.2.1 software with reference to using village administrative boundaries from Sleman Regency and Magelang Regency. Then the village administration map is grouped into one included in the Krasak River watershed as shown in figure 1.

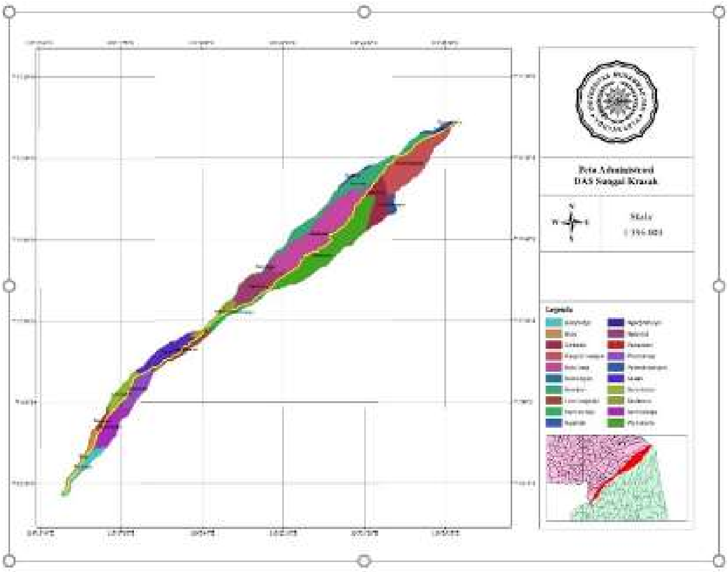


FIGURE 1. Administration map of Krasak Watershed

TABLE 4. Population and area each administrasion region inside the watershed of Sleman Regency

Sub-District	Area inside the Watershed (Ha)	Population Density (individual /Ha)	Prediction of Total Population inside the Watershed
Turi	770	15	11,288
Tempel	892	27	24,079
Pakem	425	9	3,760
Total	**2,087**	**8,794**	**39,127**

TABLE 5. Population and area each administrasion region inside the watershed of Magelang Regency

Sub-District	Area inside the Watershed (Ha)	Population Density (individual /Ha)	Prediction of Total Population inside the Watershed
Srumbung	345	26	8,842
Ngluwar	358	30	10,809
Dukun	7	26	182
Ngablak	364	37	13,431
Salam	144	85	12,243
Total	**1,218**	**204**	**45,508**

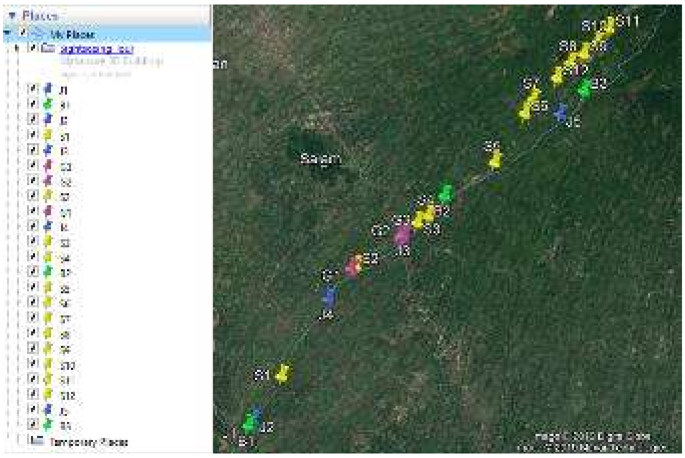
Table 4 shows the area included in the Krasak River watershed has an area of 2,087 hectares with an estimated population of 39,127 watersheds. From Table 5, it is known that the area included in the Krasak River watershed has an area of 1,218 Ha with an estimated population of 45,508 inhabitants. Land use of the Krasak River watershed is shown in Table 6.

TABLE 6. Land use area of Krasak Watershed

Land Use	Area (Ha)
Plantation	745.68
Settlement	698.74
Paddy field	1023.11
Rainfed agriculture	803.97
Total	3271.50

Infrastructure Condition

In conducting a survey on the Krasak River, first determine the locations of infrastructure located along the river with the help of Google Earth. The field survey was conducted by using survey123 for ArcGIS survey data was obtained which would later be reviewed with the regulations that had been set. River infrastructure is an important issue for river control or as a connection between one region and another which is cut off by the river. From the results of a direct survey on the Krasak River using survey123 forms, there are 29 infrastructure points located along the Krasak River (figure 2). Some infrastructures are on the Krasak River, namely bridges, Sabo dam, groundsill and retaining walls.



Information :
J : Bridge
S : Sabo Dam
B : Weir
G : Groundsill

Source: Google Maps 2019

FIGURE 2. Infrastucture location points of Krasak River

Along the Krasak River there are several infrastructures that aim to minimize debris flow and to access roads for the communities around the Krasak River, some of which are.

1. Bridge

Along the Krasak River, there are 6 bridges that are used for the people's access. The materials of this bridge consisted of concrete and steel, the condition of the bridge is fairly good, there are no major damages caused by debris flow, it's just that there is potential scour caused by the flow of water in the river cross section because there are not retaining walls on most of those bridges. The dimensions of the bridge are varied based on the width of the river. One of the bridges from the survey is located in Wonokerto Village, Sleman Regency. The scour has been found on the bridge's abutment, and there are no retaining walls before and after the bridge. The bridge does not have pillars on the river, and has river bed rock material.

2. Sabo Dam

Sabo Dams are the infrastructure which are mostly found along the Krasak River. Krasak river requires infrastructure that can withstand the debris flow. There are 16 Sabo DAMs along the Krasak River with good conditions that have been repaired due to debris flows in 2010. The dimensions of the Sabo Dam are big due to its function that holds the rate of debris flow. One of them is Sabo Dam located in Merdikorejo Village, Sleman Regency.

The condition of Sabo Dam in the picture above shows that it has been improved after the debris flow in 2010. With its improved condition, the Sabo Dam functions well and has riverbed material in the form of gravel, only a small scour is seen on the body of the Sabo Dam. Due to the little flow of water, the riverbank turns into a community plantation area. There are still a lot of sediment carried by the water flow on the upstream of Sabo Dam.

3. Weir

One of the results of an infrastructure survey in the form of a weir is a weir located in Merdikorejo Village, Sleman Regency. The condition of the weir in the picture above still functions well, and the retaining wall does not experience severe scouring, there are many large sedimentary rocks carried by the currents of the debris flow in 2010.

4. Groundsill

Along the Krasak River, only few groundsills are found. This infrastructure serves to make the slope of the riverbed sloping so that the flow of water is slower and the water gets bigger. The condition of grounsill is quite good with dimensions following the width of the river. One of them is Groundsill located in Lumbungrejo Village, Sleman Regency. The groundsill condition is still functioning properly, only seen a small scour in the retaining wall. Considering the number of infrastructures along the Krasak River, it shows that there are quite a lot of activities from the residents associated with the river. The number of infrastructures has a tendency to increase with the increase in population. The condition of the infrastructures in when the survey conducted is still good. Several Sabo dams have been renovated after the 2010 Merapi eruption. Compared with similar research by Wardani et al [21], related the urban design spatial in the Brantas River in Malang City (East Java), it shows that there is an increase in community activity and the number of infrastructure along the Brantas River. The research conducted has similarities with the results of research from Wardani et al. It means that the amount of infrastructure along a river has increased from time to time.

Riparian Area Condition

Based on Table 1 regarding the criteria for river border, it can be concluded that the Krasak River is included in a river with a width of 5 meters and 50 meters from the right and left bank of the river. These criteria are set because the Krasak River is located outside the city and has embankments in several infrastructures. Table 7 shows the land use of the riparian. Table 8 and Table 9 show the settlement condition in the riparian area. Table 7 shows that the border area of the Krasak River is dominated by rice fields with an area of 67.95 hectares and has a percentage of 46.03%. Settlement area is about 1.4 Ha or has percentage of 8.04%. In addition, Table 7 and Table 8 shows the settlement area of Sleman Regency and Magelang Regency which are located on the riparian of the Krasak River. The settlement area of Sleman Regency in the riparian area is 46.66 Ha, where the Tempel Subdistrict area is the area with the most settlement area that enters a border of 32.95 Ha. In addition, the settlement area of Magelang Regency which is located in the riparian area is 36.37 Ha, where the Srumbung District area is the most extensive area of settlements in the border area of 23.03 Ha.

TABLE 7. Land use area inside the riparian area

Land Use	Area (Ha)	Percentage of Land Use
Plantation	49.41	33.47
Settlement	1.48	8.04
Paddy field	67.95	46.03
Rainfed agriculture	18.39	12.46
Total	**147.62**	**100**

TABLE 8. Settlement percentage each administrasion region inside the riparian area of Sleman Regency

Sub-District	Area inside the Riparian (Ha)	Settlement Area (Ha)	Settlement percentage inside the Riparian
Turi	22.19	13.71	18.55
Tempel	39.47	32.95	44.60
Pakem	12.23	0.00	0.00
Total	**73.89**	**46.66**	**63.15**

TABLE 9. Settlement percentage each administrasion region inside the riparian area of Sleman Regency

Sub-District	Area inside the Riparian (Ha)	Settlement Area (Ha)	Settlement percentage inside the Riparian
Srumbung	42.80	23.03	31.24
Ngluwur	19.37	5.71	7.74
Dukun	0.00	0.00	0.00
Ngablak	2.71	0.00	0.00
Salam	8.85	7.63	10.35
Total	**73.73**	**36.37**	**49.33**

Based on research by [22], the largest land use in the riparian of in upstream Cimanuk watershed is agriculture of 62% and settlement of 1%. [23] reported land use of riparian of Sumbergunung River in Batu City, Malang, the area of agricultural land is approximately 27.16% and settlement is 1.4%. Compared to the two studies before, the condition of the riparian in the Krasak River, the area for settlement is wider. The dominance of land use on the Krasak River is similar to the land use on the upstream Cimanuk River, which is dominated by agricultural land. However, land use in the Krasak River is different from the results of land use research in Sumbergunung River, Kota Batu, Malang, where agricultural land use is 27.16%. The dominance of land use in the Sumbergunung River is for non-cultivation use of 48.43%.

CONCLUSION

Based on the results of the survey and analysis of data taken from Sungak Krasak, it shows that the infrastructure on the Krasak River is still functioning properly, because after the debris flow in 2010 all damaged infrastructure has been repaired. It is just that small damage is seen in the form of scour caused by river water flow. Overall, the condition of the infrastructure in the Krasak River has good conditions and functions, because all of the damaged infrastructure after the lahar flooding in 2010 has been improved. However, due to the long period of time of the repair and survey period, there are several infrastructures that suffer from minor damage in the form of scouring on the part of the building. Based on the analysis of population density along the Krasak River, it is evident that there are still many people who build buildings in the river border area. Because of the increasing number of people which has resulted in the shifting of land functions, and the lack of government information on border areas. Therefore, some locations of the settlement are in the riparian area or debris prone area.

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