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Formation analysis and characteristic estimation of the debris flow disaster of Mengdong River, Malipo County on September 2nd, 2018

CHEN Zhi^{1,2*}, LIU Chuanqiu², ZHOU Yue¹

¹ Faculty of Environmental Science and Engineering, Kunming University of Science and Technology, Kunming 650500, China;

² Yunnan Institute of Geological Engineering Survey and Design, Kunming 650041, China;

*Corresponding author: CHEN Zhi; email: 251030793@qq.com; phone:15587231431.

ABSTRACT: Based on the on-site investigation of debris flow disasters in Mengdong River Basin of Malipo County on September 2, 2018, the characteristics of disasters and their formation and evolution process are analyzed from the aspects of source, topography and water resources. Heavy rainfall is the inducement factor of this debris flow. The complex topographic and geomorphological features in the channel provide conditions for the evolution and scale-up of the debris flow: (1) hundreds of shallow soil landslides in the region provide sufficient material resources for the debris flow, enhance the hydrodynamic conditions of the debris flow and increase the amount of erosion along the way; (2) multiple bedrock entrapments and falls in the channel enlarged the debris flow. The scale and velocity of debris flow; (3) The volume weight of debris flow increases gradually with the supply of solid materials along the way. The study shows that precipitation is the fundamental cause of debris flow. The precipitation causes the initiation and overlap of landslide, slope and channel sources in the valley. From the development trend, the debris flow in the valley is in the stage of high frequency development, and the possibility of large-scale debris flow still exists. The possibility and frequency of occurrence will be greatly increased. High frequency and small and medium-sized debris flows will be the characteristics of debris flow activities in this gully in the future. It is necessary to control ditches in time and strengthen monitoring and early warning.

1. Introduction

Yunnan, as the representative of the climatic zone of the low latitude plateau, the special geographical location is affected by the tropical storms generated by the southwest monsoon, the western Pacific, the Bengal, B. Of and the South China Sea, and the spatial and temporal distribution of the heavy precipitation events and extreme precipitation events is very complicated, and there are obvious differences with other parts of the country[1-2]. The geological hazards induced by heavy precipitation in Yunnan are characterized by a wide range of points and complex and diverse types of geological hazards [3], especially flash flood, debris flow and landslide disaster, The serious threat to the life and property safety of the people in the mountain area is the main factor restricting the development of Yunnan, the situation of disaster prevention and reduction is grim [4]. The debris flow in Yunnan province is dominated by gully debris flow, which causes great disasters when the debris flow in gully is broken, such as the mudslide in Venezuela, South America, killed 50,000 people in 1999 and a



mudslide in Zhouqu, Gansu province, China, killed 1744 people in 2010[5]. There are 3 main ways of formation of gully debris flow: ① Ahead of the flood starting, the accumulation of the provenance from landslide and collapse in the ditch bed generates the gully mudslide. The strong rainfall confluence forming the powerful flash flood is the formation characteristic of this kind of debris flow; ② A number of shallow landslide collections in the Basin Form Gully mudslides. And a long period of rainfall forms the formation of many shallow landslides in the channel, and the flow of flash floods out of the channel is the formation characteristics of such mudslides; ③ Glacial lake outburst erosion ditch bed and slope to form gully debris flow, higher temperature induced glacier frontier fracture and fell into the glacial lake, causing the moraine Lake outburst to form a powerful outburst flood, the formation of gully debris flow is the formation of such debris flow characteristics [6-7]. The gully mudslides induced by shallow landslide are mainly distributed in the eastern coastal areas of China, such as Liaoning, Zhejiang, Fujian and Taiwan, and there are sometimes such mudslides in western China [8]. With the increasing impact of climate change on extreme weather and climate events in Yunnan [9], the intensity and frequency of heavy precipitation have increased everywhere, which increase the risk of flash flood geological disasters, especially the increase of heavy precipitation events in the main flood season, which results the increasing frequency of geological disasters such as flash floods, mudslides and landslides [10]. Many scholars at home and abroad have done some research on the starting of debris flow, and some good criteria for determining the starting of debris flow have been obtained in the research results. Among them, the most representatives are Cui Peng and Dai Fuchu and other researchers at home. The experimental study on the starting mechanism of debris flow was carried out by Cui Peng in Jiuzhaigou in 1989 [11-12], and three main factors affecting the starting of debris flow were considered in the experiment: bottom bed slope, particle grading and water condition. The site survey and test of the 2013-07-10 debris flow disaster in Taoguan gully were carried out, and the mechanism and development trend of debris flow were revealed [13]. In addition, Dr. Iverson of the United States Geological Survey [14-15], drawing on the theory of pore water pressure growth and dissipation in soil mechanics, studied the mechanism of pore pressure growth, dissipation and maintenance during the start and movement of debris flow.. From 3:00 to 4:00 a.m. on September 2, 2018, a large number of landslides occurred on the shallow surface of the ditches and banks of the river basin caused by a single point of heavy rainfall (211.9 mm from 8:00 on September 1 to 8:00 on September 2, and 97.4 mm from the maximum rainfall in an hour). About 550 landslides occurred in the area above the bridge of the local government stationed in Mengdong River and in the Shuichongxiang and Xiangcaopeng valleys, which triggered a huge mountain flood and debris flow disaster. The disaster caused 10 deaths, 7 injuries, 11 loss of contact, and many houses were damaged and some collapsed. The debris flow deposits seriously blocked rivers, silted streets and shops. A large number of farmland was buried and the direct economic loss reached 1.4 billion yuan. Hundreds of landslides are developed in the current debris flow ditches. Loose material sources are extremely abundant. Under the adverse factors such as single rainstorm or persistent heavy rainfall, the possibility of debris flow disaster breaking out again is extremely great, which seriously threatens the lives and property safety of about 3000 downstream residents, schools, institutions and institutions. The hazard level of debris flow is very large and the danger level is very large. At present, the study of this debris flow event has not been carried out. This paper studies the topography and rainfall conditions of this kind of debris flow, and then studies the relationship between these two conditions, and puts forward the critical conditions of debris flow outbreak under this kind of geological conditions, which lays a foundation for predicting and forecasting the gully debris flow induced by shallow landslides.

2. Material and Methods

2.1. Background of the study area

2.1.1. Regional environment

Malipo County is located in the south of Yunnan-Guizhou Plateau in the middle mountains valley area,

which is located in the south of the Tropic of Cancer with low latitude. The county climate summer is mainly controlled by the ocean warm current northward, the winter is mainly affected by the cold plateau of the south, the main climate type is the humid mountain monsoon climate in the subtropical plateau. The precipitation in Malipo County is abundant, the average annual rainfall is 1059.5mm, the average annual rainfall in Mengdong town is 1430.9mm, The rainy season usually lasts from April to October every year, the main strata distributed in the Basin are the Quaternary period debris flow accumulation layer (Q_4^{sef}), artificial stacking layer (Q_4^{ml}), residual slope accumulation layer (Q_4^{el+dl}), alluvium and diluvium (Q_4^{al+pl}). The regional metamorphic rocks widely distributed in the basin are located in the Dulong metamorphic area, which is the outer spin layer of Laojunshan spiral structure-lotus structure. The metamorphic rocks in the basin can be divided into granitic gneiss and parametamorphic rocks according to their genesis. The study area is located in the southeast of the Lotus-like structure system in Laojunshan. The Lotus-like structure in Mount Laojunshan has a strict influence on the distribution and development of landslides and debris flows in the basin. The main faults in this area are arc oblique thrust faults of Jinzhushan-Mengdong, and faults of unknown nature. There is no large earthquake record in history and the intensity of the earthquake is weak. However, in recent years, there have been successive earthquakes with magnitude of 5.25-5.5 in Vietnam, which have a certain impact on the study area.

2.1.2 Watershed characteristics

The geographical coordinates of the study area are between 22°50'00"~22°55'00" east longitude 104°37'30"~104°45'00" north latitude. Mengdong River is the first tributary of Panlong River, a tributary of the Red River. Its general flow direction is from south-west to north-east. The total length of the main stream is 23.5 km, with a drop of 950 m and an average longitudinal slope of 40.4. The watershed area is 134.2 km², with an average annual runoff of 134 million m³. Xiangcaopeng and Shuichongxiang gullies are tributaries of Mengdong River in the study area. The bank collapse is serious, and most of them are concentrated and patches of shallow soil landslides. The micro-landform of the government of Mengdong Township is an alluvial platform in mountain valleys. The residential area of the township government is about 500 m long, 500 m wide and about 0.25 km². It is located at the intersection of the mainstream of Mengdong River and its tributary, the branch of Shuichongxiang and Xiangcaopeng. The upper reaches of the mainstream of Mengdong River pass through the northwest side of the township government's residential area, the branch of Shuichongxiang passes through the East side, and It passes through the middle part of the mountain and is generally in the Piedmont area, which is located at the boundary of erosion and accumulation.

2.2. Nature and geological background of debris flow

2.2.1. Rainfall condition

Water is one of the basic conditions for the formation of debris flow, the water flow in this area is mainly from atmospheric precipitation, The rainfall from 8:00 on August 30 to 8:00 on August 31 is 21.8 mm; from 8:00 on August 31 to 8:00 on September 1 is 21.7 mm; from 8:00 on September 1 to 8:00 on September 2 is 211.9 mm; and from 8:00 on September 2 to 8:00 on September 3 is 46.2 mm. Rainfall usually tends to increase with the increase of altitude. Therefore, it can be inferred that the precipitation in the early stage is more than 67.3 mm, and the precipitation in the day is also more than 104 mm. Rainfall is the main factor to stimulate the shallow landslide and debris flow in Mengdong Township. Obviously, the rainfall conditions causing the "9.02" debris flow are characterized by large rainfall, long rainfall duration and high rainfall intensity. According to the literature [19], the critical rainfall of debris flow in Wenshan area is 115.2-164.0 mm, and the hourly rainfall intensity is 50-80 mm. The stimulated rainfall intensity fully satisfies the rainfall conditions of "9.02" debris flow in Mengdong Township..

2.2.2. Provenance condition

The solid loose material sources of debris flow gully in the study area are mainly landslide, slope erosion and gully bed accumulation. The provenance conditions of each ditch are as follows:

- (1) Landslide: There are 565 landslides in the basin, most of which are located directly in the gully.

The current situation has basically caused slip damage. According to the investigation, about 80% of the landslides located in the gully are directly involved in 9.02 mega-debris flow activities. About 20% of the current landslides are left on the slope or accumulated at the foot of the slope. About 60% of the landslides are involved in 9.02 debris flow activities. According to the field investigation, it is estimated that about 15% of the landslides can directly participate in the next debris flow activity. 90% of the landslide deposits stay directly on the road surface, about 10% cross the road, enter the debris flow channel along the slope or gully, and participate in debris flow activities.

(2) Slope erosion Category: The study area belongs to the southwest earth-rock mountainous area in China with hydraulic erosion as the main factor. Combining with vegetation type, topographic gradient and disaster development on the slope, the area calculated by the source amount is measured on the topographic map. Because the areas with severe erosion are mostly located on the gully bank, 70% of the water can directly participate in debris flow activities, and the areas with moderate and mild erosion are mostly far away from the gully. According to 20% of the debris flow movable animal source, the age is 30 years. According to the erosion modulus of each region, the solid loose matter of debris flow can be provided annually in different areas of the debris flow Valley according to the following formula: $W = A \times M$. In style: W -annual soil erosion total, t/a; A -soil and water loss area, km²; M -erosion modulus, t/km²·a.

Tab.1 Statistics about different types of loose materials in the study area of debris flow basin

PT	GN	SR (10 ⁴ m ³)	DR (10 ⁴ m ³)	POS (%)	MRS (10 ⁴ /m ³)	PTOMR (%)	Basic characteristics
Landslide	MD.R	229.70	42.99	18.72	107.95	31.51	315 places
	SCX	283.70	56.03	19.75			239 places
	XCP	45.96	8.93	19.42			60 places
Slope Erosion	MD.R	217.90	121.80	55.90	213.62	62.35	Various types of genetic deposits
	SCX	127.60	79.16	62.04			
	XCP	20.48	12.66	61.82			
Channel Accumulate	MD.R	12.69	12.06	95.00	21.07	6.15	Accumulates Distributing along Channels
	SCX	8.25	7.84	95.00			
	XCP	1.24	1.18	95.00			
Total		925.34	342.64				

* (In the above tab, PT is short for provenance type, MD.R is short for the gully name Mengdong River; SCX is short for the gully name Shuichongxiang; River; XCP is short for the gully name Xiangcaopeng; SR refers Static reserves; DR refers Dynamic reserves; POS refers Percentage of static reserves; MRS refers Momentum reserve subtotal; PTOMR refers Percentage of total momentum reserves). And as the following tables; Statistical estimation of all kinds of momentum reserves is based on natural repose angle, slope erosion modulus and channel cutting depth, respectively.)

(3) Trench bed deposits: Hundreds of landslides in the basin provide abundant material sources for the outbreak of 9.02 debris flow. After the outbreak of 9.02 debris flow, part of the loose material sources provided by landslides are taken away with debris flow, and part of them are accumulated at the wide and gentle channel or at the intersection of branch and main channel due to the weakening of hydrodynamic conditions of channel widening and longitudinal slope slowing down. According to field investigation, Specific data are shown in Table 1 above.

From the view of the point of the distribution sources, there is no trend of special concentration distribution of various source points, in each branch and main ditch are distributed, in terms of the total amount of source, static reserves and dynamic reserves, MD.R rank first, XCP rank the third, after the heavy precipitation, the number of disintegrating sources has surged, And the blockage outburst caused by the channel, which leads to the increase of the starting amount of the channel accumulation source, all provide the conditions for the gestation and occurrence of the "9.02" large debris flow in the peach groove.

2.2.3. Topographic condition

The debris flow basin of Mengdong River is a "ladle" shape with an area of 14 km², which can be summarized as "three sides surrounded by mountains, middle Valley and East outlet". Its topography has catchment conditions. The slope of the middle reaches is 25 to 55 and the gullies are mostly "U" shaped. The downstream terrain is relatively flat. The whole debris flow basin of Shuichongxiang is in a "ladle" shape with an area of 5.98 km². It can be summarized as "three sides surrounded by mountains, middle Valley and North outlet". The upstream gullies of the basin are mostly "V" shaped. There are some water-fall canals, ranging in height from 1.5 to 3 m, and the downstream terrain is relatively flat. The whole debris flow basin in the Xinagcaopeng gully is "leaf" shape, the basin area is 0.88 km², the area of adverse geological phenomena and slope erosion is more developed, gully banks and gully beds accumulate a large number of loose solid sources. There are some water-falling ridges with a height of about 1.5 m, and the downstream terrain is relatively flat.

The topographic characteristics of the above three debris flow gullies are shown in the below Tab.2.

Tab.2 Characteristic table of debris flow basin

Contents	MD.R			SCX			XCP		
	FA	CA	AA	FA	CA	AA	FA	CA	AA
A (km ²)	12.245	14	0.065	4.82	5.98	0.062	0.726	0.8	0.05
H (m)	432	41	8	500	42	8	289	19	10.5
L (km)	3.65	6.34	0.7	2.98	5.01	0.47	1.18	1.99	0.42
I (‰)	118.36	75.87	11.43	168	109.78	17.02	244.92	160.05	25
		20.6			26.92			48.72	

* (In the above tab,A refers Drainage area;H refers Relative elevation difference;L refers Channel length;I refers Longitudinal gradient;FA refers Formation area;CA refers Circulation area; AA refers Accumulation area)

3. Results

3.1. The outbreak and movement characteristics of "9.02" debris flow

According to the on-site investigation, at 3-4 a.m. on Sep 2nd, 2018, there was a debris flow in the market town of Mengdong Township, Malipo County. The debris flow was divided into three parts. Three debris flows (Mengdong River, Xiangcaopeng and Shuichongxiang) scoured the market town at the same time and surrounded the market town. According to the on-site investigation and the statistics of sludge removal project, 1.16 million m³ of debris flow deposits were cleared in four days. The single debris flow is large, and the three debris flows are super large. According to the mud scar section, the peak flow of debris flow in Mengdong River, Shuichongxiang and Xiangxiangpeng estuaries is estimated to be 310 m³/s, 170 m³/s and 97 m³/s, respectively.



Pho.1 The 9.02 Debris Flow Disaster Panorama

3.2. Dynamic characteristics of "9.02" debris flow

Debris flow volume weight, velocity of movement, flow rate and total amount of primary erosion are important dynamic characteristics of debris flow, and also important parameters for engineering prevention and control [9-10]. The average volume weight of "9.02" debris flow is 1.65 t/m³, which belongs to viscous debris flow. The flow rate of debris flow is determined by precipitation, basin area and flow velocity.

The maximum daily rainfall in Malipo County and Mengdong Township over the years was calculated by weighted average statistics, and the empirical frequency curve was drawn. Pearson III distribution curve was selected to fit the distribution line. By mathematical statistics calculation, the average daily maximum rainfall was calculated to be 88mm, variation coefficient CV was 0.42, CS was 3.5CV=1.47. Chapter 19 of the hydrological Manual of Yunnan Province shows that the once-in-100-year ratio coefficient is 2.31, the once-in-50-year ratio coefficient is 2.08 and the once-in-30-year ratio coefficient is 1.88. By measuring the typical mud-trace section area and the longitudinal slope of the channel in the circulation section of the Mengdong River basin, the rain flood correction method is used, and combined with the blockage outburst of the loose source of the channel, the overall average value of the blockage coefficient is 2.32, and the middle and outlet parts of the circulation area can be obtained according flow velocity and flow values at typical section locations. Combined with the calculation results of mud trace investigation method, it is shown that the rainfall frequency corresponding to the debris flow is equivalent to 100 years. Considering the duration of the "9.02" debris flow outbreak of about 2 h, the total amount of a debris flow and the total amount of solids of the peach closed ditch groove can be obtained according to the formula, as shown in table 3. The accumulation area and the average stacking thickness of the debris flow in the town area of the Gully estuary, as well as the scale of the outlet and dredging, can determine that the flow of the mudslide is 1.1 million m³, and compared with the results of table 2, it also shows that it is roughly equivalent to the scale of the rain in 20.

The design of clear water flow is calculated by two kinds of common small watershed rainstorm flood calculation methods, that is, hydrology Research institute method and hydrological manual method, by comparison, the calculation results of Hydrology Research Institute are more in line with the results of field survey and access investigation, and after consideration of various factors, the water flood peak flow is calculated by hydrology research method. The flow rate is calculated by rain flood correction method (Dongchuan debris flow formula) and morphological investigation method respectively to determine the optimum flow rate of debris flow. By comparison, the flow rate is calculated by rain flood correction method. Rain Flood correction method

$$Q_c = Q_w \times (1 + \varphi) \times D_c \quad (\text{Flow formula of Dongchuan mudslide})$$

In the formula: Q_c -debris flow (m³/s);

Q_w -Design Water flow (m³/s), using Yunnan Province Hydrological manual method to calculate the

value; D_c -the blockage coefficient of debris flow; φ -debris flow sediment correction coefficient, $\varphi = (p_c - 1) / (p_H - p_c)$. The results of debris flow calculation calculated by rain flood correction method are shown in the table3 below.

Tab.3 The results of a debris flow and total run-off volume calculated by rain flood correction method

Gully name	Frequency (P%)	Q_w (m ³ /s)	φ	D_c	Peak flow rate	Total amount	Total Solid Quantity
					m ³ /s	×104m ³	×104m ³
MD.R	3.3	79.7	0.74	2.32	321.37	30.62	22.6
	2	88.176	0.74	2.32	355.56	33.88	25.01
	1	97.93	0.74	2.32	394.88	37.63	27.77
SCX	3.3	31.02	0.79	2.32	128.69	31.41	13.86
	2	35.26	0.79	2.32	146.29	35.71	15.76
	1	40.08	0.79	2.32	166.3	40.59	17.92
XCP	3.3	9.58	0.79	4.45	76.12	22.14	9.77
	2	10.89	0.79	4.45	86.51	25.16	11.11
	1	12.35	0.79	4.45	98.18	28.56	12.6

4. Discussion

4.1. Analysis on the mechanism of "9.02" debris flow disaster

The river basin is abundant rainfall, three-dimensional small area of the climate is more prominent, vegetation cover in the basin is very good, gully coastal slope groove collapse is serious, rich trench bank accumulation and slope loose debris for the occurrence of debris flow provides a wealth of source conditions; Coupled with the gully catchment conditions are good, sufficient water power. For the above conditions, debris flow outbreak is inevitable. Traditionally, areas with good vegetation cover have a light soil erosion and are not prone to mudslides, and no debris flow has been recorded in this area before. But vegetation is only one aspect, the key is also rainstorm and geological source factors. (1) First, in the area of debris flow formation, under the action of early concentrated rainfall, the original geotechnical body has tended to saturation, the late rainfall has formed runoff; (2) Surface runoff infiltrates and scour the loose debris of the broken surface, carrying a large amount of loose material to gather in the ditch to form a flash flood; (3) The debris of the collapsed pile on the trench bank is infiltrated and disintegrated, and the part of the trench bed accumulation is restarted again, and (4) the terrain in the basin is relatively high and poor Thus developed into a mudslide.

4.2. Analysis on the development trend of debris flow

The debris flow gully in the study area has the material and topographic conditions of debris flow outbreak. As long as it is induced by continuous rainstorm, a debris flow may occur. Its scale depends on loose material sources, hydrodynamic conditions, blockage degree of gully bed and engineering geological conditions of rock and soil mass. The scale of debris flow activity will deteriorate with the further deterioration of ecological and geological environment, and the intensity of debris flow activity will be determined comprehensively. The increase is inevitable. The development trend of debris flow is predicted as follows:

(1) In the basin, the rock mass is strongly weathered, the structure is loose, the slope is steep and the water retention of vegetation is poor, the slope erosion is serious, and the landslide is very developed. With the arrival of the rainy season, the number, scale and scope of landslides will continue to expand, and the total amount of movable solid loose materials and the scope of recharge will also increase day by day, resulting in the scale of debris flow disaster control projects will also expand.

(2) After the 9.02 debris flow disaster, a large amount of loose accumulation material was accumulated in the gully slope and gully bed. The structure of sediments is loose and most of them are

overhead. In case of large floods, it is very easy for the deposits in the gully bed to reactivate and participate in debris flow activities.

(3) According to the analysis of regional meteorological data, the frequency of extreme rainstorms has increased in recent years, especially in the past 20 years, 24 hours of rain intensity, 1 hours of rain intensity showed an overall upward trend, providing sufficient hydrodynamic conditions for the outbreak of debris flow. On the whole, the project to control the number of sources, scale, recharge range of debris flow ditch basin with the intensification of extreme weather, geological environmental conditions gradually worse and increasing, may trigger large-scale debris flow disaster, if a large-scale debris flow, will seriously threaten downstream residents, schools, institutions, A total of about 3000 people in the public institutions of life and property safety, the resulting loss of human property will not be estimated.

5. Conclusions

Malipo 9.02 Large debris flow is caused by strong rainfall in the gully type of large low-frequency viscous debris flow, and the bulk is between the $1.60\sim 1.67\text{g/cm}^3$. From the start mechanism of the debris flow, the above loose source involved in debris flow activities contain 3 forms: ① granite and gneiss weathering layer deep, under the action of rainfall to trace erosion of the rock and soil slope debris flow recharge, ② early rainfall duration, large rainfall, resulting in the loose accumulation of yinjiao slope in the state of water, due to heavy precipitation induced by a large number And landslide accumulation, the source of the disintegrating is directly involved in the recharge due to the flood side erosion, and the source of the ③ Groove is recharged by the flood or debris flow. There will still be a trend of frequent outbreaks in 10 years. The peak flow rate of this debris flow water flushing Groove is $168.63\text{m}^3/\text{s}$, the flow rate is 2.72m/s , the flushing amount is $138,600\text{ m}^3$, the peak flow rate of fragrant straw shed is $96.80\text{m}^3/\text{s}$, the flow rate is 2.69m/s , the flushing amount is $97,700\text{ m}^3$, and the debris flow activity has the short excitation time, the fast flow rate, Large flow, large scale, long duration, occurred in the night, resulting in heavy losses and other characteristics. In order to reduce the threat of debris flow to the safety of personal property such as downstream villages, market towns and school hospitals, we should take timely control works to control the channel and strengthen the monitoring and early warning.

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