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Evaluation of kinematic parameters and characteristics of the source zone of the debris flow in Kongniba Watershed

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Abstract

The characteristics of the source zone of the debris flow watershed is one of the most significant factors governing debris flows initiation, at the same time it also plays a crucial role for disaster risk evaluation. With the aim of obtaining the basic characteristics of the source zone and computing the kinematic parameters, field investigations were conducted comprehensively, combining with the results of remote sensing interpretation, the origin and distribution regulations can be identified, and total amount of the loose solid materials can be determined, the corresponding value is 4.91×10^6 m^3. Using the collected data of this watershed, and with the help of previous theoretical models, the kinematic parameters under different rainfall frequencies are calculated, which including debris flow discharge, total volume of one-time debris flow and the total volume of solid materials. Such parameters are helpful and essential for debris flow disasters evaluation, prevention and designing mitigation measures.

Keywords: Kinematic Parameters; Field Investigations; Source Zone; Kongniba Watershed

1. Introduction

Debris flows are very destructive and unpredictable natural processes in mountain regions worldwide. Debris flows are not only responsible for repeated blockage of national highways and rivers but also responsible for loss of life and property and also cause damage to the environment every year in the mountainous regions [1-6]. Therefore, understanding the initiation and runout characteristics of surges is essential when planning debris flow mitigation [7]. China has a vast territory and complex terrain, of which mountainous areas cover 6.66 million km^2, accounting for 69.4% of the total land area; and the population residing in mountainous areas accounts for more than 1/3 of the total population in China [8]. The mountainous area in southwest China is prone to geological disasters, among which mudslide is one of the main geological disasters, causing severe economic losses and casualties. In 2003, the debris flow in Danba, Sichuan Province caused 51 people dead or missing, and destroyed 73,136 m^{2}of woodland, farmlands, and residential areas [9].The '8.13' debris flow disaster in the Sichuan Province caused 47 people dead or missing, 20.9% of the houses were damaged, and the direct economic loss exceeded 600 million RMB [10]. According to the 2016 National Bulletin of Geological Hazards, 954 geological disasters occurred in Chongqing, Sichuan, Guizhou, Yunnan, and Tibet, and caused 134 people dead or missing, and accounting for 33.1% of the total casualties of that year. Economic losses amounted to 1.29 billion RMB, accounting for 40.6% of the total economic loss of that year. Typical disasters include the "5·8" large debris flow disaster in Kangning, Fujian Province, with 50 casualties, and a direct economic loss of 6 million RMB. In addition, the "7·6" large debris flow disaster in Yecheng, Xinjiang, with 50 casualties, and a direct economic loss of 280 million RMB.

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In recent years, due to the construction of large-scale projects in the valley (such as hydropower stations, landfills, etc.), the losses caused by debris flow disasters have been more serious [11,12]. Debris flow risk assessments can not only present a reference for project site selection, preliminary design, construction organization design, etc., but also provide a basis for debris flow forecasting and early warning, and disaster prevention and mitigation.

2. Survey of the Kongniba Valley watershed

2.1. Channel characteristics

With the development of ditches and frequent debris flow disasters in Kangding city, many scholars have studied the characteristics of debris flow disasters [11-13]. The Kongniba ditch is locates on the right bank of the Dadu River at the exit of the Seyu tunnel in the Kongyu Township, Guzan Town, Kangding City. The intersection of the ditch and the Dadu River is at 102°04’03” E and 30°35’57” N. The basin area covers 100.48 km^2, the length of the main ditch is 17.54 km, and the No.11 branch ditch is 4.71 km long, converging at 101°57’13” E and 30°36’05” N. The maximum elevation of the main ditch is 4121 m, the relative elevation difference is 2465 m, and the overall longitudinal gradient is 141‰. The slopes on both sides of the bank are steep, with an average slope of 50 ° and local slopes of up to 80 °. The middle and lower shrubs and trees on both sides of the mountain are well mixed and covered; the upper part is dominated by shrubs, and some of the bedrock is exposed. The upper reaches of the channel host a fragrant pig breeding farm, the middle reaches of the channel a hydroelectric power station, there are two quarries in the middle and lower reaches of the channel, the right bank of the Seyu tunnel and Kongniba ditch junction contains a gypsum field, and a garbage disposal factory is located near the mouth of the channel.

2.2. Geological conditions of the Kongniba ditch

2.2.1. Engineering geological conditions

The Kongniba gully is located at the intersection of the southwestern end of the Songpan-Ganzi fold system (level I), the southwestern end of the Longmen fold belt (level II), the western edge of the Yangzi block (level I), the northern end of the Kangdian axis (level II), and the Jintang arc structure. The structure belongs to the intersection of the Yunnan meridional structural belt and mountain- structure. It was formed during the Proterozoic and directly controlled the formation of various types of magmatic rocks during this eon. The ditch area mainly consists of the Jixinliangzi anticline, Beimushan arc thrust, and Yaotangzi thrust. (Figure 1).

Within the Kongniba gully watershed, the east side is deeply cut. It is located in a seasonal branch ditch on the right bank of the Dadu River. The terrain is high in the west and low in the east. The elevation ranges from 1656 m to 4121 m. Overall, the ditch is tongue-shaped; the middle and upper reaches of the main ditch are “V”-shape, the downstream channel from the garbage disposal to the Dadu River confluence is slightly sloped, and the valley section and the No.1 branch ditch are both “U”-shaped. The Kongniba ditch area is strongly deformed, with outcropping mylonite. Most of the gneiss in the complex body is oriented at 40~60° NE or extends in the east-west direction, forming a series of anticline, syncline (shape) folds with an axial direction that is almost orthogonal to the distribution direction of the complex body (rock belt). The middle and lower reaches of the gully are dominated by marble and slate, which are associated with a large intrusion which was violently emplaced during the Jinning-Chengjiang period. The rock masses are mostly distributed in the shape of large rock strains and rock bases, and have become exposed due to quarry mining. The area accounts for around 80% of the entire complex. The fault zone, which was formed during the Chengjiang-Jinning period, traverses the central part, and its strike is close to the northwest, inclined to the northeast, with an inclination of 60-70 °, extending to the northwest and southeast.

Joints are developed in the area, and most of them appear in the form of conjugate shear joints in the fold wings. The tension joints are especially developed at the top of the dome-shaped anticline, leading to strong weathering and denudation, and the terrain appears as a saddle-shaped anticline valley. The joint development is relatively weak in the centre of the syncline, and consists mainly of shear joints, resulting in strong weathering and denudation. The strata in the basin mainly comprise Quaternary Holocene collapsed slope deposits and the Chengjiang-Jinning Kangding complex (r2). The middle and lower reaches are affected by human activity, and the Quaternary Holocene artificial accumulation layer (Q_4^{ml}) is the dominant layer in this area.

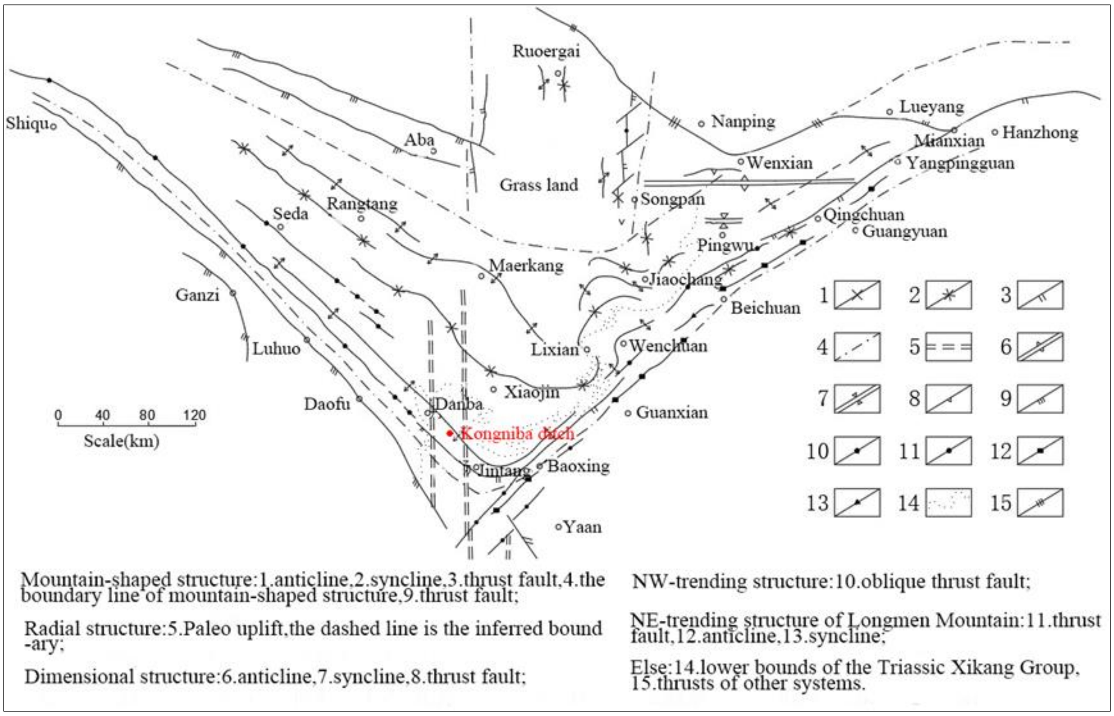

Figure 1 Tectonic outline of the Kongniba watershed

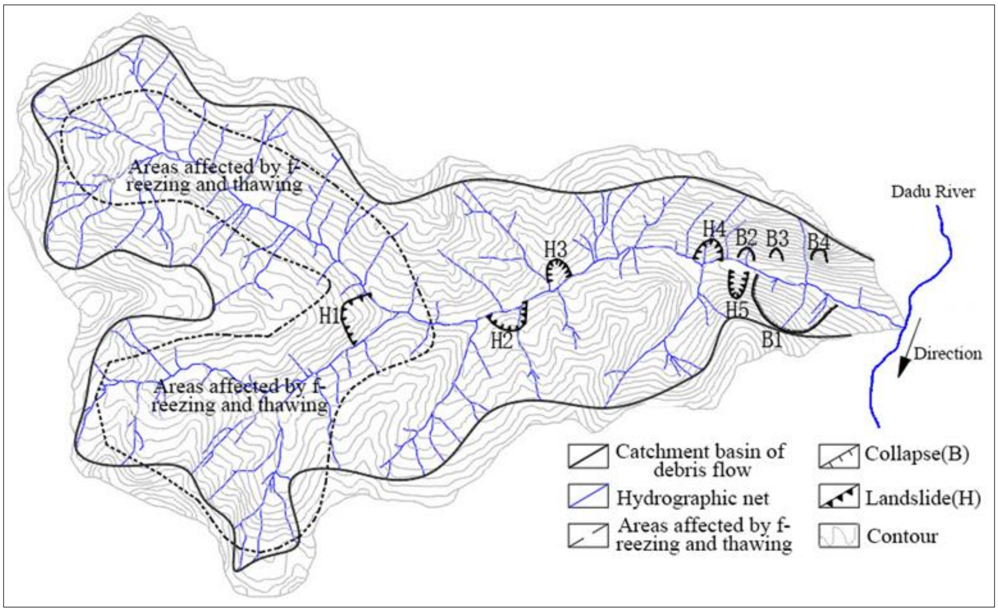

Figure 2 Overview of the Kongniba watershed

2.2.2. Hydrogeological conditions

The Kongniba ditch originates from the snow mountains. Its trench is about 17.5km long, with a slope drop of 141‰, and a catchment area of 100 km^2. The water in the ditch is derived from rainfall and ice-snow melt in alpine and extremely alpine mountains. The wet season is from June to September, and the water supply during the dry season is dominated by meltwater from ice and snow, with a volume of 20301/s·km^2. The Kongniba Valley is a sub-humid climate zone on the Qinghai-Tibet Plateau. According to statistics from the Jintang Township Meteorological Station in Kangding City, the annual average temperature is 7.1ºC, the monthly average minimum is -14.7 ºC, the monthly average maximum temperature is 15.7 ºC, and the annual rainfall is 803.8mm. The most concentrated rainfall occurs from June to September, accounting for 60% to 85% of the annual rainfall; most of the rain is heavy and continuous, with a maximum daily rainfall of 96.1 mm, the longest continuous period of rain being as long as 58 days, and a total rainfall of 427.5 mm for that period [14,15]. The frequency of maximum rainfall data for Kangding City is once in 100 years, once in 50 years, once in 20 years, and once in ten years, respectively (Table 1).

Table 1 Maximum rainfall data in Kangding City

Frequency	1 hour rainfall (mm)	6 hour rainfall (mm)	24 hour rainfall (mm)
Once in 100 years	38.36	52.75	76.80
Once in 50 years	26	44.25	70.8
Once in 20 years	22.25	39.25	62.8
Once in 10 years	16.63	35	56

The specific plateau climatic conditions in Kangding City often cause geological disasters such as mudslides and landslides due to heavy local short-term rainfall. At the same time, they are also an important external factor that directly stimulates geological disasters and provide the main dynamic conditions for the outbreak of debris flows and landslides.

3. Source conditions of debris flows in the Kongniba gully

3.1. The influence of neotectonic activity on debris flow provenance

The Kongniba ditch is subject to young and strong tectonic activity, and the regional geological structure is relatively active. The basement of Kangding has a complex geological structure and well-developed active faults. It is located at the intersection of the Xianshuihe, Longmen mountain, and Anning river seismic zones. The three seismic zones converge in a "Y" shape near Kangding County. Therefore, seismic activity in Kangding County is particularly intense and frequent (Table 2). The distance between the Xianshui river fault zone and the study area is roughly 50km, which has a significant influence on this watershed. According to historical records, 43 earthquakes of magnitude 5 or more have occurred along the Xianshui river fault zone since 1700, of which the largest took place on February 6th, 1973; the intensity of the Luhuo 7.9 earthquake reached a Mercalli intensity of X and its focal depth was 17km. Additionally, an earthquake of magnitude 7.25 occurred between Luhuo and Daofu on March 24, 1923, one of magnitude 7.25 occurred in Kangding on April 14, 1955, an earthquake with a magnitude of 7.5 occurred in Duotang with a Mercalli intensity of IX. About 90% of the houses in Kangding County collapsed, 50% of which collapsed absolutely; in total, over 600 houses collapsed and more than 500 were destroyed. At the same time, more than 30 collapses and landslides were induced in the Zheduo River area. A magnitude 7.5 earthquake occurred in Moxi, Kangding, on June 1st, 1786. Following the Yajiang earthquake which occurred on February 13-14, 2001, in Yajiang, Kangding, Jiulong, and Litang, over 7,100 households and more than 35,000 people were affected, and over 27,000 houses were damaged to different extents, causing economic losses exceeding 200 million RMB. Among them, 1278 households and over 6000 people were affected in Kangding County. On February 27th, 2008, an earthquake of magnitude 4.7 occurred in Sandaoqiao, Kangding County, which caused a communications interruption in Kangding City, a large-scale blackout, and varying degrees of damage to more than 7,000 residential houses, as well as affecting more than 4,000 people. The 2008 "5.12" Wenchuan Earthquake and the "4.20" Lushan Earthquake were felt in this area, causing rock collapses in many places along the Dadu River and Wasigou. These neotectonic movements and earthquakes have all provided a large number of potential sources for debris flows in the Kongniba gully.

Seismic activity affects the landform patterns and rock and soil structures of slopes in watersheds; it results in the development of fissures and an increased thickness of unstable rocks and soils, which provide abundant materials for debris flows [12,16]. Indeed, a large number of landslides and collapse deposits have been generated in the Kongniba ditch as a result of seismic activity. Some slopes and rock masses are in a critical state of landslides affected by earthquakes, and rock collapse and landslides are further likely to occur under the influences of rainfall and other external forces.

Table 2 Earthquake statistics of Kangding City

Time	Epicentral location	Magnitude	Intensity
1748.10.12	Kangding (E:101.5 ° N:30.2 °)	5	IX
1786.06.01	Kangding (E:102.1 ° N:29.7 °)	7.5	X
1925.07.10	Kangding (E:102.0 ° N:30.0 °)	5.5	VII
1932.03.06	Kangding (E:101.8 ° N:30.1 °)	6	VII
1949.11.12	Kangding (E:102.2 ° N:30.1 °)	5.5	VI～VII
1952.06.26	Kangding (E:102.2 ° N:30.1 °)	5.75	VII
1955.04.14	Kangding Zheduotang (E:101.9 ° N:30.0 °)	7.5	IX
1955.10.01	Kangding (E:101.4 ° N:29.9 °)	5.75	VII
1972.04.08	Kangding (E:101.8 ° N:29.4 °)	5.2	VI
1972.09.27	Kangding (E:101.39 ° N:30.11 °)	5.8	VII
1976.08.11	Between Kangding and Kowloon (E:101.5 ° N:29.5 °)	5.5	VII
2001.02.14	Between Kangding and Yajiang (E:101.5 ° N:29.15 °)	6	VII
2001.02.23	Between Kangding and Yajiang (E:101.5 ° N:29.15 °)	6	VII
2008.02.27	Kangding Sandao Bridge (E:101.9 ° N:30.1 °)	4.7	VII

3.2. Sources of debris flows and flood residues

Due to the influences of previous debris flow events and alluvial diluvial activity , there are a large number of loose solid materials in the watershed. The longitudinal slope of the ditch of the No.1 branch inclines steeply upwards and gently downwards. The longitudinal slope of the upstream channel is 336‰, and the longitudinal slope of the middle and downstream channels is 163‰. The trench as a whole is "U" shaped with a relatively flat bottom and an average width of 60 m. The mouth of the ditch crosses the main ditch in a "horn" shape at 101°57'55" E and 30°36'05" N.

The branch gully presents obvious features of alluvial-proluvial deposits (Figure 3), and hosts a large number of material sources and broken woods left behind by early alluvial deposits. The source of the material in the trench mainly consists of boulders, with an average thickness of 5 m, and the total amount of residue sources in the branch trench is 1615500 m^3.

Figure 3 No.1 branch groove provenance characteristics

Figure 4 Provenance characteristics of the main ditch

The main ditch has a total length of 17.5 km, the upstream longitudinal gradient is about 140‰, the midstream longitudinal gradient 110‰, and the downstream longitudinal gradient is approximately 148‰. There are few deposits in the upstream channel, with an average thickness of 3 m. The two banks are steeply cut into a "V" shape. The total amount of loose material in the upstream channel is 790020 m^3. The middle and downstream accumulation layer is about 6m thick (Figure 4), with a total accumulation of roughly 2154180 m³. The total source of alluvial and alluvial debris flow residues in the main ditch is 2,944,200 m³.

3.3. Landslide source replenishment

The Kongniba ditch is a landslide-prone area. The new and old landslides are alternately distributed along both banks of the channel, providing a large amount of material sources for the channel. There are five large-scale landslides (including unstable slopes) (H1-H5) (Figures 5 and 8), which are distributed in the middle and lower reaches of the channel. The largest H1 landslide is at the intersection of the No.1 branch ditch and the main ditch, belonging to the old landslide. The slope height is 224 m, and the slope width is 50 m; the slope's oblique distance is 391 m, and the slope gradient is 35 °. The main material of the slope is gravel soil, and the slope toe is seriously eroded. The slope vegetation consists mainly of herbaceous plants with a storage capacity of 200,000 m³. The H2 landslide is located in the middle of the main ditch, where the channel road changes bank; half of the landslide slides into the channel, and the other half of the landslide covers the road. The sliding surface is trapezoidal as a whole, carrying a volume of 200 m³. The H3 landslide is located 500 m from the H2 landslide, with a length of 15 m, a slope height of 18 m, and the corresponding volume is 1000 m³. The main component of the landslide is gravel soil. The H4 and H5 are mainly unstable slopes formed by marble mining. They are located in the downstream channel of the gully. They are diagonally separated from each other by around 200 m. The total volume of the H4 slope is 4000 m³. The total volume of the H5 slope is 3000 m³, and the foot of the slope provides temporary housing for the factory (Figure 8). The landslide deposits are relatively loose and prone to migration under the action of heavy rainfall, floods, and mudslides.

Figure 5 H1 landslide

Figure 6 H2 landslide

Figure 7 H3 landslide

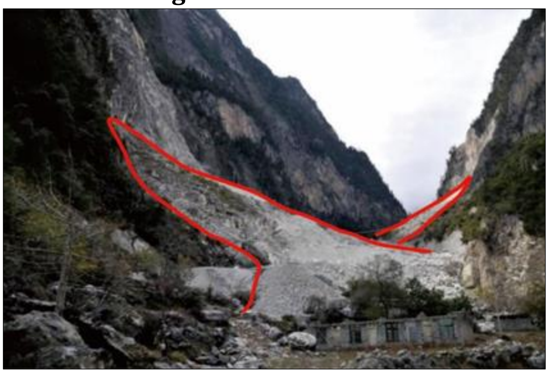

Figure 8 Unstable slopes H4 and H5

3.4. Replenishment of collapsed sources

Collapses are mainly concentrated in the downstream part of the channel. The left bank of the channel is steep, with an average slope of 60 ° dominated by small-scale collapses whose distribution is relatively loose. The total volume of the deposits from collapses on the left bank is around 1.4×10^4 m³. The right bank is a group of collapsed bodies distributed along the channel, with a length of about 1380m along the line, dominated by weathered limestone and marble, with a total volume of 110400 m³. The structure of the deposit is loose, and it is prone to migration under heavy rainfall.

3.5. Freeze-thaw deposits

At an altitude of more than 3000 m, the intersection of the main ditch and the No.1 branch ditch experiences cold winter weathering from the starting point to the upper end of the main ditch and the No.1 branch ditch. Due to the characteristics of high altitude and large temperature differences between day and night in this region, freeze-thaw action occurs repeatedly, forming a large number of potential material sources. As shown in Figure 1, the total volume of material sources which are in a semi-cemented state and that affect the channel is 3×10^4 m^3, and such kind of materials is prone to partial erosion under the impact of floods and small debris flows, and may become mobilised under the action of large debris flows.

4. Debris flow hazard assessment

4.1. Debris flow bulk density analysis

According to the specification of geological investigations for debris flow stabilisation, combined with the characteristics of the debris flow channel, the Kongniba ditch has a quantitative score of 117 points for the susceptibility of debris flows and a corresponding gravity of 1.84 g/cm^3. According to the debris flow particles (<0.005 mm) deduced by Chen et al [9], the relationship between the content and bulk density of the debris flow is given by:

$$\gamma_c = -1.32\times10^3 x^7 - 5.13\times10^2 x^6 + 8.91\times10^2 x^5 - 55x^4 + 34.6x^3 - 67x^2 + 125x + 1.55$$

Where γ_c is the debris flow density (g/cm^3), and x is the clay content in the debris flow deposit sample. The average clay content value of the Kongniba ditch deposits was determined to be 0.32% using the sieving test. Substituting into the above formula, the bulk density of the Kongniba ditch can be figure out and the value is 1.95 g/cm^3. The results of the two calculation methods are close. Comprehensively analyzing the influential factors and the local geological conditions, combing with historical data, the bulk density of the debris flow is determined, the corresponding value is 1.90 g/cm^3.

The bulk density of the debris flow is positively correlated with the scale of debris flow outbreak. According to "China Debris Flow", the relationship between the bulk density and frequency of debris flow within a hundred years is as follows:

$$\gamma_c' = \gamma_c + 0.122 \ln p'$$

Where γ_c' is the bulk density of debris flows with different frequencies (g/cm^3), γ_c is the debris flow bulk density estimated once a century (g/cm^3), and p' is the debris flow outbreak period (year). Since debris flow did not break out for a long time, the calculated bulk density was used as the bulk density standard of debris flows. The calculated bulk density of debris flows with 100, 50, 20, and 10-year return periods is shown in Table 3.

Table 3 The bulk density of debris flows in the Kongniba gully with different outbreak frequencies

Frequency (%)	<1	1	2	5	10
Bulk density (g/cm^3)	1.90	1.90	1.82	1.70	1.62

4.2. Debris flow velocity analysis

The Kongniba ditch is a diluted debris flowand "Debris Flow Control, in view of its similarity to the diluted debris flows in the southwest mountainous area. The formula of the debris flow in the southwest region was employed to calculate debris flow velocity:

$$V_c = \left(\frac{M_c}{a}\right) \cdot R^{\frac{2}{3}} \cdot I_c^{\frac{1}{2}}$$

$$a = \left(1 + \phi_c \gamma_s\right)^{\frac{1}{2}}$$

$$\phi_c = \frac{\gamma_c - \gamma_w}{\gamma_s - \gamma_c}$$

Where R is the hydraulic radius of the debris flow (m), M_c is the coefficient of roughness of the debris flow gully bed, a is the resistance coefficient, γ_s is the bulk density of solid particles (g/cm³), γ_c is the bulk density of debris flows (g/cm³), and γ_w is the bulk density of water (g/cm³).

According to the characteristics of the river bed of the Kongniba ditch, the roughness coefficient of the dilute debris flow is 9.0, the bulk weight of solid particles is 2.6 g/cm³, and the flow velocity of the debris flow in Kongniba ditch is 2.44 m/s (Table 4).

Table 4 Calculation results of debris flow velocity in the Kongniba ditch

Location of section	Longitudinal gradient (‰)	Depth of mud (m)	Roughness value (Mc)	a	Flow velocity (m/s)
50m upstream at the junction of the No.1 branch channel in the middle reaches	140	2	9.0	2.19	2.44

4.3. Analysis discharge of the debris flow

Debris flow discharge is an important parameter for evaluating the disaster resistance of existing buildings. To study the debris flow disaster characteristics of the Kongniba gully, the debris flow discharge was calculated using the matching method and morphological investigation method.

4.3.1. Calculating the flow rate of debris flows with the matching method

The method involves calculating the peak discharge of rainstorm in small watersheds under different frequencies according to the hydrological method, and then, considering the blockage of the channel, selecting a blocking coefficient to calculate the debris flow. The maximum discharge is calculated according to the reasoning formula of "Handbook of Heavy Rain and Flood in Small and Medium Watersheds of Sichuan Province":

$$Q_P = 0.278\psi \frac{S}{\tau^n} \cdot F$$

$$\psi = f(\mu, \tau^n)$$

$$\tau^n = f(m, s, J, L)$$

Where Q_P is the designed discharge of storm floods with frequency P (m³), ψ is the Peak runoff coefficient, τ is the confluence time of the basin (h), s is the rainstorm intensity (mm/h), F is the watershed area (km²), μ is the infiltration strength (mm/h), n is the rainstorm index, m is the confluence parameter, L is the length of the river from the exit section along the main river to the watershed (km), and J is the bed gradient (‰).

According to the specification of geological investigation for debris flow stabilisation, the discharge of debris flow is calculated as:

$$Q_C = \left(1 + \frac{\gamma_c - \gamma_w}{\gamma_s - \gamma_c}\right) Q_P \cdot D_C$$

Where Q_C is the peak discharge of debris flows with frequency P (m^3/s), Q_P is the designed discharge of storm floods with frequency P (m^3), and D_C is the debris flow blockage coefficient.

According to the channel characteristics, the debris flow blockage coefficient of the Kongniba gully was taken as 1.5, and the peak runoff coefficient and watershed time were determined according to the trial algorithm provided in the "Handbook of Heavy Rain and Flood in Small and Medium Watersheds of Sichuan Province". The calculation results are shown in Table 5.

Table 5 Calculation results of the hole mud dam ditch allocation method

Frequency/%	1	2	5	10
Peak flow of rainstorm flood (m^3/s^{-1})	596.12	392.45	329.23	235.55
Debris flow peak discharge (m^3/s^{-1})	2043.84	1207.54	877.95	576.86

4.4. Calculation of debris flow discharge on the basis of morphological adjustment method

The maximum mud level and vairation of cross section of a debris flow can be determined according to the mud marks. Based on field investigations, the area of the cross section can be computed, and subsequently the discharge of the debris flow can be calculated through the following equation:

$$Q = A_{SC} \times V_C$$

Where A_{SC} is the flow area of the cross section (m^2), and V_C is the average velocity (m/s).

Through field investigations and measurements of the cross-sectional area, combined with the calculation of the flow velocity and morphological adjustment method, the discharge of the debris flow in the Kongniba ditch was calculated to be 585.60 m^3/s. The calculation results is close to the once-in-ten-years debris flow discharge that calculated through the matching method.

4.5. Analysis of total discharge of the debris flow

The calculation of the total discharge of the debris flow is of great significance for the hazard identification and prevention. It is difficult to calculate the total discharge of the debris flow because some debris flows are removed by water and mobilised into the river channel. This work adopted the empirical formula method to calculate the total discharge of debris flow according to its duration and maximum discharge, referring to "Debris Flows in China".

The total amount of a debris flow is calculated through following equation:

$$W_C = \frac{19TQ_c}{72}$$

The total discharge of solid materials washed out by a debris flow is given by:

$$W_S = C_V W_C = \frac{\gamma_C - \gamma_W}{\gamma_S - \gamma_W} W_C$$

Where W_C is the total discharge of a debris flow (m^3), W_S is the total solid materials pass through the cross section (m^3), and C_V is the volume concentration of debris flow sample.

The drainage area of the Kongniba ditch is 100.48 km^2, the main ditch is 17.54 km long, and the eruption time is about 120 mins. Combining with the bulk density and flow characteristics of the debris flow even, the total discharge of the debris flow under different frequencies was calculated (Table 6).

Table 6 Total estimated debris flows in the Kongniba gully

Frequency (%)	Bulk density g/cm^2	Time (s)	Debris flow discharge (m^3/s)	Total volume of debris flow ($10^4 m^3$)	Total primary solids in debris flow ($10^4 m^3$)
1	1.90	7200	2043.84	388.33	218.44
2	1.82	7200	1207.54	229.43	117.58
5	1.70	7200	877.95	166.81	72.98
10	1.62	7200	576.86	109.60	42.47

5. Conclusion

The basin area of the Kongniba gully is wide and rainfall concentrated within several months. During dry season, most of the flow is intercepted by small hydropower stations, and the rainfall has little effect on the middle and lower reaches of the channel. However, heavy rainfall occurs during the wet season, which has a certain impact on the construction of the downstream garbage treatment plant. In addition, in recent years, the local geological structures have become more active, the disturbance of engineering activities are more frequent, and the dynamic source reserves of mud and stone have increased sharply. Debris flow disasters may occur under the action of rare and severe rainstorm events. The dynamic parameters of debris flows in the Kongniba gully were calculated according to the statistics of channel sources and the hourly rainfall with 100-year, 50-year, 20-year, and 10-year return periods, providing a reference for the prevention and mitigation of debris flow disasters in the Kongniba gully.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare no conflict of interest.

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