Response to the Reviewer 2

Summary:

The authors use a flume study to understand the effects of outburst flooding on downstream sandbar development. Different dam geometries (width and downstream slope angle) and a constant dam height were used. The upstream pool was allowed to fill and then overtop and fail under the same constant flow rate in all experiments. The authors relate bar frequency and volume to different dam geometries, and also note that bars tend to grow upstream during the experiments. The authors proceed to relate their observations to the flow hydraulics and sediment concentrations during the experiment. While the experimental set up seems reasonable, and the general result reproducible, there are several parts of the analysis that are flawed. For example, the "sandbars" are not scaled appropriately, and in fact the median grain size is gravel in the experiment. Instead, these grains are equivalent to very coarse (boulders?) grains in the field scale. The framing of the introduction and paper in general is therefore not appropriate. Further, the Froude numbers during these experiments are all supercritical, leading to spurious correlations between transport capacity and flow depth (for example, I assume that dimensionless shear stress is calculated using subcritical flow assumptions via the depth-slope product embedded in u). Nor is it clear how sediment concentration (figure 8) was calculated with the reference to Laursen given. Later, they use the Meyer Peter-Muller equation to calculate bedload, but, again, not considering the supercritical flow regime of the experiments and the influence on energy slope as far as I can deduce. Therefore, it is difficult to interpret whether any of the results in sections 4 and 5 are valid.*

Thanks a lot for the reviewer's comments. As the reviewer concerned, the bar formed in the experiment was composed of a lot of coarser materials, which should be named "boulder bar". We have corrected the term "sandbar" to "boulder bar" in the revision.

Considering the content of the original manuscript is more, and the sections 4 and 5 have caused the reviewer greater confusion, we have deleted the sections 4 and 5 of the original manuscript after our careful consideration. And in the revised manuscript, the influence of the dam volume and the released flood volume on the growth of the boulder bar was added (section 4 of the revision), and the results of this experiment were compared with the Yigong flood in the Discussion section (section 5 of the revision), which proved the reliability of the results of this experiment. It shows that the research results of this paper can provide reference for the research on the formation and development of the boulder bar formed by the overtopping outburst flood. The revised sections 4 and 5 are as follows：

"4. Influences of the dam volume and the released flood volume on total boulder bar volume

The boulder bar's formation and development are inseparable from the combined action of outburst flow and sediment. The landslide dam can provide materials for the development of the boulder bar, while the outburst flow provides hydraulic conditions.

Figure. 7 shows the boulder bars' total volume on the river bed when the dam fully failed. It can be seen that the total volume of the boulder bars is much lower than the dam volume. The volumes were about 0.079 to 0.127, 0.017 to 0.078, and 0.015 to 0.041 times of the initial dam volumes for the boulder bars near the upstream reaches, the boulder bars near the middle reaches, and the boulder bars near the downstream reaches, respectively. The ratio of the total volume of the boulder bars to the dam volume is 0.138 to 0.208. It shows that only a small part of the dam material participates in the boulder bar's formation and development. During the process, most of the dam material was taken away by the outburst flow. Moreover, when the dam volume decreases, the amount of sediment involved in the development of the boulder bar decreases. The total volume of the boulder bars on the river bed also shows a decreasing trend.

This experiment counted the released flood volume during the dam failure process, as shown in Fig. 8. It could be seen that the released flood volume in the dam failure process of the T1 to T8 experiments decreased. According to Figs. 7 and 8, it could be found that with the decrease of the released flood volume, the total volume of boulder bars on the river bed shows a decreasing trend. When the released flood volume is small in the dam failure process, a small amount of flood is not enough to transport many dam materials to the downstream riverbed. There is less sediment on the riverbed, and the deposit that can participate in the boulder bar's growth is less. Therefore, the total volume of the boulder bars on the river bed at the moment of complete dam failure decreased with the decrease of the released flood volume.

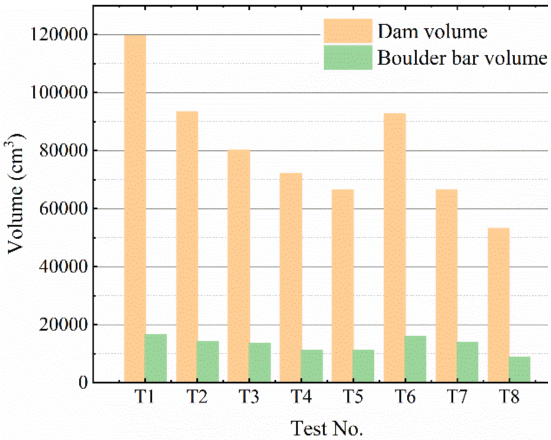


Figure. 7 The boulder bar's total volume and dam volume

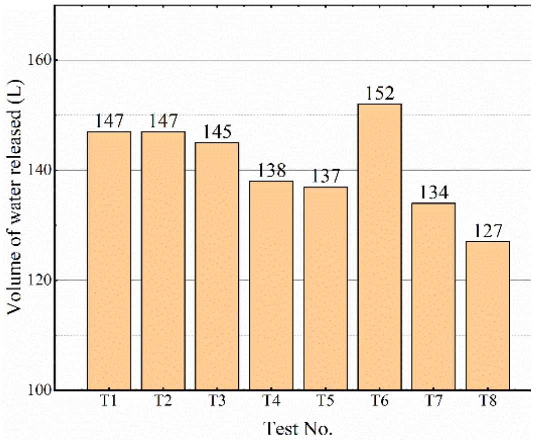


Figure. 8 The volume of water released during the dam failure.

5. Discussion

The field data of the Yigong landslide dam are used to verify the reliability of the results in this paper. Turzewski et al. (2019) investigated the boulder bars in the Yigong River triggered by the Yigong landslide dam outburst flood in 2000. They found that the number of boulder bars is about 0.69 to 0.77 times the ratio of river bed length to dam length for the boulder bar frequent region. In this study, boulder bars were distributed in the 8 m length of the channel, which is 4 to 7 times of dam length. It reflected the number of boulder bars was 0.4 to 1.0 times the ratio of river bed length to dam length. By comparing the experimental data and the field data of Turzewski et al. (2019), it can be found that field data falls within the range of experimental data. Experimental models took more influence factors into account in this paper, while the field data of Turzewski et al. (2019) only focused on the Yigong landslide dam case. This may be why the field data range is smaller than the experimental data in this paper.

Wu et al. (2020) classified the boulder bars in the downstream reaches of the Yigong River into three types according to their shapes and used the length to width ratio as the indicator of a bar shape. The 16 boulder bars in the downstream reaches of the Yigong River have a length to width ratio of 2.5-15. As can be seen from Fig. 9, the length to width ratio of the boulder bar formed in this experiment is in the range of 7 to 16, which indicates the field data could prove the experimental results.

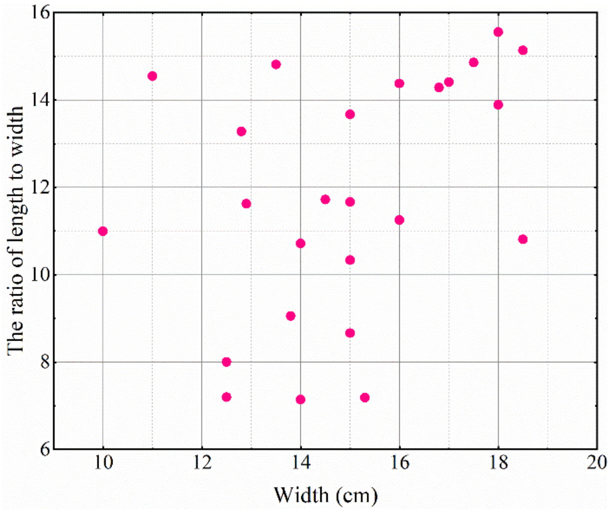


Figure. 9 The ratio of boulder bar length to width

Turzewski et al. (2019) measured the sizes of boulder bars. They found that grain sizes of boulder bars decrease downstream. In this experiment, boulder bar materials from different river bed sections were collected. And after screening and analysis, it was found that as the distance between the boulder bar and the dam increases, the particle diameter in the bars shows a decreasing trend, as shown in Fig. 10. This feature is consistent with the description of Turzewski et al. (2019).

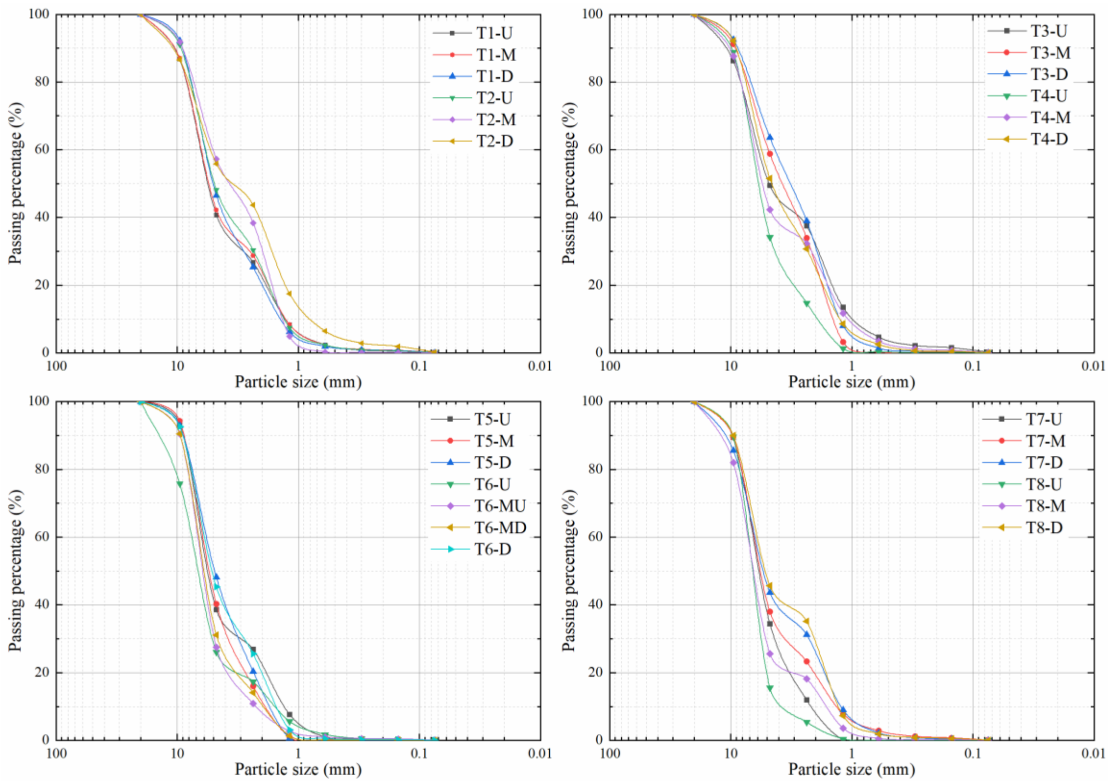


Figure. 10 Gradation curve of the boulder bar materials. Notation: U, M, D, MU, and MD, represent the boulder bar near the upstream reaches, the boulder bar near the middle reaches, the boulder bar near the downstream reaches, the boulder bar near the middle-upstream reaches, and the boulder bar near the middle-downstream reaches, respectively.

Based on the above points, it can be seen that the experimental results in this paper are consistent with the actual boulder bars in the field. Therefore, the experimental results can provide guidance for the field study of the boulder bar formed by the outburst flood."

General Comment:

Introduction: make it clear how the background information will provide context for the results of the study. For example, the reference to Demirci et al. (2014) does not provide much insight into how these results for a coastal beach will provide context for this study. The authors could use the introduction to describe more precisely how these different previous studies relate to sandbars formed in settings 1, 2, and 3 described on lines 67-70. And then state how the sandbars in this study fit within one of those settings, or whether they are some different phenomenon related to outburst floods (as is implied). Further, the references should be more directly related to the coarse-grained alternate bars that form during the experiment, rather than sandbars.

Thanks a lot for your comments. According to your valuable suggestion, we have corrected the term "sandbar" to "boulder bar" in the revised manuscript. Also, we have rewritten the introduction part of the article and recited references related to the boulder bar to ensure the correct citation of the references. The rewritten Introduction is as follows:

"Activities such as rainfalls and earthquakes often cause landslides, which block the river to form a water-retaining body similar to a reservoir dam, called a landslide dam (Takahashi, 2007; Costa and Schuster, 1988; Casagli, 2003). According to statistics, 85 % of the dams failed within one year after formations, and more than 50 % of the dams breach with overtopping mode (Costa and Schuster, 1988). When the dam breach, the storage water erupt and flow to the downstream riverbed.

Many studies on the influence of flood geomorphology and sedimentary characteristics have proved that the outburst flood energy is huge, and it can entrain and transport materials of various sizes, from clay to boulders. A large number of boulders gather in the river to form bars, namely boulder bars. The downstream riverbed's geomorphology will be significantly affected and undergo significant changes (Lamb and Fonstad, 2010; Maizels, 1997; Russell and Knudsen, 1999; Marren and Schuh, 2009; Benito and O'Connor, 2003; Carling, 2013; Wu et al., 2020). Boulder bars are one common landform formed during the outburst flood evolution (Turzewski et al., 2019; Jiang and Wei, 2020; Wu et al., 2020). For example, in the 2000 year, Yigong outburst flood, due to its huge lake storage, formed many huge boulder bars on the river bed. The boulder bars had a significant impact on the development of the river. And Wu et al. (2020) investigated the impact of this event on river morphology and analyzed the shapes and geometric characteristics of the boulder bars caused by the overtopping flood. And they found that the boulder bar components are poorly sorted. Turzewski et al. (2019) studied the particle gradation of the boulder bars during the Yigong River landslide dam failure process. They found that the boulder bars' particle sizes decrease along the lower reaches of the river bed. But they did not analyze the evolution characteristics of boulder bar's size in detail. Lamb and Fonstad (2010) suggested that the rising and falling stages of the outburst flood had a greater impact on riverbed geomorphology and analyzed the characteristics of the median diameter of material in boulder bar.

Because lack of field investigations about the growth characteristics of boulder bars during the landslide dam failure process in the field, some researchers had conducted landslide dam failure experiments in the lab (Jiang and Wei, 2020; Ashworth, 1996). Ashworth (1996) used flume experiments to study the boulder bar's growth. However, in their experiment, the inflow conditions are quite different from the outburst flood. Therefore, the research results' applicability to the boulder bar formed by the outburst flood remains uncertain. Jiang and Wei (2020) qualitatively analyzed the formation process of boulder bar in the evolution of overtopping outburst floods using dam failure experiments and initially discussed the characteristics of geometric dimensions of boulder bars after dam failure. However, the characteristics of the boulder bar's positions and geometric sizes during the dam failure process have not been analyzed.

Above all, no matter whether it is field observations or indoor experiments, the boulder bar's development characteristic during the landslide dam overtopping failure process has not been proved. This paper focuses on the formation processes, the geometrical size characteristics of boulder bars in the downstream channel during the overtopping failure process, and how the dam volume and the released flood volume affect boulder bars' total volume. Firstly, through flume experiments, boulder bars' formation processes on the downstream channel under the dammed lake failure condition were reproduced. Then, based on the experimental data, the development characteristics of boulder bars' upstream and downstream edges were analyzed. Furthermore, statistical analysis of boulder bars geometrical dimensions at each moment during the failure process, such as length, width, height, and volume, had been carried out to obtain boulder bars' size characteristics. And then, by analyzing the total volume of the boulder bar under different dam volumes and the released flood volumes, the influences of the released flood volume and dam volume on the boulder bar total volume were obtained. Finally, compare the boulder bar formed by the Yigong outburst flood and the boulder bar formed by the experiment to verify this experiment's reliability."

Section 3: It would be very useful to have some information on grain size on the bars in this section. Much of the sediment in the experiment seems equivalent to boulders in the field case, and the coarse sediment seems to comprise much of the bar material. Even in that case, the grain size of the sediment is going to be a very important factors in depositional patterns and should also be reported.

We fully agree with the reviewer's opinion. We report the material size information of the boulder bar downstream of the river bed (section 5 in the revised manuscript). We found that the farther away from the dam, the smaller the median particle size of the boulder bar material for the boulder bar on the river bed. The experimental results are in good agreement with the Yigong flood (Turzewski et al., 2019). We have added the related descriptions and explanations in the 3th paragraph of section 5. The details are as follows：

"Turzewski et al. (2019) measured the sizes of boulder bars. They found that grain sizes of boulder bars decrease downstream. In this experiment, boulder bar materials from different river bed sections were collected. And after screening and analysis, it was found that as the distance between the boulder bar and the dam increases, the particle diameter in the bars shows a decreasing trend, as shown in Fig. 10. This feature is consistent with the description of Turzewski et al. (2019).

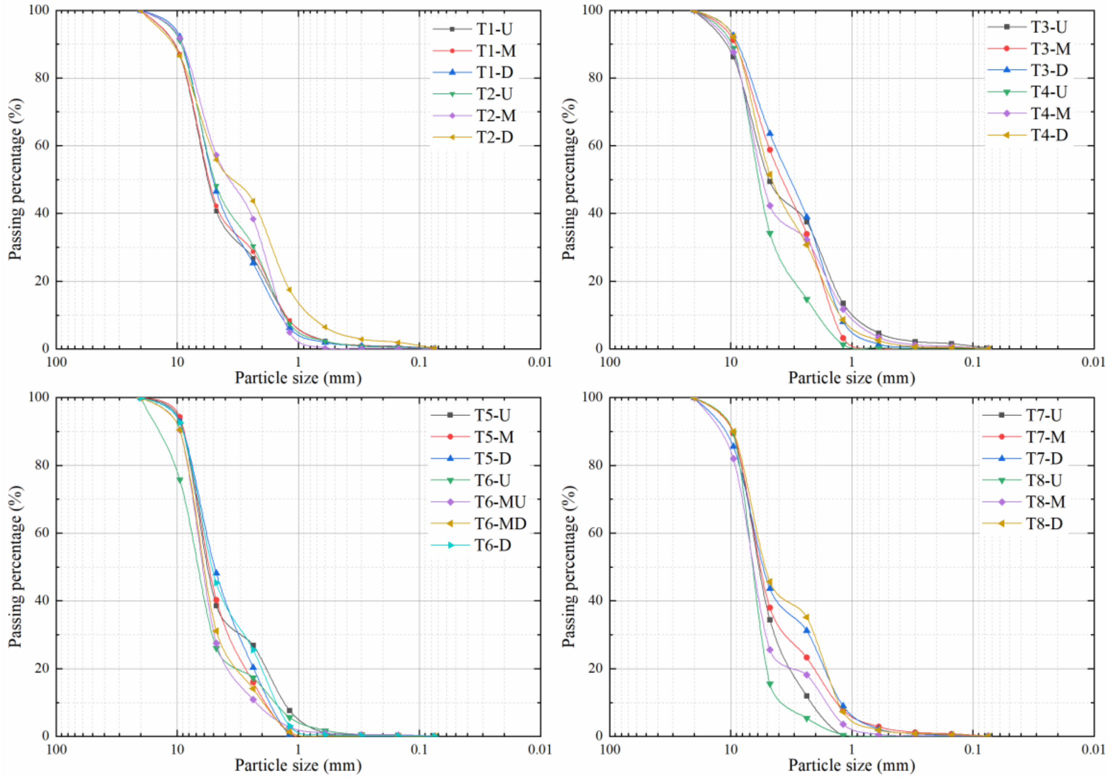


Figure. 10 Gradation curve of the boulder bar materials. Notation: U, M, D, MU, and MD, represent the boulder bar near the upstream reaches, the boulder bar near the middle reaches, the boulder bar near the downstream reaches, the boulder bar near the middle-upstream reaches, and the boulder bar near the middle-downstream reaches, respectively. "

Reference:

Turzewski, M.D., Huntington, K.W., and Leveque, R.J.: The Geomorphic Impact of Outburst Floods: Integrating Observations and Numerical Simulations of the 2000 Yigong Flood, Eastern Himalaya, Journal of Geophysical Research: Earth Surface, 124, 5, https://doi.org/10.1029/2018JF004778, 2019.

Section 4: It is confusing that sediment concentration is calculated using a reference to Laursen, with no reference to how this was done or whether we are talking about bed load or suspended load. For true sandbars, it seems that the suspended sediment component would dominate. Later in this section, the MPM formula is used for bed load transport capacity, but how is u defined given the supercritical flow conditions. I don't know if it is appropriate to use MPM without consideration of the effect of Froude number on the energy slope; this may lead to spurious negative correlations between Froude number and transport capacity.*

Thanks a lot for the reviewer's comments. it is difficult to measure the concentration and sediment carrying capacity of outburst flow exactly and timely during experimental process. So, we adopted the calculated methods to obtain the concentration and sediment carrying capacity values in the first version manuscript. But the calculated values may be different with the experimental data. The content of section 4 in the original manuscript may cause confusion to the readers. Therefore, we decided to delete the content of section 4 in the original manuscript The section 4 of the revised draft is as follows:

"4. Influences of the dam volume and the released flood volume on total boulder bar volume

The boulder bar's formation and development are inseparable from the combined action of outburst flow and sediment. The landslide dam can provide materials for the development of the boulder bar, while the outburst flow provides hydraulic conditions.

Figure. 7 shows the boulder bars' total volume on the river bed when the dam fully failed. It can be seen that the total volume of the boulder bars is much lower than the dam volume. The volumes were about 0.079 to 0.127, 0.017 to 0.078, and 0.015 to 0.041 times of the initial dam volumes for the boulder bars near the upstream reaches, the boulder bars near the middle reaches, and the boulder bars near the downstream reaches, respectively. The ratio of the total volume of the boulder bars to the dam volume is 0.138 to 0.208. It shows that only a small part of the dam material participates in the boulder bar's formation and development. During the process, most of the dam material was taken away by the outburst flow. Moreover, when the dam volume decreases, the amount of sediment involved in the development of the boulder bar decreases. The total volume of the boulder bars on the river bed also shows a decreasing trend.

This experiment counted the released flood volume during the dam failure process, as shown in Fig. 8. It could be seen that the released flood volume in the dam failure process of the T1 to T8 experiments decreased. According to Figs. 7 and 8, it could be found that with the decrease of the released flood volume, the total volume of boulder bars on the river bed shows a decreasing trend. When the released flood volume is small in the dam failure process, a small amount of flood is not enough to transport many dam materials to the downstream riverbed. There is less sediment on the riverbed, and the deposit that can participate in the boulder bar's growth is less. Therefore, the total volume of the boulder bars on the river bed at the moment of complete dam failure decreased with the decrease of the released flood volume.

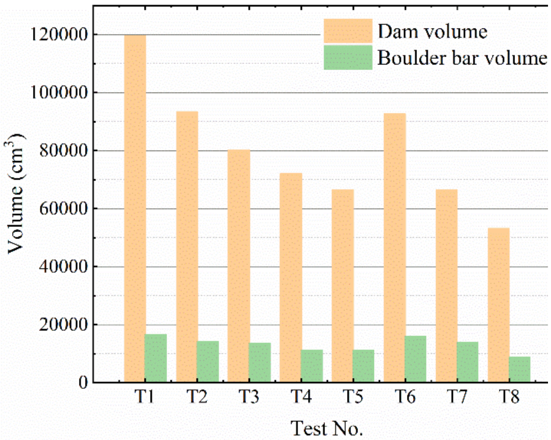


Figure. 7 The boulder bar's total volume and

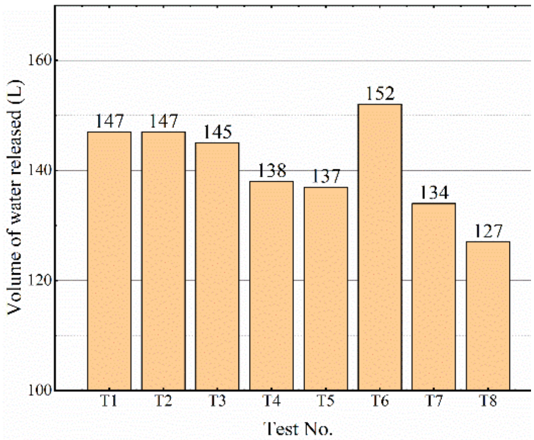


Figure. 8 The volume of water released

dam volume	during the dam failure. "

Section 5: given the unknown equation to calculate sediment concentration, and uncertainty in the calculation of sediment transport capacity described above, I don't know how to interpret the results of this section.

Thanks a lot for the reviewer's comments. After our careful discussion, we decided to delete section 5 from the original manuscript. In the revised manuscript, we compared the experimental results with Yigong case and discussed the reliability of experimental results in section 5. The section 5 in the revised manuscript is as follows:

" **5. Discussion**

The field data of the Yigong landslide dam are used to verify the reliability of the results in this paper. Turzewski et al. (2019) investigated the boulder bars in the Yigong River triggered by the Yigong landslide dam outburst flood in 2000. They found that the number of boulder bars is about 0.69 to 0.77 times the ratio of river bed length to dam length for the boulder bar frequent region. In this study, boulder bars were distributed in the 8 m length of the channel, which is 4 to 7 times of dam length. It reflected the number of boulder bars was 0.4 to 1.0 times the ratio of river bed length to dam length. By comparing the experimental data and the field data of Turzewski et al. (2019), it can be found that field data falls within the range of experimental data. Experimental models took more influence factors into account in this paper, while the field data of Turzewski et al. (2019) only focused on the Yigong landslide dam case. This may be why the field data range is smaller than the experimental data in this paper.

Wu et al. (2020) classified the boulder bars in the downstream reaches of the Yigong River into three types according to their shapes and used the length to width ratio as the indicator of a bar shape. The 16 boulder bars in the downstream reaches of the Yigong River have a length to width ratio of 2.5-15. As can be seen from Fig. 9, the length to width ratio of the boulder bar formed in this experiment is in the range of 7 to 16, which indicates the field data could prove the experimental results.

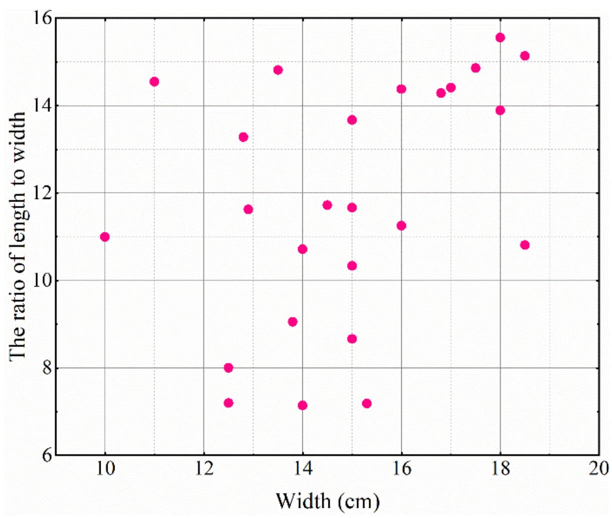


Figure. 9 The ratio of boulder bar length to width

Turzewski et al. (2019) measured the sizes of boulder bars. They found that grain sizes of boulder bars decrease downstream. In this experiment, boulder bar materials from different river bed sections were collected. And after screening and analysis, it was found that as the distance between the boulder bar and the dam increases, the particle diameter in the bars shows a decreasing trend, as shown in Fig. 10. This feature is consistent with the description of Turzewski et al. (2019).

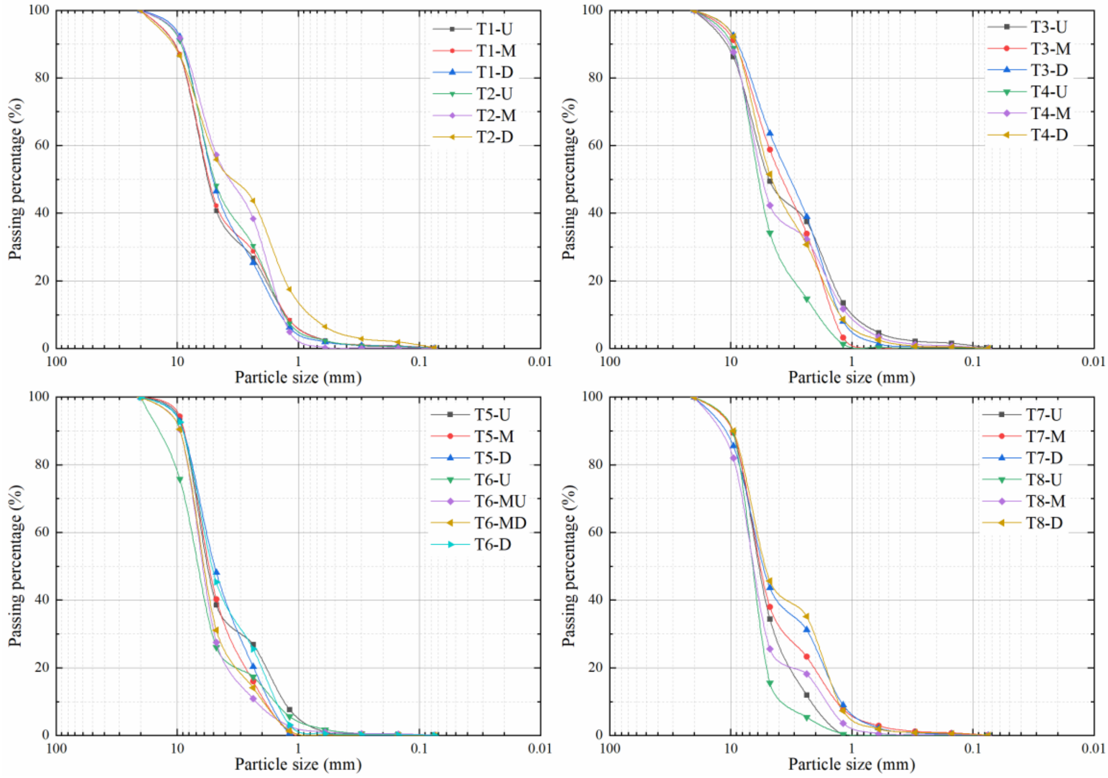


Figure. 10 Gradation curve of the boulder bar materials. Notation: U, M, D, MU, and MD, represent the boulder bar near the upstream reaches, the boulder bar near the middle reaches, the boulder bar near the downstream reaches, the boulder bar near the middle-upstream reaches, and the boulder bar near the middle-downstream reaches, respectively.

Based on the above points, it can be seen that the experimental results in this paper are consistent with the actual boulder bars in the field. Therefore, the experimental results can provide guidance for the field study of the boulder bar formed by the outburst flood."

Line Comments:

29: It "is" found. . .

Thanks for the reviewer's guidance. The line 29 in the original manuscript is related to the Froude number. In the revised manuscript, we have deleted the content related to the Froude number. Therefore, this sentence is no longer in the revised manuscript.

35: Exchange "reference the research on" with "can be applied to"

Thanks a lot for the reviewer's comments. We have made corrections in accordance with the reviewer's requirements. See the line 32 of the revised manuscript for details: "results in this paper can be applied to the river channel's geomorphological characteristics analysis triggered by overtopped landslide dam failure."

41: delete "collapses" and just use "landslides"

Thank the reviewer for this suggestion. We have made corrections in accordance with the reviewer's requirements. See line 38 of the revised manuscript for details: "Activities such as rainfalls and earthquakes often cause landslides, which block the river to form a water-retaining body similar to a reservoir dam, called a landslide dam (Takahashi, 2007; Costa and Schuster, 1988; Casagli, 2003). "

60: "At present, much research. . ."

Thanks a lot for the reviewer's comments. We have corrected the sentence in the revision.

74: throughout the introduction, I suggest replacing semicolons with periods and starting new sentences.

Thanks very much for the reviewer's comments. We have rewritten the introduction section in the revised manuscript based on your valuable suggestion.

118-131: good concluding paragraph of the introduction

Thanks very much for the reviewer's compliment. We used these sentences in our rewritten Introduction:

"Above all, no matter whether it is field observations or indoor experiments, the boulder bar's development characteristic during the landslide dam overtopping failure process has not been proved. This paper focuses on the formation processes, the geometrical size characteristics of boulder bars in the downstream channel during the overtopping failure process, and how the dam volume and the released flood volume affect boulder bars' total volume. Firstly, through flume experiments, boulder bars' formation processes on the downstream channel under the dammed lake failure condition were reproduced. Then, based on the experimental data, the development characteristics of boulder bars' upstream and downstream edges were analyzed. Furthermore, statistical analysis of boulder bars geometrical dimensions at each moment during the failure process, such as length, width, height, and volume, had been carried out to obtain boulder bars' size characteristics. And then, by analyzing the total volume of the boulder bar under different dam volumes and the released flood volumes, the influences of the released flood volume and dam volume on the boulder bar total volume were obtained. Finally, compare the boulder bar formed by the Yigong outburst flood and the boulder bar formed by the experiment to verify this experiment's reliability. "

156: spelling: "gravels"

Thanks a lot for the reviewer's comment. We have revised the spelling of the "gravels" : "The dam materials used in this study were mixtures of sand and gravels, with a median particle size D_{50} of 3.8 mm. "

156-157: Was there any dimensional scaling of the grain size? What would this sediment size correspond to in a field setting?

Thanks a lot for your comments. Although, there was not any dimensional scaling of the grain size, the type of materials used in the tests was similar to the filed, and the materials could ensure the overtopped failure mode happen for the tests. Most of the barrier dams in the field are mixtures of fine particles and coarse particles, therefore, we selected mixtures of sand and gravels as the experimental materials. With reference to Vallejo and Mawby (2000) and Wan and Fell (2008), considering the limitations of the experimental flume space and the size of the dam model, the experimental material adopted a median particle size of 3.8mm mixtures of sand and gravels to improve the possibility of overtopping failure of dam model. Therefore, the selection of dam model and material in this experiment could meet the experimental requirements.

Reference:

Vallejo L. E., Mawby R.: Porosity influence on the shear strength of granular material–clay mixtures, Engineering Geology, 58(2):125-136, https://doi.org/10.1016/S0013-7952(00)00051-X , 2000.

Wan C. F., Fell R.: Assessing the Potential of Internal Instability and Suffusion in Embankment Dams and Their Foundations, Journal of Geotechnical and Geoenvironmental Engineering, 134(3):401-407, https://doi.org/10.1061/(ASCE)1090-0241(2008)134:3(401), 2008,

180: Were the balls buoyant in the flow?

We are honored to be able to answer the reviewer's confusion. The balls used in the experiment have a small mass and can float on the flow surface, and can be used to measure the flow velocity.

188: Are you only able to measure the height along the flume wall? Rather than the average height across the channel?

We are honored to answer the reviewer's questions. We could measure the height along the flume wall timely and conveniently during the dam failure process. Although, the height of other positions maybe different with the section along the flume wall, but the difference is small. So we selected the boulder bar's section along the flume wall as concerned positions of the boulder bar and measured the height of the boulder bar of these positions. Because of the irregular shape of the boulder bar, the height of the boulder bar is different at different position, so we take the average height along the wall of the flume as the representative height value of the boulder bar.

220: Are these sandbars or gravel bars? They look to be dominated by the coarse fraction in the photos.

Thanks a lot for the reviewer's reminder that gravel bars were formed in the river bed during the dam failure in the experiment, which corresponds to the boulder bar formed by the outburst flood in the field. We have also corrected this concept in the revised manuscript.

227-229: This sounds like alternate bar formation, for which there is significant literature that was not discussed in the introduction.

Thanks a lot for the reviewer's comment. As the reviewer mentioned, we have changed the concepts of "sandbar" to "boulder bar". In the revised manuscript we have rewritten the Introduction on "boulder bar".

314-316: I don't understand why a smaller discharge would lead to a larger bar spacing. Please elaborate.

It is a great honor for us to explain this phenomenon to the reviewer. Maybe we did not describe it clearly that the "discharge" is "inflow discharge". We have clarified this term in the revision. Although the inflow discharge in the experiment is small, but the stored water volume behind the dam may be large. When the water volume in front of the dam is large enough, the landslide dam will be over-topped, and the dam will be failure very quickly. Water will be released in a short time, and the outburst discharge may be large (Jiang and Wei, 2020; Carrivick 2010; Jiang and Wei, 2018). We have deleted the confusing sentences. In order to facilitate the readers to understand the degree of amplification of the discharge, we also give the peak discharge of 8 sets of experiments (Figure 1).

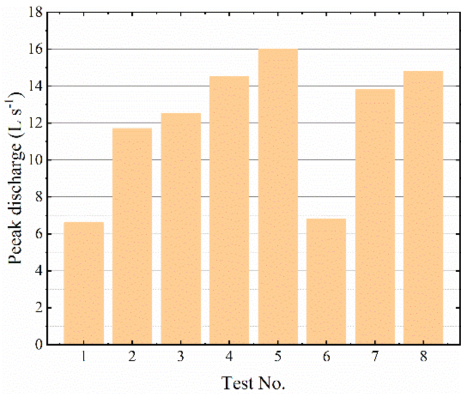


Figure 1. The breaching discharge hydrographs for T1 to T8 tests

Reference:

Carrivick, J. L.: Dam break–outburst flood propagation and transient hydraulics: a geosciences perspective. J Hydrol, 380(3–4):338–355, https://doi.org/10.1016/j.jhydrol.2009.11.009, 2010.
Jiang, X. G. and Wei, Y. W.: Natural dam breaching due to overtopping: effects of initial soil moisture. Bull Eng Geol Environ 78, 4821–4831, https://doi.org/10.1007/s10064-018-01441-7, 2018.
Jiang, X.G., and Wei, Y.W: Erosion characteristics of outburst floods on channel beds under the conditions of different natural dam downstream slope angles, Landslides, 1-12, https://doi.org/10.1007/s10346-020-01381-y, 2020.

297-324: It would be useful to have a table or figure to show these differences between the experiments explicitly, or discuss in the context of Figure 5.

Thanks a lot for the reviewer's advice. We have revised the figure as the reviewer's suggestion. With the new Figure 4 in the revised manuscript, it is easy to understand the characteristic of the position of the boulder bar.

401: Please provide some more on the calculation based on Laursen; bed load? Suspended load?

After careful consideration, we decided to delete the calculation of the concentration in the revised manuscript. There is no more content related to concentration in the revised manuscript.

407-422; Figure 8: I have no basis to judge any of this section because I do not know how the authors calculated these values with the available data. Using the surface velocity in different sections as measured with ball movement? What was the grain size used in the concentration calculation?

After careful consideration, we decided to delete the calculation of the concentration in the revised manuscript. There are no more contents related to concentration in the revised manuscript.

422: Spelling: abdomens? I think a different word was intended.
Thanks a lot for the reviewer's suggestion. We replaced "abdomens" with "waists" in the revised manuscript (see line 259 in the revised manuscript).

444: Were the concentration calculations using Laursen based on bedload as well?

Thank you very much for the comment. After careful consideration, we decided to delete the calculation of the concentration in the revised manuscript. There are no more contents related to concentration in the revised manuscript.

451: equation 4 is not correct – need to square u in the numerator*

Thanks a lot for the reviewer's correction. We have deleted equation 4 in the revised manuscript.

473-477: Not sure I agree with this logic. These Froude numbers are well over 1 in the supercritical regime. The shear stress as calculated is lower at higher Froude numbers because it will be shallower, but the velocity will actually be even greater.

Thanks a lot for the reviewer's comment. This comment is very helpful to us. We all agree with the reviewer's point of view. After our discussion, we have deleted this part in the revised manuscript.

Figure 3: It looks like these are essentially alternate bars forming in a straight flume channel – you state that this is similar to the field setting, but are the bar locations sometimes also controlled by the presence of obstructions?

Thanks a lot for the reviewer's comment. The question raised by the reviewer is very valuable. Boulder bar locations are sometimes controlled by the presence of obstructions. The river bed downstream terrain conditions of the field landslide dam are more complicated. In the lab, we simplified the experimental conditions. For example we simplified the channel shape and omitted the obstacle in the channel. The straight channel used in the tests is a common simplified model (Jiang and Wei, 2020; Chen et al., 2015). It is convenient for us to use the straight channel model to summarize the characteristics of boulder bar's formation and development. When the river bed in the experiment is not of equal width and straight, it is not conducive to drawing a general rule. In addition, the experimental dam model designed according to the method of Zhou et al., (2019) can reflect the actual characteristics of the field landslide dam. And according to the research of Vallejo and Mawby (2000) and Wan and Fell (2008), the materials for this experiment can be meet the experimental requirements.

Reference:

Chen, S. C., Lin, T. W., and Chen, C. Y.: Modeling of natural dam failure modes and downstream riverbed morphological changes with different dam materials in a flume test, Engineering Geology, 188, 148-158, https://doi.org/10.1016/j.enggeo.2015.01.016, 2015.

Jiang, X. G., and Wei, Y. W: Erosion characteristics of outburst floods on channel beds under the conditions of different natural dam downstream slope angles, Landslides, 1-12, https://doi.org/10.1007/s10346-020-01381-y, 2020.

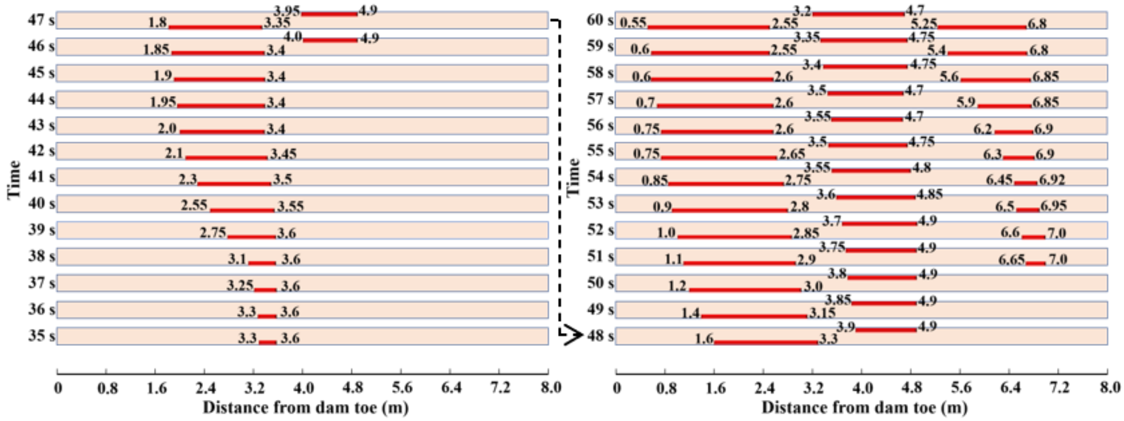
Vallejo L. E., Mawby R.: Porosity influence on the shear strength of granular material–clay mixtures, Engineering Geology, 58(2):125-136, https://doi.org/10.1016/S0013-7952(00)00051-X , 2000.

Wan C. F., Fell R.: Assessing the Potential of Internal Instability and Suffusion in Embankment Dams and Their Foundations, Journal of Geotechnical and Geoenvironmental Engineering, 134(3):401-407, https://doi.org/10.1061/(ASCE)1090-0241(2008)134:3(401), 2008,

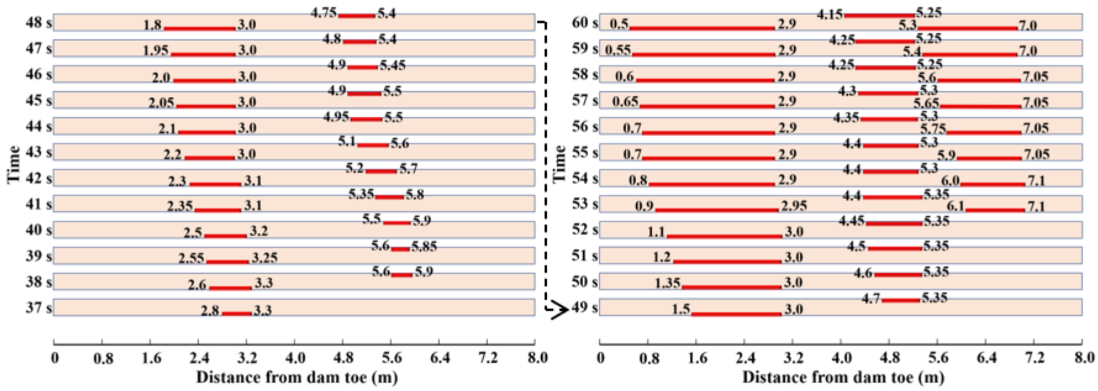
Zhou, G. G. D., Zhou, M. J., Shrestha, M. S., Song, D. R., Choi, C. E., Cui, K. F. E., Peng, M., Shi, Z. M., Zhu, X. H., and Chen, H. Y.: Experimental investigation on the longitudinal evolution of landslide dam breaching and outburst floods, Geomorphology, 334, 29-43, https://doi.org/10.1016/j.geomorph.2019.02.035, 2019.

Figure 4: I wonder if this figure could be simplified to focus on the key points in the discussion of the figure that describe the 3 variations of response.

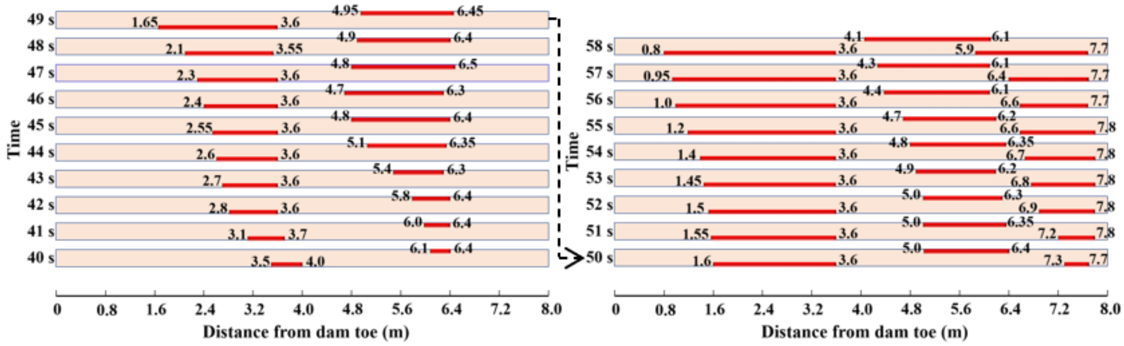
Thanks a lot for the reviewer's comment. Figure 4 in the manuscript shows the change of the position of the boulder bar during the dam failure process. Figure 4 can very intuitively and vividly express the change of the position of the boulder bar over time. Therefore, if possible, we would like to retain the contents of Figure 4. The revised Figure 4 is as follows:



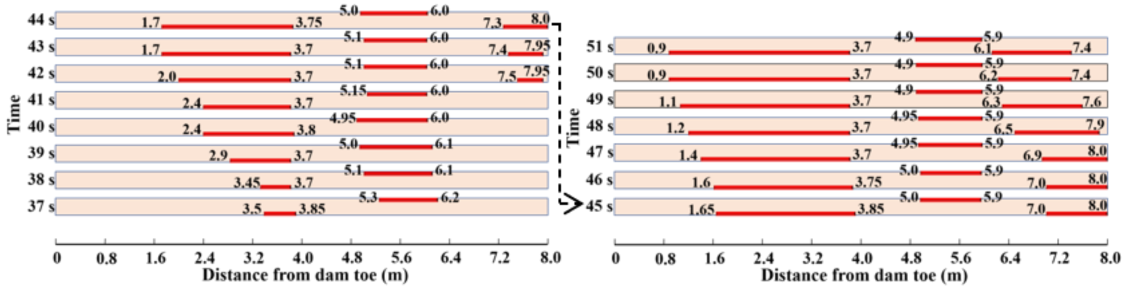
(a)



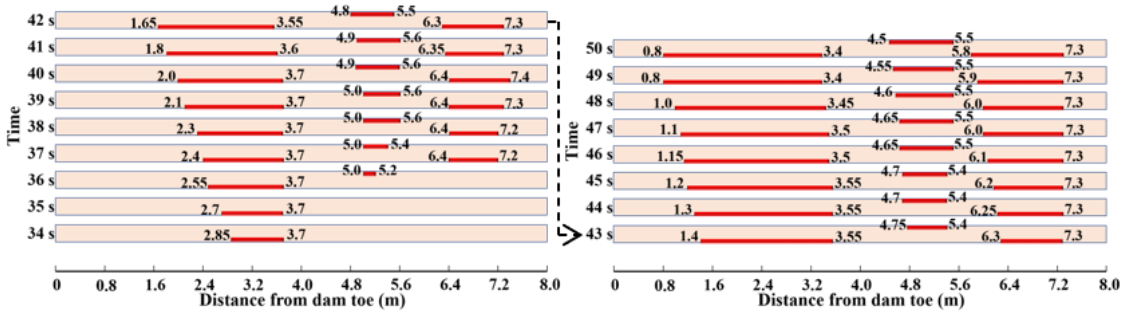
(b)


Time
0 0.8 1.6 2.4 3.2 4.0 4.8 5.6 6.4 7.2 8.0
Distance from dam toe (m)

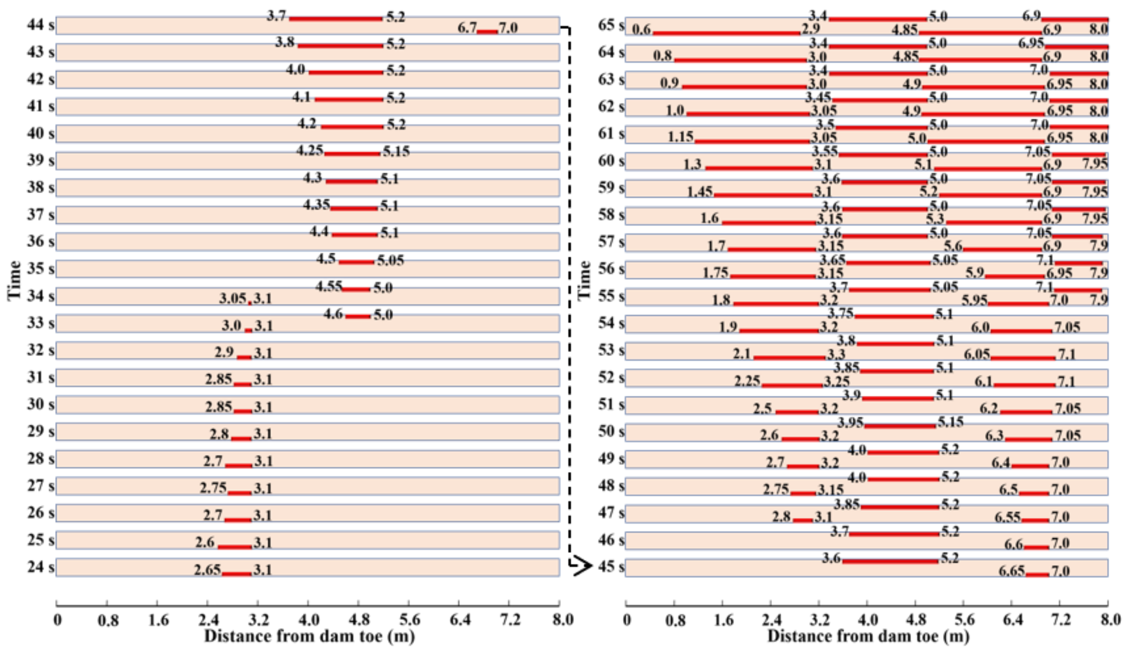
(c)


Time
0 0.8 1.6 2.4 3.2 4.0 4.8 5.6 6.4 7.2 8.0
Distance from dam toe (m)

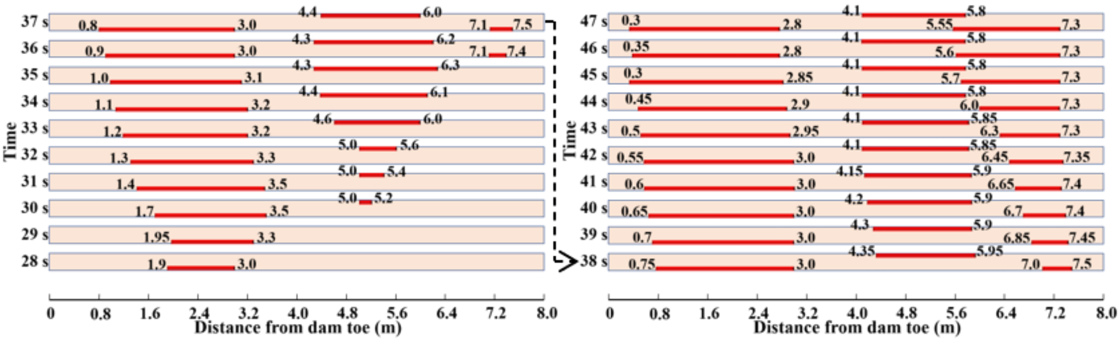
(d)


Time
0 0.8 1.6 2.4 3.2 4.0 4.8 5.6 6.4 7.2 8.0
Distance from dam toe (m)

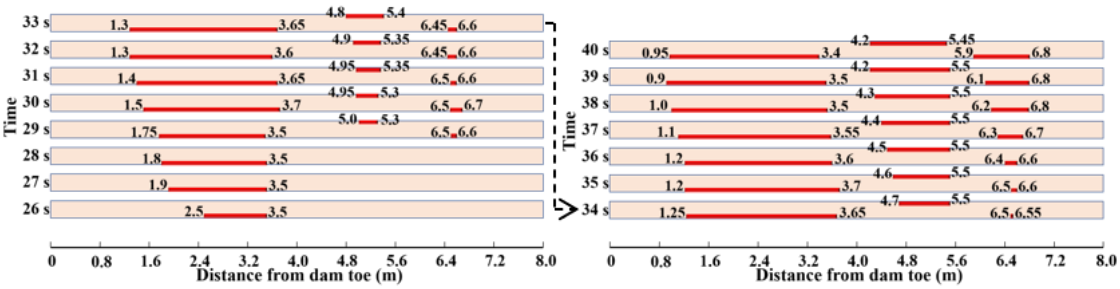
(e)


Time
0 0.8 1.6 2.4 3.2 4.0 4.8 5.6 6.4 7.2 8.0
Distance from dam toe (m)

(f)



(g)



(h)

Figure. 4 The boulder bars' locations during the dam failure process. Notation: (a) to (h) represent the boulder bars' locations for T1-T8 tests, respectively. The red lines in the figure represent the boulder bars, and the orange rectangles represent the channels. The numbers at both ends of the red lines represent the distances between the upstream and downstream edges of boulder bars and the dam toe.

Figure 5: This is a complex of a figure relative to its discussion in the text; the scale bar doesn't allow us to see much of a trend except for length. There is not consistency in the labeling scheme (dots for length, triangles for width, for example; same colors for the same model runs).

Thanks a lot for the reviewer's comment. According to the reviewer's suggestion, we have modified Figure 5 in the manuscript. We hope that the revised figure can satisfy the reviewer. The revised figure is in the following:

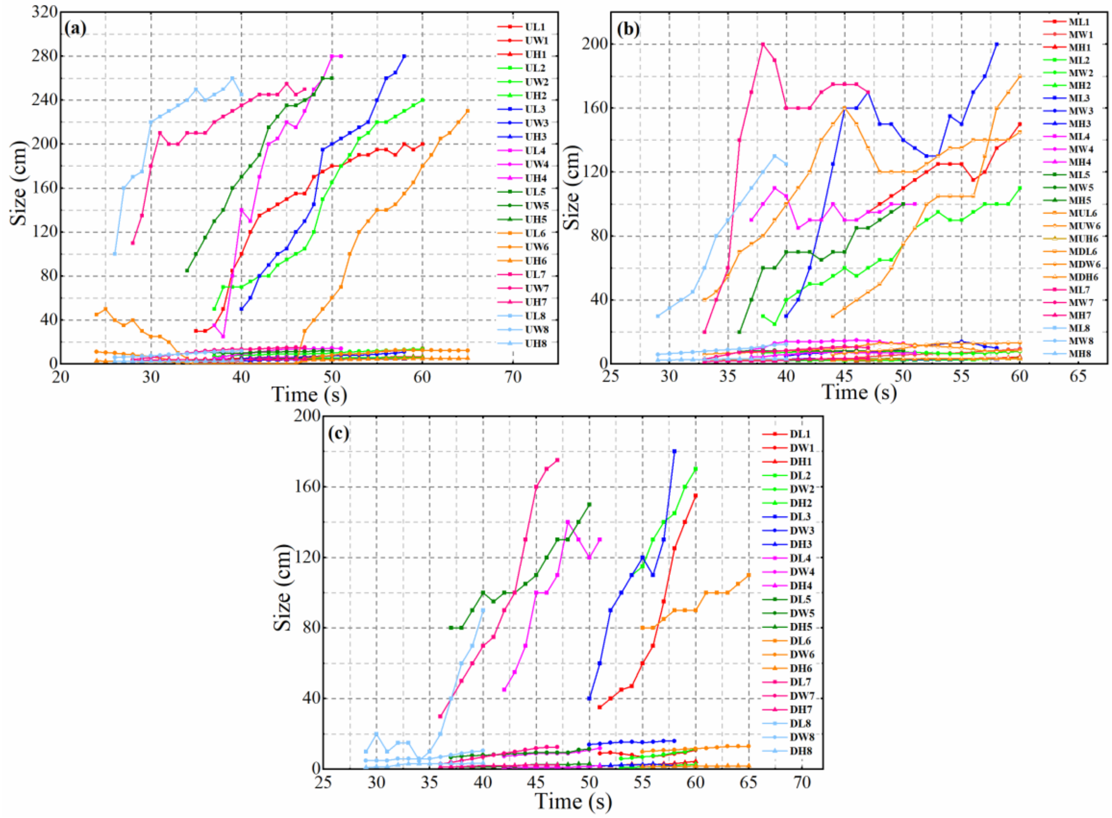


Figure. 5 The lengths, widths, and heights of the boulder bars: (a) sizes of the boulder bars near the upstream reaches; (b) sizes of the boulder bars near the middle reaches; (c) sizes of the boulder bars near the downstream reaches. Notation: L, W, and H represent the length, width, and height of the boulder bar, respectively. i represents the Ti experiment. For example, MUL6 indicates the length of the boulder bar near the middle-upstream reaches for the T1 test.

Figure 6: Same comment as figure 5 with regard

Thanks a lot for the reviewer's comment. This suggestion is very helpful to us. We have modified Figure 6 in the manuscript as suggested by the reviewer, as shown in the figure below

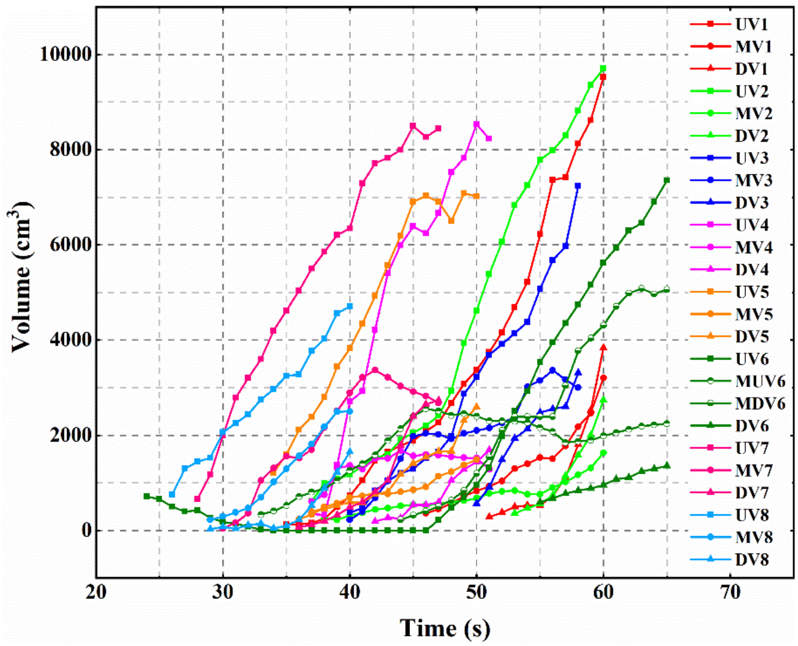


Figure. 6 Volumes of boulder bars. Notation: UVi, MVi, DVi, MUVi, MDVi represent the volume of the boulder bar near the upstream reaches, the boulder bar near the middle reaches, the boulder bar near the downstream reaches, the boulder bar near the middle-upstream reaches, and the boulder bar near the middle-downstream reaches, respectively. For example, UV1 means the boulder bar's volume near the dam toe of the T1 test