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Extended Abstract
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Applying HEC-RAS 2D to simulate the landslide dam breach in Feng-Ping stream watershed, Hualien County, Taiwan

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1. Introduction

Landslide dam breach posts a significant threat to the downstream population and property (Liao et al., 2018). These dams are typically located in the mountainous area where people are difficult to arrive. However, the flooding caused by the landslide dam breach often larger than induced by rainfall events in the watershed. In addition, the available alarm time is usually short for evacuation (Becker et al., 2007). Therefore, there is a need to develop a quickly assessment tool for the landslide dam identification to predict the flooding after the landslide dam breach. In this study, BigGIS was utilized to identify the backwater area of the landslide dam and HEC-RAS model used to simulate the flow range after the landslide dam breach.

2. Materials and Methods

2.1 Study area and the backwater range identification for landslide dam

According to the news report on 22, April, 2022, the landslide dam (23.496232, 121.256382) was investigated recently that was formed in the upper Feng Ping watershed, Hualien County, Taiwan (Figure 1B). The watershed area is 265 square km, including 156 square km for the upper watershed area and 109 square km for the downstream watershed area of the landslide dam, as shown in Figure 1A.

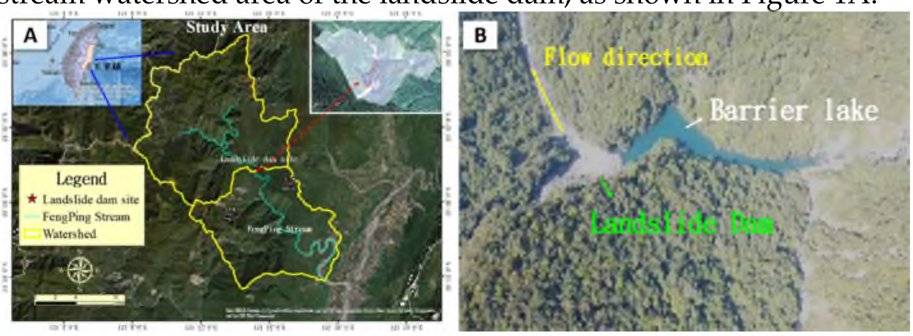

Figure 1. Feng-Ping watershed. A) Study area; B) landslide dam image (ftvnews)

To estimate the backwater area and volume for landslide dam by the cut-fill tool in BigGIS. The backwater area will be identified when the range specifying the dam elevation manually is consistent with SPOT image recorded on 18, April, 2022 as possible, as shown in Figure 2. The water accumulation behind the landslide dam is about the size of 38 swimming pools. The dam geometric are listed in Table 1.

Figure 2. The backwater area identification for landslide dam. A) Satellite image (SPOT) on 18, April, 2022; B) the cut-fill tool to estimate the backwater volume**.**

Table 1. The landslide dam data

Backwater area (ha)	Backwater volume (m^3)	Dam crest elevation (m)
2.44	**123,000**	**637**

2.2 Precipitation boundary condition

In this study, Hec-Ras model was used to simulate the two-dimensional flow of landslide dam breach due to a 24-hours rainfall event. For precipitation boundary condition, a 24-hours storm for seven return period were designed (Figure 3).

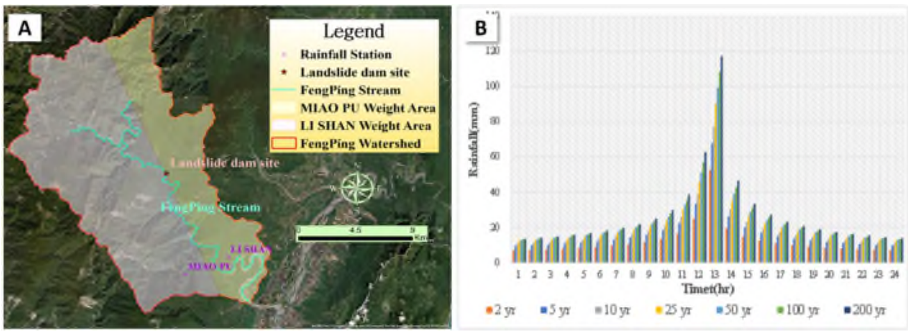

Figure 3. A 24-hours storm design for return period, 2, 5, 10, 25, 50, 100, 200yr. A) the area weights of MIAO PU and LI-SIIAN rainfall stations were analyzed by Thiessen method; B) the rainfall intensity design by Horner Equation.

2.3 Dam breach parameter settings and Model scenario simulation

The field data for dam geometry, dam-breach formation time, and dam failure mode are difficult to be observed. In practice, we focus on overtopping is assumed in dam failure mode. Dam breach formation time is set to 0.5 hr. Initial water stage behind the landslide dam is 637 m as the same value as dam crest elevation in table. 1. Finally, two scenarios were simulated. First, to simulate the flow path of water accumulation behind the landslide dam during the dam breach. Second, to simulate the downstream inundation range for rainfall induced dam breach.

3. Results and Discussion

In first scenario, after the dam breach, the 123,000 m^3 water will flow 2.25 km to the downstream. There are still 14.6 km far away from the downstream villages.

In second scenario, the downstream villages will be inundated up to 3 m due to a 24-hours storm event, as shown in Figure 4. The inundation depth also is displayed on Google Earth, as shown in Figure 5. We inferred that the landslide dam breach induced by rainfall causes damage to the downstream villages might be related to larger runoff because of the large basin area.

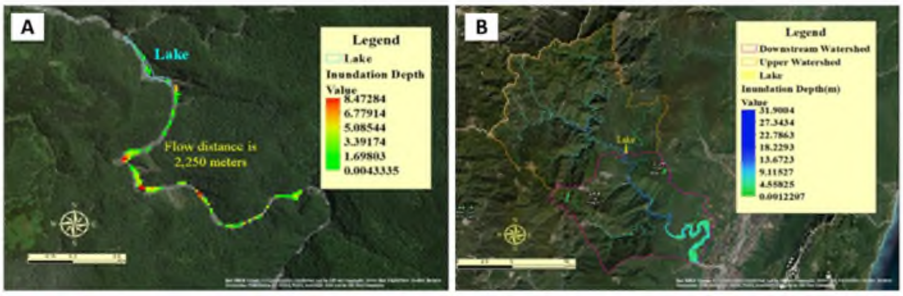

Figure 4. HEC-RAS dam breach simulation. A) The inundation depth after breach; B) the inundation depth with a 24-hours storm for 200-year return period.

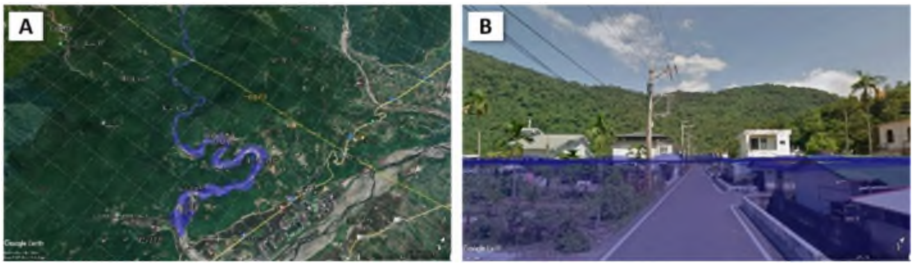

Figure 5. A) The boundary nesting in Google Earth; B) the street view vision.

4. Conclusions

Evaluating the damage of landslide dam breach to the downstream livings is a difficult work due to lack of the field data. However, it is possible to identify backwater range of the landslide dam quickly by using satellite image and cut-fill tool in BigGIS. In addition, by using HEC-RAS dam breach model, the backwater flow after the dam breach could be predicted and evaluated the possible influence area. Based on the simulation results, the influence area of flooding is only 2.25 km. It is still 14.5 km far away from the downstream villages. More importantly, we should pay attention to the damage of the landslide dam breach induced by rainfall events rather than the lake flow in the Feng-Ping watershed.

References

1. Becker, J. S.; Johnston, D. M.; Paton, D.; Hancox, G. T.; Davies, T. R.; McSaveney, M. J.; Manville, V. R., Response to Landslide Dam Failure Emergencies: Issues Resulting from the October 1999 Mount Adams Landslide and Dam-Breach Flood in the Poerua River, Westland, New Zealand. *Natural Hazards Review. ASCE*. 2007
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The information link of BigGIS (SWCB)

Introduction

- Landslide dam breach poses a significant threat to the downstream population and property (Liao et al., 2018).
- These dams are typically located in mountainous areas, and the subsequent flooding caused by the landslide dam breach is more significant than that induced by rainfall events in the watershed. In addition, the available alarm time is usually short for evacuation (Becker et al., 2007).
- Therefore, there is a need to develop a quick assessment tool for landslide dam identification to predict flooding after the landslide dam breach.
- In this study, BigGIS was utilized to identify the backwater area of the landslide dam, and the HEC-RAS model was used to simulate the flow range after the landslide dam breach.

Materials and Methods

The landslide dam (coordinates **N**23.496232, **E**121.256382) was reported on 22 April 2022 and is located in the upper Feng Ping watershed, Hualien County, Taiwan (**Figure 1**). The backwater area and volume of the landslide dam were estimated by the cut and fill tool in BigGIS (**Figure 2**, https://gis.swcb.gov.tw/map/), and the geometric data of the landslide dam was listed in Table 1.

In this study, a 24-hours rainfall event for seven return periods was designed and served as a precipitation boundary condition (**Figure 3**). The HECRAS model was applied to simulate the landslide dam breach with overtopping failure, breach formation time is set to 0.5 (hrs.), and the trigger failure water stage is set to 637 m.

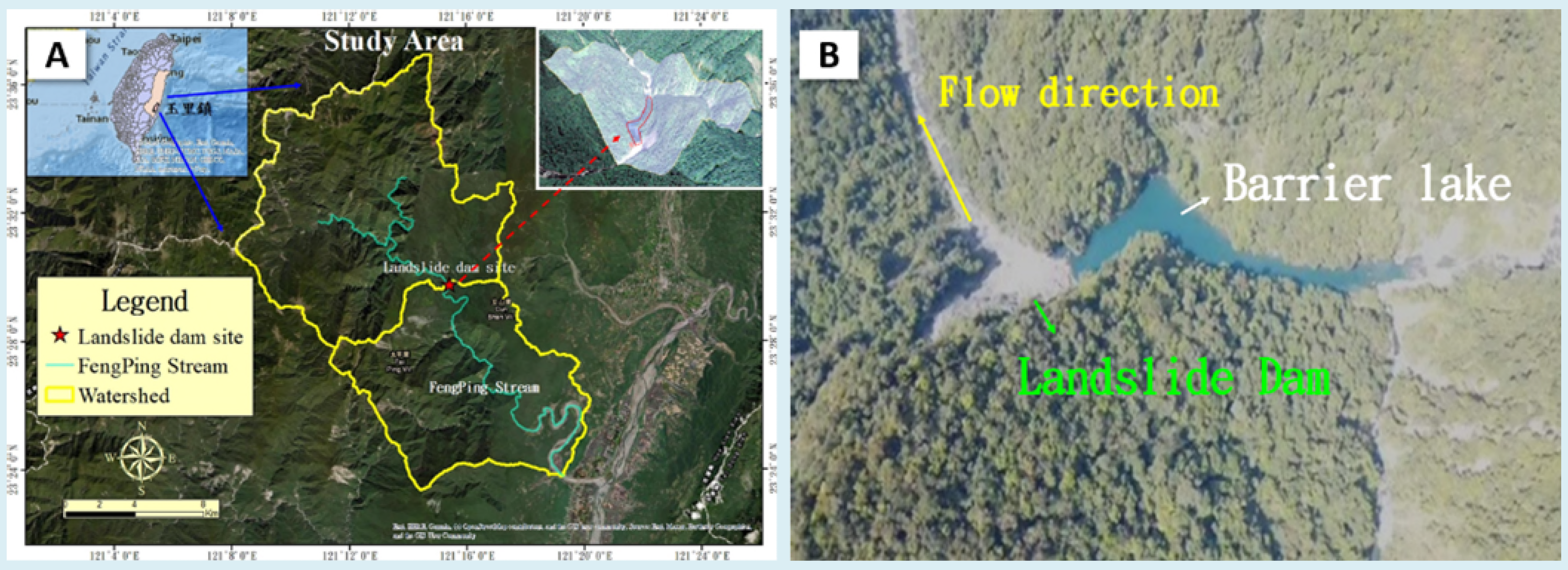

Figure 1. The study area (A) Feng-Ping watershed; (B) Landslide dammed lake image (ftvnews: 22, April, 2022).

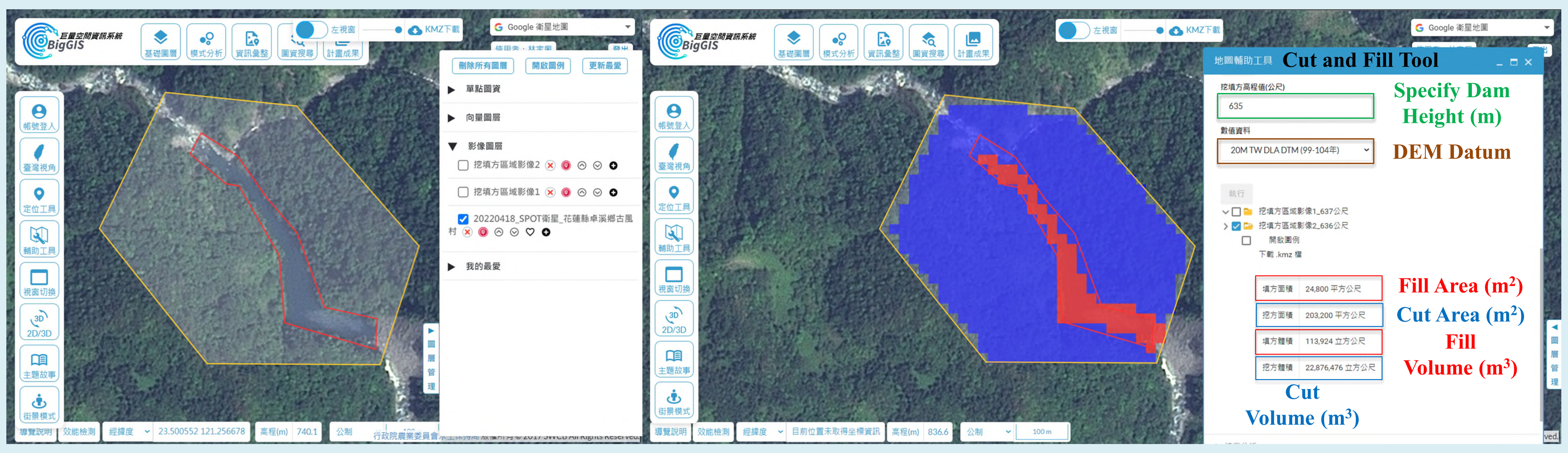

Figure 2. The backwater data identification (A) Backwater area (red polygon); (B) Backwater volume (red area).

Table 1. The Geometric Data of Landslide Dam and Barrier Lake

Backwater Area (ha)	Backwater Volume (m³)	Dam Crest Elevation (m)
2.44	123,000	637
2.12	115,903	635
0.76	40,952	630
0.4	15,836	625
0.08	1,891	620
0	0	615

BigGIS Data: DEM (5m*5m); Satellite image (SPOT; 18, April 2022)

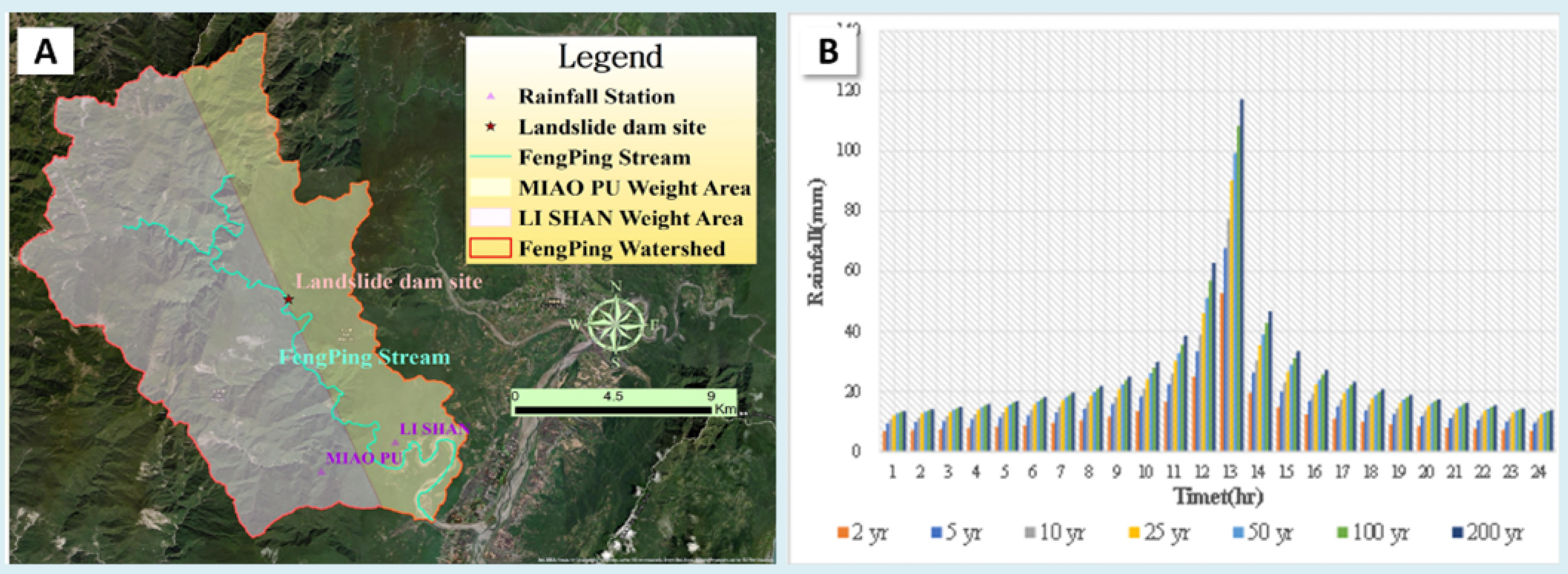

Figure 3. The precipitation boundary condition (A) Rain gauge; (B) Return periods of 24-hour design storm hyetograph.

Results and Discussion

- First scenario is to simulate the flow path of water accumulation behind the landslide dam during the dam breach with a backwater volume of 123,000 (m³). The second scenario is to simulate the downstream inundation range after dam breach caused by a 200-year return period of the designed rainfall.
- In the first scenario, the dam breach with a water volume of 123,000 (m³) shows the flow traveling distance is about 2 km downstream (**Figure 4A**).
- In the second scenario, the downstream villages will be inundated up to 3 m due to a design storm rainfall of a 200-year return period (**Figures 4B and 5**).
- The simulated results indicated that the rainfall events case caused significant damage may be attributed to the increased runoff due to the large basin area.

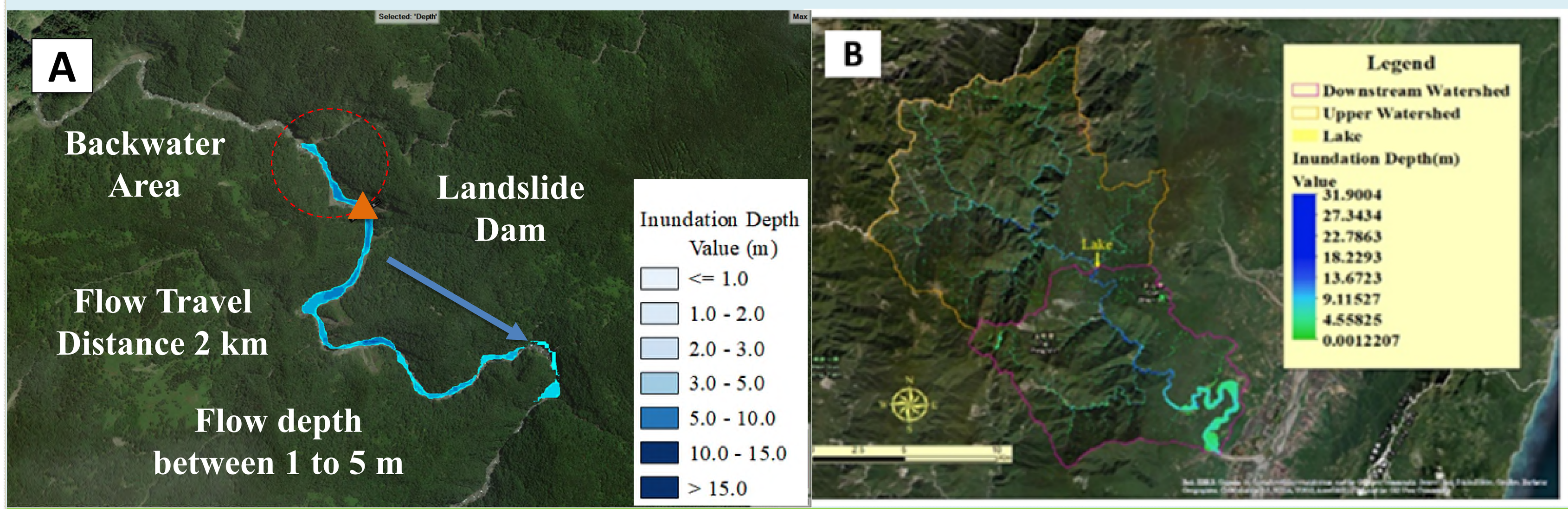

Figure 4. Simulation of landslide dam breach
(A) Flow distance after an outburst of stored water; (B) Inundation depth for a 200-year return period.

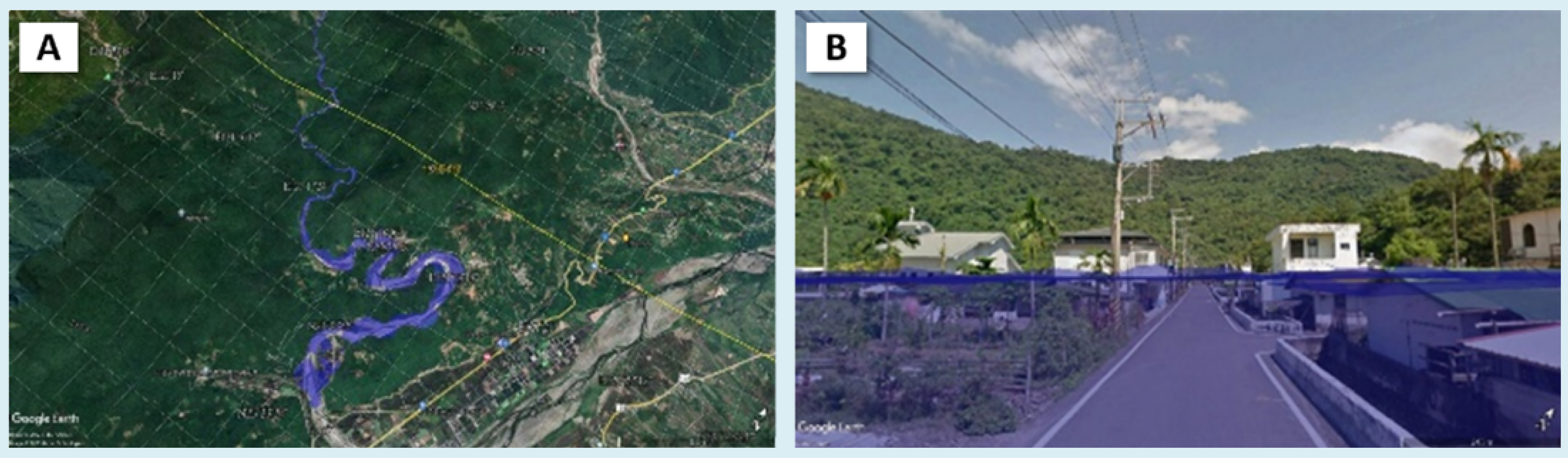

Figure 5. The inundation depth displayed in Google Earth (A) Plain view; (B) The street view.

Table 2. The Parameters of the simulation

Scenario	Boundary Condition	Dam Crest Elevation (m)
1	Storage Volume	637
2	Design storm hyetograph	637

Manning's n set to default; breach formation time 0.5 hour; failure mode overtopping; breach progression sine wave; DEM (5m*5m) used to set up HEC-RAS 2D flow area

Conclusions

1. In scenario 1, the flow travel distance from the landslide dam breach is only 2 km, which is still 15 km from the downstream village.
2. In scenario 2, the landslide dam breach induced by the infrequent rainfall events were more severe damages than the outburst of stored volume.
3. The satellite image and cut-fill tool in BigGIS can quickly identify the backwater range of the landslide dam.
4. The HEC-RAS can provide necessary information for officials to evaluate the potential risk to downstream villages, which can be helpful for disaster prevention and mitigation planning.

References

1. Becker, J. S.; Johnston, D. M.; Paton, D.; Hancox, G. T.; Davies, T. R.; McSaveney, M. J.; Manville, V. R., Response to Landslide Dam Failure Emergencies: Issues Resulting from the October 1999 Mount Adams Landslide and Dam-Breach Flood in the Poerua River, Westland, New Zealand. *Natural Hazards Review*. ASCE. 2007
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