# Train Derailment Induced by a Post-Earthquake Debris Flow in Hualien, Taiwan

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## 1. INTRODUCTION

On 3 April 2024, a M7.2 Hualien Earthquake occurred and resulted in 1,942 coseismic landslides and areas reached $1.52*10^7 m^2$. The Taiwan Railway Express train was derailed by debris that flowed and hit the bridge abutment, causing the train damage and injuring people on 21 June 2024, at 4:50 PM. Satellite images, rainfall data, field investigation, and numerical models were used to analyze the debris flow impact and develop engineering recommendations (Fig. 1). The survey data showed that debris flows along the left side of the river surged onto railway due to the presence of a convex bank and sediment deposition. This study used the pre-event digital elevation model (DEM) as initial topographic data, and the post-event DSM from UAV aerial photos served to verify the simulation results. The simulation indicates that the convex bank affects the debris flow path and impact zone. The simulated result provides the authorities with the necessary information for a debris flow mitigation plan.

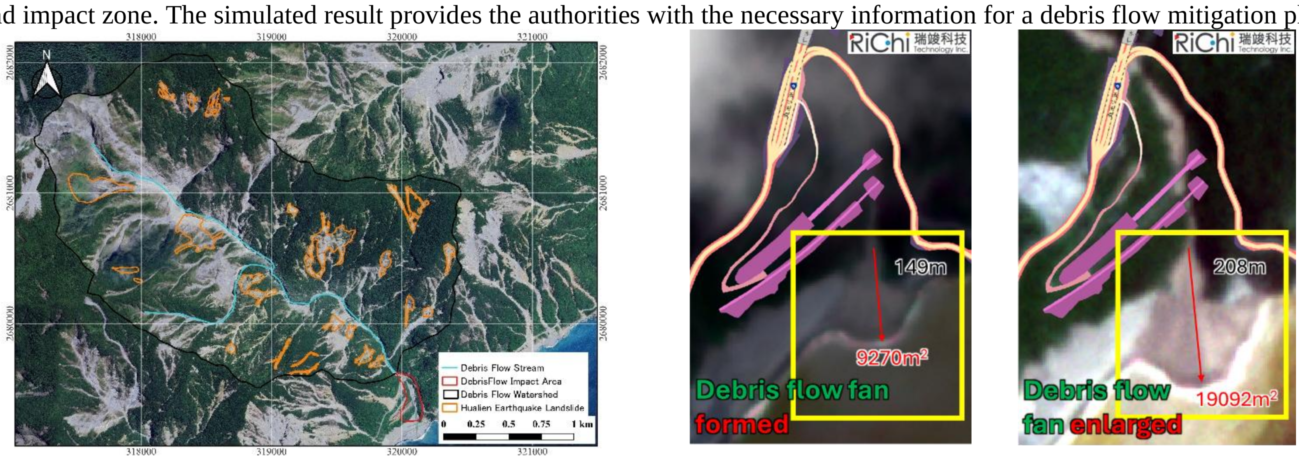
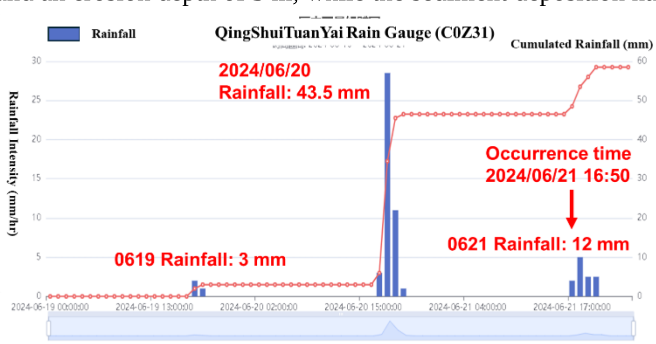



**Fig. 1** Location of the study area: Digital Elevation Model (left) and satellite images (right).

## 2. MATERIALS AND METHOD

### (1) Site condition

The Hualien earthquake triggered 25 coseismic landslides in the catchment, covering an area of $31.7*10^4$ $m^2$, and the landslide ratio reaches 6%. The train derailed at 4:50 PM (June 21, 2024), with a total precipitation was only 12 mm (Qingshuituanyai Rain Gauge, C0Z31) and a rainfall intensity was 5 mm/hr. To analyze the debris flow impact behavior, this study utilized field investigation data, satellite images, and a digital surface model (resolution 0.5 m x 0.5 m) from UAV photos. The first wave of debris flow occurred around 4:00 to 5:00 PM on June 20th, forming a debris flow fan with an area of 9,270 $m^2$, potentially raising the riverbed. The second wave of debris flow occurred at 4:30 PM on June 21st and resulted in the debris flow fan enlarging to 19,092 $m^2$ (Fig. 2). Due to the river's convex bank and deposition on the right bank, the debris flowing along the left bank was directed towards the bridge abutment. According to the survey data, the debris flow path had a width of 9 m and an erosion depth of 3 m, while the sediment deposition had a length of 18 m on the convex bank.



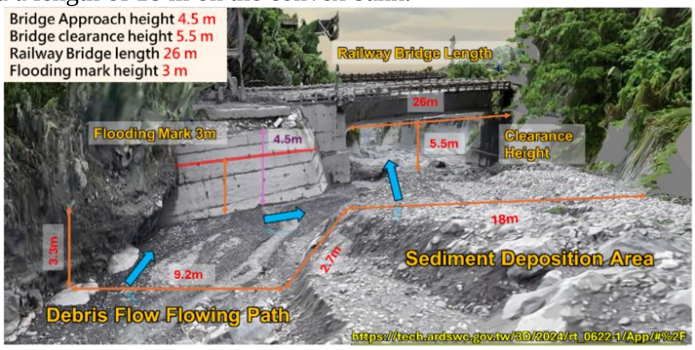




**Fig. 2** Rainfall record of Qingshuituanyai Rain Gauge **Fig. 3** UAV 3D model of post debris flow event (date: 2024/06/22)

### (2) Scenario of debris flow simulation

This study applied the Hyper Kanako 2D debris flow model to simulate debris flow event, considering a return period of 50 years and riverbed dredging effects. The Hyper Kanako 2D model used the pre-event DEM as initial geometry data and with a mesh size of 2m x 2m. The designed rainfall runoff hydrograph served as the boundary condition for the debris flow numerical simulations. Due to the presence of a convex bank and previous sediment deposition in the channel, engineering design considered three different types of riverbed dredging scenarios to mitigate the debris flow impact. The parameters used in this study are listed in Table 1 with scenarios including the train derailment event, design return period event, and different riverbed dredging engineering.

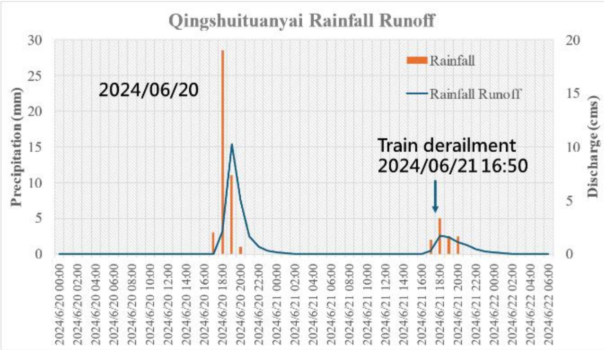



**Fig. 4** Flow hydrograph condition

**Table 1** Parameters of the debris flow simulation

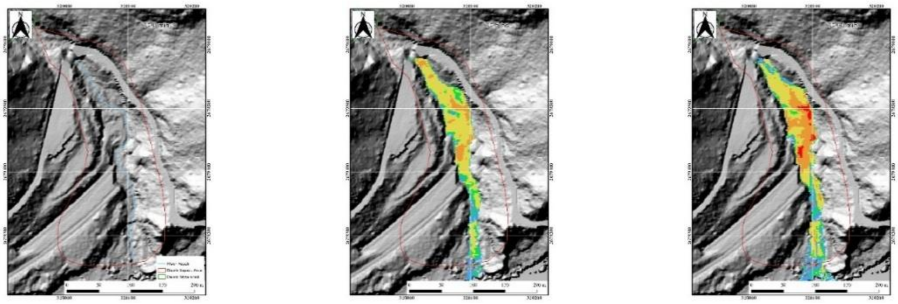
| Case Number | Discharge | Model parameter | | |
|---|---|---|---|---|
| | $Q_p$ ($m^3$/s) | Mesh size | Cv% | Engineering |
| Run 1 | 10 | 2 | 0.3 | Non |
| Run 2 | 135 | 2 | 0.3 | Non |
| Run 3 | 135 | 2 | 0.3 | Dredge1 |
| Run 4 | 135 | 2 | 0.3 | Dredge2 |
| Note | $Q_p$: Peak discharge; Cv: Concentration (%); Dredge1: from the inlet to the convex area. Dredge2: from the inlet to the submerged dam. | | | |

## 3. RESULTS AND DISCUSSIONS

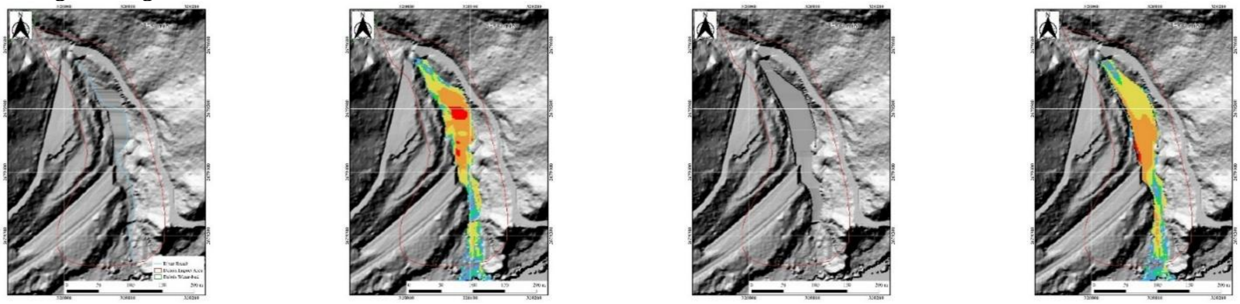
The simulation result of the train derailment event indicates that the direct impact of the debris flow on the railway abutment was caused by presence of a convex bank sediment deposits (Fig.5-b). Furthermore, the 50-year return period simulation shows increased sediment deposits along the left bank, potentially leading to surge onto the railway (Fig.5-c). Hence, considering the riverbed dredging engineering, excavating from the inlet to the convex area, the simulation results indicate that the sediment mainly deposits before the railway abutment (Fig.5-e). In the case of excavation from the inlet to the downstream submerged dam, the simulation results show sediment deposits along right bank with a decreased deposition depth (Fig.5-g).

## 4. CONCLUSIONS

This study employed a model that considered riverbed dredging effects under scenarios including a non-dredged case and various dredge lengths. The simulation results showcase different sediment deposit locations in response to the variations in dredge engineering effects. The result indicates that the railway bridge contraction potentially narrowed the debris flow transport capacity, which led to debris deposition in front of the railway bridge. Engineering work to reduce convex deposits and concave erosion can help avoid debris flow impact on the railway abutment. The field survey and numerical simulation conducted in this study can provide the authorities with the necessary information for regular riverbed dredging and mitigation planning.



a. Non engineering condition　b. Simulation result of Run 1　c. Simulation result of Run 2



d. Dredge1 Condition　e. Simulation result of Run 3　f. Dredge3 Condition　g. Simulation result of Run 4

**Fig. 5** The debris flow disaster simulation results: (left) Cross section, (mid) location of bridge and retaining wall, (right) inundation area.

## References

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**Keywords: Hualien earthquake, Debris flow, Field survey, convex bank effect, Hyper Kanako 2D.**