Date of Submission	13 June 2025

IPL Project (IPL-274) Annual Report Form

Period of activity under report
from 1 January 2024 to 31 December 2024

1. **Project Number and Title:**
   IPL-274: Understanding the seismic response of large-scale geological hazards for developing early warning methods

2. **Main Project Fields**
   Select the suitable topics. If no suitable one, you may add new field.
   (1) Technology Development
   B. Hazard Mapping, Vulnerability and Risk Assessment
   (2) Targeted Landslides: Mechanisms and Impacts
   A. Catastrophic Landslides
   (3) Capacity Building
   B. Collating and Disseminating Information/ Knowledge
   (4) Mitigation, Preparedness and Recovery
   A. Preparedness

3. **Name of Project Leader:** Yifei Cui
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   Core members of the Project:
   1) Dr. Yan Yan/Associate Professor, School of Civil Engineering, Southwest Jiaotong University (SWJTU), China
   2) Dr. Hui Tang/ Senior Scientist, German Research Center for Geosciences (GFZ), Germany
   3) Dr. Fan Xie/ Senior Research Scientist, Institute of Geophysics, China Earthquake Administration, China
   4) Dr. Shuofan Wang/ Post-Doctoral Fellow, River Research Institute, Department of Hydraulic Engineering, Tsinghua University, China

4. **Objectives** (5 lines maximum)
   Based on the laboratory experiments, numerical simulation, and field monitoring, this research aims to develop a new physical model for the seismic signal generated by mass movements considering the basal force, together with a seismic inversion model considering path effect by improving empirical green's functions, finally propose a seismic signal based early warning system combining on-site monitoring, fast numerical simulation, and big data analysis.

5. **Study Area**

The Parlung Tsangpo River Basin, Tibet, China; Wenchuan earthquake area, Sichuan, China
Illgraben, Switzerland

6. **Project Duration**

2024.1-2027.12

7. **Report**

1) Progress in the project (30 lines maximum)

i. A series of multi-scale flume experiments were conducted to investigate the relationship between debris flow dynamics and basal forces. Results revealed:

   a) The probabilistic distribution of basal impact forces under different flow regimes.

   b) Quantitative relationships between seismic amplitude characteristics and dynamic parameters such as flow velocity and particle composition.

   c) Classification criteria for debris flow flow-type identification based on seismic response features.

ii. Numerical Modeling Development: A 1D–2D coupled numerical model was established to simulate debris flow processes with erosion amplification. The model accounts for entrainment effects and improves the accuracy of mass and momentum prediction. A Monte Carlo-based framework was also developed for probabilistic risk analysis of landslide–dam-break disaster chains under varying conditions.

iii. Field Monitoring: A dense seismic sensor network was deployed at Dongchuan Debris Flow Observation Station to monitor full-scale flume tests. The collected high-resolution seismic data improved understanding of signal attenuation, energy transmission, and flow dynamics, providing essential input for model calibration.

iv. Signal Recognition and Inversion: A debris flow detection method based on statistical features was enhanced using machine learning to improve event recognition accuracy. Seismic signals were used to estimate landslide volume and calibrate simulations, supporting the reconstruction of landslide–tsunami hazard chains.

v. International Collaboration: Joint fieldwork with German partners was conducted in mountain catchments near Beijing and at the Brinzauls landslide in Switzerland. These activities promoted technical exchange and led to the submission of two co-authored journal papers.

vi. Dissemination: Nine peer-reviewed papers were published, including six in top SCI journals.

One invention patent and one software copyright were obtained. Project members presented research at major conferences such as EGU and AGU.

2) Planned future activities or statement of completion of the Project (15 lines maximum)

i. Develop an integrated model linking fluid parameters, seismic signals, and basal impact forces, and establish a coupled inversion framework combining seismic analysis and numerical simulation to reconstruct the dynamics of landslides and debris flows.

ii. Derive spatially varying basal resistance coefficients based on micro-scale simulations and field seismic data; enhance computational efficiency through 1D/2D hybrid solvers and GPU-based parallelization.

iii. Construct a real-time, non-contact seismic monitoring and visualization system capable of automatic hazard event detection and rapid response.

iv. Expand the debris flow scenario database and conduct large-scale flume experiments under varied hydrological and topographic conditions to validate the generalizability of the inversion models.

v. Integrate multi-source data—including GIS, remote sensing, and seismic signals—to strengthen regional hazard identification and quantitative risk assessment, providing technical support for early warning systems.

3) Beneficiaries of Project for Science, Education and/or Society (15 lines maximum)

i. The project promotes scientific understanding of the seismic response and dynamic processes of large-scale landslides and debris flows.

ii. It benefits engineering applications, enabling accurate modeling and risk prediction of mountain hazards.

iii. Results are valuable for early warning agencies, with potential to implement real-time seismic-based hazard detection systems.

iv. The collaboration fosters international education through fieldwork, co-authored publications, and joint academic exchange.

v. The methodologies and findings support policy-makers and disaster management agencies in developing effective mitigation strategies in high-risk mountainous areas.

vi. Results contribute to global knowledge-sharing platforms such as the Progress in Landslide Research and Technology (P-LRT) series and WLF conferences.

vii. The technical foundation laid in this project can facilitate future implementation of

AI-assisted early warning systems in vulnerable regions.

4) Results (15 line maximum, e.g. publications)

[1] Yao Li, **Yifei Cui**, Xie Hu, et al. (2024). Glacier retreat in Eastern Himalaya drives catastrophic glacier hazard chain. Geophysical Research Letters, 51 (Top SCI)

[2] Jun Fang, **Yifei Cui,** Haiming Liu. (2024). Effects of retained dry material on the impact, overflow and landing dynamics, Journal of Rock Mechanics and Geotechnical Engineering, (Top SCI)

[3] **Yifei Cui**, Yao Li, Hui Tang, et al. (2024). A digital-twin platform for cryospheric disaster warning, National Science Review, Volume 11, Issue 10, nwae300 (Top SCI)

[4] Chenyang Wang, **Yifei Cui**, Jiayan Nie, et al. (2024). 3D printing-aided numerical study of particle shape effect on behaviours of dry granular flows interacting with rigid barriers. Computers and Geotechnics, 167, 106038

[5] Jian Guo, **Yifei Cui** (2025). Amplification of Landslide Hazards Due to Terrain Modification in Jintian Village During the Ms 6.2 Jishishan Earthquake. Progress in Landslide Research and Technology, Volume 4 Issue 1

[6] Conferences: Invited presentations at EGU 2024, AGU 2024, China Rock 2024, Boao DRR Forum, and ICL-KLC Workshop 2024

Note:

1) If you will change items 2-6 from the proposal, please write the revised content in Red.
2) Please fill and submit this form to ICL Network <icl-network@landslides.org>
3) Reporting year must be one or two years (Maximum).