Investigating the Groundwater Variation and Deformation Kinematics of Large-scale Landslide Under Different Rainfall Patterns Using 3D FEM Analysis

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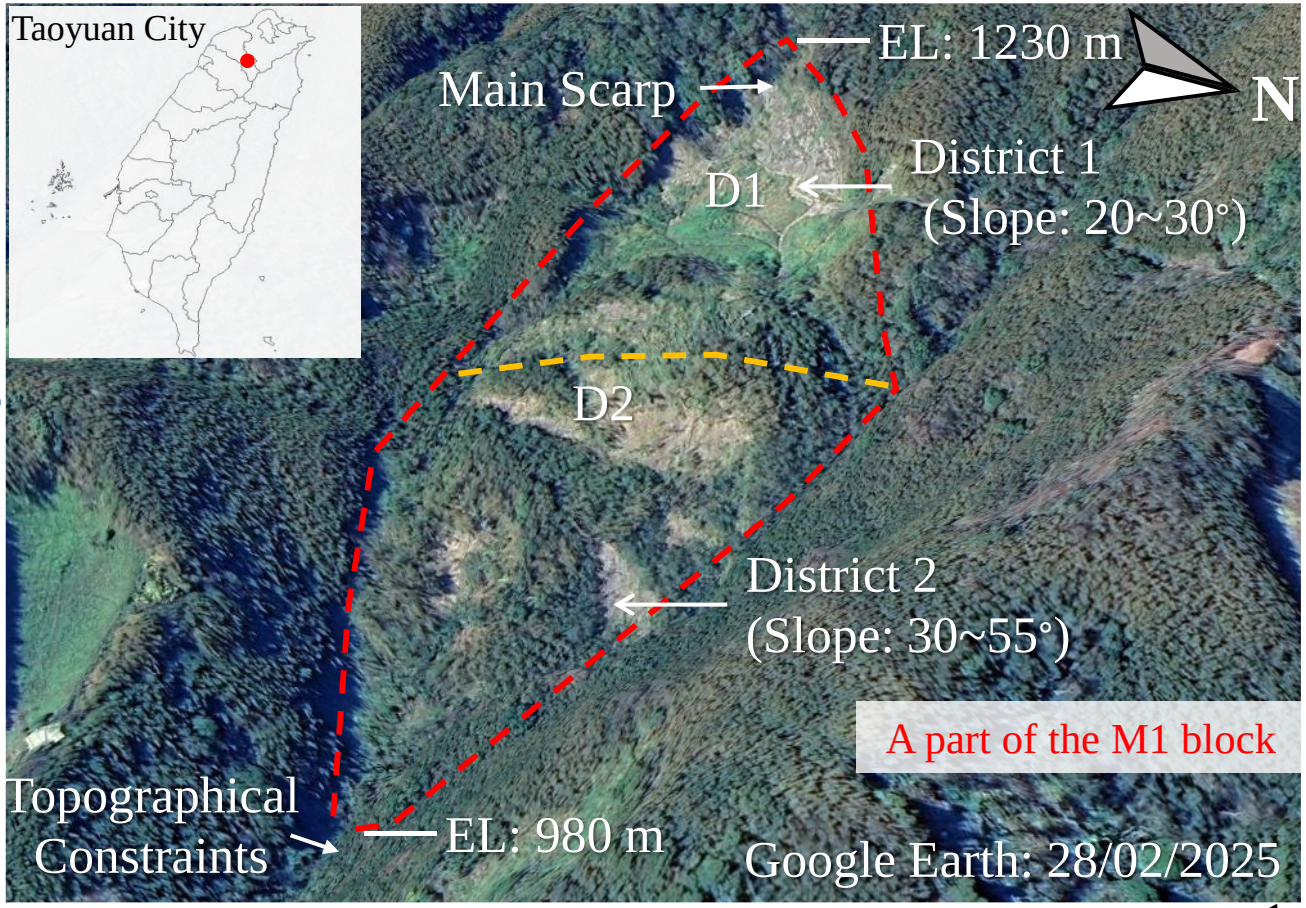
NH3.4 Effects of climate and environmental changes on landslide activity

This presentation will answer the following questions.

1. Why did we choose the Guanghua landslide?

2. How to evaluate **climate and environmental changes?**

3. How to evaluate **landslide activity?**



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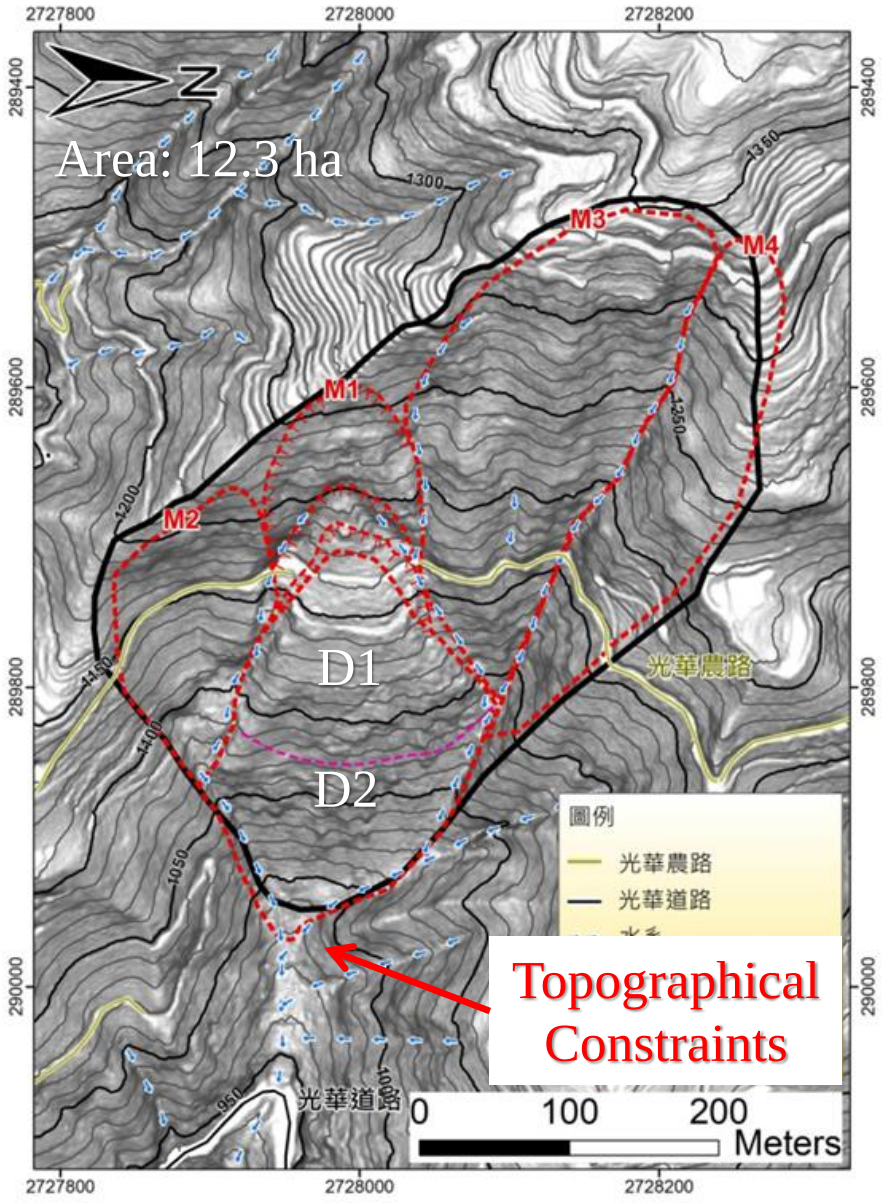
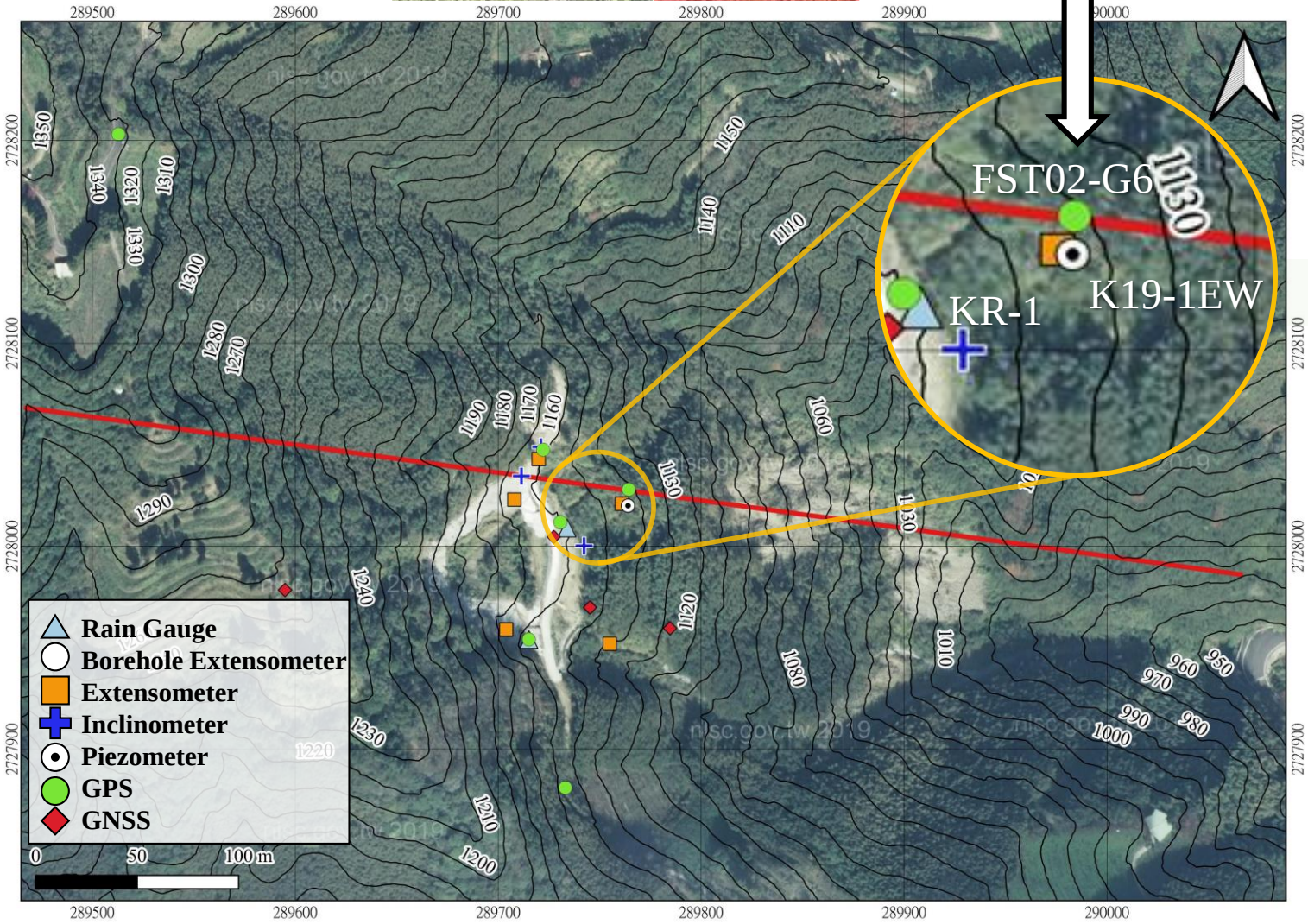
Introduction

The slope and the location of monitoring instruments

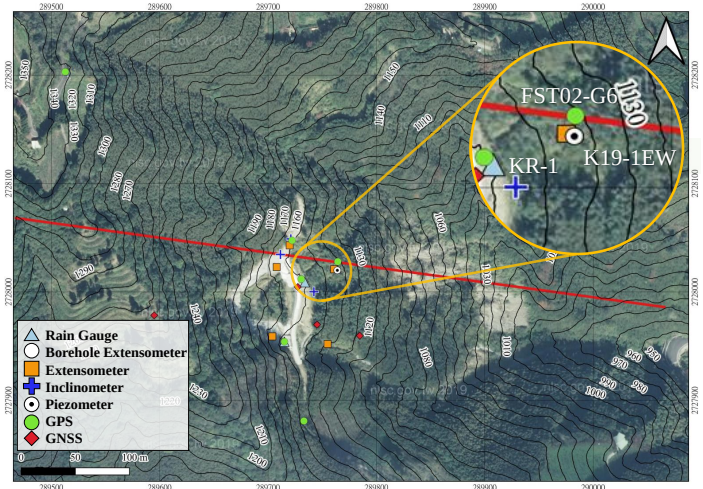


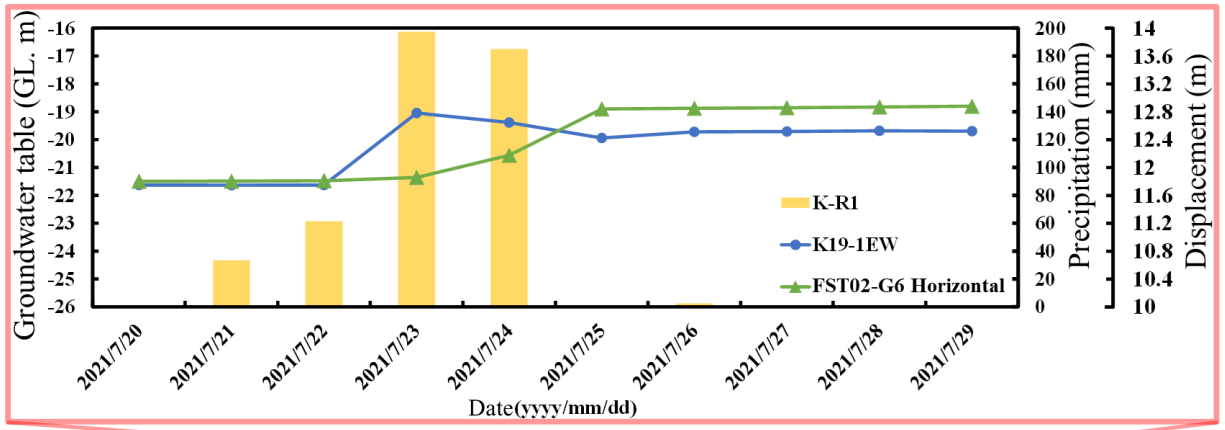
Main instruments used in this research

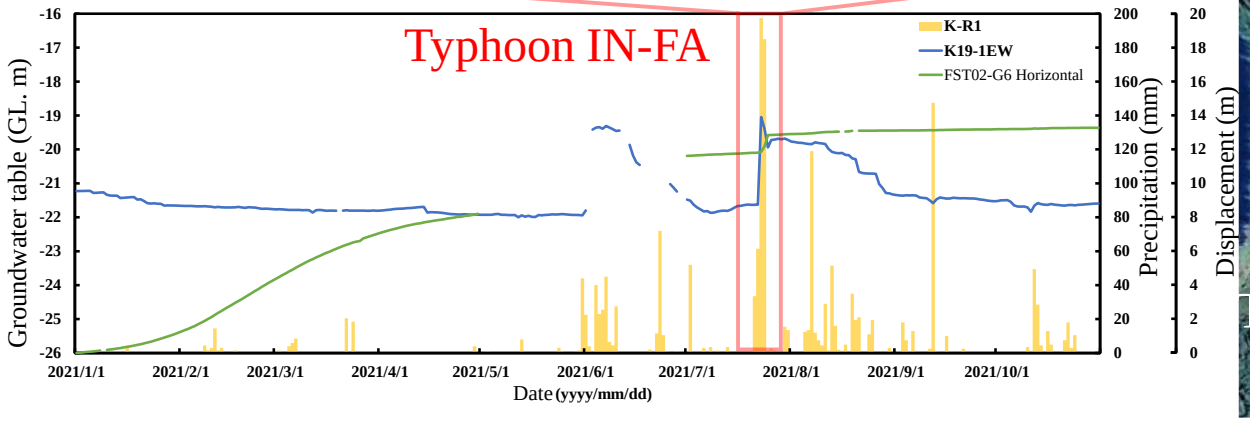


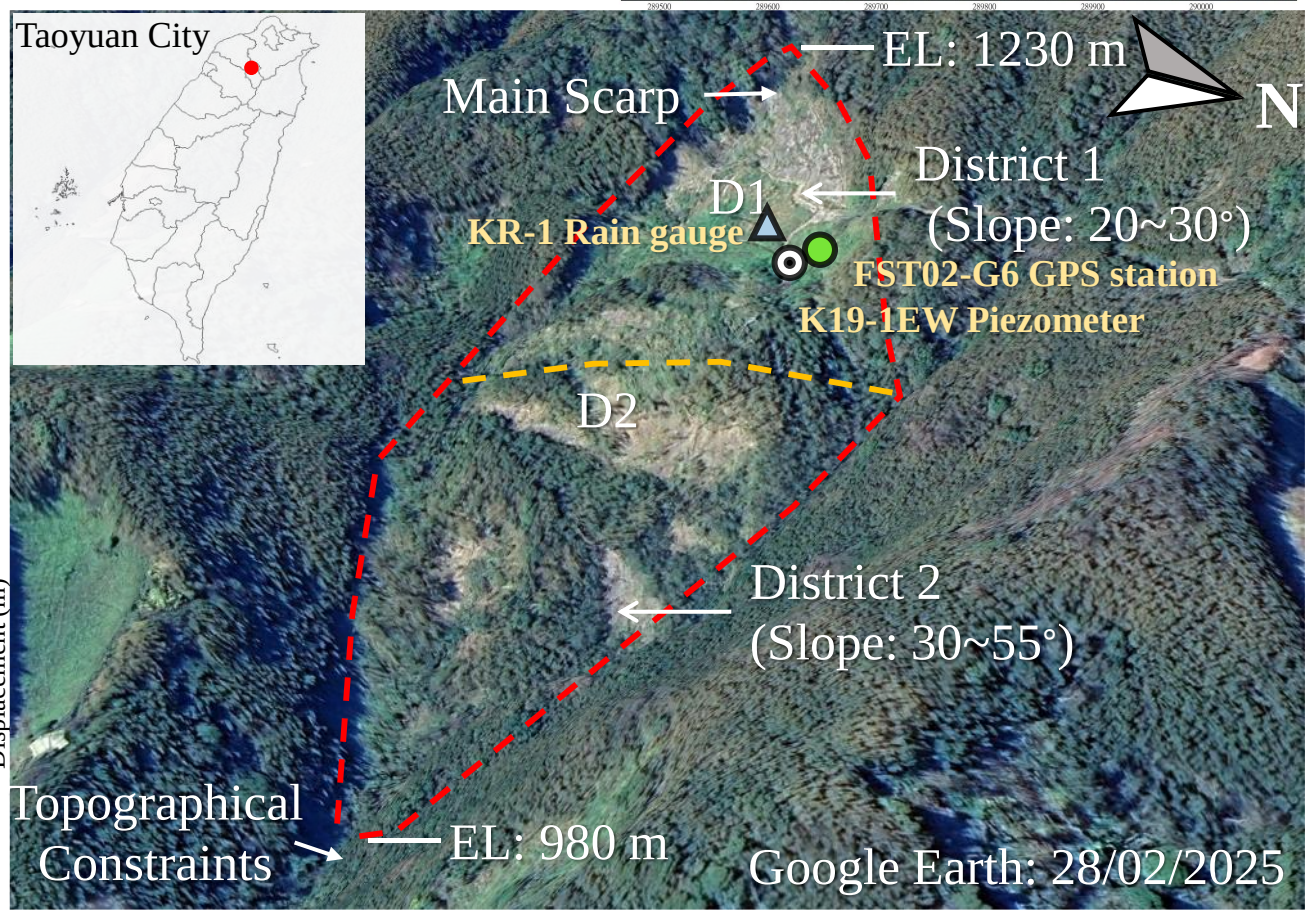
The Guanghua large-scale landslide potential area

Whole area:12.3 ha (M1, M2, M3, and M4 block)
Active area: 3.4 ha (M1 block)
Geological condition: Balin Formation (Pl), mainly consisting of hard shale and slate
Cumulative precipitation during Typhoon IN-FA(2021) event: 475 mm
The Guanghua landslide is affected by Topographical Constraints



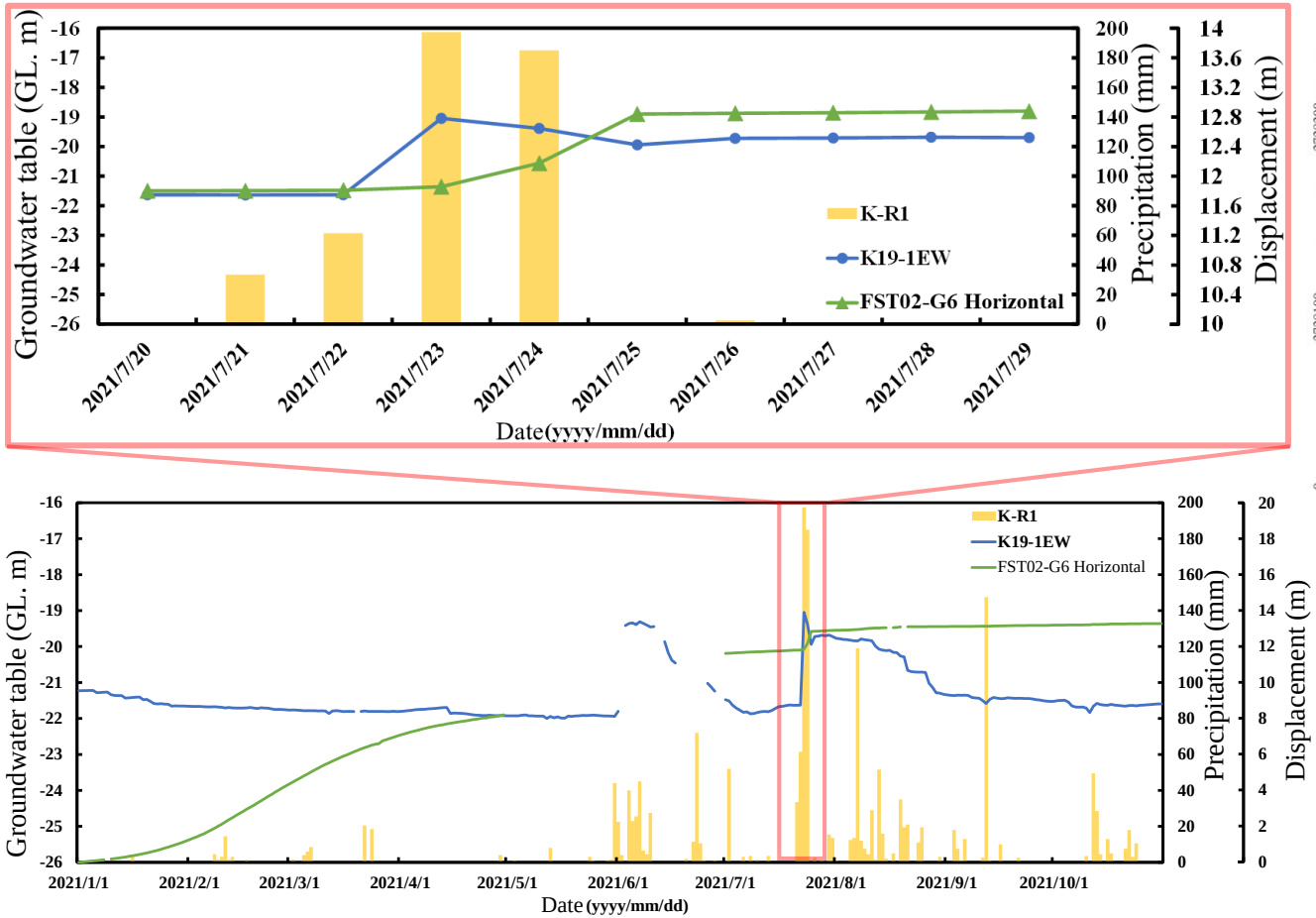


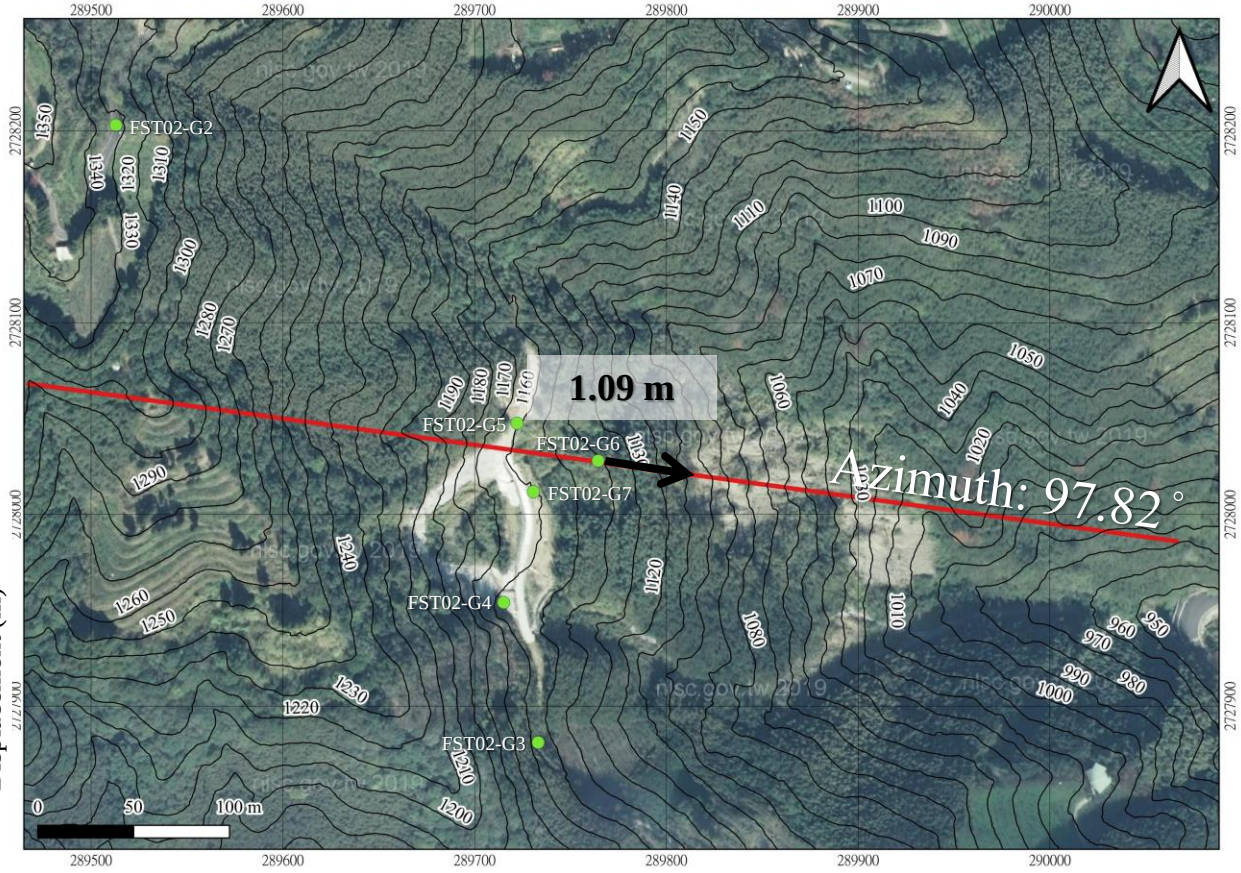




Introduction

Monitoring data from these three instruments during Typhoon IN-FA

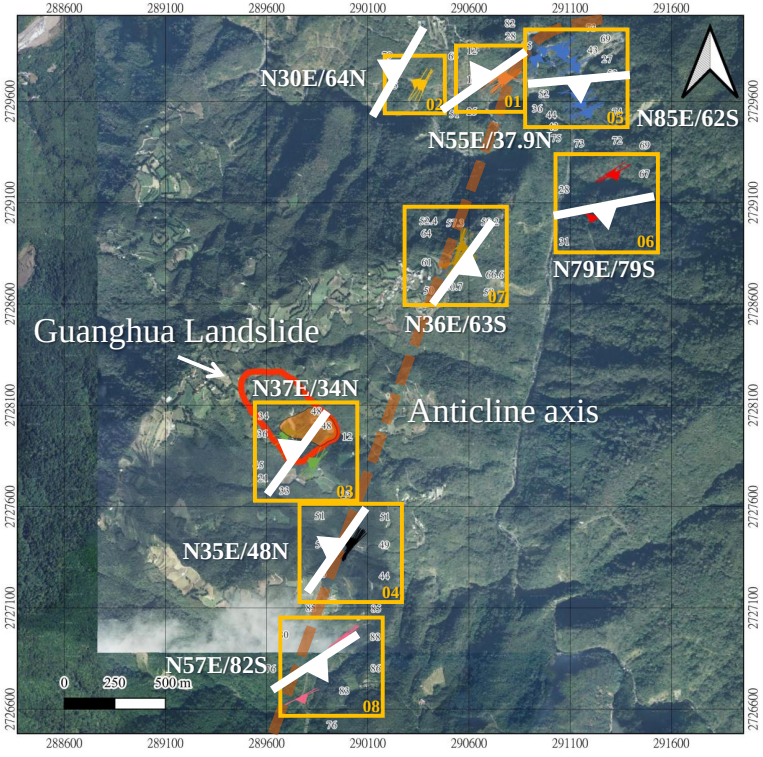


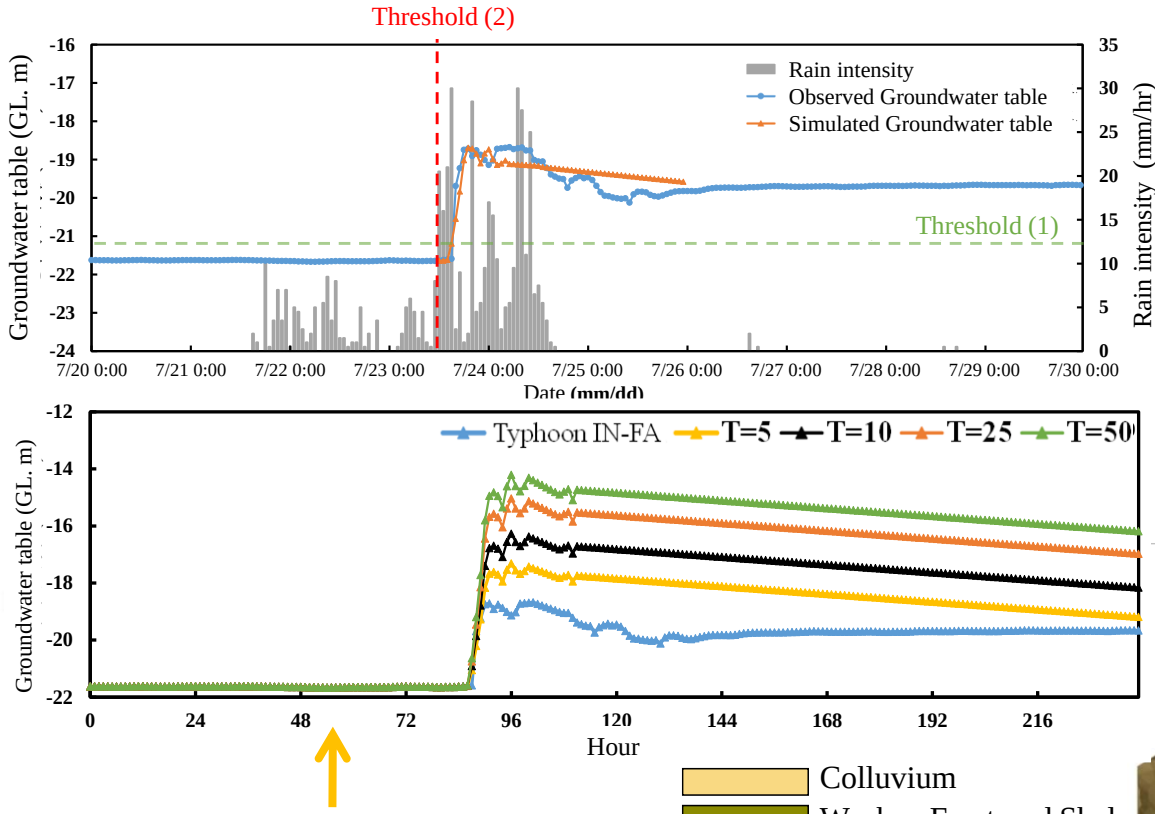


How to evaluate the climate and environmental changes

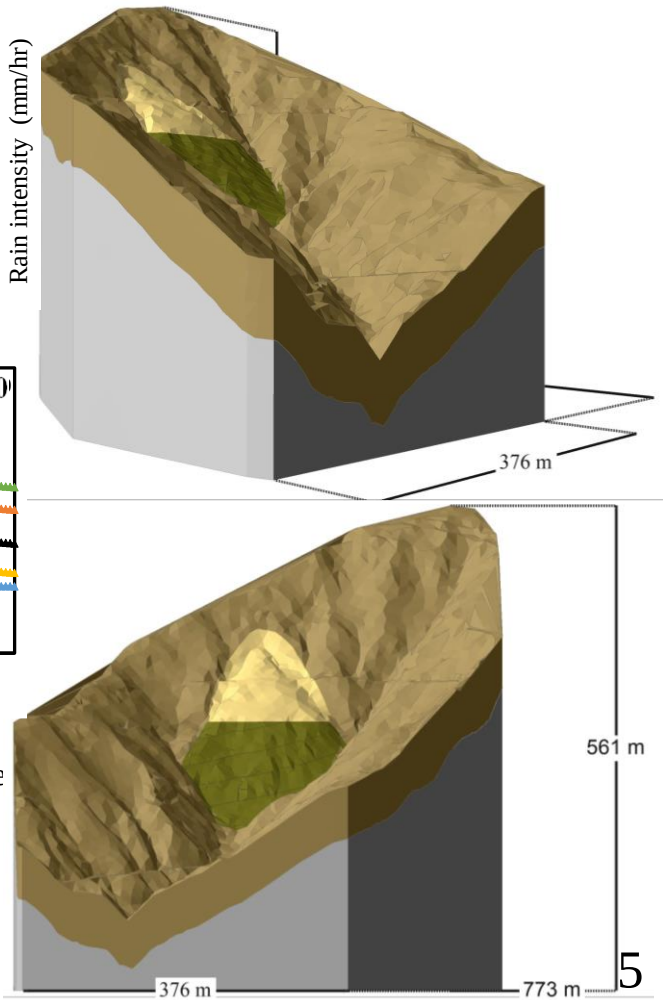
Outcrop investigation, Evaluation of groundwater table, and Numerical model

Outcrop investigation + Direct Step Method of Groundwater Hydrograph(DSM-GH) + Numerical model





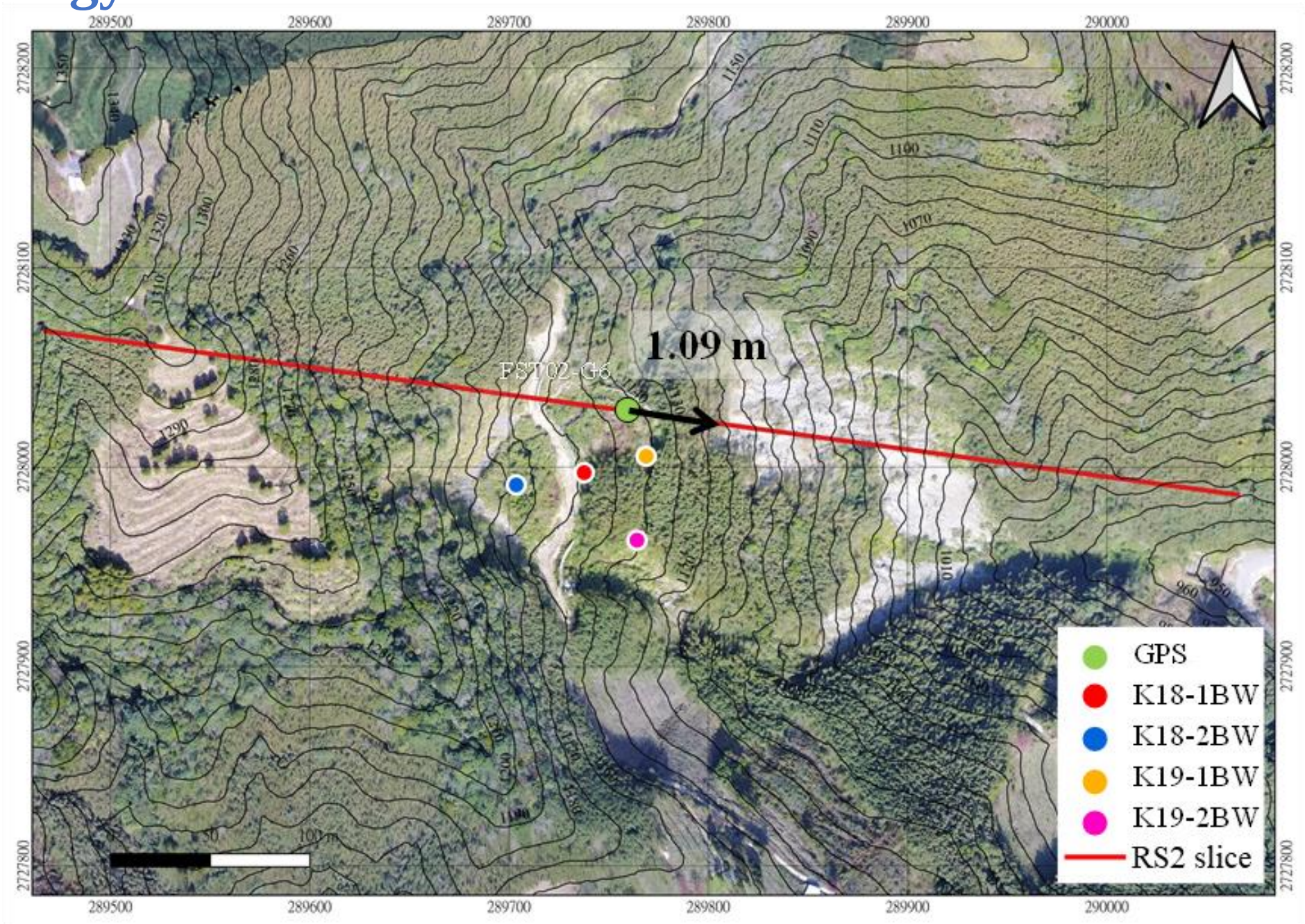
The groundwater table changes under different rainfall return periods



RS2 RS3

2D/3D FEM Analysis Software

Methodology



Methodology

Direct Step Method of Groundwater Hydrograph

$$h_t = h_{t-1} + I - O$$

$$h_{t,temp} = h_c + e^{-kt} \cdot (h_{t-1} - h_c)$$

$$h_{t-1} - h_{t,temp} = O$$

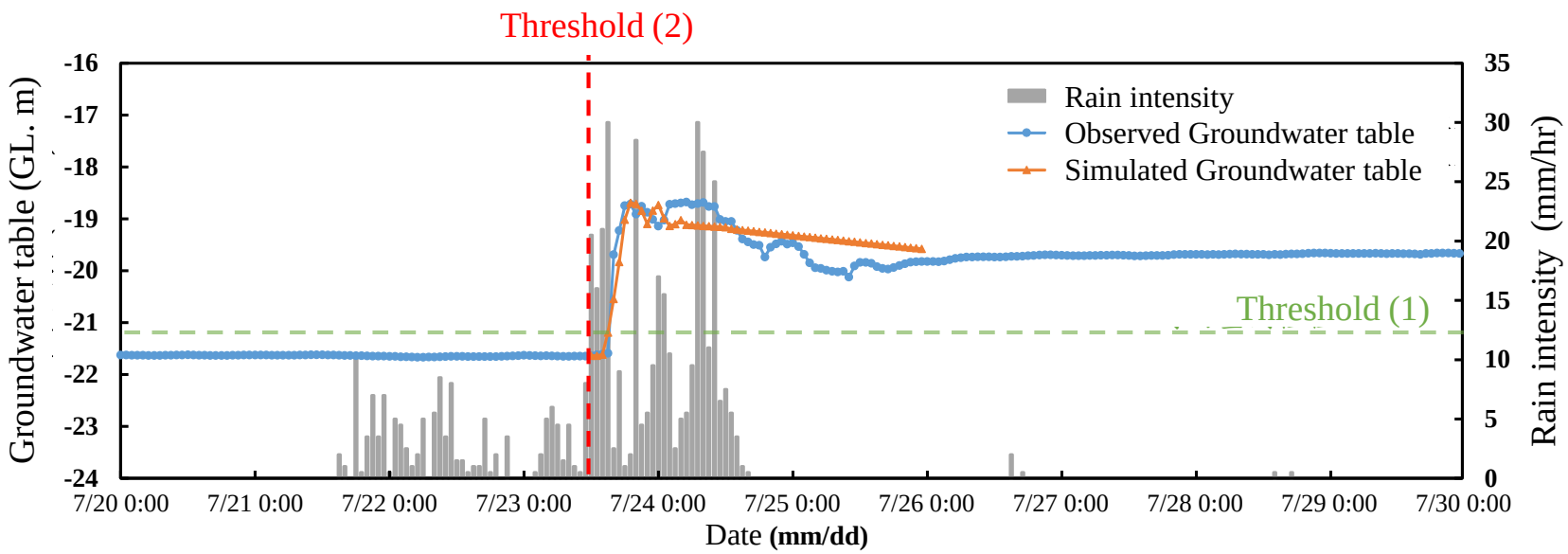
k=0.01 (hr^-1)

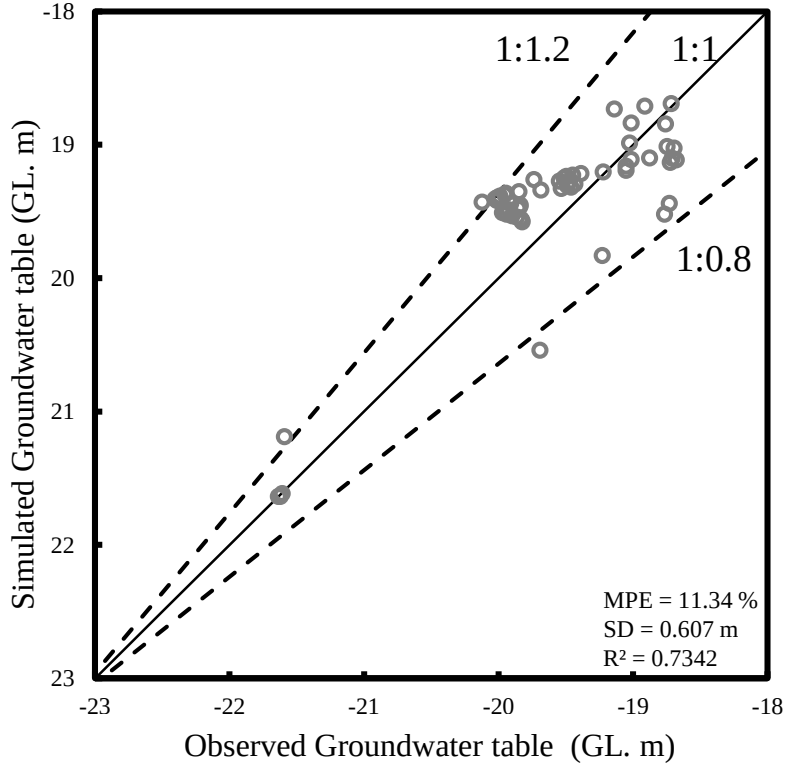
k=0.00001 (hr^-1) When rainfall intensity < 4 mm/hr

Threshold：(1) Rainfall intensity reaches 12 mm/hr
(2) Cumulative rainfall exceeds 130 mm

Unit hydrograph

t	0	1	2	3	4	5
U(1,t)	0	0.001	0.020	0.015	0.001	0.001

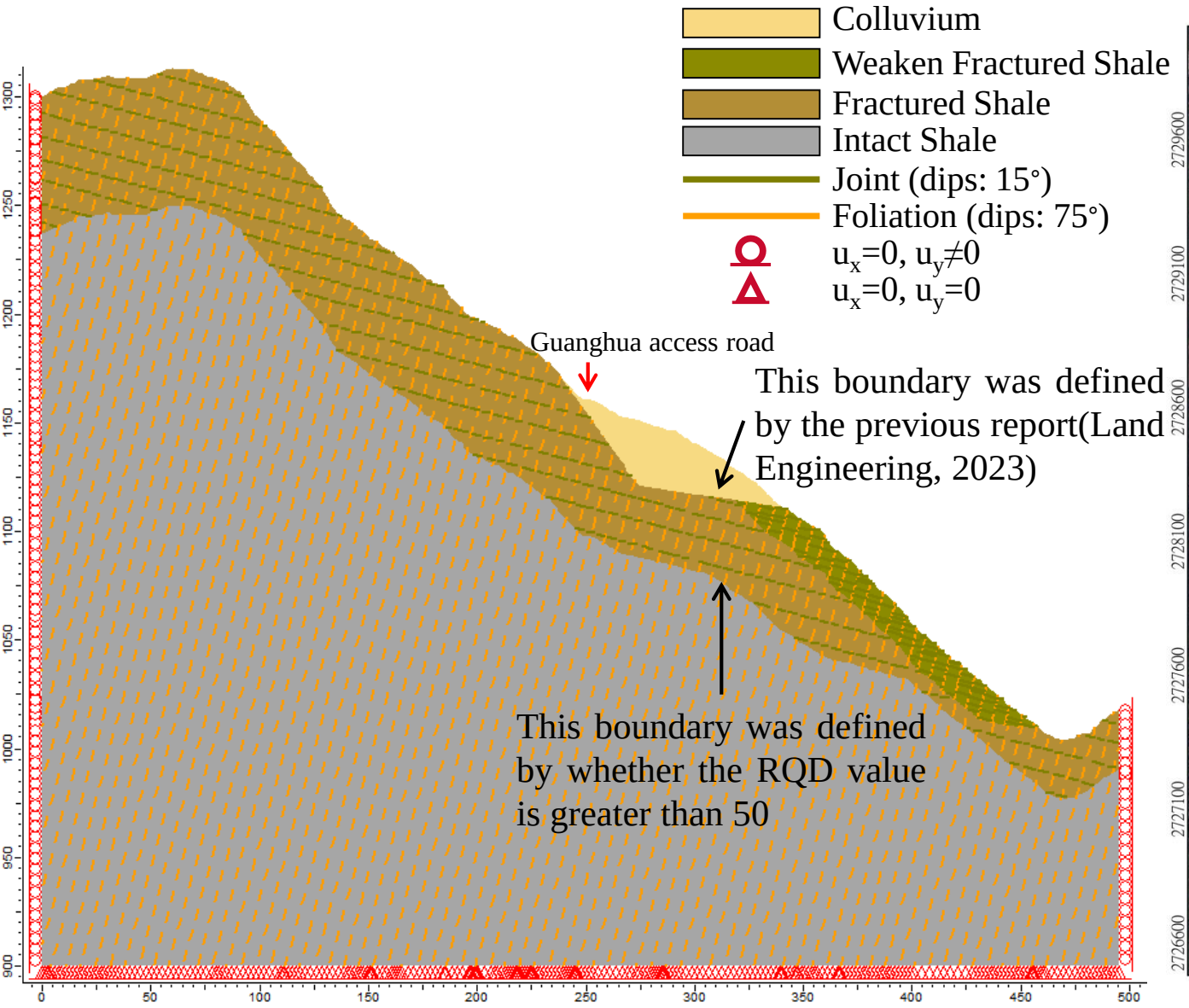


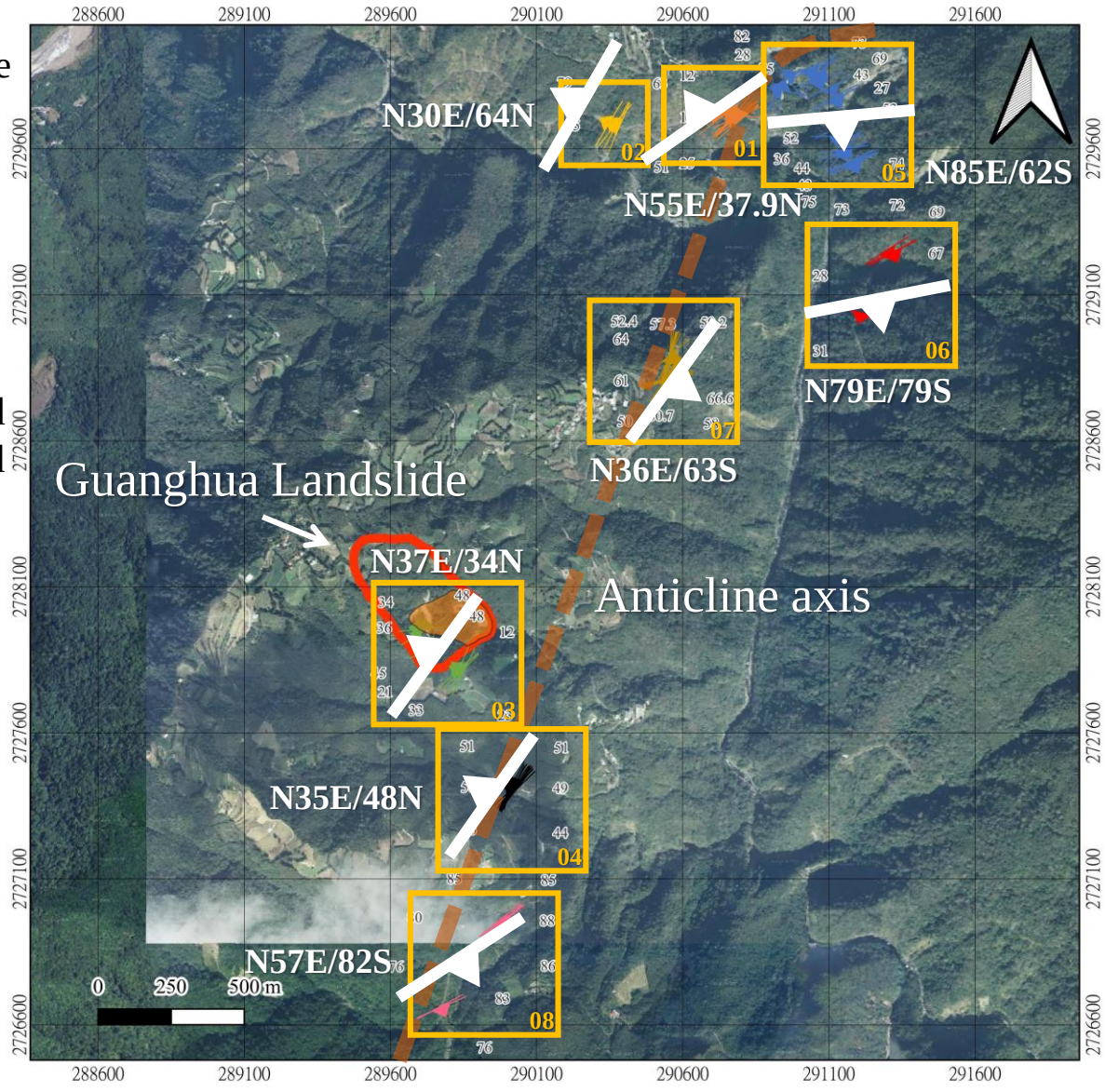


Methodology

Numerical model established and outcrop investigations

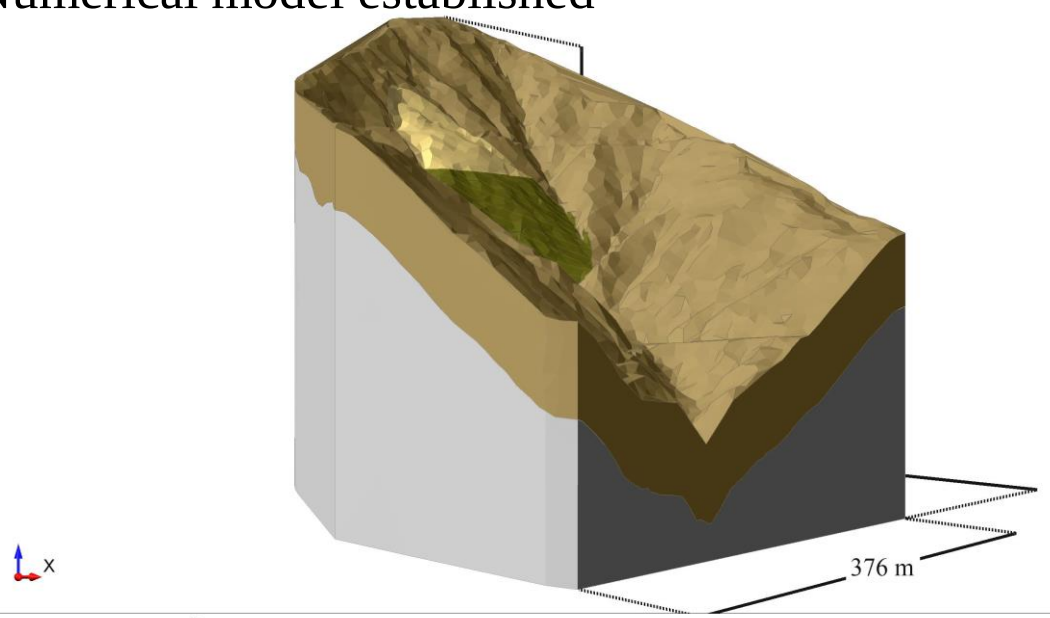
RS2 RS3

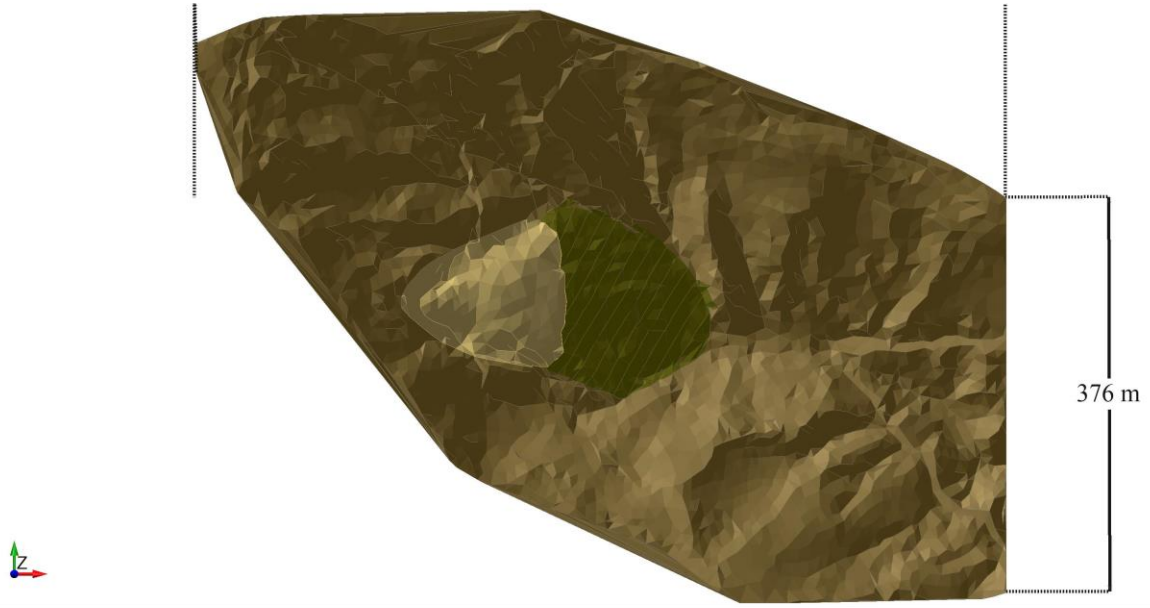


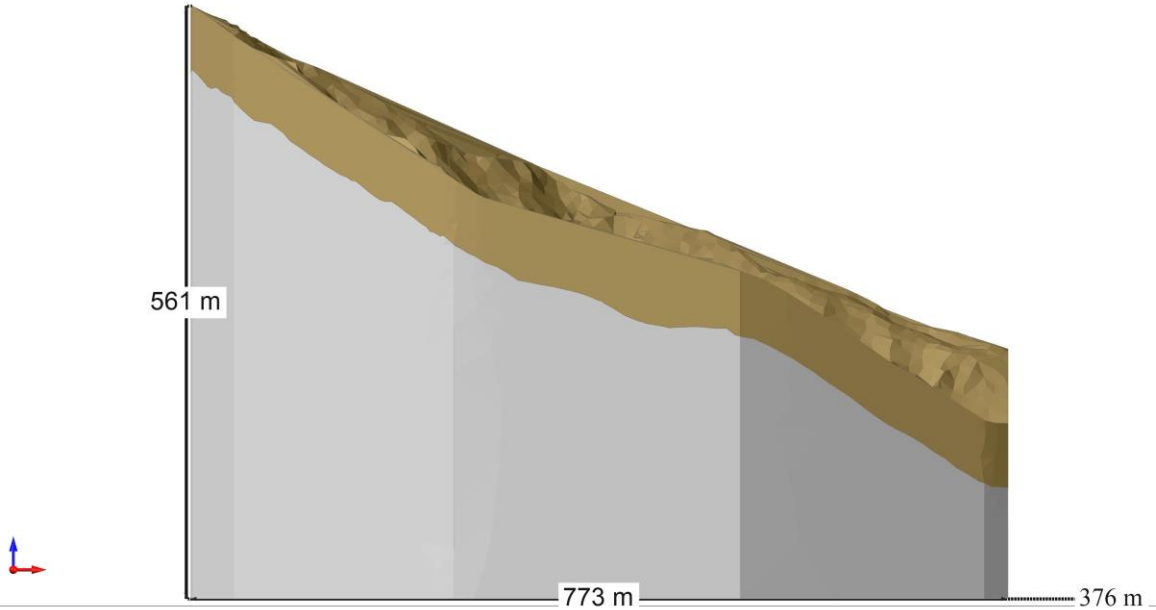


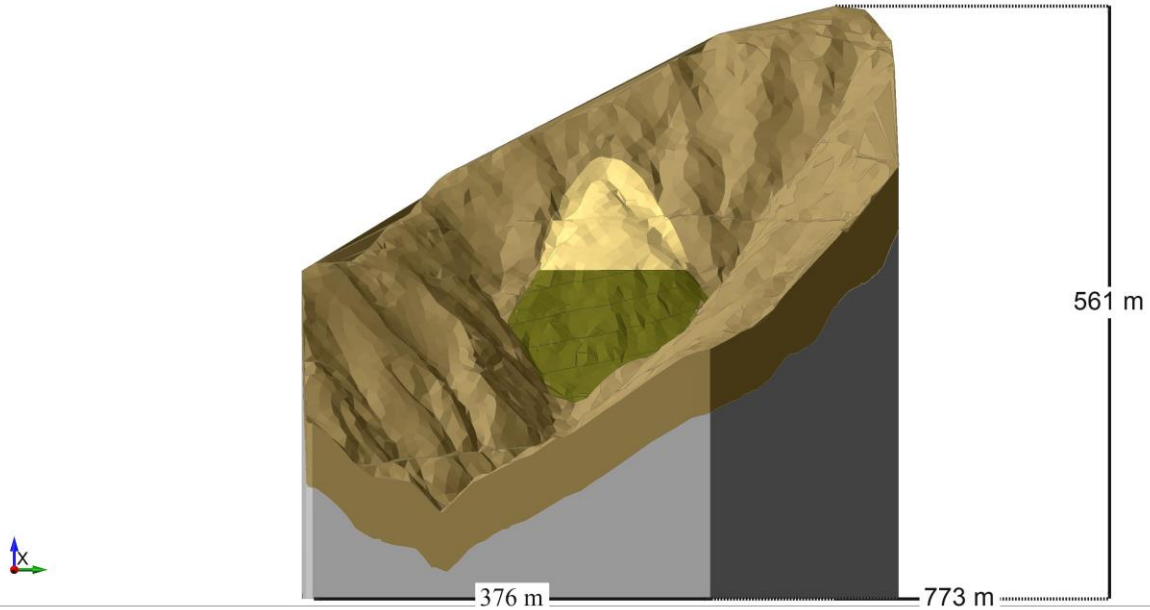
Methodology

Numerical model established





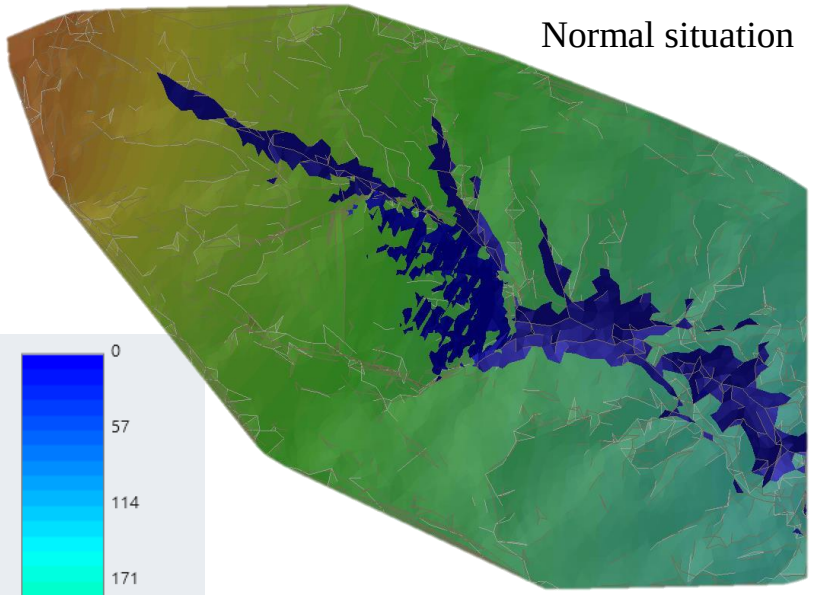




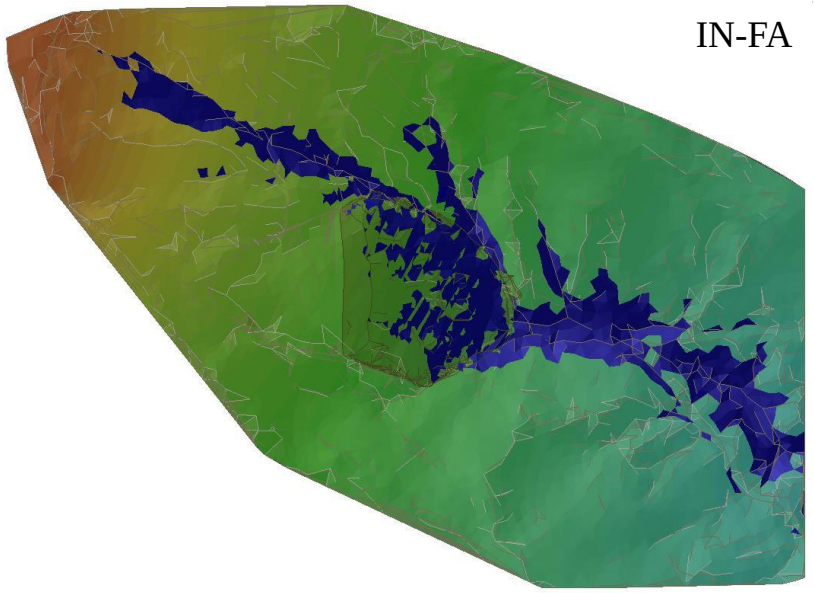
Results

Groundwater outflow

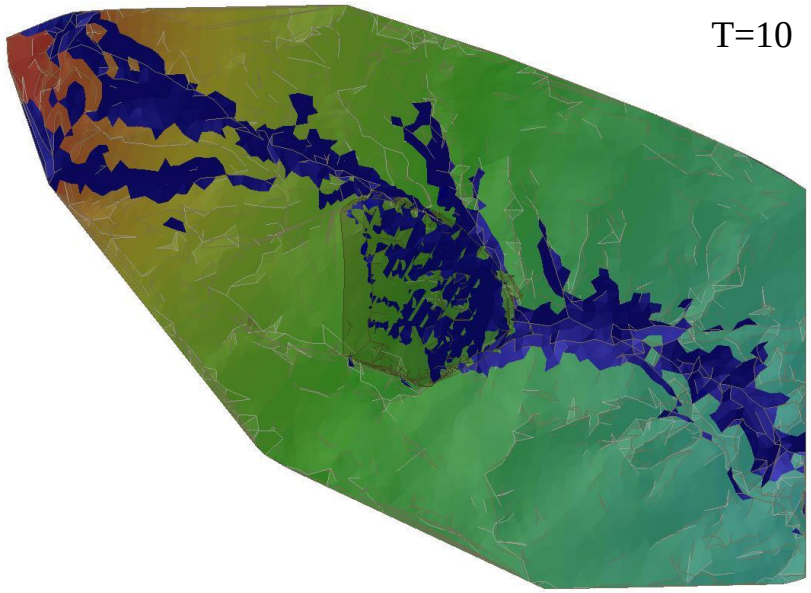
Normal situation



IN-FA



T=10



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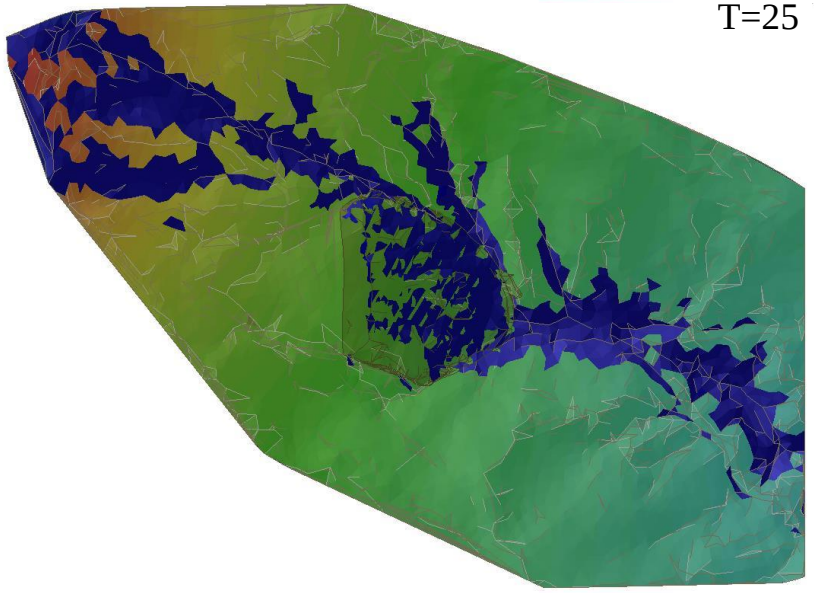
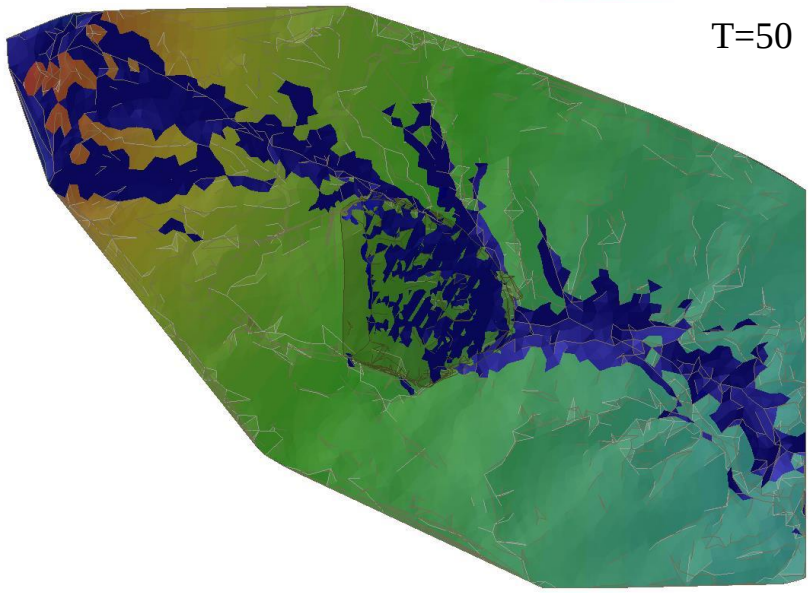
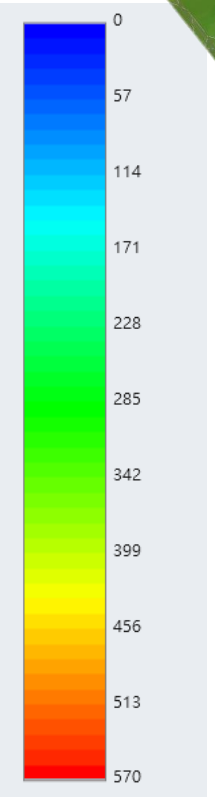


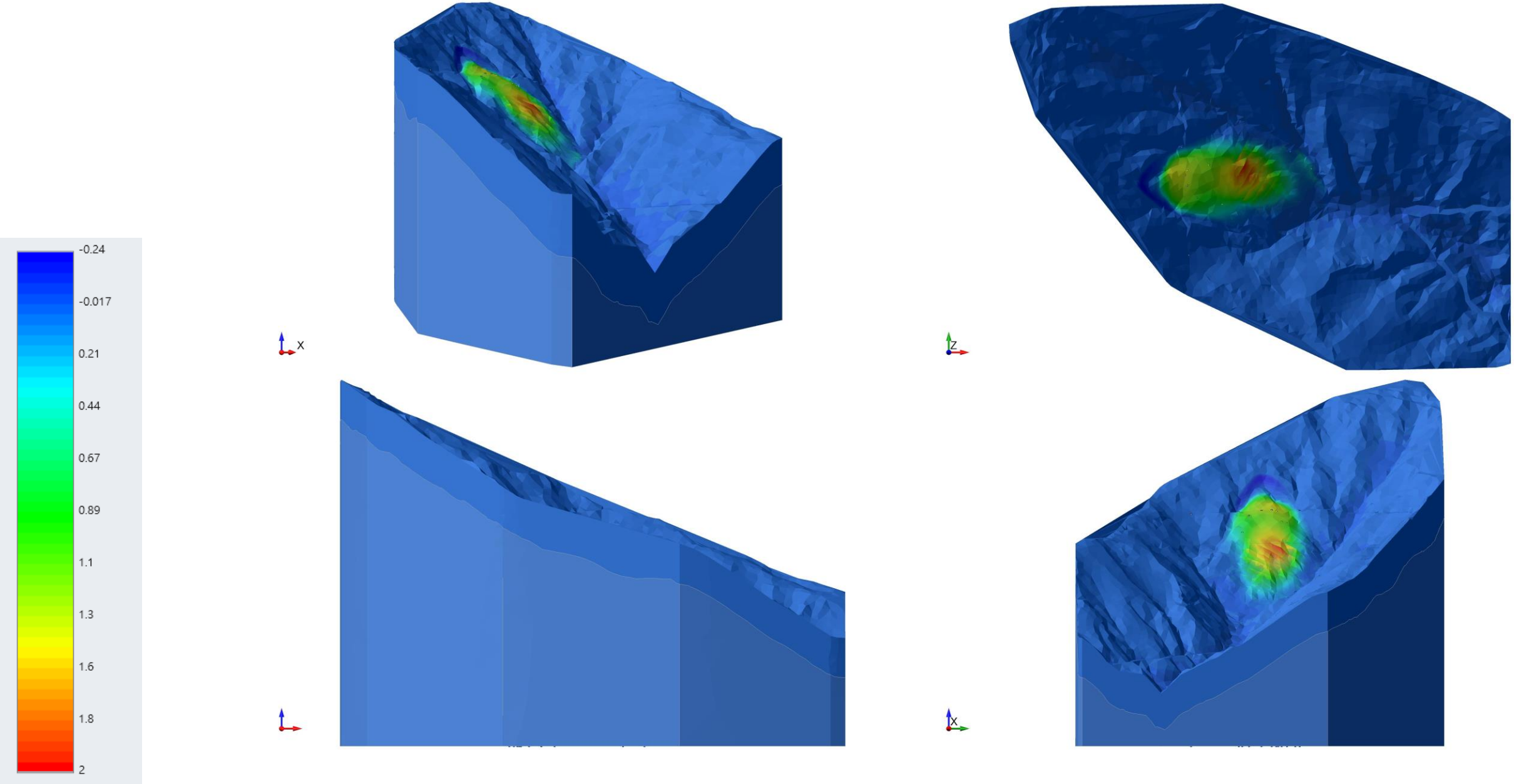
T=50





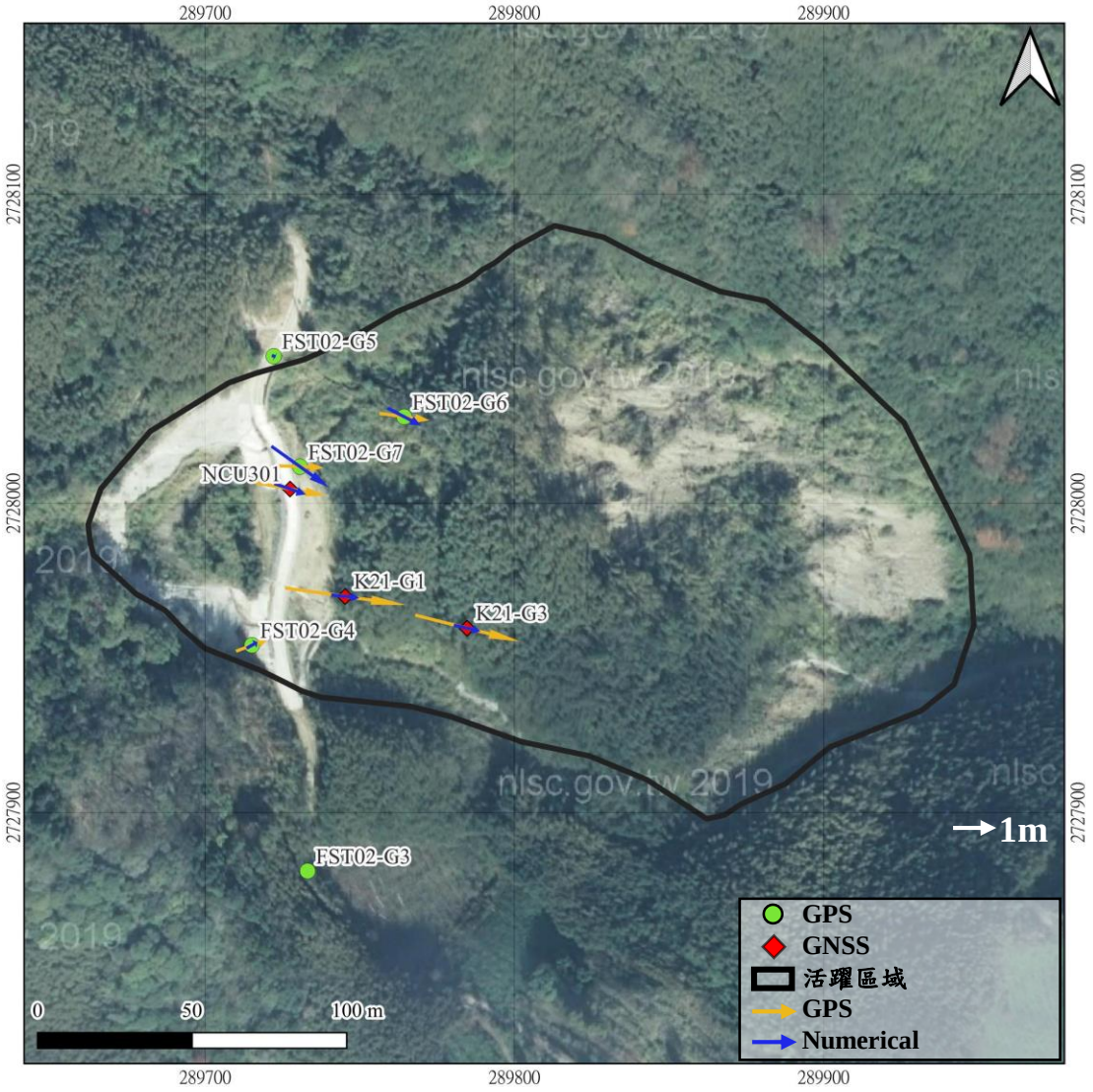
Results

East-West directional displacement results of the 3D numerical analysis



Results

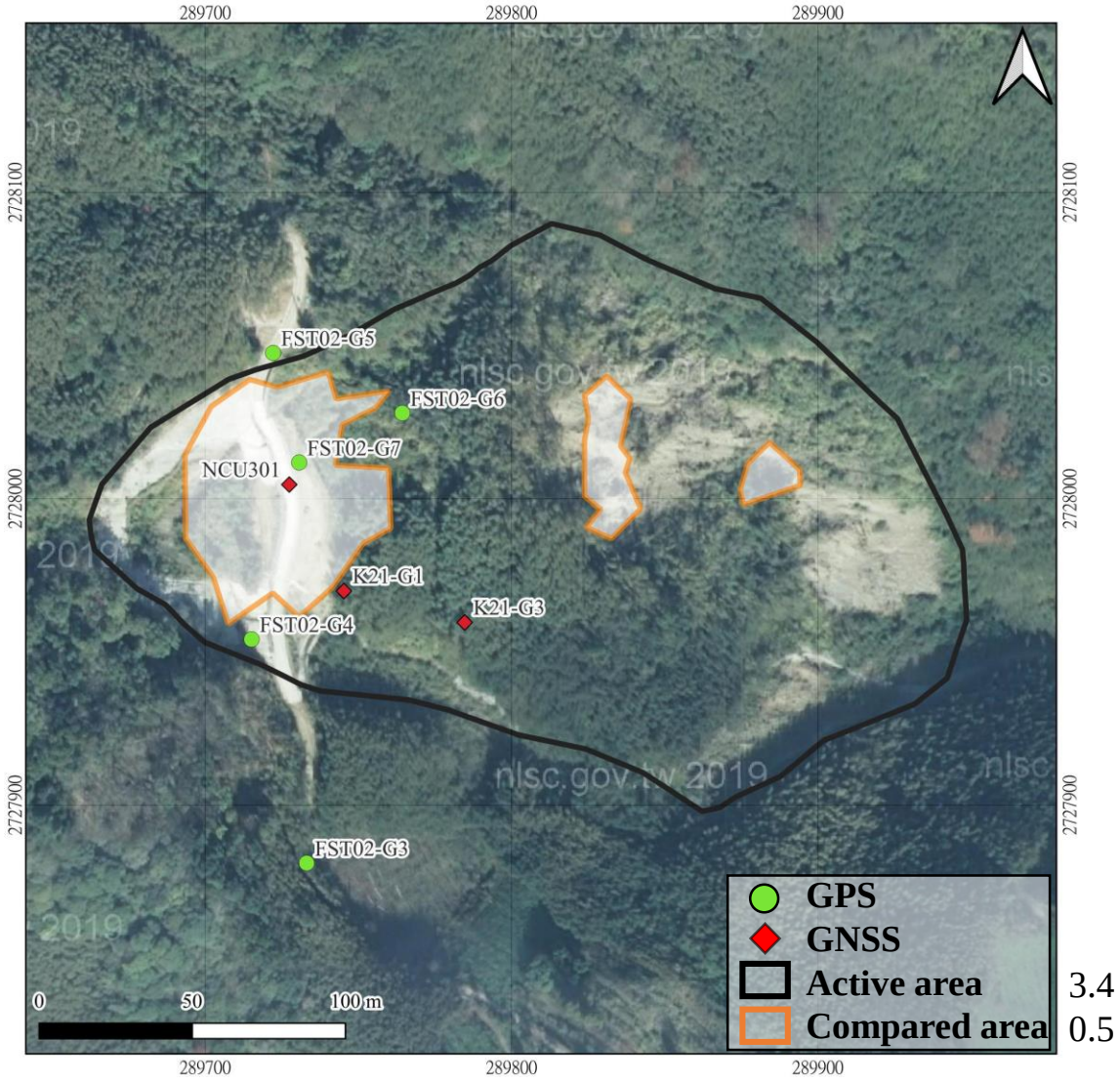
Numerical analysis vs. GPS during Typhoon IN-FA

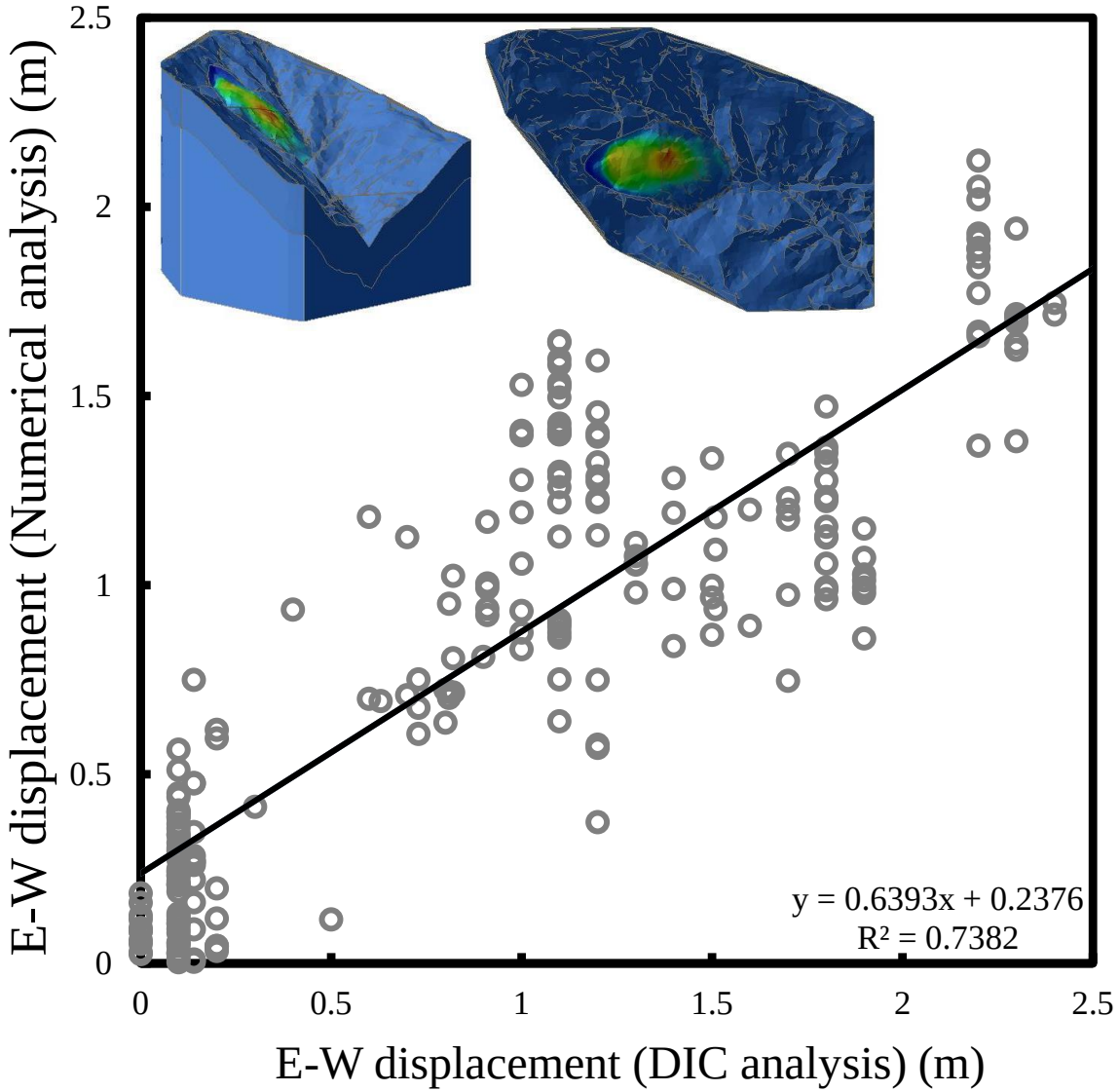


GPS/GNSS站	Horizontal displacement(m)		Azimuth(°)		Vertical displacement(m)	
	GPS	Numerical	GPS	Numerical	GPS	Numerical
FST02-G3	0.006	0.001	59.0	135	-0.035	-0.862
FST02-G4	0.741	0.534	69.1	60.0	-0.746	-0.862
FST02-G5	0.020	0.071	102.8	150.6	-0.016	-0.169
FST02-G6	1.090	1.128	97.7	104.3	-1.088	-1.754
FST02-G7	1.004	1.488	92.4	113.7	-0.863	-2.820
K21-G1	2.624	0.987	98.0	92.7	-2.105	-1.760
K21-G3	2.318	0.668	104.1	93.7	-2.066	-0.940
NCU301	1.565	1.232	100.3	100.7	-1.470	-2.265

Results

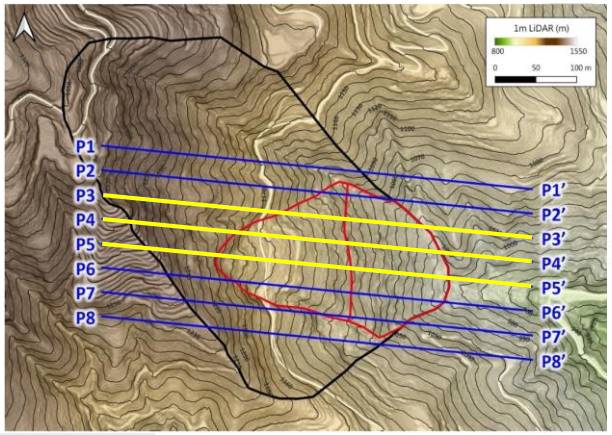
Numerical analysis vs. DIC analysis (Digital Image Correlation) during Typhoon IN-FA

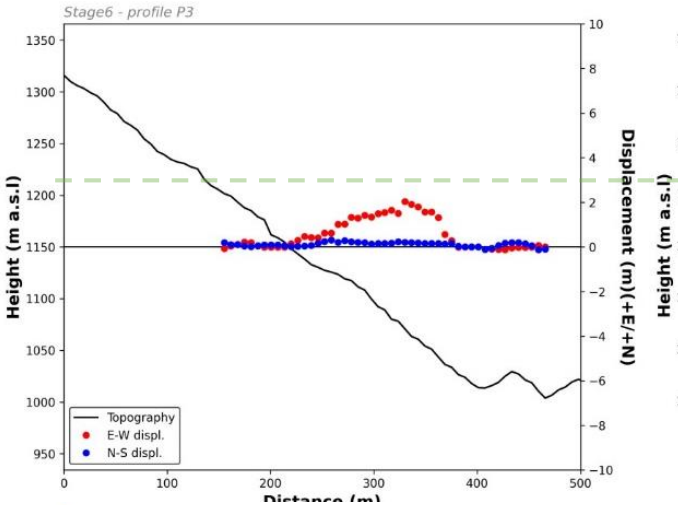


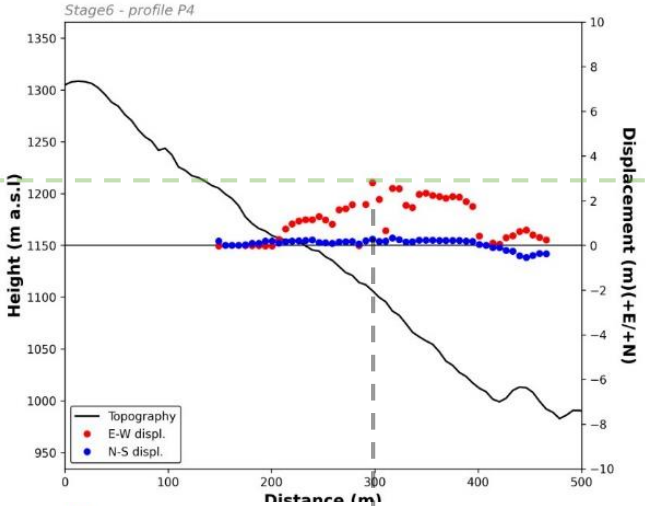


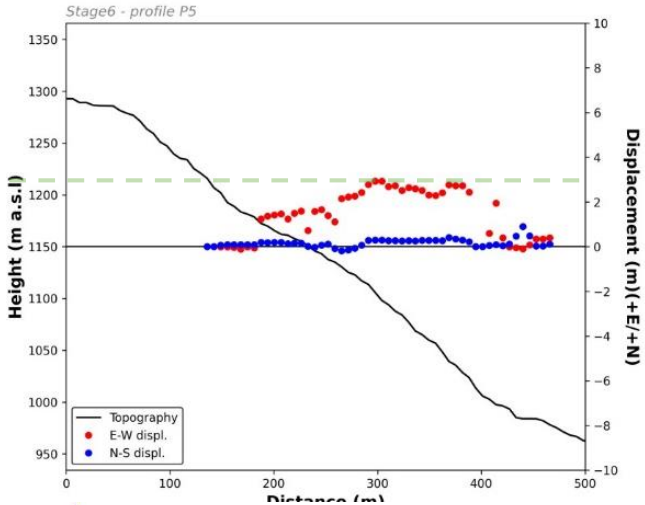
Results

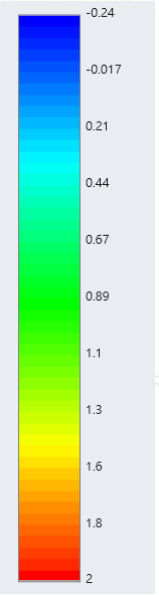
Numerical analysis vs. DIC analysis (Digital Image Correlation) during Typhoon IN-FA

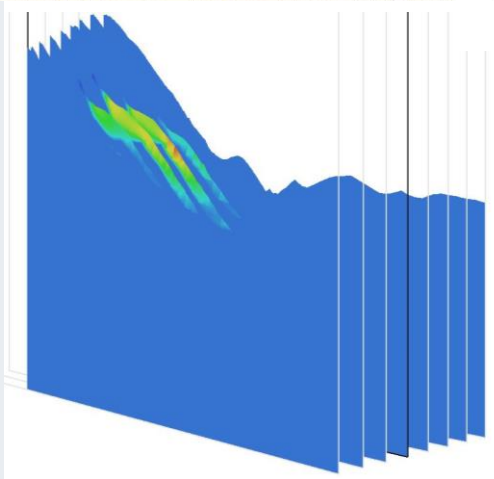


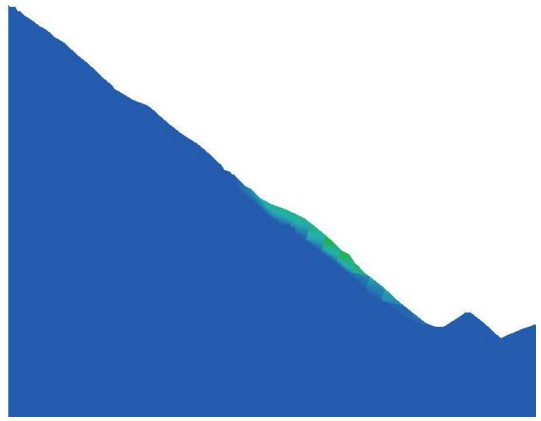


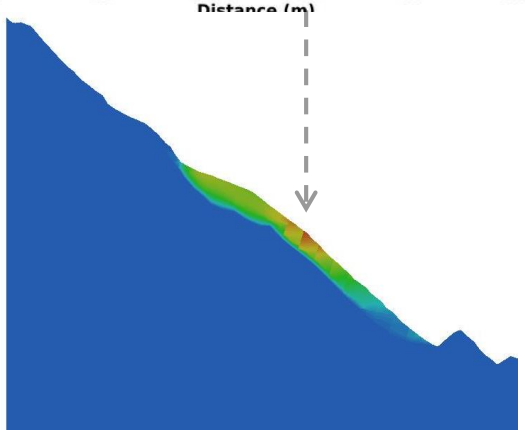


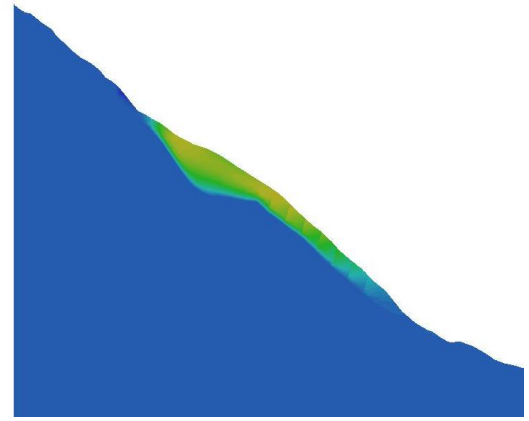






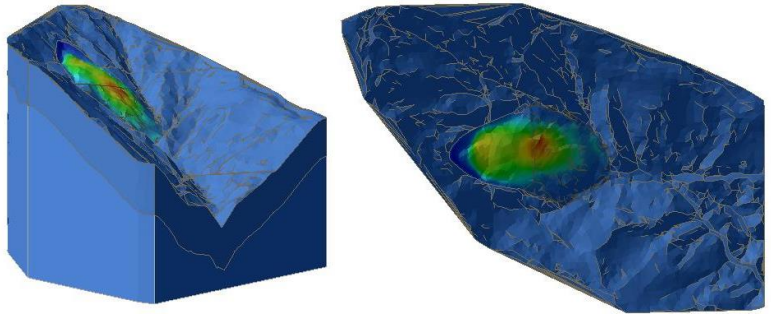


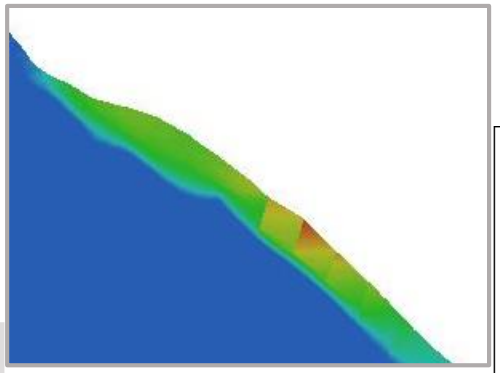


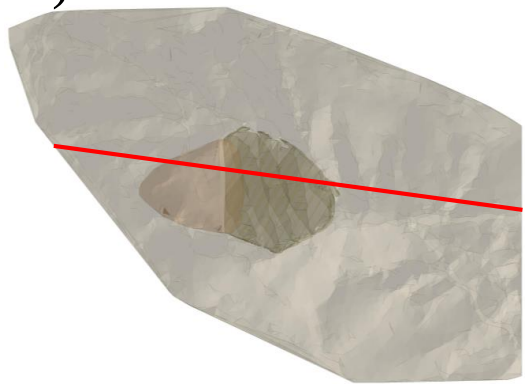


Results

East-West directional displacement results of the 2D and 3D numerical analysis (Typhoon IN-FA)

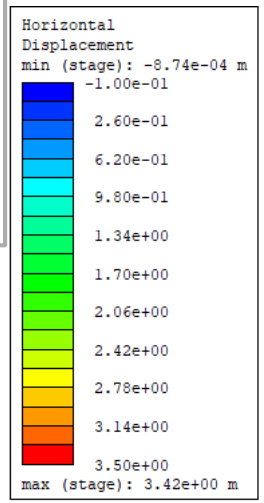


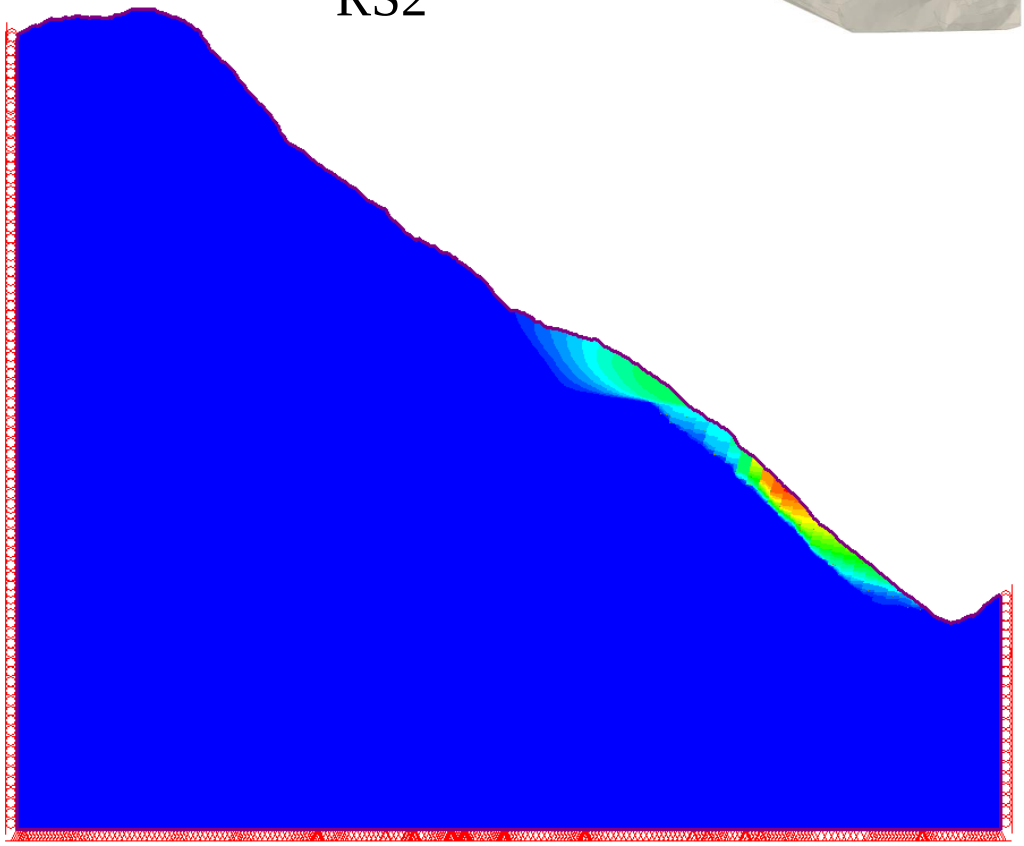




RS3

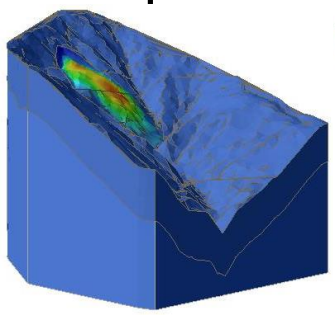
RS2

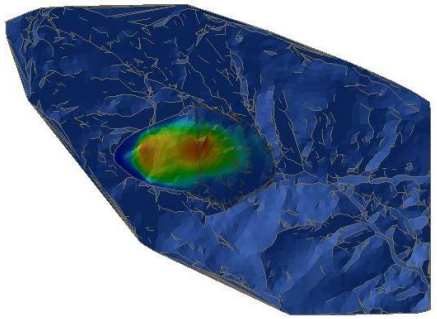




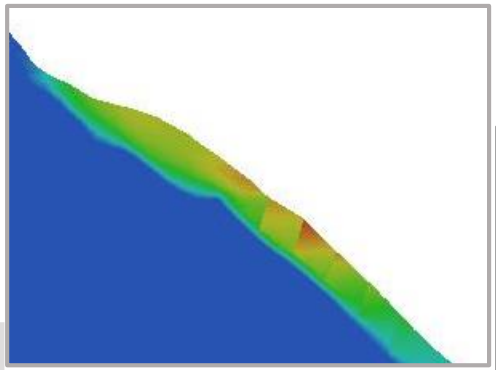
Results

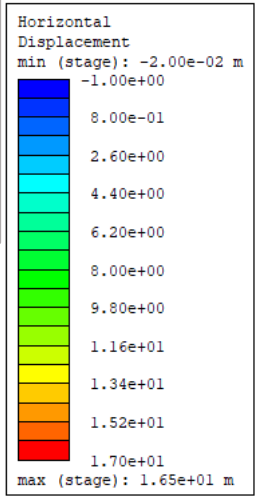
Comparison between 2D and 3D numerical analyses: T = 50

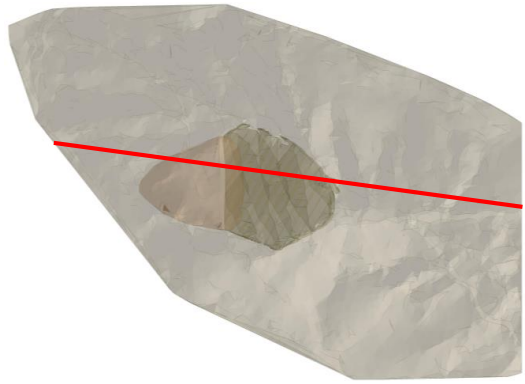




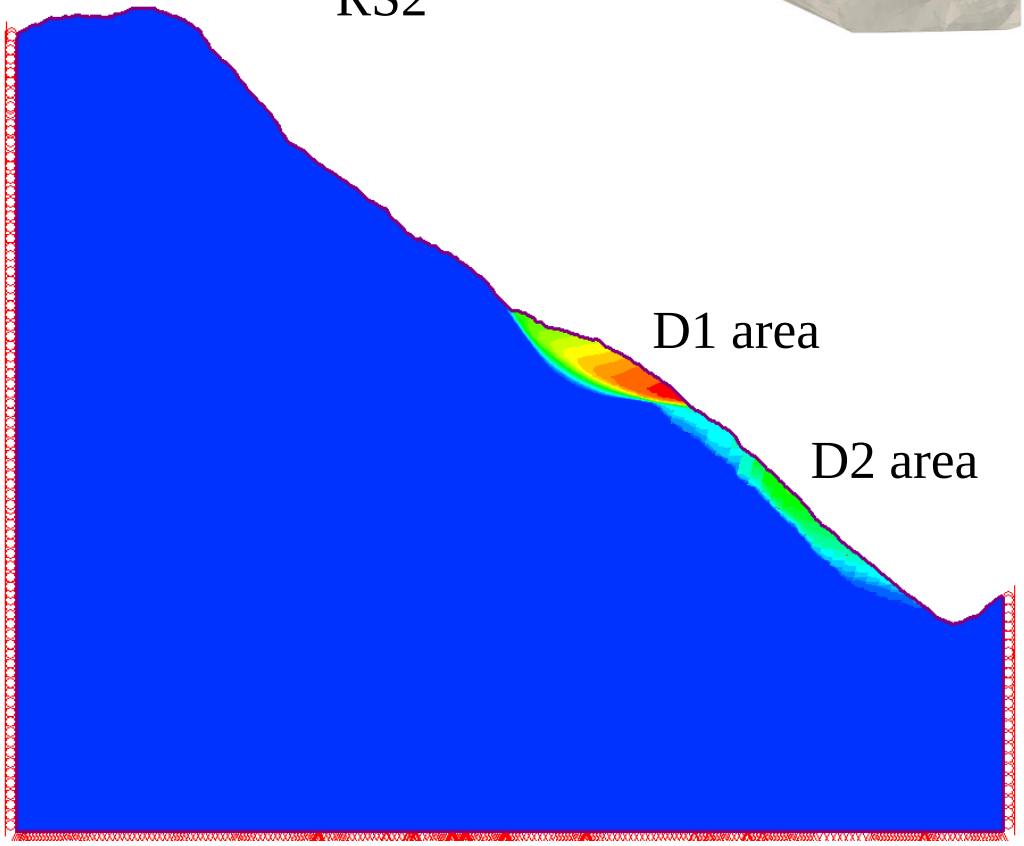
RS3





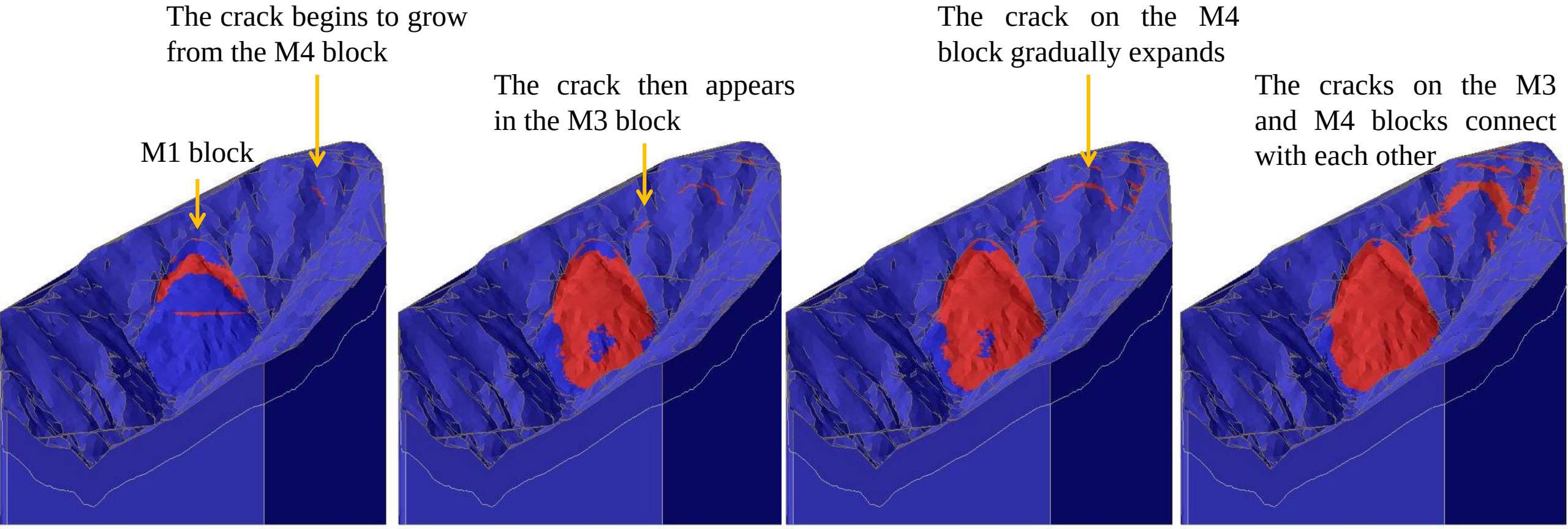


RS2



Results

SSR analysis: T=50 (Cumulative precipitation 1032 mm)



Results

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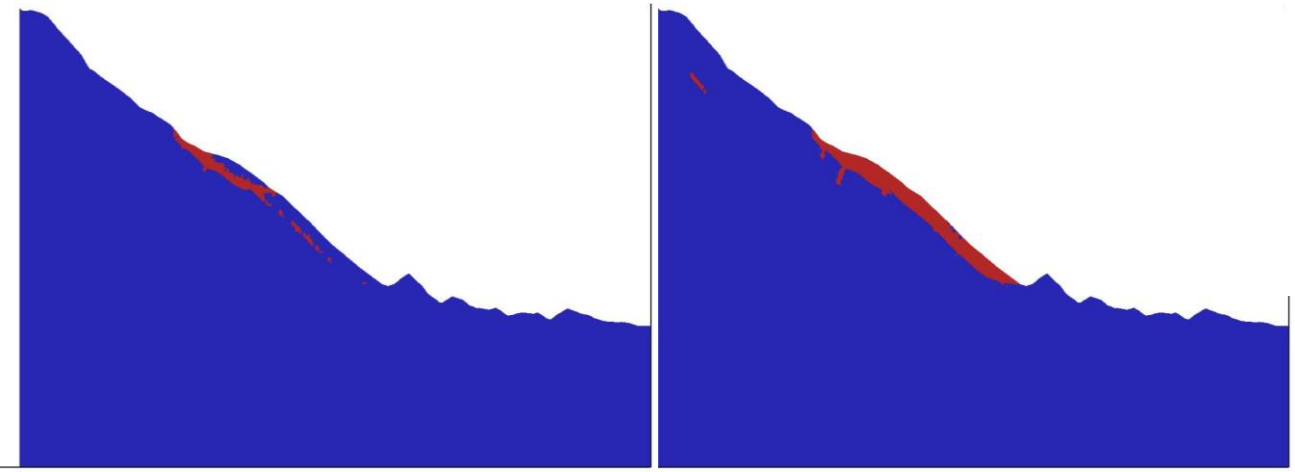
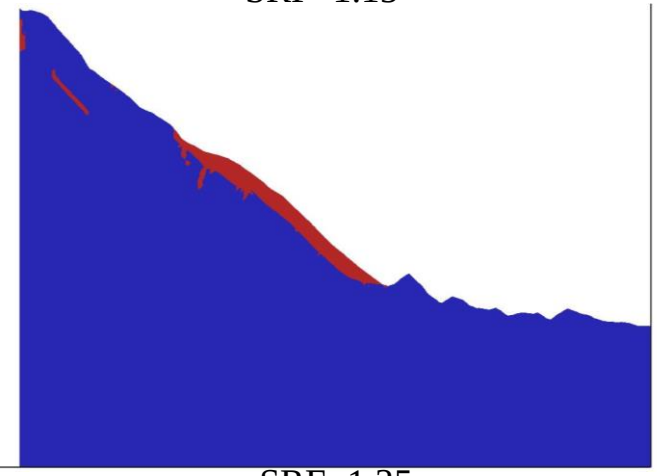


SRF=1.15

SRF=1.25



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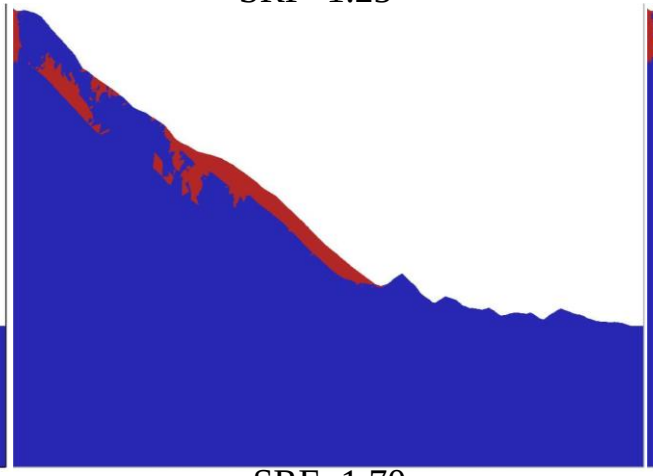

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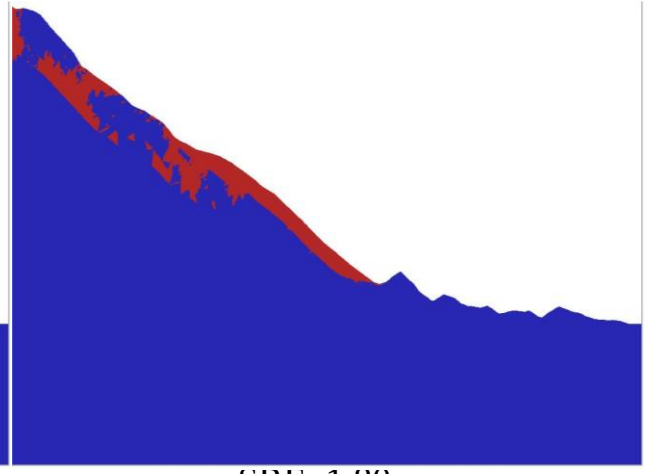

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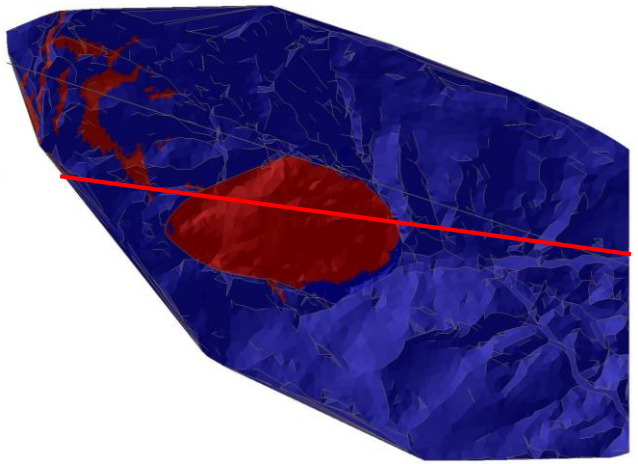
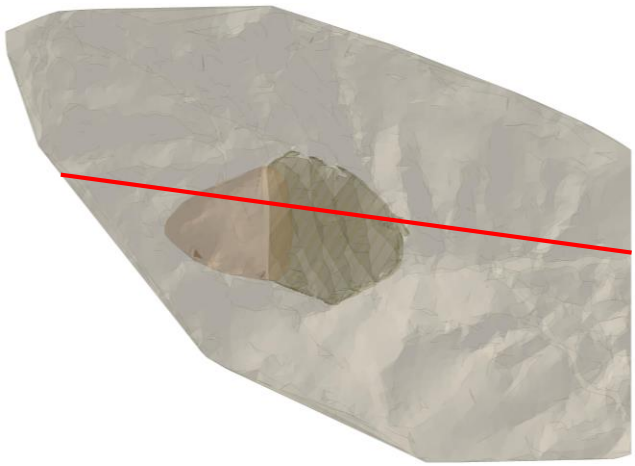
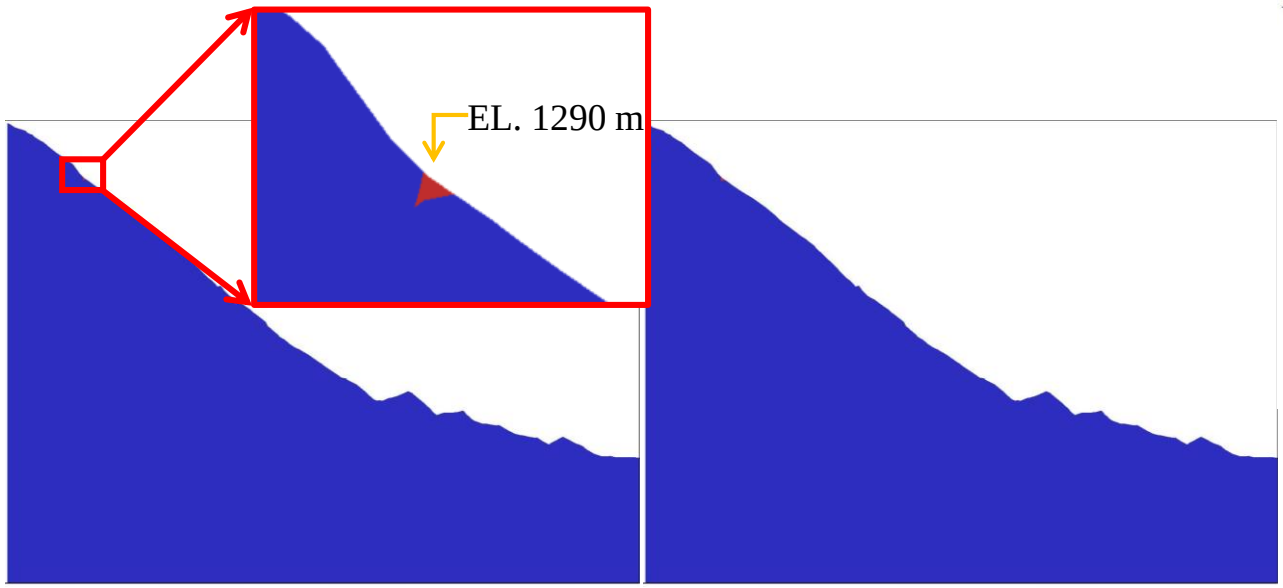




Results

SSR analysis: T=50 (Cumulative precipitation 1032 mm)



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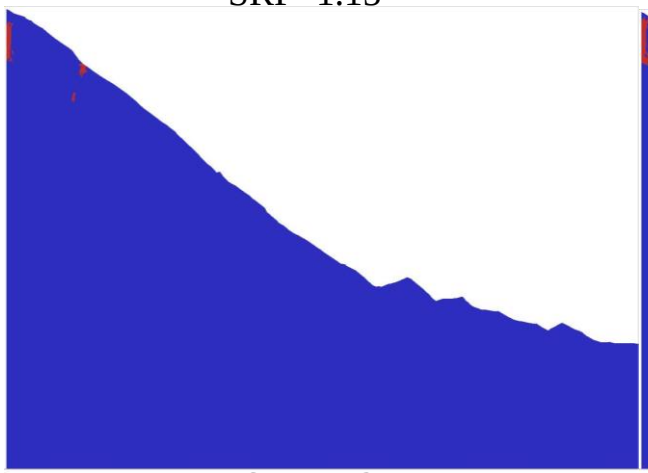

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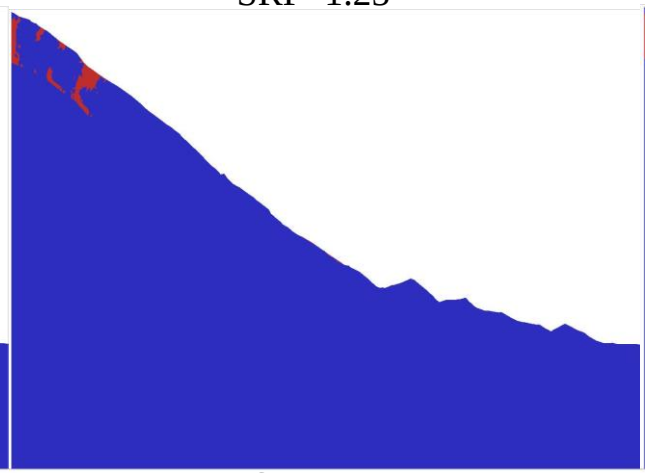

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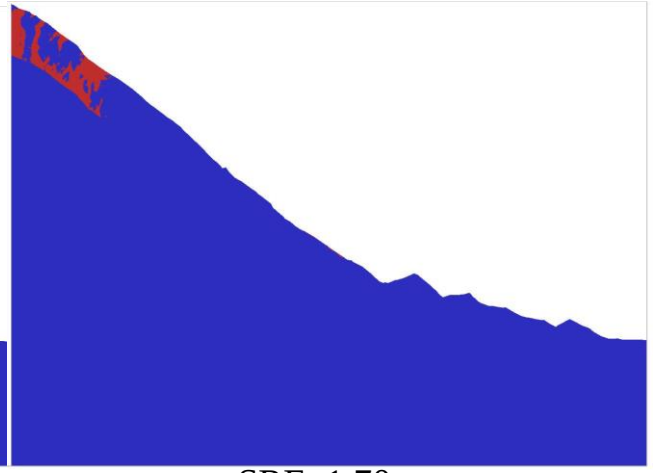

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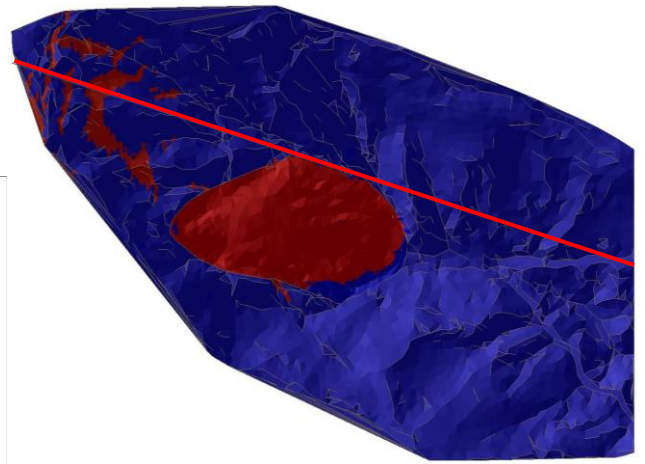

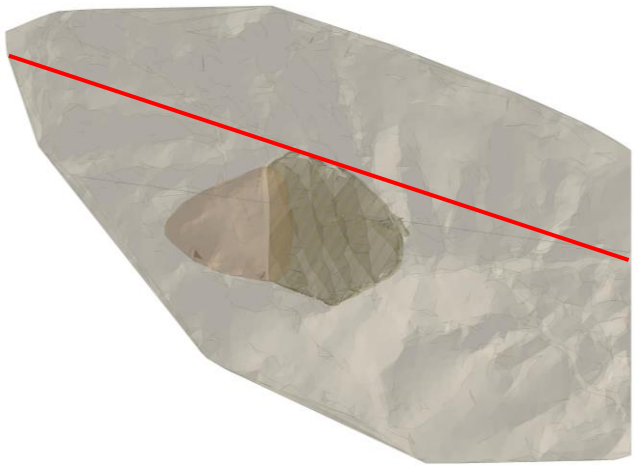

Summary

1. Outcrop investigations play an important role in geotechnical engineering, especially when conducting research on large-scale landslide areas.

2. 3D numerical analysis, compared to 2D numerical analysis, are more effective in analyzing the impact of topographical constraints on high activity slopes.

3. Using 3D numerical analysis, the interactive behaviors of different blocks can be explored.

4. The DSM-GH can be used to quickly evaluate the groundwater table changes in different rainfall.

5. DIC results can assist in confirming the reliability of simulations in numerical analysis.

Thanks for listening!

1. Why did we choose the Guanghua landslide?

Rainfall and groundwater table changes influence the deformation of the Guanghua landslide. Additionally, it is impacted by the topographical constraints, making it necessary to conduct 3D numerical simulations.

2. How to evaluate climate and environmental changes?

This research evaluated the groundwater table changes under different rainfall return periods.

3. How to evaluate landslide activity?

2D and 3D numerical analyses were conducted to find the potential landslide trends of the slope.

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We are glad to have more discussions later

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