Project Title: **SLOPE-AI (Smart Landslide Observation and Prediction Enhanced with AI) for Reliable and Economical IoT-Based Landslide Monitoring**

Background :

Landslides are among the most destructive natural hazards, causing loss of life, property damage, and environmental degradation, especially in tropical ASEAN regions where heavy rainfall and seismic activity are frequent triggers. Effective monitoring and early warning systems are essential for reducing risks. However, traditional geotechnical tools such as inclinometers and piezometers, although accurate, are expensive and require complex installations, making them impractical for widespread use in high-risk areas.

To address these limitations, this project proposes SLOPE AI, or Smart Landslide Observation and Prediction Enhanced with AI, an IoT-based landslide monitoring and early warning system. It incorporates low-cost IoT sensors, including tilt, moisture, rainfall, and seismic vibration sensors, which will be calibrated against conventional instruments using machine learning to ensure accuracy. Sensor placement will be based on geotechnical assessments conducted in the early phase of the project. The system uses AI to analyze historical and real-time data to predict landslide events and generate timely alerts. Communication between sensors and microcontrollers will rely on a low-energy peer-to-peer network, and alerts will be transmitted in real time through mobile networks to enable rapid response.

Project Title: **SLOPE-AI (Smart Landslide Observation and Prediction Enhanced with AI) for Reliable and Economical IoT-Based Landslide Monitoring**

Targets:

1. To develop a low-cost IoT-based landslide monitoring and early warning system (SLOPE AI) integrating tilt, moisture, rainfall, and vibration sensors with AI-driven prediction capability.
2. To calibrate and validate the IoT sensor data against conventional geotechnical instruments to ensure accuracy and reliability in various field conditions.
3. To implement and field-test the SLOPE AI system in selected landslide-prone areas and evaluate its effectiveness for real-time monitoring and early warning applications.

Speaker: Norinah Abd. Rahman

Project Duration : May 1st, 2025 – April 30th, 2027

Project Budget: Year 1- USD 40,000 Year 2- USD 40,000

Project Title: **SLOPE-AI (Smart Landslide Observation and Prediction Enhanced with AI) for Reliable and Economical IoT-Based Landslide Monitoring**

Project Members :

Universiti Kebangsaan Malaysia (MALAYSIA): Norinah Abd Rahman (Leader), Ros Nadiah Rosli, Anuar Kasa, Ahmad Nazrul Hakimi Ibrahim, Siti Fatin Mohd Razali, Nor Fadzilah Abdullah, Asma' Abu Samah, Mohd Hariri Arifin, Khairul Nizam Abdul Maulud

Mapua University (PHILIPPINES): Jennifer C. Dela Cruz, Cyrel O. Manlises, Dionis A. Padilla, Joseph Bryan G. Ibarra

Universitas Syiah Kuala (INDONESIA): Reza P Munirwan, Yusria Darma, Munira Sungkar

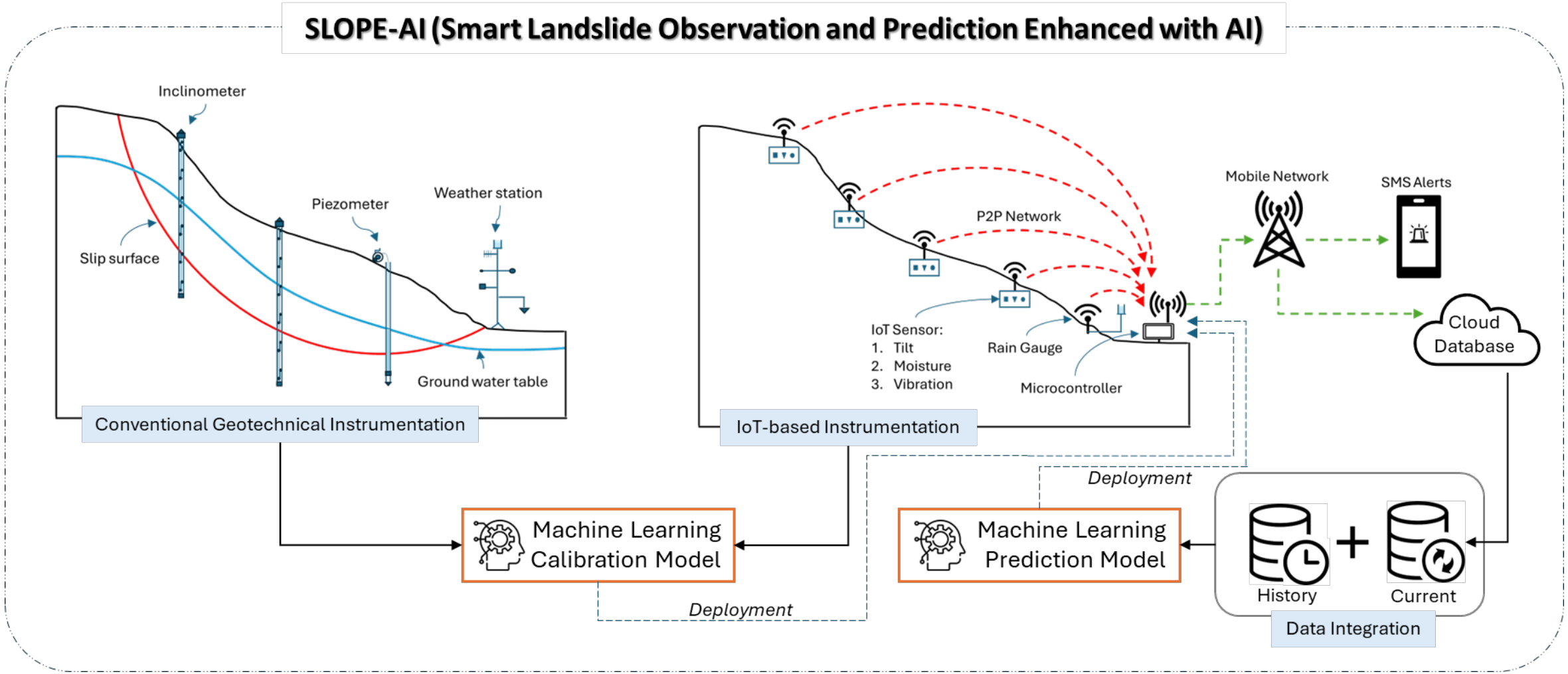
National University of Laos (LAOS): Phoummixay Siharath, Phanthoudeth Pongpanya, Somchay Vilaychaleun, Keophousone Phonhalath, Banthasith Vongphuthone

Consultface Sdn. Bhd. (MALAYSIA): Mohd Farid Ahmad @ Majid, Azilah Ismail,

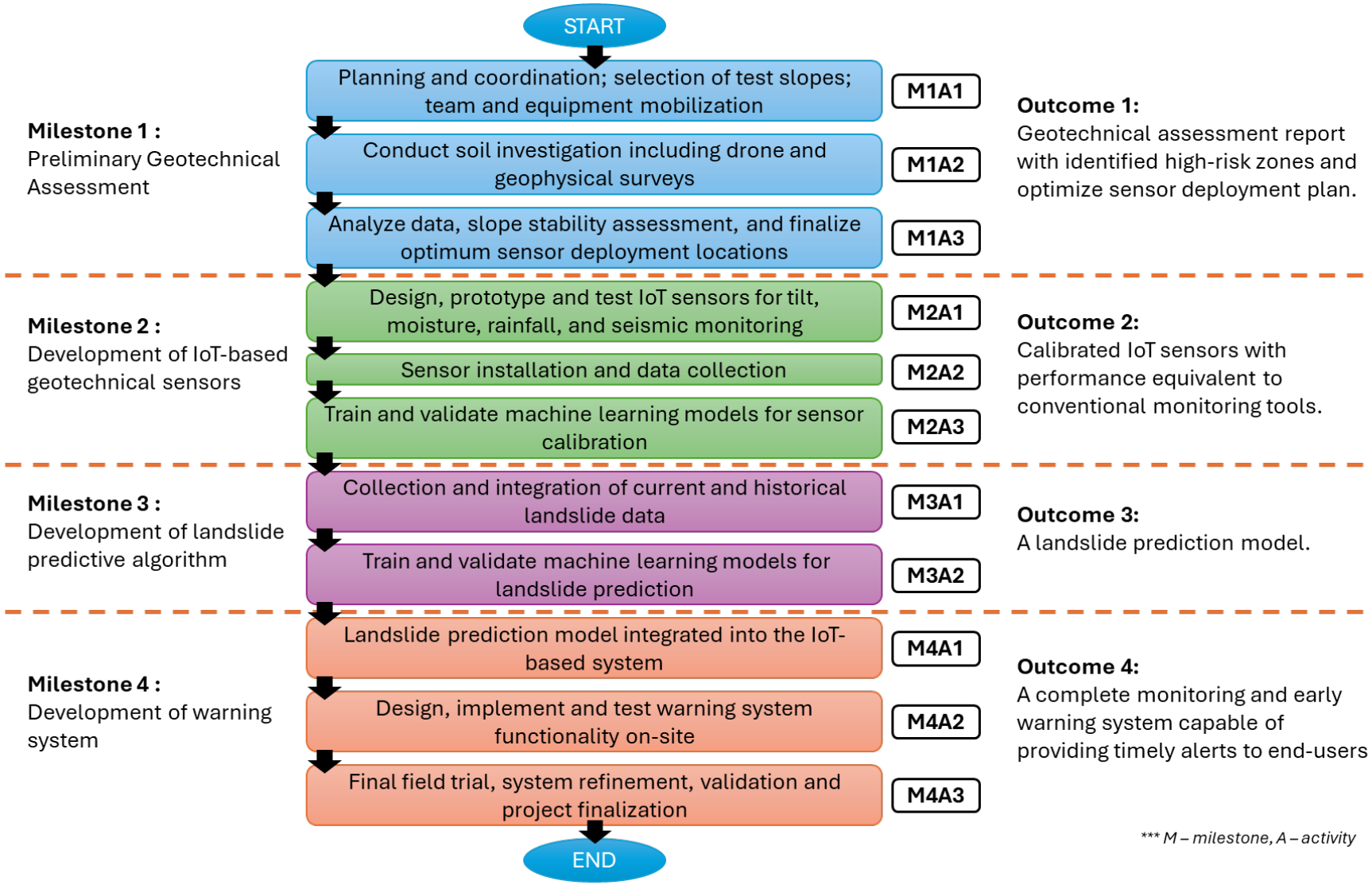
Geoventure Solution Sdn. Bhd. (MALAYSIA): Ahmad Zulqurnain Ghazalli, Nur Zulfa Abdul Kalid

Slopes Engineering Branch, Public Works Department (MALAYSIA): Mohamad Niizar Abdurahman, Nursalbiah Hamidun, Fazilah Hatta, Wan Muhammad Hafiz Zakaria

Project Title: **SLOPE-AI (Smart Landslide Observation and Prediction Enhanced with AI) for Reliable and Economical IoT-Based Landslide Monitoring**



Project Title: **SLOPE-AI (Smart Landslide Observation and Prediction Enhanced with AI) for Reliable and Economical IoT-Based Landslide Monitoring**

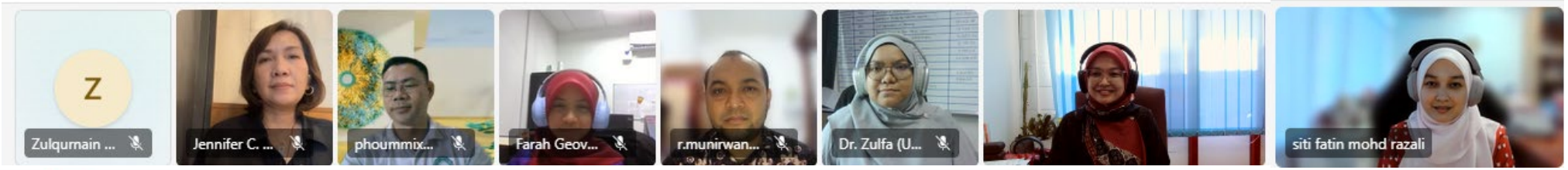


*** *M – milestone, A – activity*

Project Title: **SLOPE-AI (Smart Landslide Observation and Prediction Enhanced with AI) for Reliable and Economical IoT-Based Landslide Monitoring**

Research Activities	2025						2026												2027					
	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6
Planning and coordination; selection of test slopes; team and equipment mobilization																								
Conduct soil investigation including drone and geophysical surveys																								
Analyze data, complete slope stability assessment, and finalize optimum sensor																								
Design, prototype and test IoT sensors for tilt, moisture, rainfall, and seismic monitoring																								
Sensor installation dan data collection																								
Train and validate machine learning models for sensor calibration												Train						Test						
Collection and integration of current data and historical landslide data																								
Train and validate machine learning models for landslide prediction																								
Landslide prediction model integrated into the IoT-based system																								
Design, implement and test warning system functionality on-site																								
Final field trial, system refinement, validation and project finalization																								

Project Activities: Meeting & Communication

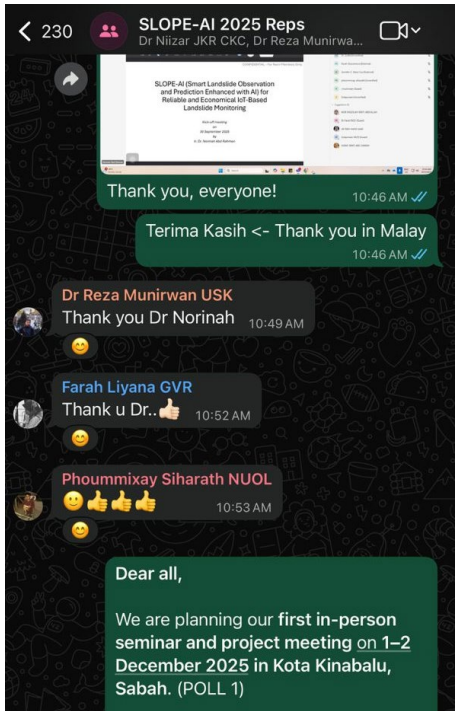


Online Meeting

- 30 April 2025
- 25 September 2025
- 30 September 2025

Fast communication through WhatsApp Group

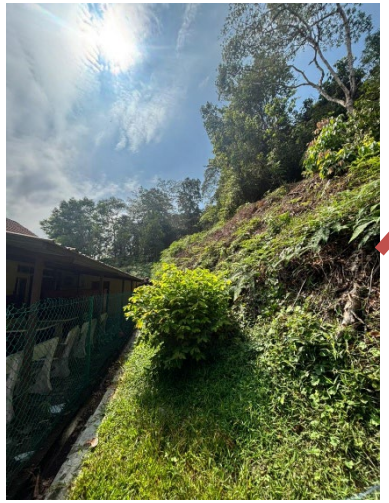
- All the time!



Project Activities: Preliminary Site Visit

SLOPE 1: UNIVERSITI KEBANGSAAN MALAYSIA (2°55'22.3"N, 101°46'28.1"E)

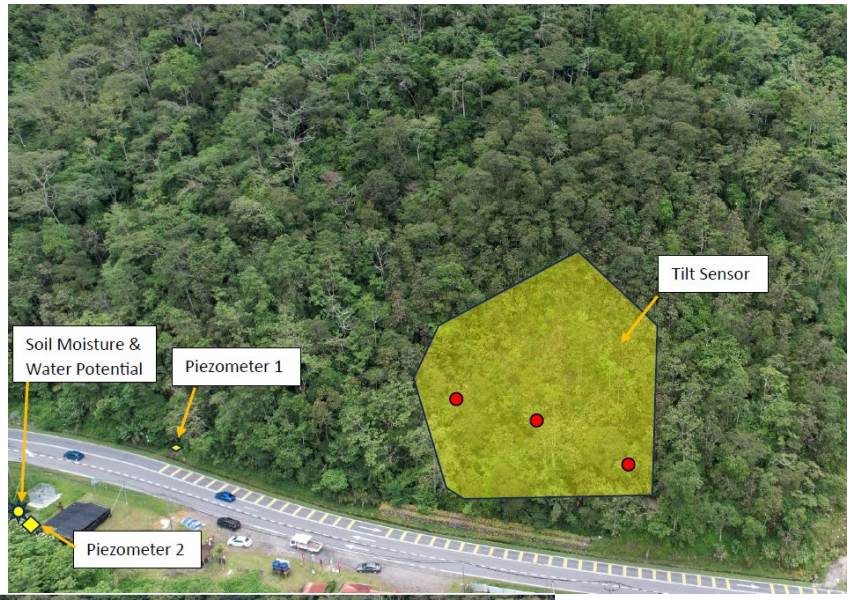
25 June 2025

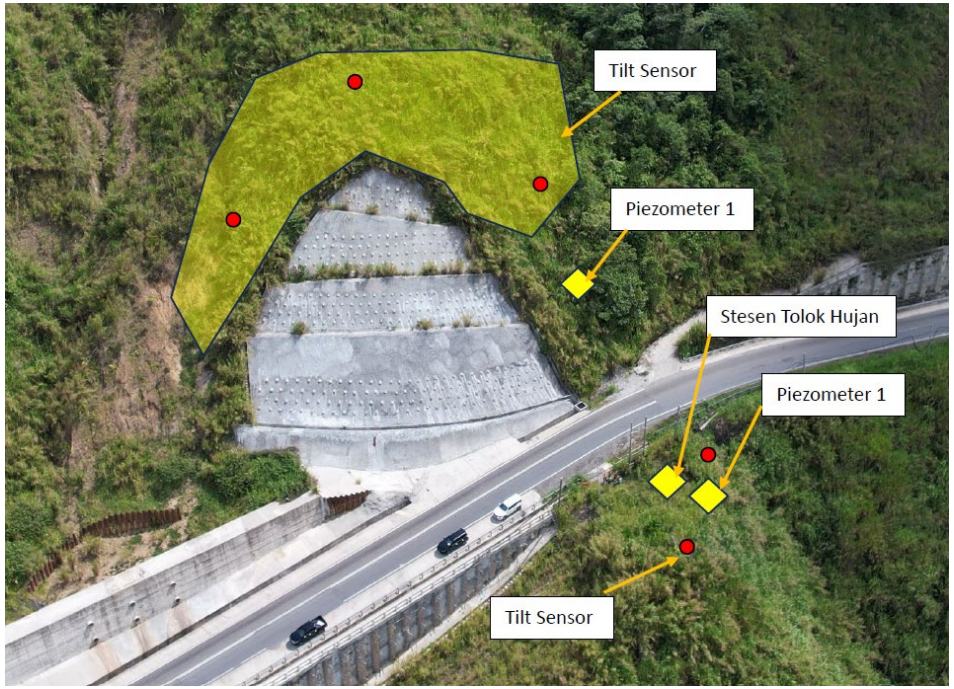


Project Activities: Preliminary Site Visit

SLOPE 2: RANAU SABAH MALAYSIA (2°55'22.3"N, 101°46'28.1"E)

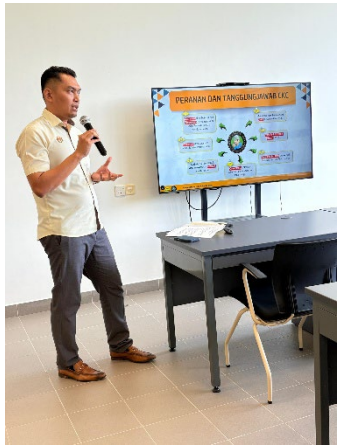
SLOPE 3: RANAU SABAH MALAYSIA (2°55'22.3"N, 101°46'28.1"E)





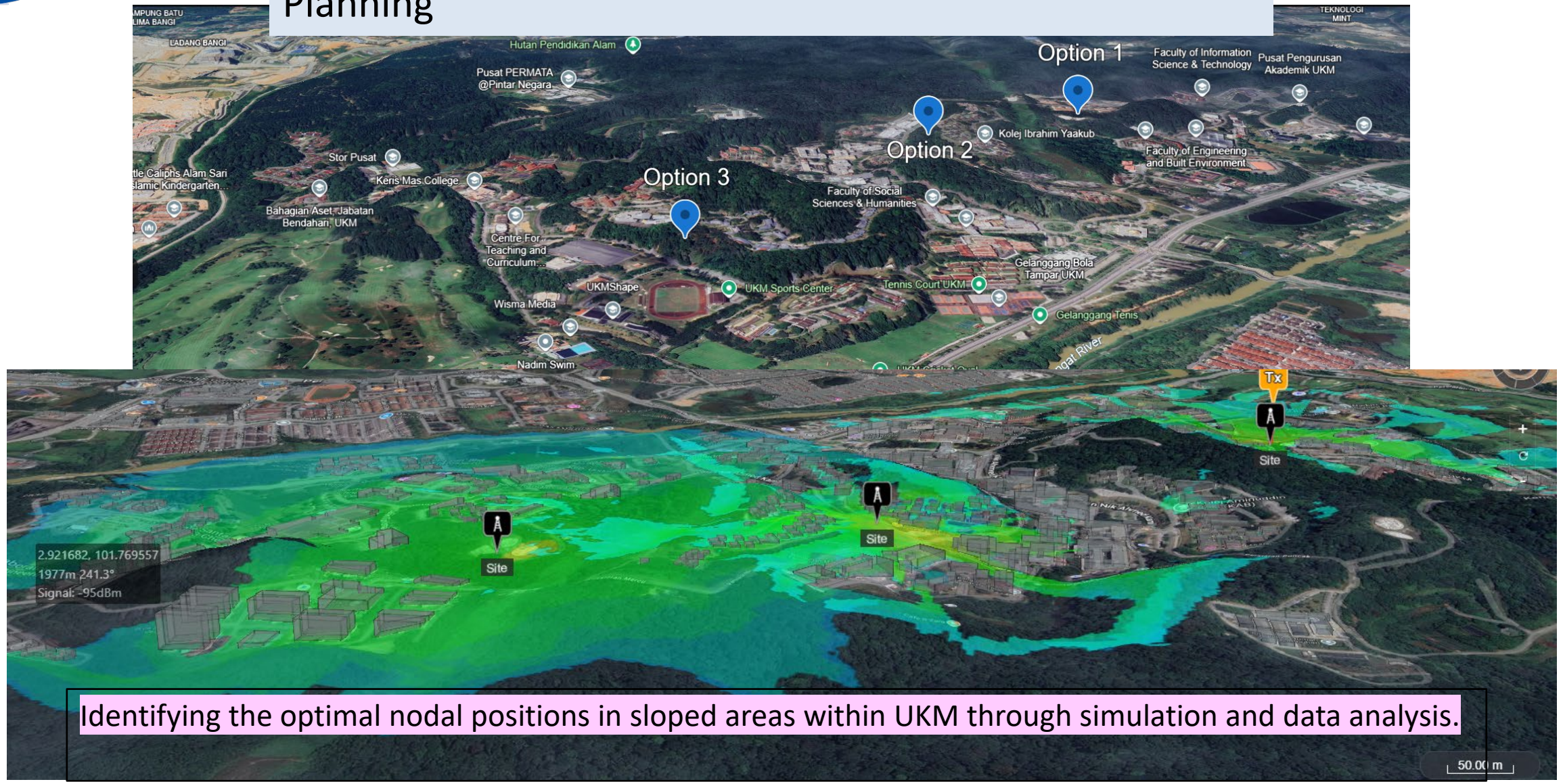
5 September 2025

Project Activities: Half-Day Seminar on Slope Monitoring



8 July 2025

Project Activities: Wifi-Halow Sensor Networks Planning



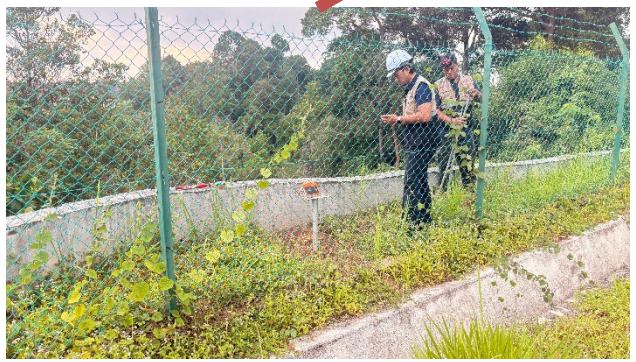
Identifying the optimal nodal positions in sloped areas within UKM through simulation and data analysis.

Project Activities: Wifi-Halow Sensor Networks Planning

Metric	Route 1	Route 2	Route 3
SNR	Poor SNR, red-yellow zone dominates.	Fluctuating SNR, improves in second half.	**Excellent SNR throughout**, -10 dB to 0 dB, very stable.
Terrain Impact (SNR)	Urban, obstructed by buildings.	Heavily vegetated and hilly terrain.	Mostly open terrain, few blockages.
Path Loss	Good at start (<100 dB), stabilizes around 100–110 dB.	**Best path loss**, improves over distance, stays below 100 dB.	**Consistent, low path loss**, quick recovery from yellow to green.
Terrain Impact (PL)	Minor obstructions from buildings.	Gradual elevation helps improve loss; minor foliage.	Slight elevation gain, benefits from clearer LoS.
Received Power	Strong at first (-50s dBm), drops fast beyond 600 m, worst: -133 dBm.	Very strong initially, but ends in extreme fade (-197 dBm).	**Stable received power**, mostly above -95 dBm, worst ~ -108 dBm.
Power Stability	Inconsistent, weak beyond midpoint.	Very inconsistent, steep dropoff.	**Consistent across route**, minimal drop.
Effective Range	~600–700 m usable.	First 1 km usable, last third very weak.	Full route mostly usable (>90% of points above sensitivity).
Obstacles	Dense buildings.	Terrain, foliage, and turns.	Few terrain dips, but mostly clear.
Deployment Suitability	Good for short-range or urban repeater layout.	Needs relay or smart placement to avoid fade zones.	**Ideal for continuous long-range comms with stable quality.**

Project Activities: Sensors Installation

6 October 2025
Tilt sensor x 3



29 October 2025
Weather station

Societal Impact:

> The **SLOPE AI system** enhances **community safety and resilience** by providing **real-time landslide monitoring and early warning** using low-cost IoT and AI technologies. It **empowers local authorities and communities** to take timely preventive actions, while also **building local capacity** through training in digital and geotechnical applications. The project further **promotes regional collaboration and data sharing** across ASEAN for **sustainable slope management and disaster risk reduction**.

Conclusion:

- SLOPE AI enables real-time landslide monitoring and prediction using low-cost IoT sensors and AI, making slope management more accessible for remote and high-risk areas
- The system supports community safety, disaster preparedness, and regional collaboration, contributing to resilient infrastructure and sustainable development
- The project has achieved some key progress, including the selection of three slopes for calibration, initial conventional sensor installation, and stakeholder engagement through meetings and a half-day seminar

Future works:

- Continue the development of the SLOPE AI system, followed by calibration using conventional geotechnical instruments.
- Collect and analyze previous landslide data to enhance AI prediction accuracy.
- Conduct comprehensive field testing on three selected slopes, including geophysical surveys, geotechnical assessment and soil sampling, mapping, hydrological observation, and communication system testing
- Organize a one-day seminar for local participants to share knowledge and promote community awareness on landslide monitoring and prevention.