



## INTEGRATION OF MULTI-SENSORS DATA IN DETECTING SLOPE MOVEMENT BASED ON THRESHOLD VALUES

Hazwani NK<sup>1</sup>, Rohayu CO<sup>1</sup>, Fathoni U<sup>1</sup>, Aiman I<sup>1</sup>, Amiruddin Z<sup>1</sup>, INZ Baharudin<sup>1</sup>, Rasyikin R<sup>1</sup>, N. M.Din<sup>1</sup>, H. Hussain<sup>1</sup>, M. Z. Jamaludin<sup>1</sup>, Z Baharuddin<sup>1</sup>, S. Zulkarnain<sup>1</sup>, A. Z. Arazad<sup>2</sup> and H. Yusop<sup>2</sup>

<sup>1</sup>Centre for Forensic Engineering, Universiti Tenaga Nasional, Jalan Ikram-Uniten, Kajang, Selangor, Malaysia

<sup>2</sup>NB Research Sdn Bhd.

E-Mail: [hazwani@uniten.edu.my](mailto:hazwani@uniten.edu.my)

### ABSTRACT

Malaysia has a number of power lines for electricity supply generated by Tenaga Nasional Berhad (TNB). The company has owned 95% of power lines from North to South of Peninsula Malaysia. In order to maintain the quality of power transmission for the country, it is very important for TNB to monitor the stability of their transmission towers (pylons). Unfortunately, most of these transmission towers are located at very hilly and remote areas. Conducting inspection at those areas are not efficient since the staffs are exposed to wild animals, not cost effective and always require longer inspection time due to weather condition. Therefore, a new technique which is implementing a stability threshold value by installing selected sensors at the critical slope is introduced to improve the efficiency of current slope monitoring procedure. Four (4) sensors which are piezometer, inclinometer, raingauge and soil moisture probe are installed to monitor four (4) parameters that cause landslide. Based on one-cycle (1 year) of data collection, three (3) threshold values have been identified to be as an alert value for the monitoring system.

**Keywords:** slope movement, transmission line, threshold value.

### INTRODUCTION

Tenaga Nasional Berhad (TNB) has owned 95% of power lines in Peninsula Malaysia. The power chains lie from North to South through various landuse and topography. Concern on the stability of transmission tower (pylon) and quality of power supply, it is important for TNB to monitor all transmission towers which are located at landslide area. Current technique implemented is limited to human ability, time taken for tower inspection, high cost, and areas which are vulnerable to wildlife.

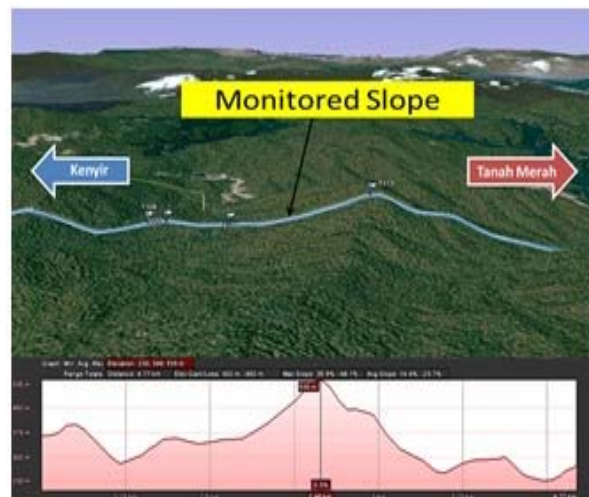
In Malaysia, various techniques practice nowadays are focusing more on detecting slope movement without considering real-time data transfer and developing threshold values. Lembaga Lebuhraya Malaysia (LLM) applying large-scale assessments in prioritizing slope maintenance along roads and highways. While medium-to-small-scale assessments in controlling development in hilly areas are widely used by Jabatan Kerja Raya (JKR), Jabatan Perancang Bandar dan Desa (JPPD) and Jabatan Mineral & Geossains (JMG). [1]

In this study, a new technique (very-small-scale) is developed by implementing monitoring threshold values. Selected sensors are installed at the critical slope to improve the efficiency of current slope monitoring procedure. New techniques and latest technology are needed to develop a good monitoring system of landslide hazard in order to mitigate the hazard effectively. Nevertheless, if the technique does not benefit the society, the risk assessment main target can be classified as a failure since it does not contribute to the diminishing risk impact to the society. Therefore, the system is combined with real-time data transfer to promptly alert the maintenance team and provide instant information to warn the society about the landslide hazard.

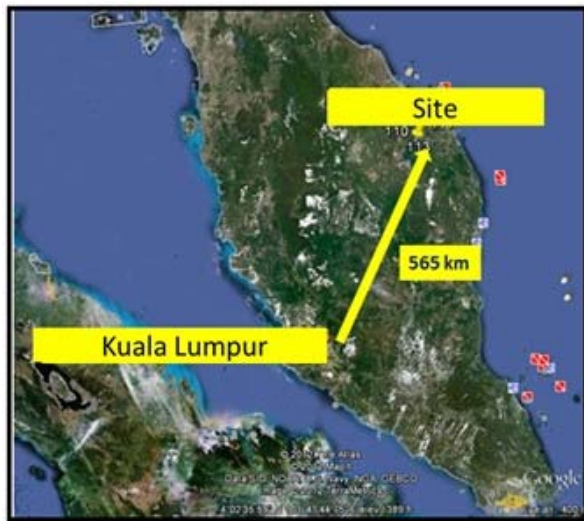
### METHODOLOGY

#### Study Area

A transmission tower which has a critical slope due to landslide hazard is selected to be monitored. After conducting site survey at several places around Peninsula Malaysia, a critical slope is found at hilly and very remote area in Kenyir, Terengganu (Figure-1), which is 525km from Kuala Lumpur (Figure-2). There is a movement activities on the slope, by referring to the crack sign occur on concrete drain, as shown in Figure-3. The overall view of the slope as shown in Figure-4.



**Figure-1.** The study area is located at very remote and hilly area.



**Figure-2.** Distance from Kuala Lumpur to the study area.



**Figure-3.** Crack sign indicates movement occurs at the slope.

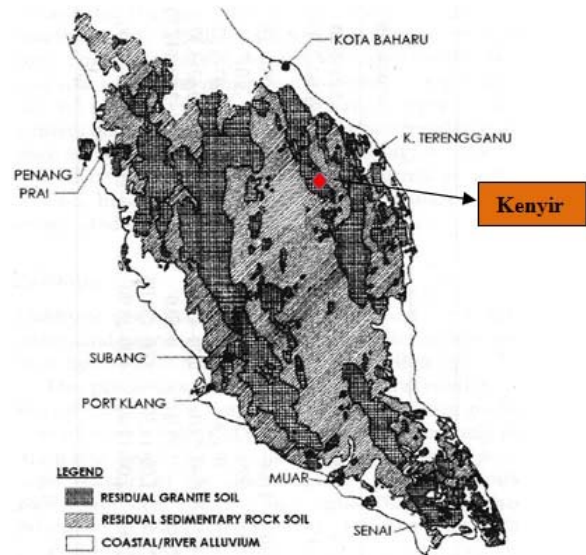


**Figure-4.** View under the transmission tower.

Malaysia is a tropical country with 80% of the land covered by residual soil. Figure-5 shows the distribution of residual soils in Peninsular Malaysia [2]. Based on the figure, Kenyir lies on residual granite soil, which is usually degrades into the bedrock and undergone

chemical weathering process that always occur in tropical and high humidity area [3].

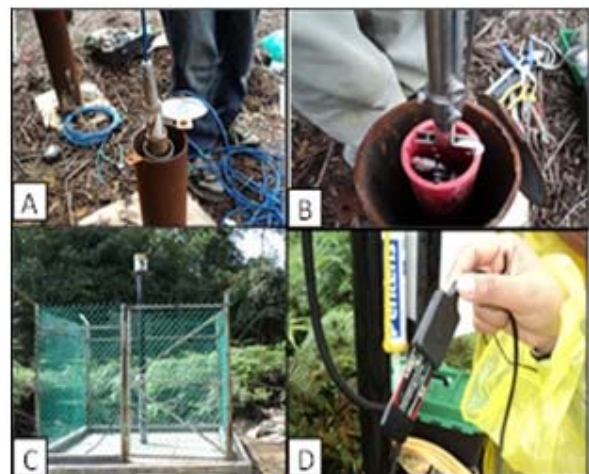
Referring to Köppen Climate Classification, Malaysia is one of the countries classified as Tropical Rainforest Climate (Equatorial Climate, Af) with precipitation values not less than 60mm for every month. There is frequent and heavy rainfall throughout the year with no dry season. Therefore, the possibility for landslide to occur is higher.



**Figure-5.** Distribution of tropical residual soils in Peninsular Malaysia (Ooi, 1982).

### Types of Instruments

Once the site is identified, study on sensors to be used is carried out. The slope monitoring sensors to be considered are inclinometer, piezometer, rain gauge and soil moisture probe (Figure-6).



**Figure-6.** The sensors. A: piezometer, B: inclinometer, C: rain gauge, D: Soil moisture probe.



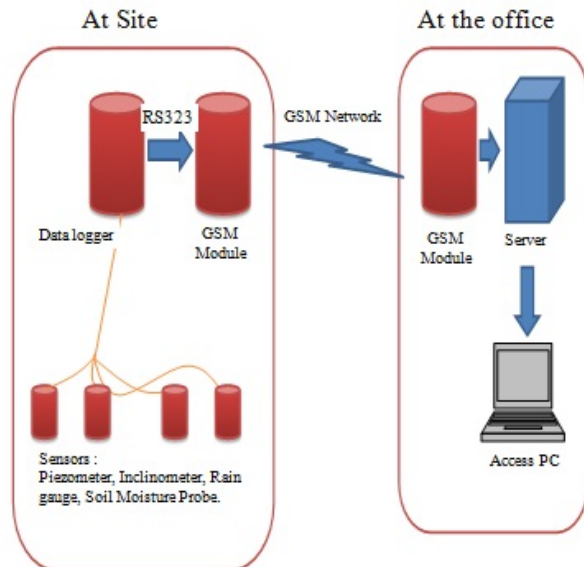


Those sensors must be calibrated in the laboratory before installation at site. Another test to be carried out is the effect of high voltage transmission line on the electrical signals from sensors and other electronic equipment.

#### On-Site Data Collection and Data Transfer

Figure-7 illustrates the connection layout between sensors, data logger and the server, while Figure-4 shows actual location for the site and the server.

Data from all sensors are collected and logged into the data logger. The data logger will store a raw data and transfer the data to the office via GSM modem modules. The server which is located at the office will receive and processed the data in a system that was specially designed to process data from various types of sensors. Procedure on communication method was discussed in detail in previous research paper [4].



**Figure-7.** Connection layout between sensors, data logger and server.

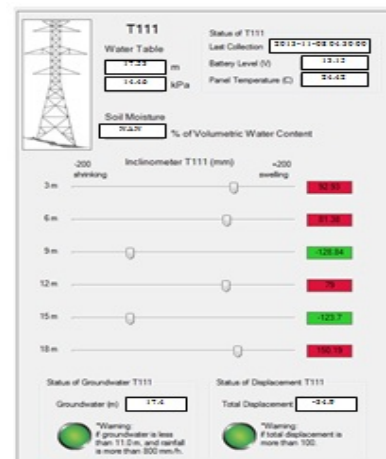
#### Data Monitoring at the Office

The data logger received output from various sensors that have different units, which are summarized in Table-1.

**Table-1.** Function of all sensors and its unit.

Type of Sensor	Function	Final Unit
Raingauge	To record rainfall intensity	mm/hr
Piezometer	To detect water level	m
Inclinometer	To detect soil movement in slope	mm
Soil Moisture Probe	To detect soil surface moisture	% of Volumetric water Content

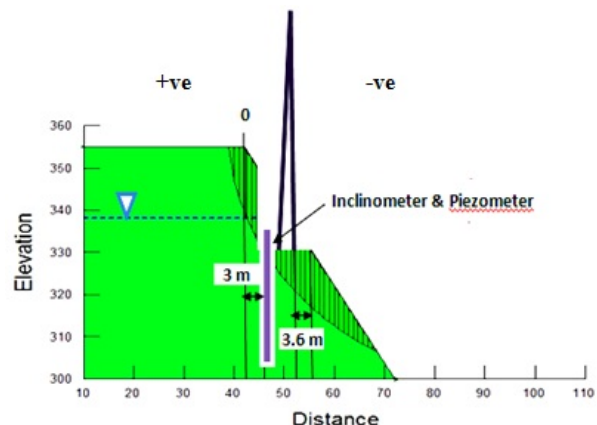
Since the data logger received various output from those sensors, formulas provided by manufacturer were used during data processing stage in order to produce the final unit. All data are transferred to the office in Digital ASCII format, via GSM Module. After getting into the server, those data need to be retrieved and processed again, before it can be transformed into a monitoring system. The monitoring system has been designed with user friendly interface to transform all the information, as shown in Figure-8.



**Figure-8.** System with special interface which is designed to monitor the slope.

#### Analysis of Data and Determination of Threshold Value

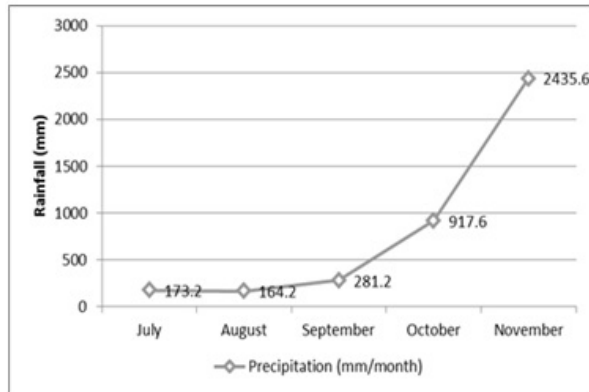
The threshold value is determined based on observation of normal range for positive and negative movement recorded by inclinometer (Figure-9), normal range for ground water level recorded by piezometer and total rainfall received on the slope itself, recorded by raingauge. In order to get accurate monitoring value, the data is captured at 30 minutes interval and monitored for 1 year to complete one cycle of monitoring duration.



**Figure-9.** Positive and negative side for slope movement (inclinometer reading).



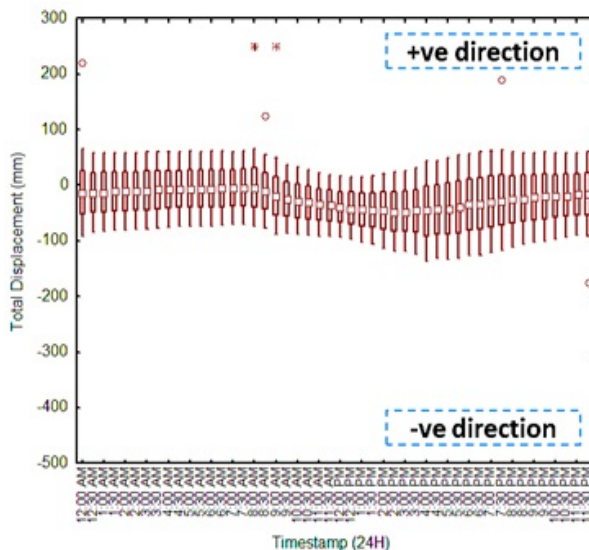
Graph in Figure-10 is plotted based on data collected by rain gauge. The data prove that the study area has experienced monsoon season (heavy rain) since the reading is increased from September to November. In Terengganu, monsoon season is normally occur from November to February.



**Figure-10.** Graph of rainfall received at the study area (precipitation mm/month).

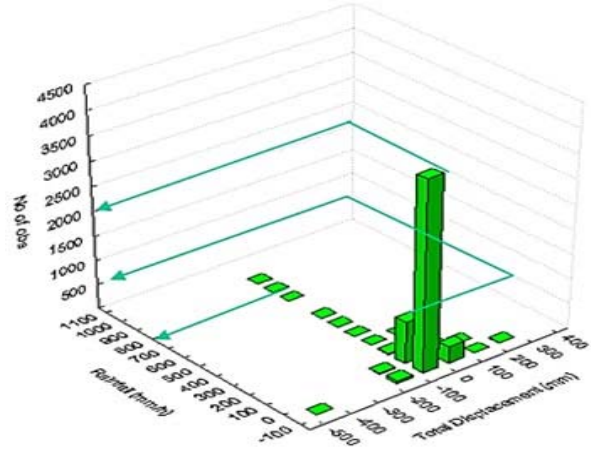
Statistical Analysis Method has been applied in analyzing all data. Box Plot (BP) is used to detect normal positive and negative slope movement while Bivariate Histogram (BH) is used to detect normal value of ground water level and received rainfall.

Figure-11 shows the BP for Total displacement vs time. It clearly indicates the maximum positive and negative value of the slope, which is 100 mm. Therefore, the alert threshold value for slope movement is decided to be +100 mm, which is when the slope is moving towards positive direction.



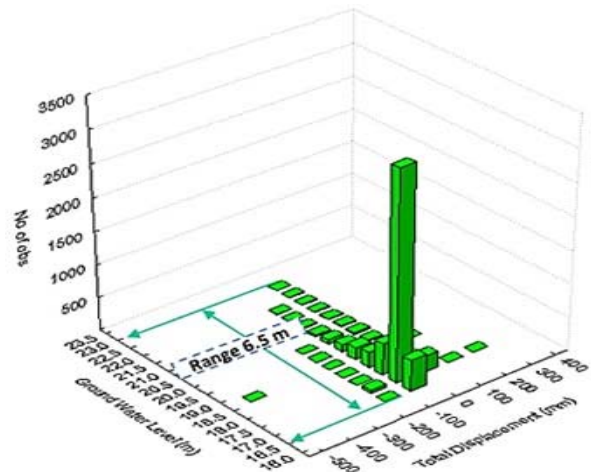
**Figure-11.** Box plot (BP) method in detecting normal positive and negative direction of the slope movement.

Referring to the rainfall axis plotted in BH Figure-12, the maximum rainfall recorded is 1000 mm/h while the normal value recorded is less than 100 mm/h. The total rainfall will increase gradually before it reaches the maximum value. Therefore, 800 mm/h has been set up as alert threshold value in the system.



**Figure-12.** Bivariate histogram for total displacement vs rainfall.

Figure-13 shows a BP for Total Displacement vs Ground Water Level. Referring to the ground water level axis, the normal fluctuated value is between 16.5 m to 23.5 m from the ground level, which is in 6.5 m range. The alert threshold value is decided to be 11 m, since the soil will be saturated as the ground water level is increasing.

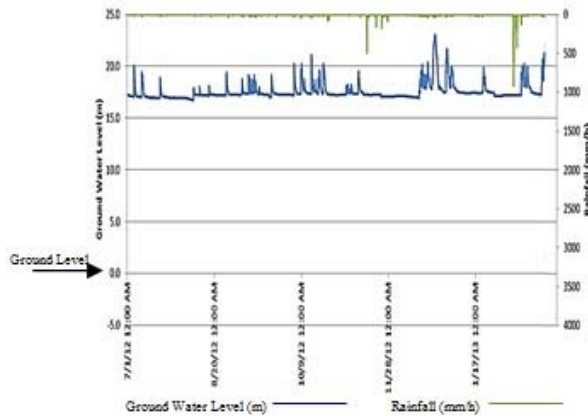


**Figure-13.** Bivariate histogram for total displacement vs ground water level.

On the other hand, ground water level in the rock fall and landslide deposits has seasonal fluctuations which are affected by the rainfall [5]. Therefore, in order to determine the relationship between ground water level and precipitation of rainfall into the soil, a simple graph is plotted using Microsoft Excel, as shown in Figure-14.



Referring to the graph, the ground water level increased as rainfall increased. But, there are different in time for rainfall to reach the ground water. This phenomenon indicates that type of soil at T111 is very good in absorbing water and has been confirmed by laboratory test, as Sandy SILT.



**Figure-14.** Relationship between rainfall and precipitation of rainfall to the soil.

## CONCLUSIONS

As a conclusion, the study area is lies on residual granite soil, which is usually degrades into bedrock and undergone chemical weathering process. Type of soil plays a big role in slope stability since capability of retaining and absorbing water is depending on the soil properties.

Since type of soil at the study area is Sandy SILT, heavy rainfall does not cause any changes to its ground water level. This phenomenon indicates a sign of heavy surface run-off that will cause erosion and leads to landslide. Nevertheless, the soil shows shrinking and swelling behavior (moving positive and negative direction).

Based on one-cycle (1 year) of data collection, three (3) threshold values have been identified to be as an alert value for the monitoring system, which is summarized in Table-2.

**Table-2.** Threshold values.

Parameter	Threshold Value
Ground Water	< 11m (0 is at ground level)
Rainfall	>800 mm/h
Total Displacement	> +100

Therefore, maintenance team will be alerted by the system if any unusual data is recorded. Immediate action can be taken in order to protect the transmission tower structure.

Nevertheless, the threshold values are independent and specialize for the studied slope. It is applicable for the same type of slope properties within 100 meter radius. Therefore, the same set of instruments is

needed to monitor other critical slopes since different slope properties might have different range of movement.

## REFERENCES

- [1] Suhaimi Jamaludin, A. N. (2006). Landslide Hazard and Risk Assessment L: The Malaysian Experience. IAEG 2006 Engineering Geology for Tomorrow's Cities, (p.55). Nottingham, United Kingdom.
- [2] Bujang B.K.Huat, David G.Toll & Arun Prasad (2012). Handbook of Tropical Residual Soils Engineering.
- [3] Press, F. & Siever, R. (1994). Understanding earth. W.H.Freeman & Co Ltd.
- [4] R. C. Omar, A. Ismail, N. H. N. Khalid, N.M. Din\*, H. Hussain, M.Z. Jamaludin, F. Abdullah, A.Z.Arazad & H.Yusop (2013) Real time monitoring of slope condition for transmission tower safety in Kenyir, Malaysia. IOP Conference Series: Earth and Environmental Science 16 (2013), doi:10.1088/1755-1315/16/1/012132
- [5] Fawu Wang, Tonglu Li, Landslide Disaster Mitigation in Three Gorges Reservoir, Springer, China 2013