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Full Length Research Paper

Monitoring of shallow landslide in Tun Sardon 3.9 km Pinang Island, Malaysia

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The objective of this paper is to monitor the slope movement before a landslide occurrence. Inclinometer, piezometer and rain gauge were installed to monitor the slope. In the study area, water level of all piezometers is showing cyclic trend correlated with rainfall intensity. Observation made on July 30th 2010 and November 4th 2010 show soil movement in positive direction (towards slope). A relation between soil movement and high intensity of rainfall during this period was inferred which can be consider as a potential threat for mankind.

Key words: Shallow landslide, slope movement, Tun Sardon 3.9 km Penang.

INTRODUCTION

Malaysia is a tropical country with high rainfall intensity. Many landslides in Malaysia are related to rainfall and granitic slope especially in Penang Island which generally consists of granite. Penang island is a small island with a size of 293 km^2 (Figure 1). More than 50% of the area consists of hills and mountains topography (Institute of Strategic and International Studies and Penang Island Development Corporation, 1991). However, Penang Island is one of the most rapidly developing states in Malaysia. In terms of land use, 6.406 ha of the land was gazetted as Permanent Forest Reserve (PFR) where administration, management and conservation of forest and forestry departments were provided by National Forestry Act 1984 (New Straits Times, 28/8/01). In Penang Island, rate of urbanization has reduced the forested area in the mountains, which quite high around 75% in 1991 and 86.1% in 2000 (Chan, 1998). Large areas of land are being cleared for housing estates, hotels, and apartments which have resulted in erosion and landslides.

Landslide can be a factor that leads to loss of lives and property, for example the Bukit Antarabangsa landslide in December 2008, the collapse of the Highland Towers luxury condominium (caused by landslide) in 1993 which claimed 49 lives, the Pos Dipang landslide which claimed 40 lives in August 1996 (mostly houses on steep hill slopes), the Genting Highland landslide tragedy in July 1995 which killed 20 persons and injured 23 others, the occurrence of 60 landslides in Penang in September 1995, the north-south highway landslide near Gua Tempurung in January 1996 which claimed one life and caused massive traffic jams for weeks, the spate of landslides in Cameron Highlands (a highland resort) in which one person was buried alive and hundreds were evacuated (Chan, 1998).

In early 1980, Tun Sardon road was developed to 8.5 km. It was a part of the ring road in the south-west of Penang Island that connected Relau and Balik Pulau. The road development has triggered slope natural stability. A lot of cut slopes formed over road cross with high slope angle. Heavy rainfall on September 2008 caused a numbers of landslides which disturbed traffic. The landslide happened at a numbers of critical cut slope point (>30°) such as: 0.6, 3.9, 4.5 and 6.3 km. Tun Sardon road lies in the zone that has a high risk of landslide susceptibility level (Lee, 2006).

A shallow landslide occurred along at 3.9 km Tun Sardon roadside after a heavy rainfall event on September 6, 2008 in the Penang Island (Figure 2). The Tun Sardon event occurred due to a 160 mm of continuous rainfall in 8 h. The rainfall increases the pore water pressure as well as increases soil unit weight. After sufficient saturation, the residual soils might have caused the slope to fail (Habibah et al., 2009).

Previously, not much work has been done on landslide hazard and risk analysis on Penang Island. Toh (1999),

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Figure 1. Location map of study area in Penang Island.

Figure 2. Landslide at 3.9 km Tun Sardon road of Penang.

Ooi (1999) and Pradhan et al. (2010) presented some case studies of Penang Island dealing with preventive and remedial work for rock falls involving granite boulders; for example, the use of wire nets and fences, cables and rock anchors, and the concreting together of loose boulders.

The main objective of this research is to investigate and analyze the shallow landslide occurrence at 3.9 km Tun Sardon road (Figure 1). Inclinometer test to get soil's movement and piezometric measurements to get the water level fluctuations were carried out during this study.

MATERIALS AND METHODS

Study area

Penang is one of the 13 states of Peninsular Malaysia, situated at the northwestern coast and constituted by two geographically different lands - an island with an area of 293 km^2 called Penang Island and a portion of mainland called Butterworth with an area of 738 km^2, connected through a 13.5 km long Bridge. It is bounded to the north and east by the state of Kedah, to the south by the state of Perak, and to the west by the Straits of Malacca. The island is located between latitudes 5° 8' N and 5° 35' N and longitudes 100° 8'E and 100° 32' E (Ong, 1993).

According to the Malaysian Meteorological Department, the temperature of the northern part of Penang ranges between 29 and 32°C and mean relative humidity varies between 65 and 96%. The highest temperature is during April to June and the relative humidity is lowest in June, July and September. The amount of rainfall in the study area varies between 13 and 302 mm per month in 2010.

Rainfall in Penang Island averages between 2,670 and 6,240 mm per annum (Figure 3). There are two distinct wet seasons from September to December and from February to May each year. The rainfall on Penang Island peaks between March and May and from November to December. It has been recorded that single-day rainfall highs range from 87 to 200 mm. It is during such times that many streams and rivers in Penang Island overflow, flooding the surrounding areas, and landslides such as debris flow occur along the river valleys. These landslides mainly consist of flows, rockfall and shallow soil slips that take place during 3 to 4 h of high-intensity rainfall (Pardhana, 2010).

Geology and geomorphology

The study area is in the southern part of Penang Island, measuring approximately 500 m^2. It has unstable elevations, rugged topography and rapid undulations and is characterized by a dense vegetation cover. The topography of the area has been assessed on the basis of the digital elevation model (Figure 4) and field survey. Elevation in the study area ranges from 280 to 350 m above mean sea level. In general, higher elevations are in the northern part, while relatively low elevations are encountered in the western part, along the road. General slope of the area is towards the road, which is in the NW (North west) direction. Slope is mainly planar, though in some parts it tends to be circular. The angle of the slope varies from 40 to 45°.

Classification of slope surface morphology was divided into planar slope, hollow and ridge. At 3.9 km of Tun Sardon road, it was classified as planar slope surface (Figure 5). Research on failure characteristic in Shikoku Island by Dahal et al. (2008) and supported by Avanzi et al. (2004) showed that slopes with hollow surface showed more landslide frequency. However, Jacobson et al. (1993) found that planar slopes are more susceptible to failure than other configuration of slope morphology. This analysis showed there were different results among researchers, although tendency of landslide for certain location is not only influenced by geomorphology. Sometimes the effect from impermeable bedrock was more than the geomorphological factor. The 3.9 km Tun Sardon road slope failure was a result of this factor.

Correlation between landslide area and slope gradient was also analyzed. Dahal et al. (2008) and Avanzi (2004) categorize slope gradient into 4 groups: 30 - 35, 35 - 40, 40 - 45, and >45°; it was observed generally from analysis that the slope gradient between 40 - 45° showed higher frequency of landslides. The present study area falls under this category, that is, slope gradient 40 - 45°.

Cut slope is not a prominent feature, and in many places, to prevent the rock fall retaining walls, anchors and wired fencing are present.

Geologically, the study area is located on the western flank of the main range, which is composed of granite. The granite in Penang Island is classified on the basis of the proportion of alkali feldspar to total feldspars (Ahmad et al., 2006). The regional geology map of the study area is shown in Figure 6.

From the field survey, it is shown that all stages of weathering have resulted in the formation of soil. The rock shows at least two sets of prominent joints.

Weathering of granite has resulted in the formation of granitic soil which is spread over almost the entire hilly terrain. Granitic boulders

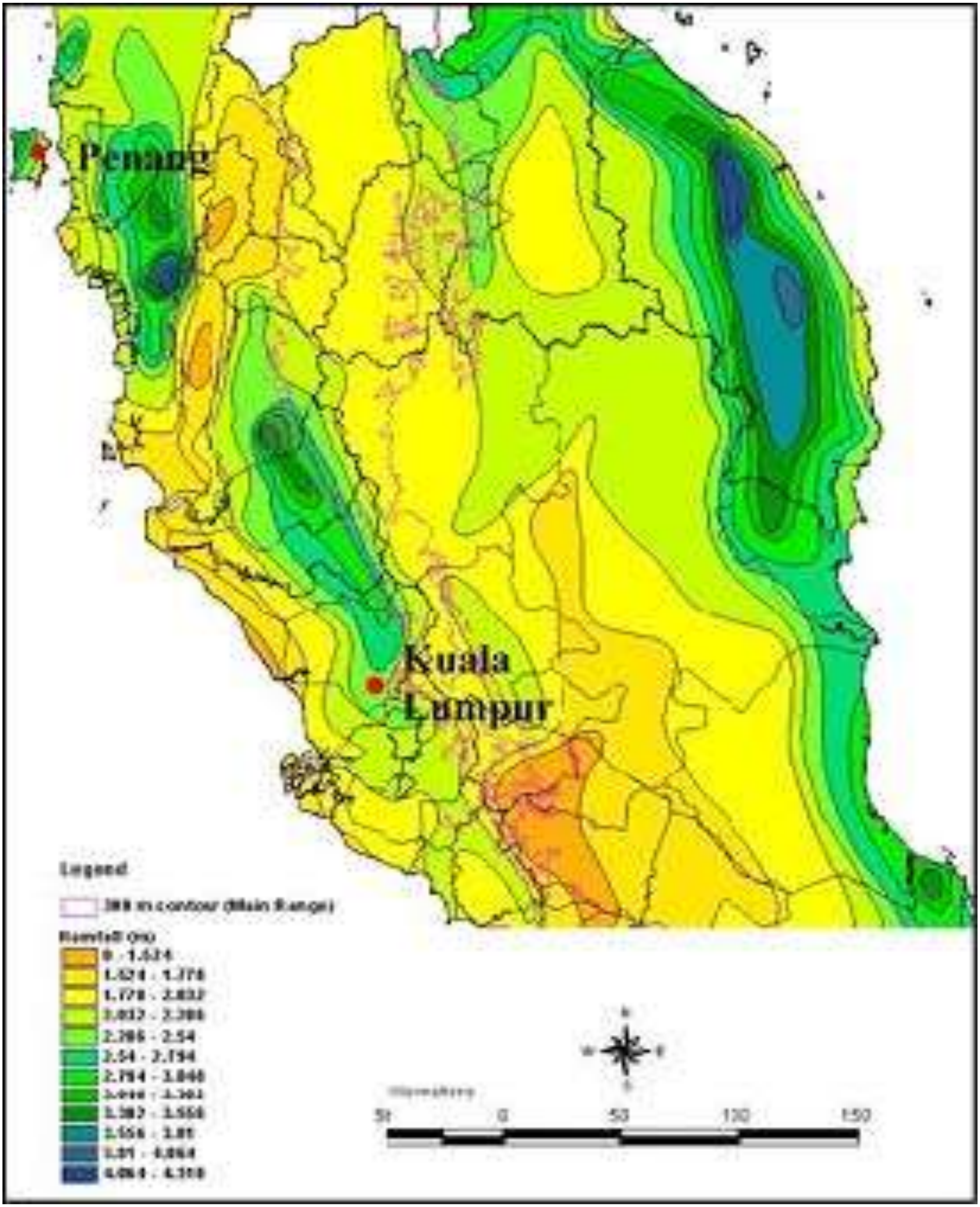

Figure 3. Rainfall distribution for Peninsular Malaysia (Courtesy: Malaysian Meteorological Department).

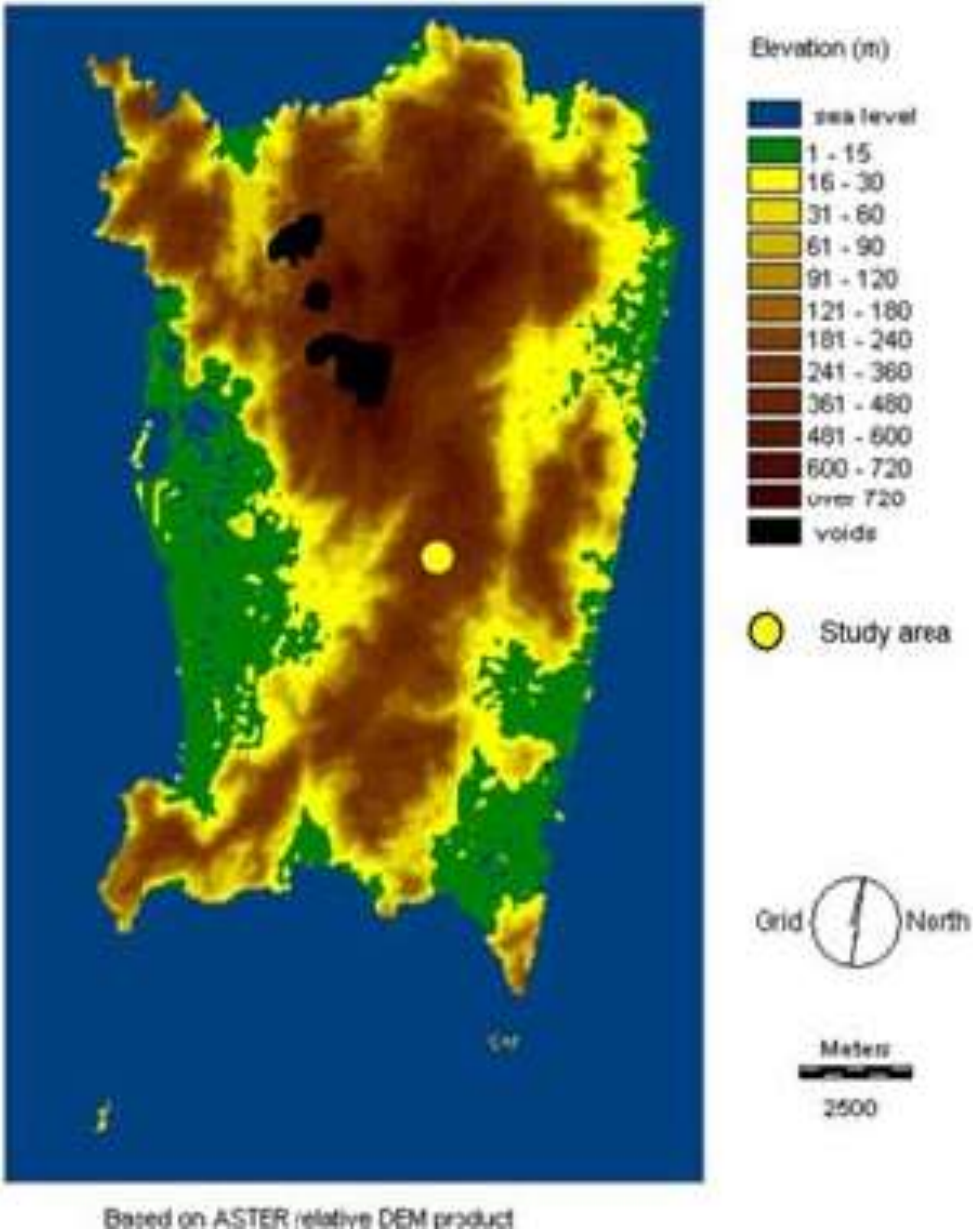

Figure 4. Digital topography of Penang Island.

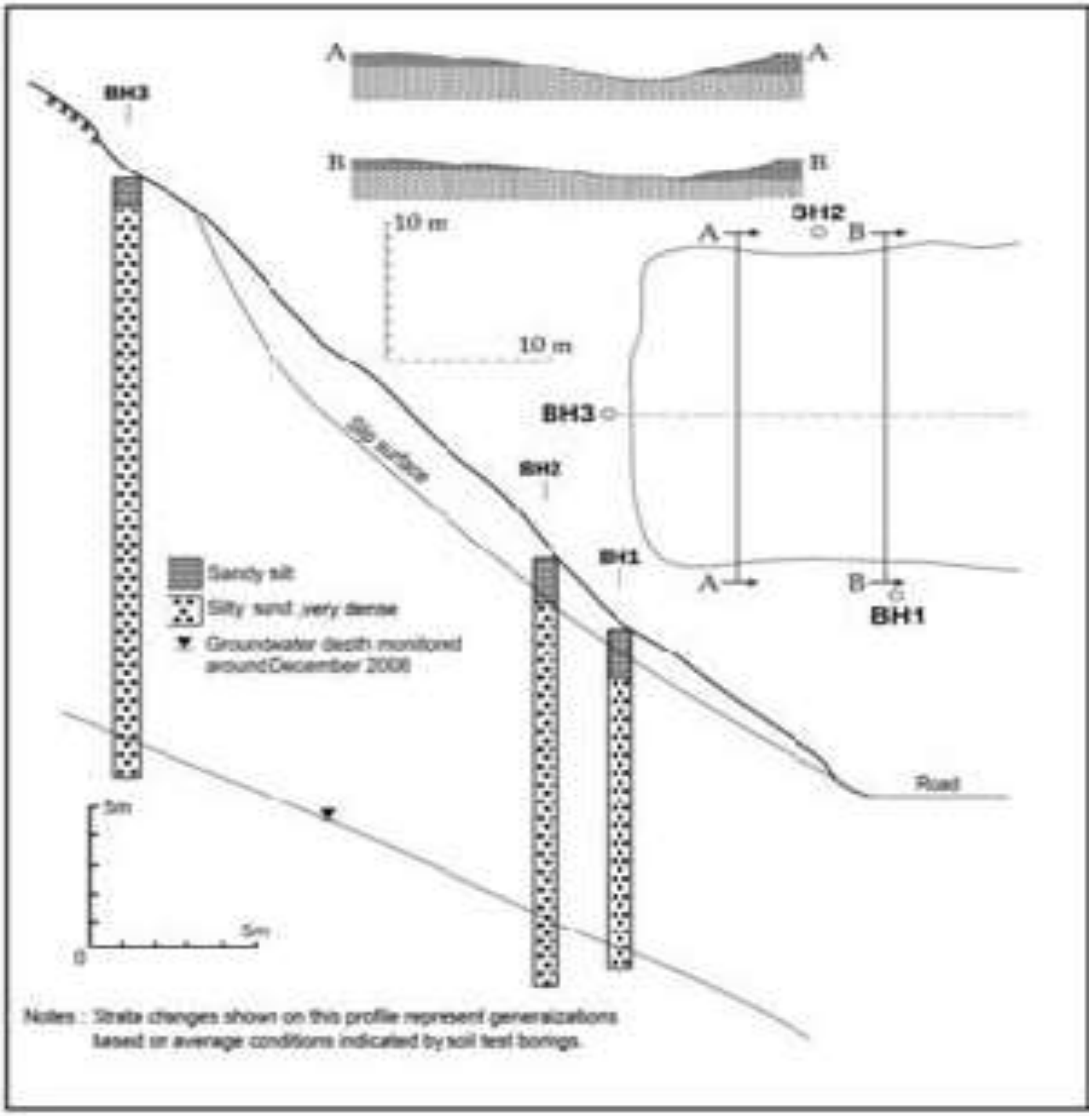

Figure 5. Generalized subsurface profile of slope and cross section.

and pebbles are necessary components of the soil cover. The soil consists of grains of quartz, feldspar and clayey content derived as a result of weathering of feldspars to sericite/illite. Soil has a tendency to be slippery due to the heavy rainfall on the account of the presence of clayey content in substantial proportion. The thickness of the soil layer is changes from place to place. Numerous granitic boulders, formed as a result of exfoliation weathering, occur in loose state.

Weathering of granites in the study area has resulted in the distribution of boulders in the soil profile and hillside development has evidently given rise to distinct landslides and rock fall problems.

Most of the landslides involved almost exclusively the soil, a possible connection between bedrock permeability and landslide susceptibility was supposed (Avanzi et al., 2004). The slope lithology in the study area is a thin (<3 m) layer of residual soil. Layer below the failure surface is of dense decomposed rock and having low permeability. The possibility of failure is higher when the sandy upper strata overlying denser material have a high permeability value. This type of setting favours the shallow landslide.

The slopes with impermeable bedrock have more tendencies for landslide event compared to slope with permeable bedrock

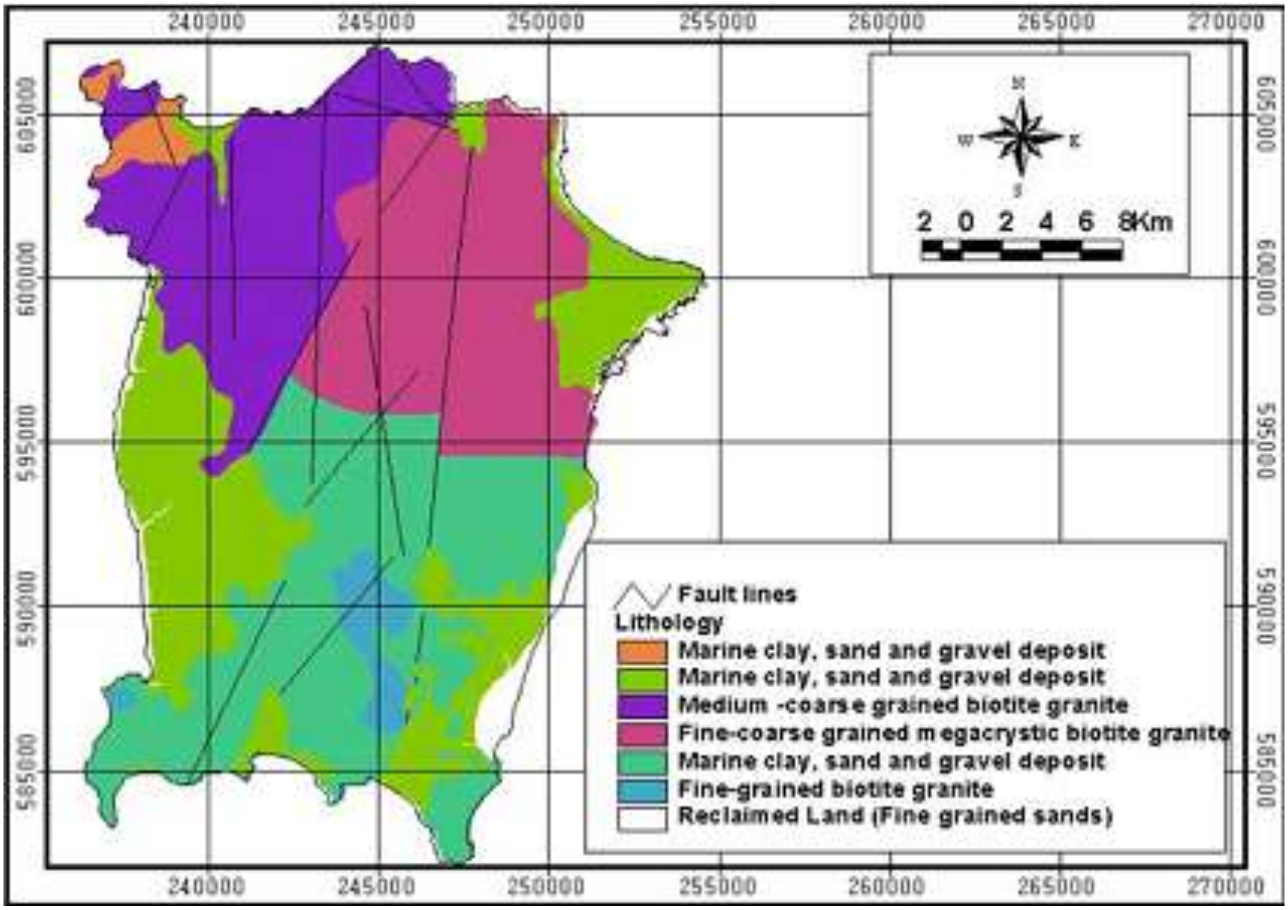

Figure 6. Regional geological map of Penang Island (after Ahmad et al., 2006).

(Matsushi et al., 2006). The impermeable bedrock, by contrast, allows occurrence of saturated subsurface storm flow, draining runoff though a thin permeable soil layer upon the bedrock. This causes a transient positive pressure head. The resulting decrease in the effective stress at the soil bedrock boundary causes a landslide. In this case, if soil is sufficiently thick, one can often expect rainfall-triggered landslides because of the low permeability of the bedrock.

Fence diagram

A fence diagram based on drilling logs of the bore holes drilled by the CE Instruments SDN BHD Malaysia has been prepared (Figure 7). The fence diagram depicts the vertical and lateral disposition of subsurface material in the study area to a depth of 21 m below ground level (bgl). A perusal of fence diagram shows the occurrence of a single aquifer (silty sand) to a depth of 21 m bgl. The top clay layer (sandy silty) is persistent throughout the area varying in thickness from 1.6 to 3.2 m. The material in this layer is fine to coarse grained and is dark brownish gray in color. This top clay bed is underlain by a single granular zone which extends downwards to different depth varying up to 21 m bgl.

This clay bed consists of one large granite lens, approximately 3.6 m long and at the most 1 m thick, which pinches towards B3 (NW). The granite is slightly to completely weathered, particularly along and adjacent to joints. Joints are close to very closely spaced and rough and undulatin with dip varying from horizontal with respect to the drilling axis to 30°.

The granular zone (silty sand/gravel) is also intercalated by granite lenses which are fine to coarse grained and brown in colour. These granitic lenses have, in particular, been intersected by Drillhole B3. This hole has encountered 5 such lenses varying in thickness from < 50 cm to about 2 m.

The granular zone is composed of fine to coarse sand and gravel and form about 60 to 75% of the total formation encountered in drilling. The color of the sand varies from yellowish to brown, probably because of variation in the iron content. This granular zone behaves as potential aquifer.

RESULT AND DISCUSSION

Rainfall and water level

The daily rainfall data was collected from Tun Sardon raingauge station. Graphs of daily rainfall and water level were (Figure 8) prepared to see the impact of rainfall on water table. The close analysis of the graphs shows that rainfall is a major source of groundwater recharge. This is depicted in the rise of water level at the end rainfall. Groundwater recharge is maximum in rainfall period and minimum in non-rainfall time period.

Water level data of 3 piezometers (BH1, BH2, and

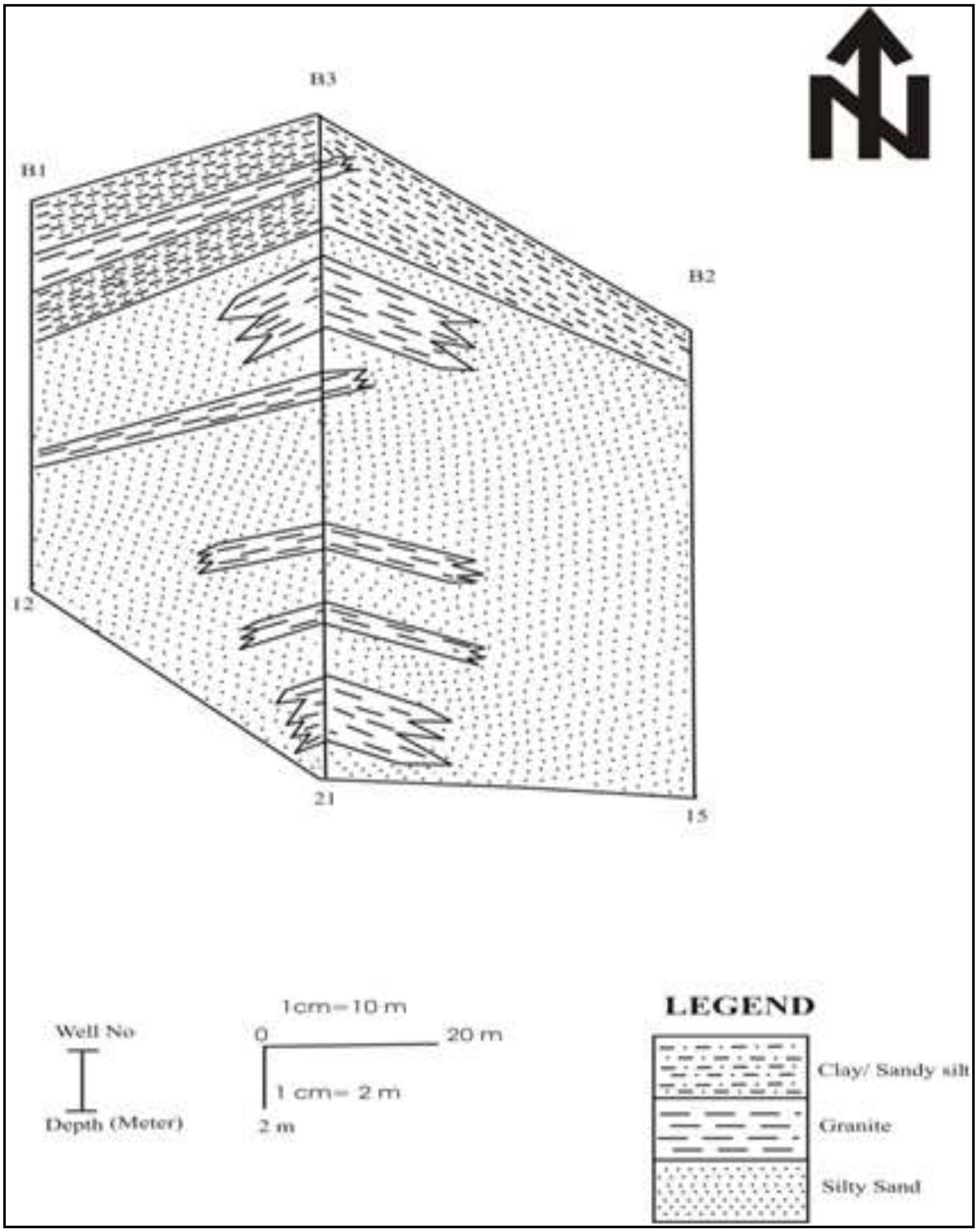

Figure 7. Fence diagram.

BH3) were collected from the site and was utilized to prepare graph (Figure 8) with a view to study water level fluctuation with respect to time and space and dependence on natural phenomenon.

Water levels in unconfined aquifers are affected by direct recharge from precipitation, evapotranspiration, and sometimes changes in atmospheric pressure. The water level, therefore, has a rising and declining trend with respect to time and a function which causes such rises in water levels, that is, availability of rainfall (Walton, 1970).

Perusals of these piezometric graphs indicate that the water level fluctuation is cyclic and sinusoidal as a function of time and space. Water level fluctuation within BH1 (WL1) and BH3 (WL3) coincides with the occurrence and non-occurrence of rainfall events. More precisely, water level rise lags the rainfall occurrence in WL1 and WL3. In paucity of groundwater abstraction, the decline or recession in water level is attributed to aquifer flows. Also some amount of water may loss due to vertical flows and joint leakages. Although, water level at BH2 (WL2) has acquired a flat trend not affected by rainfall events

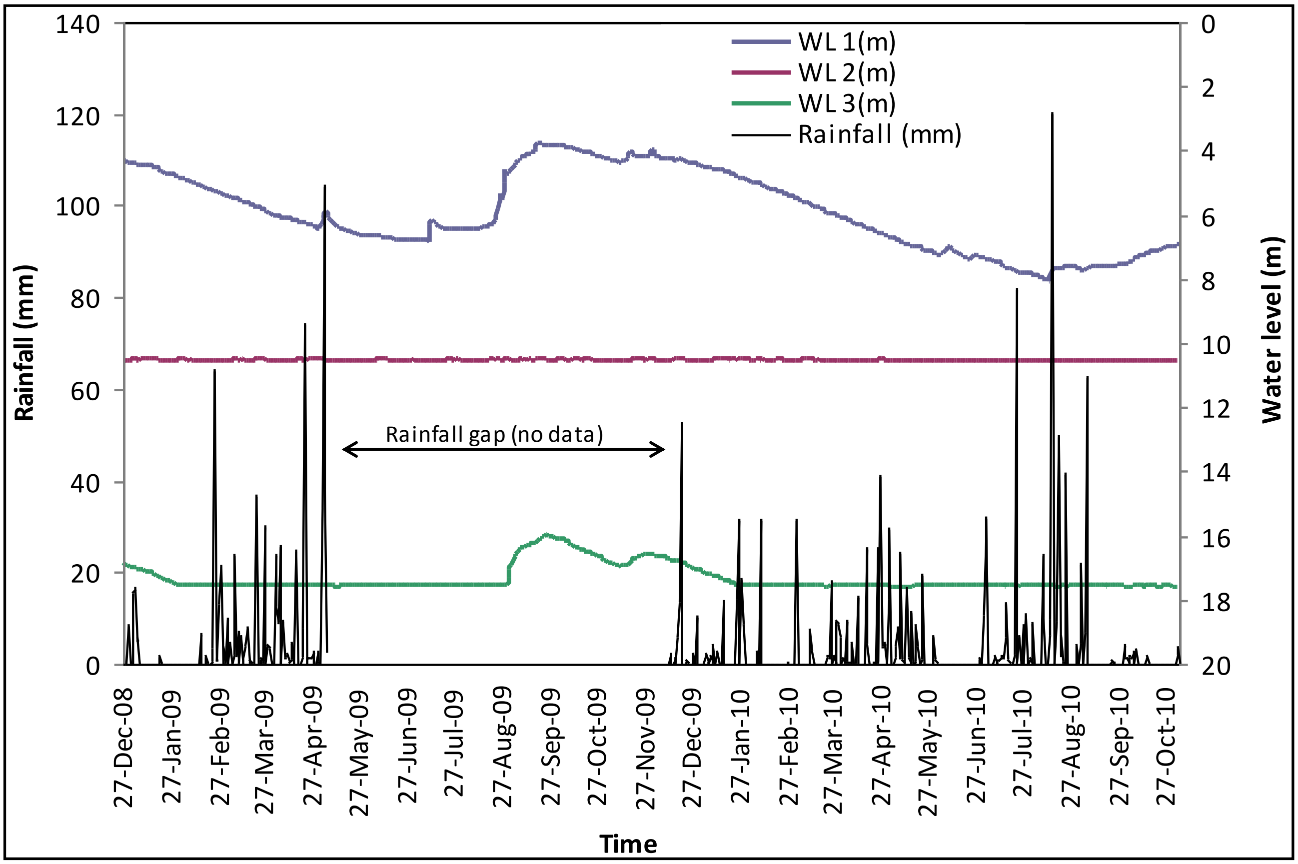

Figure 8. Rainfall and water level relationship.

and subsurface flows. The flat trend ca not be explained alone with the fact that it has got comparative flat gradient. One possibility is that the rainfall recharge and subsurface outflows go concurrently, thus, nullifying the effect of each other.

Slope movement

Slope inclinometer is used to determine the magnitude, rate, direction, depth, and type of landslide movement. This information is usually important to understand the cause, the behavior, and the remediation of a landslide. Inclinometer is very sensitive to movement. A boulders or groundwater flow that hit inclinometer will give effect to movement.

Slope movement (Figure 9), 14 to 18 m layer moved heading towards upslope with 18 mm and the maximum value was recorded on May 5, 2009. Probably instrument problem, loose packing of boulders during this particular depth, ground water flow, and road vibration due to heavy traffic which pressed on inclinometer casing has effect on the movement to upslope. From the field investigation, it has been observed that over all slopes of the beds is towards the road, that is, NW direction, so probably due to the aforementioned effects the upslope movement occurred. From surface until 14 m depth, the soil movement on maximum down slope was less than 5 mm. But in 30th July 2010 and 4th November 2010, the slope movement attained was 60 mm up to the depth of 2 m. After this depth, the movement is showing reduction towards zero value. It can be concluded that the slope movement at shallow depth is due to intensification of rainfall event during this period. It is evident that the upper layer which is clay/ sandy silt up to 3.6 m may saturate due to high and continuous rainfall resulting in loose bearing capacity of soil particle which in turn induces surface movement. Therefore, the vulnerability of surface movement with high intensity rainfall event may prove disastrous for mankind.

CONCLUSION

Penang Island is one of the developing states in Malaysia with land being cleared for housing estates, hotels, and apartments resulting erosion and landslides. Here, granite soils are widely recognized to be vulnerable to landslides.

Generally, in the present investigation, all piezometers

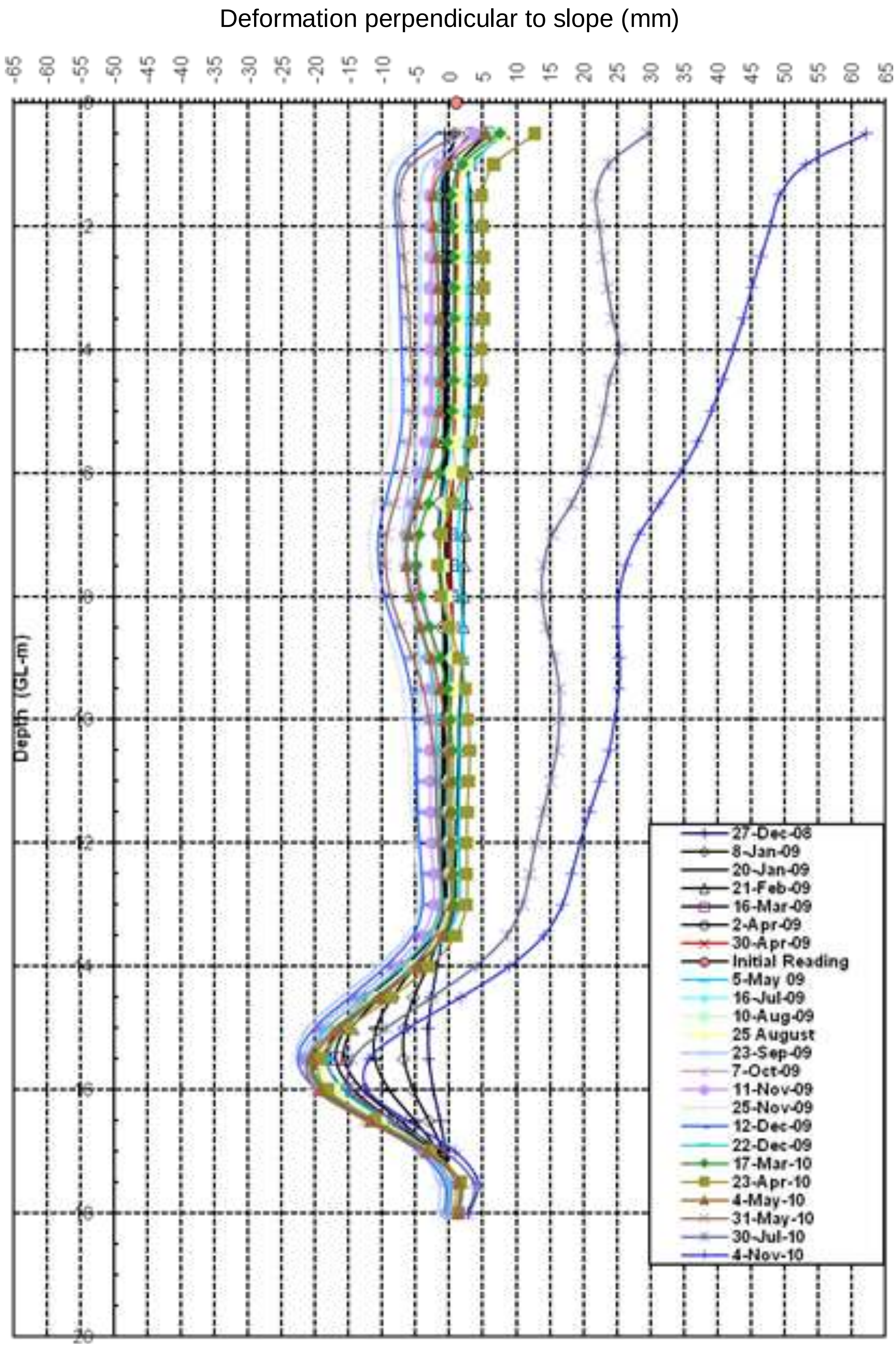

Figure 9. Slope movement.

show declining trend due to less amount of rainfall and also some amount of water loss may be due to subsurface aquifer flows along joints causing leakages. Among all the piezometer, the BH3 is showing progressive declining trend which is pronounced and persistent.

It was noticed that soil movement towards slope up to the depth of 2 m on July 30 and November 4, 2010, was due to intensification of rainfall event during this period. The vulnerability of surface movement with high intensity rainfall event proved disastrous

Landslide hazards in Pinang Island are common; the frequency of such hazards has been increasing in the last few years. The threat to lives, property and traffic is posed by severe landslides after heavy rainfall. Therefore, the present study suggests immediate need to establish a good meteorological and hydrological monitoring network in mountainous regions especially within landslide prone areas.

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REFERENCES

Ahmad F, Yahaya AS, Farooqi MA (2006). Characterization and Geotechnical Properties of Penang Residual Soils with Emphasis on Landslides. Am. J. Environ. Sci., 2(4): 121-128.

Avanzi GD, Giannecchini R, Puccinelli A (2004). The influence of the geological and geomorphological settings on shallow landslides. An example in a temperate climate environment: the June 19, 1996 event in northwestern Tuscany (Italy), Eng. Geol., 73(3-4): 215-228.

Chan NW (1998). Responding to landslide hazards in rapidly developing Malaysia: a case of economics versus environmental protection. Disaster Prev. Manage., 7(1): 14-27.

Dahal RK, Hasegawa S, Nonomura S, Yamanaka M, Masuda T, Nishino K (2008). GIS-based weights-of-evidence modelling of rainfall-induced landslides in small catchments for landslide susceptibility mapping. Environ. Geol., 54(2): 314-324.

Habibah L, Khaizal, Younus AK, Baddrul, Fauziah A (2009). Mechanism of shallow landslide at 3.9 Km Tun Sardon Road of Penang Island, Malaysia: Proceedings of the South China Sea Tsunami Work shop held at Universiti Sains Malaysia.

Institute of Strategic and International Studies and Penang Development Corporation (1991). Penang Strategic Development Plan 1991-2000, Final Report to the Penang State Government, Penang.

Jacobson RB, McGeehin JP, Cron ED, Carr CE, Harper JM, Howard AD (1993). Landslides triggered by the storm of November 3–5, 1985, Willis Mountain anticline, West Virginia and Virginia. U.S. Geol. Surv. Bull., C1–C33.

Matsushi Y, Hattanji T, Matsukura Y (2006). Mechanisms of shallow landslides on soil-mantled hillslopes with permeable and impermeable bedrocks in the Boso Peninsula, Jpn, Geomorphol., 76: 92-108.

Lee S, Pradhan B (2006). Probabilistic landslide hazards and risk mapping on Penang Island, Malaysia, J. Earth Syst. Sci., 115(6): 661-672.

Ong WS (1993). The geology and engineering geology of Pinang Island. Geol. Surv. Malays., pp. ??????.

Ooi LH (1999). Rockfall protection: Technical talks, Kuala Lumpur, Geol. Soc. Malays., pp. 20-32.

Pradan B, Saro L (2010). Delineation of landslide hazard areas on Penang Island, Malaysia, by using frequency ratio, logistic regression and artificial neural network models, Environ. Earth. Sci., 60(5): 1037-1054.

Toh CT (1999). Influence of geology and geological structures on cut slope stability: Technical Talks, Kuala Lumpur, 28 Oct 1999, Geol. Soc. Malays., pp. 12-25.

Walton WC (1970). Groundwater resource evaluation, McGraw-Hill Book Company, NY 658.