Landslides in Penang Island, Malaysia: Insights on emerging issues and the role of geoscience

Nurul Syazwani Yahaya[1], Zamri Ramli[2], Alan Thompson[3], Joy Jacqueline Pereira[1,*]

[1]Southeast Asia Disaster Prevention Research Initiative (SEADPRI-UKM), Universiti Kebangsaan Malaysia, Malaysia
[2]Department of Mineral and Geoscience Malaysia (JMG), Malaysia
[3]Cuesta Consulting Limited, UK
* Corresponding author email address: joy@ukm.edu.my / pereirajoy@yahoo.com

Abstract: Inceasing demand for housing and infrastructure in Penang Island has forced development to expand into hillslope areas susceptible to geohazards such as landslides. Over the past few years landslide events have resulted in heightened concern for public safety. Development projects, many of which are of high-rise and high-density ventures, is increasingly approved on sensitive land with a history of landslide events. A field trip was conducted on 20 September 2018 involving 24 participants from various institutions to gain insights from selected development projects that are at risk of landslides. The focus was on hillslope areas at Tanjung Bungah and a road construction site at Paya Terubong. The field visit reaffirmed the importance of geoscience for land development, to identify areas susceptible to landslides and provide appropriate information for effective engineering solutions. With the advent of climate change, the country is now experiencing a rise in extreme weather phenomena, which may increase the occurrence of climate-influenced geohazards including landslides. Geoscientists have to take a more active role in reducing risks associated with geohazards, to protect communities from future disasters and ensure sustainable development.

Keywords: Landslide, geohazards, Penang, hill side development, geoscience

Abstrak: *Permintaan yang kian meningkat untuk perumahan dan infrastruktur di Pulau Pinang telah memaksa pembangunan untuk berkembang ke kawasan bukit yang mudah terdedah kepada geobencana seperti tanah runtuh. Sejak beberapa tahun kebelakangan pelbagai peristiwa tanah runtuh telah meningkatkan keprihatinan isu keselamatan awam. Projek-projek pembangunan yang kebanyakannya daripada jenis bertingkat tinggi dan berkepadatan tinggi, semakin diluluskan di tanah yang sensitif serta mempunyai sejarah kejadian tanah runtuh. Pada 20 September 2018 satu lawatan lapangan telah dijalankan melibatkan 24 peserta daripada pelbagai institusi untuk memahami isu risiko tanah runtuh di beberap projek pembangunan terpilih di Pualau Pinang. Tumpuan lawatan tersebut adalah di kawasan bukit di Tanjung Bungah dan tapak pembinaan jalan di Paya Terubong. Lawatan tersebut mengesahkan kepentingan geosains untuk pembangunan tanah, khususnya bagi mengenalpasti kawasan yang terdedah kepada tanah runtuh serta menyediakan maklumat yang sesuai untuk penyelesaian kejuruteraan yang berkesan. Dengan adanya*

perubahan iklim, negara kini mengalami peningkatan fenomena cuaca yang melampau, yang boleh meningkatkan geobencana yang dipengaruhi iklim termasuk tanah runtuh. Ahli geologi perlu mengambil peranan yang lebih aktif dalam mengurangkan risiko yang berkaitan dengan geobencana untuk melindungi masyarakat di masa depan dan memastikan pembangunan mampan.

Kata kunci: *Tanah runtuh, geobencana, Pulau Pinang, pembangunan bukit, geosains*

INTRODUCTION

Penang Island is located off the coast in northwestern Peninsular Malaysia in the Strait of Malacca. The island comprises an area of approximately 300 km^2 (Figure 1). Despite the small area, Penang Island is home to George Town, the third largest city by population in the country (Department of Statistics Malaysia, 2010). The island has a prominently hilly topography with approximately half of the area comprising steep slopes that start from an elevation as low as 18 m (Institute of Strategic and International Studies and Penang Development Corporation, 1991). In their Structure Plan for 2020, the Penang State Government has recognized highland areas with an elevation above 76 m and slope exceeding 25^o as a sensitive environment where development needs to be restricted (JPBD Pulau Pinang, 2007). As the state continues to grow economically, the associated increase of population has led to higher demand for housing and infrastructure. This has resulted in expansion of development into areas that are susceptible to geohazards, on both low-lying coastal plains as well as on hillsides. Despite the inherent risks, land development within high land and slope areas has continued, especially for residential development, thereby increasing both the likelihood and potential consequences of landslides (Lee & Pradhan, 2006). Between the years of 2008 and 2015, the City Council of Pulau Pinang (MBPP) granted a total of 56 approvals for development on land with elevation above 76 m, many of which are high-rise and high-density projects in high risk areas with history of landslides (JMG, 2017). Within the past few years, a series of unprecedented impacts from landslides in Penang Island have resulted in increasing concern for public safety.

A field trip was organised on 20 September 2018 in conjunction with the Geological Society of Malaysia's 2018 National Geoscience Conference hosted by Universiti Sains Malaysia (USM) and the Department of Mineral and Geoscience Malaysia (JMG). A total of 24 participants from various institutions, primarily young geoscientists supported by the Malaysia Window to Cambridge (MW2C@UKM) programme administered by Universiti Kebangsaan Malaysia's Southeast Asia Disaster Prevention Research Initiative (SEADPRI-UKM) and the Asian Network on Climate Science and Technology (ANCST), joined the field trip. Led by Mr. Zamri Ramli of the Department of Mineral and Geoscience (JMG), the fieldtrip was hosted by MBPP to get an overview of pertinent geohazards issues in Penang Island, specifically landslides associated with development projects. In this context, landslides refer to slope failure or mass movement in both natural and disturbed terrain. The focus was on development projects on hillslope areas including the Beverly Hills residential development at Tanjung Bungah and a road construction site at Paya Terubong. The two sites served as examples of many other development projects approved on the sensitive hillslopes of Penang Island. This paper provides a brief account of previous landslides in Penang involving the two sites and highlights some physical impacts of previous incidences to stress the importance of geoscience information to improve the situation for future development.

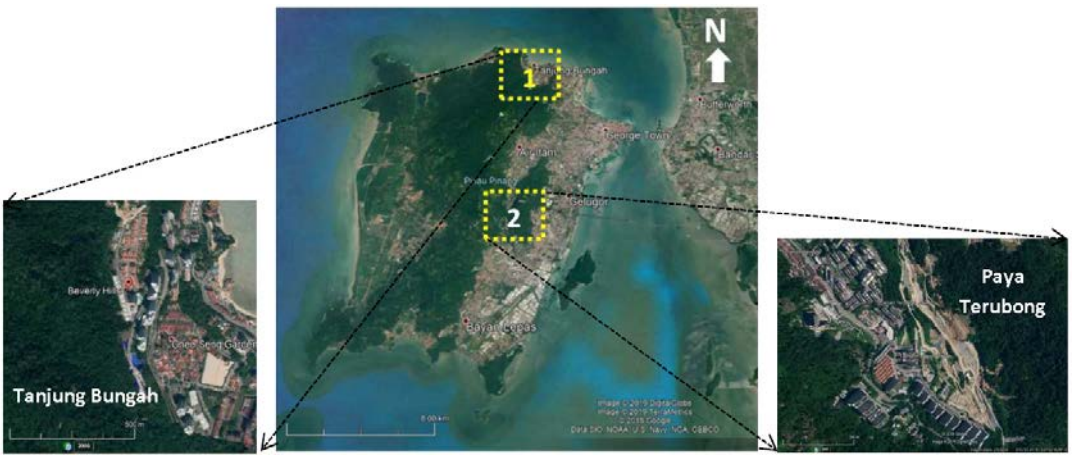

Figure 1: Penang Island - Beverly Hills in Tanjung Bungah and Bukit Kukus in Paya Terubong.

SLOPE FAILURES IN TANJUNG BUNGAH

The first site visit was to a residential project built on a hillside at Beverly Hills, Tanjung Bungah comprising 20 units of 3-storey semi-detached houses. The slope is located in close proximity to the Sg. Siru Fault and is covered by soil from weathered granite of grade V (sandy silt) to VI (clayey silt) underlain by medium-coarse grained granite-biotite bedrock (Figure 2) (JMG, 2017). The development project was approved by the City Council in 2007 and completed at the end of 2017. On 5 November 2017, while the project was still awaiting the approval for a Certificate of Completion and Compliance (CCC), the retaining wall including the road structures above it suddenly collapsed in front of the house units.

Leading up to the failure of the slope structures, the area had experienced heavy rainfall from the evening before until the next morning, during which ground movements were detected by the residents. The rainfall event, which exceeded 250 mm within 24 hours, was considered quite extreme. In the construction, the natural seasonal stream flow from the hillside was channeled to a perimeter drain constructed at the site. However during the extreme rainfall, surface runoff exceeded the capacity of the drainage system, leading to overflow that seeped through the bottom of the filled embankment (75 m long, 25 m wide and 12 m high) that supported the road platform (JMG, 2017). As the fill material for the road platform was highly permeable (sandy silt and clayey silt), this led to saturation and increased pore water pressure in the embankment and resulted in the failure of its retaining wall and rupturing of the road platform (JMG, 2017).

Geological inputs are of crucial importance in understanding slope stability and are therefore needed for safe hillside development. Prior to any slope development, geological input is required to ascertain suitability and to provide proper guideline for the Earthwork Plan Procedures that fit the sensitivity of the environment coupled with 'Good Engineering Practice' (JMG, 2017). Once a hillside development project is approved, the local authority shall appoint competent consultants to monitor the developer's adherence to the guidelines during the construction process. A Geological Terrain Map developed by the JMG shows that the Beverly Hills site is located on the boundary between land that is categorised as Class III (low suitability) and Class IV (unfavorable for development due to the extreme geotechnical constraints). In the landslide event at the Beverly Hills development

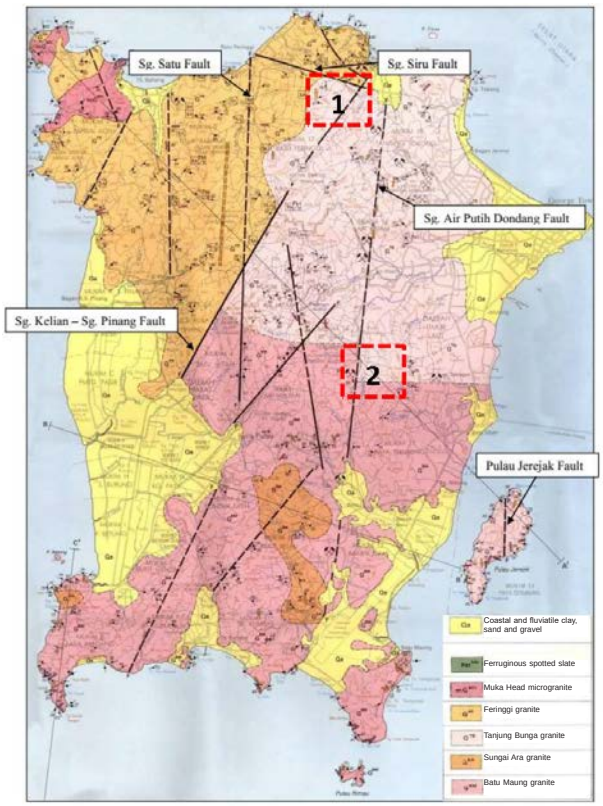

Figure 2: Geological Map of Penang Island; Site 1 (Beverly Hills) and Site 2 (Paya Terubong). [Source: JMG, 2006]

Figure 3: The front view of the collapsed retaining wall and road structures at Beverly Hills in Tanjung Bungah, Penang.

Figure 4: During the field trip, Mr. Zamli Ramli from JMG demonstrated the use of a drone for aerial site inspection of the slope condition at Beverly Hills.

site, the compliance of the earthwork conducted by the developer to existing guidelines was an issue. A historical topography map of the area revealed that the failed portion was built up on an old river channel. The design of the drainage systems reportedly did not consider worst case scenario of surface water flow during extreme rainfall events (JMG, 2017).

SLOPE FAILURES IN PAYA TERUBONG

Paya Terubong is located on the southeastern half of Penang Island. The geology forms part of the South Penang Pluton (SPP) and comprises coarse-grained and medium-grained porphyritic muscovite-biotite granite (JMG, 2006). The granite is very deeply weathered and highly variable in its geotechnical properties, with very large core stones of relatively intact granite set within highly weathered to completely weathered material. The Paya Terubong valley also marks the position of the north-south oriented Central Penang Fault Zone (Figure 2). The weathering and presence of the fault zone have both contributed to the occurrence of several landslide events in the recent past (JMG, 2006). One of the examples was on 28 November 1998, when three huge boulders (including one about the size of a double-storey house) crashed down a 30 metre high cliff, stopping just 10 m from the nearest block of residential apartments. That particular event was attributed to rock-blasting activity that was being carried out to expand the area for development. The blasting sent flying rock fragments that damaged the roof of some houses around the area, but the associated vibrations may have also triggered movement within the unstable slope. Hill cutting activity that extends above the 76 m contour, with vegetation being removed leaves steep slopes bare and exposed to direct soil erosion and gullying. In the event of a subsequent heavy rainfall, the eroded soil could turn into a mudflow that washes down to the roads and house compounds, silt up flood mitigation ponds, and increase the likelihood of flash floods downstream.

Figure 4. A view of a portion of the hillside road construction on highly unstable and steep slopes at Bukit Kukus, Paya Terubong.

A recent concern was highlighted in the area of Bukit Kukus regarding a high-density development project of four residential tower blocks of over 40 storeys, which was approved in December 2015 as well as a project for paired-road construction built directly across a steep slope, which is part of the new development in the area. In contrast to the site visit to Beverly Hills, which inspected an incident that had already occurred, the objective of the field trip to the Bukit Kukus site at Paya Terubong was to examine a development project site under construction, where there are potential future risks. The main issues discussed during the site visit were related to the risk of disturbing the stability of the slope, the adequacy of overall planning, and the extent to which the project was being developed with appropriate geoscience inputs. A month after the field trip, a landslide occurred at the Bukit Kukus construction site on 19 October 2018 claiming nine lives and injuring three others, most of whom were construction workers at the site (Bernama, 2018a). Following the incident, charges were made by the Penang Occupational Safety and Health Department against the project director for failing to ensure the safety, health and welfare at work for the employees, while the contractor was charged for failing to adhere to safe working procedures (Kaur, 2019). Similar to the case at Beverly Hills, the incident occurred following a heavy rainfall event across the state, from the afternoon two days before the event to noon the day before (Bernama, 2018b). Whilst heavy rainfall is often a key factor in triggering landslide events, along with steep slopes and inherently unstable soils, these are all conditions that occur frequently in Malaysia and need to be factored into the design of any construction work where slopes are modified or protective vegetation is removed.

THE ROLE OF GEOSCIENTISTS IN REDUCING RISK OF GEOHAZARDS

Previous landslide incidents in Penang Island have led to unnecessary loss of lives and properties, as well as environmental damage. Unless greater attention is given to recognising and dealing with the potential risks posed by geohazards such as landslides, continued development activities of a similar nature will continue to endanger the lives of the construction workers and public road users as well as compromise the safety of residents. Whilst the geohazards themselves may be seen as being part of the natural process of long-term slope development, individual slope failure events can, to a greater or lesser extent, be influenced by human activities. Inappropriate land development and inadequate engineering design can disturb the fragile stability of the hillslope areas and thereby increase the likelihood of instability (JMG, 2017). The examples seen in Penang Island should therefore be a lesson to other cities in Malaysia, which are under constant pressure for land development. With the advent of climate change, the world is now experiencing a rise

in extreme weather phenomena, which may increase the occurrence of climate-influenced geohazards such as landslides. In Malaysia, climate change is expected to result in a rising trend of annual mean temperature, occurrences of extreme weather events and increased rainfall variability (Tang, 2019). Furthermore, mean sea level is projected to rise until the end of the 21st century. Increasing rainfall variability and extremes may exacerbate the risks of landslides, by increasing the frequency, magnitude and spatial extent of the hazard. To continue with business as usual will only result in similar or worse consequences. Therefore, it becomes necessary to take into account climate change factors in development of areas that are suceptible to geohazards, particularly landslides in hillslope areas.

To improve the situation and protect communities from future disasters, both structural and non-structural approaches need to be adopted to reduce the risk of the geohazards. Whether coming from academic or industry background, geoscientists have important roles to play in both of the approaches by advancing and mainstreaming the understanding of local geohazards and taking more active roles in enforcing better policy and land development control guidelines for high risk areas, as well as ensuring proper implementation of stipulated guidelines. At present, slope protection and monitoring for land development in Malaysia is only formed in administrative measures through provision of guidelines, without specific law to enforce proper implementation of the guidelines throughout planning, during and after any slope development project. Active participation through stakeholders engagement is crucial (Too *et al.*, 2011). To support local authorities forming clearer and more stringent policies and guidelines for development projects in sensitive geological settings, it is necessary to utilise robust and updated knowledge on geohazards in the area and to ensure that this knowledge is translated into better practices on the ground. Whilst avoiding development on unstable hillslopes may be the only way of avoiding problems altogether, the pressure for development may be such that this is not always a practical solution. Where development is necessary, geoscientists can help the local authorities to make informed-decisions before granting permission for new projects by providing geohazards information such as landslide susceptibility maps. Such maps will provide information on the presence of potential hazards of an area. This will be a useful input for site planners and engineers in developing detailed design of mitigation measures for specific hazards. In order for such information to be practical and relevant to others from different fields, it is important for geoscientists to develop skills to communicate in ways that planners, engineers and other end-users are able to understand. Geoscientists can also provide other empirical inputs, including rainfall threshold calculations for landslides and floods, based on past events with appropriate modelling techniques, which can then be used to assist with evacuation and emergency response planning. Such inputs should also be continually updated to be in line with local changes in land use and variability of climate conditions in order for them to be as reliable as possible.

For non-structural approaches, adopting effective governance is crucial to mobilize community resilience towards landslide. Bearing the responsibility of having the technical knowledge, geoscientists have important role to play in building community resilience from landslide disasters through network governance for sustainability. Geoscientists have the power to change the game by being more assertive in conveying geohazards information to those who need to use it, including local authorities, developers, and property owners or communities. In this age of information, disseminating geohazards information to a wider audience, including members of the public, is now easily achieved, but needs to be undertaken carefully and responsibly so that people can understand and act upon the information without over-reacting. Through better knowledge, communities can be empowered and also able to cooperate and be better prepared in efforts to reduce landslide risks. By being more transparent, buyers can make informed decisions in purchasing properties in high risk areas and developers are more likely to be compelled to be more responsible in following stipulated development guidelines so that risks are reduced. Having informed buyers (communities) may also help developers as they (the communities and property buyers) will more readily appreciate the need for mitigation and maintenance works, and be willing to share in the costs involved, if they decide to buy. In terms of overall governance, collective solutions are required, whereby geoscientists are able to work in synergy with communities and the public at large and able to pass on important geohazards information without causing undue panic or stir conflicts.

Overcoming the various challenges to be faced in dealing with future development requires both innovative and collective solutions. In order to be able to make the best use of their specialist knowledge on geohazards, geoscientists need to be able to work in synergy with other professionals from various fields including engineers, economists, local planners, social scientists, among others, towards the betterment of the people and environment. Communication is key. Each of these points of contact will have different requirements in the way in which geohazard information is passed-on and utilised. Communication will be at a technical level between scientists and engineers, but very different approaches are needed to convey essential information to non-specialists who nevertheless need to understand the issues involved so that they can act upon them appropriately. These range from planners, local government officials and insurance companies through to members of the public at large.

By taking more active role, whilst recognising the need for appropriate liaison and communication, geoscientists have a lot to offer in reducing risks associated with geohazards and in protecting communities from future disasters, to ensure that development of the country will be more sustainable.

CONCLUDING REMARKS

Inceasing demand for housing and infrastructure in Penang Island has forced development to expand into hillslope areas susceptible to geohazards such as landslides. Between 2008 and 2015, the City Council of Pulau Pinang (MBPP) granted a total of 56 approvals for development projects on land with elevation above 76 m, many of which are high-rise and high-density projects, in areas with a history of landslide events. The field trip to the hillslope areas at Tanjung Bungah and a road construction site at Paya Terubong in Penang Island highlighted several critical aspects. Development projects in hillslope areas need to take into account rainfall extremes, topography, subsurface conditions, slope stability and other factors in the design of any construction work, especially where protective vegetation is removed. In addition, all development projects should be in compliance with existing guidelines, especially at the earthwork stage. The visit revealed the importance of geoscience for land development, to identify areas susceptible to landslides and provide appropriate information for effective engineering solutions.

Climate change is expected to increase rainfall variability and extremes and exacerbate the risks of landslides, by increasing the frequency, magnitude and spatial extent of the hazard. It is important to take into account climate change factors in development of areas that are suceptible to geohazards, particularly landslides in hillslope areas. This is especially critical for Penang Island and other cities in Malaysia, which are under constant pressure for land development and require expansion into sensitive hillslope areas. In this context, the specialist knowledge of geoscientists on geohazards and risk reduction should be harnessed and communicated effectively to other professionals including engineers and local planners as well as the community, among others. Geoscientists also have to take a more active role and acknowledge the need for appropriate liaison and communication. This will enable the geoscience profession to attain its full potential in reducing risks associated with geohazards, for protecting communities from future disasters and ensuring that development of the country will be more sustainable.

Figure 5: Dato' Yunus Abdul Razak from SEADPRI-UKM and Mr. Zamri Ramli from JMG presented a token of appreciation to the representative of MBPP for hosting the field trip.

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REFERENCES

Bernama, 2018a. Penang landslide: SAR to continue after JMG inspection [NSTTV]. News Straits Times. 21 October 2018. https://www.nst.com.my/news/nation/2018/10/423238/penang-landslide-sar-continue-after-jmg-inspection-nsttv.

Bernama, 2018b. Father pulls out son's body from landslide. News Straits Times. 20 October 2018. https://www.nst.com.my/news/nation/2018/10/423050/father-pulls-out-sons-body-landslide.

Chan, N. W., 1998. Environmental hazards associated with hill land development in Penang Island, Malaysia: Some recommendations and effective management. Disaster Prevention and Management, 7,(4), 305-318.

Department of Mineral and Geoscience Malaysia (JMG), 2017. Desk Study Report (Volume 2).

Department of Mineral and Geoscience Malaysia (JMG), 2006. Geological Traverse Survey Report (Penang Island) - (Volume 14).

Department of Statistics, Malaysia, 2010. Population Distribution and Basic Demographic Characteristics. Population and Housing Census of Malaysia 2010.

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.

JPBD Pulau Pinang, 2007. Rancangan Struktur Negeri Pulau Pinang 2020.

Kaur, B., 2019. Judges sees red over charge sheet error in Bukit Kukus landslide case. News Straits Times. 26 August 2019. https://www.nst.com.my/news/crime-courts/2019/08/516112/judge-sees-red-over-charge-sheet-error-bukit-kukus-landslide-case.

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

Site information on Beverly Hills are based on field observations by JMG KPPP on 5th – 7th November 2017.

Tang, K. H. D., 2019. Climate change in Malaysia: Trends, contributors, impacts, mitigation and adaptations. Science of the Total Environment, 650 (2019), 1858-1871.

Too, Eric G., Adnan, Najwa, & Trigunarsyah, Bambang, 2011. Project governance in Malaysia hillside developments. In: Ahmed, Syed, Adnan, Hamimah, Panthi, Kamalesh, Azhar, Salman, Takim, Roshana, & Bozai, Gazan (Eds.), Proceedings of the Sixth International Conference on Construction in the 21st Century: Construction Challenges in the New Decade, Kuala Lumpur.