DISASTER RISK REPORT:
UNDERSTANDING LANDSLIDE AND FLOOD RISKS FOR SCIENCE-BASED DISASTER RISK REDUCTION IN THE STATE OF SELANGOR

STRENGTHENING THE DISASTER RISK REDUCTION CAPACITY TO IMPROVE THE SAFETY AND SECURITY OF COMMUNITIES BY UNDERSTANDING DISASTER RISK (SeDAR)

SeDAR Malaysia-Japan
UNDERSTANDING & MANAGING DISASTER RISK

JICA Japan International Cooperation Agency

災害科学国際研究所 IRIDeS International Research Institute of Disaster Science

SELANGOR

UTM UNIVERSITI TEKNOLOGI MALAYSIA

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About this Publication:

This publication was developed by a group of individuals from the International Institute of Disaster Science (IRIDeS) at Tohoku University, Japan; Universiti Teknologi Malaysia (UTM) Kuala Lumpur and Johor Bahru; and the Selangor Disaster Management Unit (SDMU), Selangor State Government, Malaysia with support from the Japan International Cooperation Agency (JICA). The disaster risk identification and analysis case studies were developed by members of the academia from the above-mentioned universities. This publication is not the official voice of any organization and countries.

The analysis presented in this publication is of the authors of each case study.

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SELANGOR
BANGUNAN SULTAN SALAHUDDIN ABDUL AZIZ SHAH
باڠونن سلطان صلاح الدين عبدالعزيز شاه

Foreword by Y.A.B. Dato' Menteri Besar Selangor

Y.A.B. TUAN AMIRUDIN BIN SHARI, Menteri Besar Selangor

For the past few decades, the state of Selangor has had its fair share of disasters. In recent years, the state has been afflicted with floods, fires, storms, and landslides, with events becoming more frequent and extreme with the effects of climate change.

In fact, Selangor has been identified as one of the hotspot areas for landslides throughout the country in the National Slope Master Plan 2009-2023 by the Public Works Department while the Department of Statistics Malaysia has highlighted Selangor as one of the states having the highest number of floods in 2007.

Faced with these disaster events, there is a great need for the denizens of Selangor to understand the risks of disasters for better preparedness measures.

This pro-active stance is in line with Selangor's Smart Selangor initiative, which brings together all the citizens of Selangor to enhance the state's economic ecosystem through the delivery of better services in various domains, including Smart Disaster Management. We have successfully established the Selangor Disaster Management Unit for efficient and effective disaster response and management. With SeDAR, we can now gain capacity for better managing disaster risks.

Through the kind generosity of the Japan International Cooperation Agency (JICA), we are honored to be working together with esteemed institutions of higher learning such as the International Research Institute of Disaster Science (IRIDeS) of Tohoku University and Universiti Teknologi Malaysia. It is my hope that this collaboration to introduce science into disaster risk reduction will create a society of 'smart citizens' who can take active part in ensuring that their communities are safe from natural disasters.

The Selangor State Government fully supports this initiative, which will continue to benefit the people of Selangor who will continue to run this program long after SeDAR has completed its run.

My congratulations to the SeDAR Project Team for producing the first-ever publication on disaster risk in the state of Selangor.

Y.A.B. TUAN AMIRUDIN BIN SHARI
Menteri Besar Selangor

Foreword by JICA Malaysia

MR. KENSUKE FUKAWA, Chief JICA Malaysia Representative

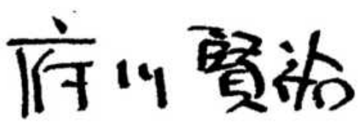
On behalf of the Japan International Cooperation Agency (JICA) Malaysia Office, I would like to express my appreciation to the project team of “Strengthening the Disaster Risk Reduction Capacity to Improve the Safety & Security of Communities by Understanding Disaster Risks (SeDAR)” – the project jointly implemented by the International Research Institute of Disaster Science (IRIDeS), Tohoku University and the Sendai City, Japan; Disaster Management Unit of the Selangor State Government and Disaster Preparedness and Prevention Center (DPPC) of Universiti Teknologi Malaysia (UTM), Malaysia – for developing the “Disaster Risk Report: Understanding Landslide and Flood Risks for Science-Based Disaster Risk Reduction in the State of Selangor.”

JICA has been promoting and supporting various countries and communities in Disaster Risk Reduction and Management (DRRM) with the understanding that DRRM is inevitable for all societies to achieve sustainable and equitable social-economic growth. Because disaster and climate related risks are becoming more complex and the effects are intensifying day by day, it is urgent and critical that stakeholders from various fields such as local governments, communities, NGOs/CBOs, academicians and private sector to work together for building disaster resilience.

Although Malaysia may not be known as the most disaster-prone country in the Asia-Pacific region, it is facing new challenges to keep its communities safe and protect the industries in the changing environment. Japan, on the other hand, has many years of coping and taking measures in preventing disaster impacts and developed its high-end technology and community-based knowledge in DRRM that has been shared with its neighboring countries in the region and beyond.

I believe this project is functioning as the platform for bringing different stakeholders together and an interface for integrating expertise and experiences for DRRM – particularly for bridging science with local actions. I hope that the project will be an invaluable co-learning experience between Malaysian and Japanese DRRM experts and people living in disaster-prone communities.

Again, I am delighted to see this report that will become the basis for future activities to strengthen disaster resilience of communities in Selangor State.



MR. KENSUKE FUKAWA
Chief JICA Malaysia Representative

Preface by IRIDeS

PROF. FUMIHIKO IMAMURA, Director of the International Research Institute of Disaster Science, Tohoku University

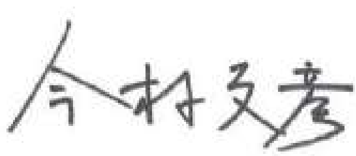
Although Malaysia is considered a country with low disaster risk, the risk is getting higher due to urban development and climate change. Disasters such as floods, landslides and others are increasing, and there is an urgent need to take the mitigation measures to tackle such multi-hazards.

The SeDAR project, with its aim of increasing safety and security of communities, assists in reducing disaster risks through understanding and recognizing disasters and their risks. Drawing on vast experience in Japan, disaster experts from the International Research Institute of Disaster Science (IRIDeS) and other universities as well as local governments in Japan have joined this project to share their experiences in disaster risk reduction (DRR), particularly at the local level. I hope the experience and lessons learnt from the Great East Japan Earthquake and Tsunami in 2011 and other numerous disasters in Japan and other countries can contribute to strengthening DRR capacity in Malaysia.

This project is carried out in the state of Selangor, near the country's capital city of Kuala Lumpur. With support and guidance from disaster experts, this project provides a platform for local communities to discuss disaster risks amongst themselves and come up with their own DRR measures. This stems from the idea that after studying the disaster history in Malaysia, reviewing the damage and impacts, and understanding the future disaster risks, then it is extremely important to explore and apply the best suitable DRR efforts based on the region's character and the social, economic, cultural, and racial backgrounds.

This project is based on collaboration and tremendous support by Universiti Teknologi Malaysia (UTM) Kuala Lumpur and the Selangor Disaster Management Unit (SDMU). It is a good example of international collaboration among academia, local communities and government.

Understanding disaster risks is the first priority action of the Sendai Framework for Disaster Risk Reduction. I look forward to its implementation together with various stakeholders in Malaysia and Japan. The output of this project shall be a model and representative case study of collaborative activities, and I hope to extend similar projects in other countries and regions.



PROF. FUMIHIKO IMAMURA
Director of the International Research Institute of Disaster Science (IRIDeS), Tohoku University

Preface by UTM Kuala Lumpur

Disaster risk is complex, systemic and interconnected. Reducing disaster risk requires a new paradigm to address the multiple and interrelated processes of vulnerability and risk.

UTM has built momentum towards this effort. Together with many strategic partners, we co-implement evidence-based local actions and advocacy campaigns at the local level in developing partnerships and coalitions for resilience. We have demonstrated the inclusion of expert and local knowledge and capacities in policies, plans and actions, which help build resilience of communities at various levels.

Given the current scenario, it is crucial to promote a transdisciplinary approach for building societal transformation towards disaster resilience. The role of science and technology in translating policy into practice and word into action is critically needed. With comprehensive disaster inventories, damages, and losses, it helps governments to downscale the current and future investment in DRR for making cities more resistant and capable of timely recovery. Disaster resilience encompasses actions beyond simply responding to and recovering from disasters.

Complacency is the greatest threat in the face of a natural hazard that knows no time or season. It is important to do as much as possible to prepare and raise the awareness in keeping risk at the forefront of people's minds. It is worth mentioning that the National Disaster Management Agency and its strategic partners including UTM have been organizing a series of disaster education and preparedness program to educate communities-at-risk and champion the local actors for strengthening disaster resilience.

Integration of disaster risk reduction and resilience is critical in all sectors to ensure vertical and horizontal policy and program coordination. It empowers authorities and local communities to attain resources, incentives, and decision-making responsibilities, as appropriate for supporting local leadership.

With DRR in mind, a cost-effective implementation of water resources, water demand and disaster mitigation are crucial to support the sustainable development of affected river basins. The use of scientific knowledge-based decision making emphasizes local risk adaptation to reduce losses of life and maintain livelihoods as well as the economic, physical, social, cultural and environmental assets of people, businesses and communities.

Intelligent data-driven repository shall be explored as a key requirement for the development of a risk management strategy, with the opportunity to enhance interactions across science, policy, and practice. The call for a better disaster database, risk register and repository has made it possible to strengthen risk governance and communication at various levels.

The role of science and technology in providing evidence for policy is gaining prominence, with demand growing for multidisciplinary enquiry to address the complex and inter-related problems of climate change, disasters and sustainable development. Innovations in methods, tools and analyses have made significant leaps in finding solutions, with more data become widely accessible.

PROF. DATUK DR. WAHID OMAR
Vice Chancellor
Universiti Teknologi Malaysia (UTM)
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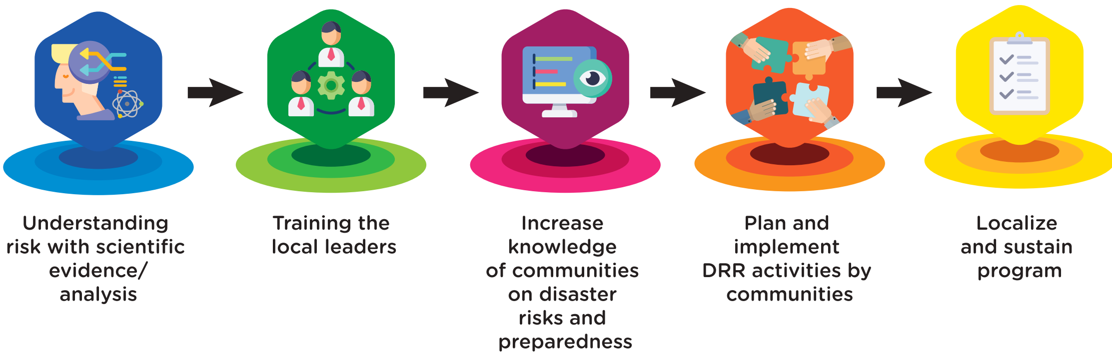
Executive Summary

This publication called "Disaster Risk Report: Understanding Landslides and Flood Risks for Science-Based Disaster Risk Reduction in the State of Selangor" is the result of the first phase of a four-year project being carried out by the Selangor State Government together with the International Research Institute of Disaster Science (IRIDeS) of Tohoku University, and the Disaster Preparedness and Prevention Centre (DPPC) of the Malaysia-Japan International Institute of Technology (MJIIT), Universiti Teknologi Malaysia (UTM), Kuala Lumpur. The project is supported and funded by the Japan International Cooperation Agency (JICA).

The Disaster Risk Report is the first step in the project "Strengthening the Disaster Risk Reduction to Improve the Safety and Security of Communities by Understanding Disaster Risks (SeDAR)", which aims to equip local governments as well as community leaders with the skills and know-how to build a disaster risk reduction program at the grassroots level, from the bottom up.

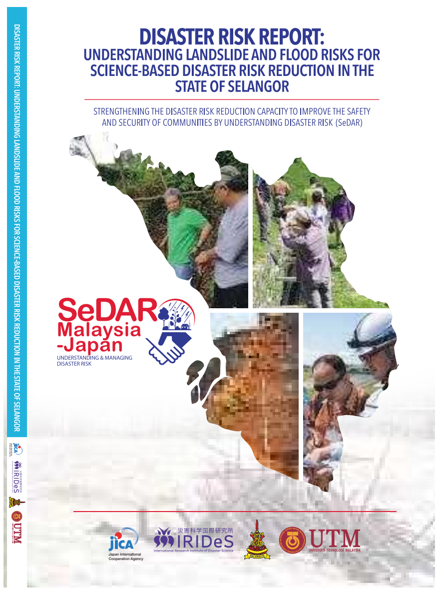
This program takes a unique approach to community by:

- Instilling a science-based understanding of disaster risks among the community leaders, member and local authorities, and
- Having them work together to develop DRR activities and programs that are best suited to their understanding and needs



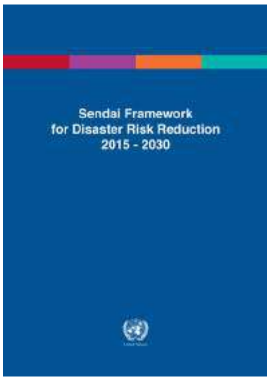
What is the Disaster Risk Report?

The Disaster Risk Report explains the risks of landslides and floods faced by communities in Selangor, in a way that can be easily understood by technical and non-technical readers alike. It serves as a communication tool for local and district authorities as well as government agencies at the district and state level to understand the hazards and risks of the project areas.



Each of the case studies showcase how science can help in identifying disaster risks. By taking a scientific approach in showing risks to community stakeholders, risk managers are better able to persuade residents to learn, design, implement and take ownership of proactive measures in safeguarding their homes, properties and lives on a long-term, sustainable basis.

What is Science-Based Risk Analysis?



Science-based risk analysis is the use of science in risk analysis. This is based on the concept of introducing science and technology in disaster risk reduction, which is highlighted in the Sendai Framework for Disaster Risk Reduction 2015-2030, in its first Priority of Action "Understanding Disaster Risk", where it emphasizes the role of science and technology in explaining disaster risk to various audiences.

The use of science and technology to show 'how and why disasters occur' can be useful in risk communication to policy makers and city planners in the development and dissemination of science-based risk knowledge, technology and innovation.

Site Selection

Four sites were selected for the JPP project. The sites are:

1. Ulu Klang, district of Gombak
2. Batu 14, district of Hulu Langat
3. Kampung Sg. Serai, district of Hulu Langat
4. Kampung Tok Muda, Kapar, district of Klang

Summary: Science-Based Risk Identification and Analysis

Landslides - Site 1: Ulu Klang

In this section, we found out that LiDAR-generated maps are a powerful communication medium for identifying landslide hazards and risks. By stripping away vegetative cover, shaded relief maps derived from LiDAR digital elevation models expose the terrain beneath to show past or current human activities as well as natural geological or hydrological processes. In this project area, the shaded relief map or hillshade view shows that what appears to be a 'natural slope' to the naked eye is in fact ridden with potential failure features. Using maps derived from remote sensing, the 'signature marks' or signs of an impending slope failure can be detected.

In this project area as a whole, we found out from the landslide hazard map that the area is largely dominated as high hazard (shown as red in Figure 1). A smaller portion of the map, in yellow, showed lower hazard levels.

From the shaded relief map, we saw that a location within the vicinity may be prone to landslides. There also appears to be an abandoned construction for a housing development downslope. As for the slope itself, there seems to be previous construction activity on terrain that seems to be deteriorating retrogressively, or eroding from the bottom up.

Figure 1. Possible failure was located in the vegetated terrain, with (A) orthophoto of the area and (B) digital terrain model viewed over the high susceptibility to landslides

Landslides - Site 2: Batu 14, Hulu Langat

The use of orthophotos and landslide hazard maps make it possible to identify and analyze unseen topography beneath dense vegetation cover. In this project area, it appears that landslides are induced by small degrees of land disturbances, particularly at toe of the slopes, and the area is largely characterized by heavy rainfall.

We saw from the various maps that original terrain in some areas have been excavated, most of the vegetation on the hills have been stripped, and building structures constructed very close to the foot of the slope to maximize the space within the designated lot. Some of these human activities appear to have taken place within the last few years, with the passage of time allowing secondary vegetation to grow and provide an appearance of undisturbed ground. Some of the slope cuttings created areas of temporary water accumulation zones, which allow water to infiltrate the soil during intense and prolonged rainfall. This can be observed in Figure 2.

Hulu Langat is a popular recreational area that serves as a forest getaway close to the city. Nestled in greenery and shady hillside forests, Batu 14 and its neighboring areas are popular destinations for resort owners, homestays, team building operators, fishing ponds operators, and other tourism-oriented businesses. However, construction on slopes need to be properly carried out to reduce the risk of failure.

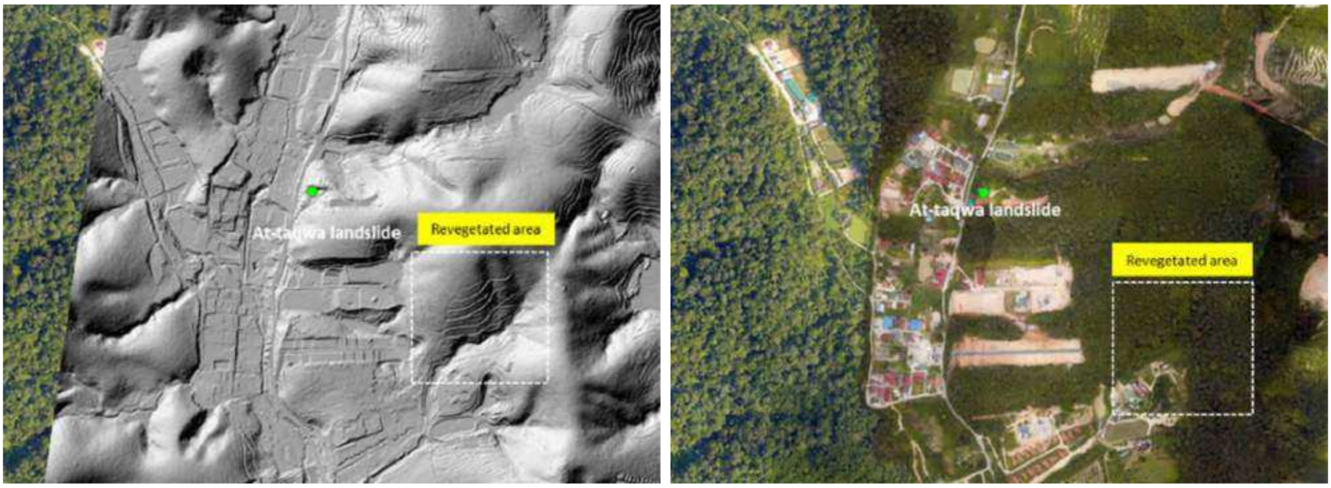


Figure 2. Orthophoto and hillshade showing some revegetated area with high degree of anthropogenic activity, e.g. slope cutting for new development in the project area in Hulu Langat

Floods - Site 3: Kampung Sungai Serai, Hulu Langat

A physical-based rainfall-runoff and flood inundation model was used to simulate the flood inundation scenario in the target area of the Sg. Langat basin.

The wettest months are April and November with average monthly rainfall exceeding 250 mm. According to accounts from the community leaders at Hulu Langat, these kinds of floods are experienced by residents three or four times a year. While these are not life-threatening, they interrupt the daily lives of residents and businesses in the vicinity, incur property losses as well as losses in small-scale agricultural activities carried out in the area.

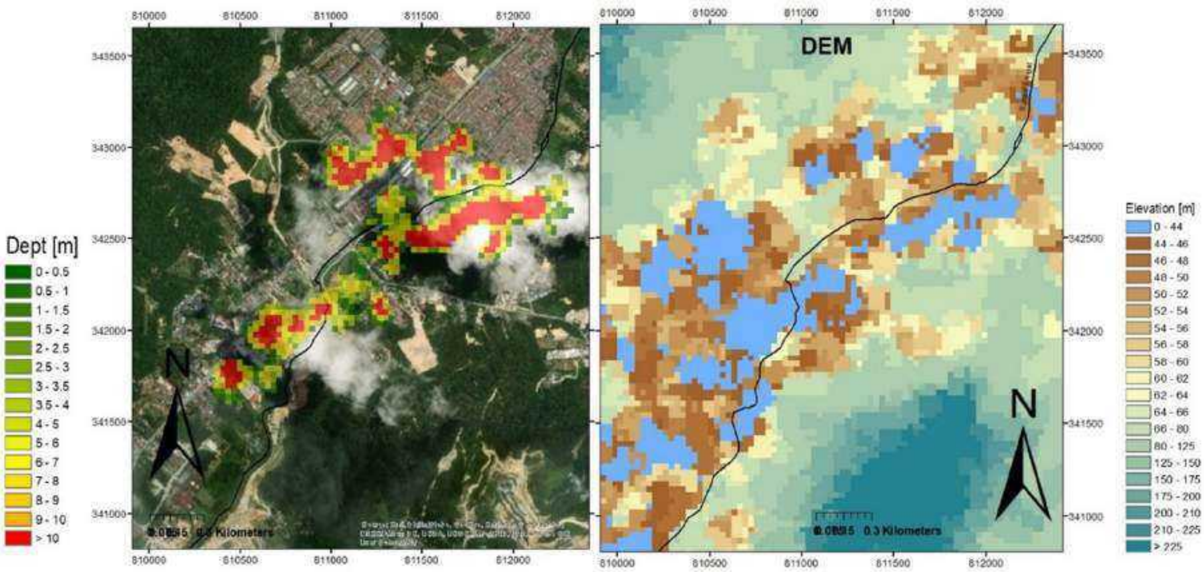


Figure 3. Simulated maximum flood inundation depth (left) and DEM elevation (right)

Figure 3 and 4 are the simulated maximum flood depth, DEM elevation, simulated maximum flood flow velocity and hydrodynamic force. Resident accounts say that the floods are frequent and thus do not evacuate when waters rise. They wait for the flood waters to recede, saying that it is easier to clear the mud left behind in the wake of the flood while it is still wet. However, the flood velocity analysis showed that there is potential for the force of flood waters to be strong enough to make it difficult for residents to stay in their houses during floods, particularly for flood events that occur in the upstream sections of the main Langat River. As such, residents need to be aware of the potential forces of flood water during extreme rain events.

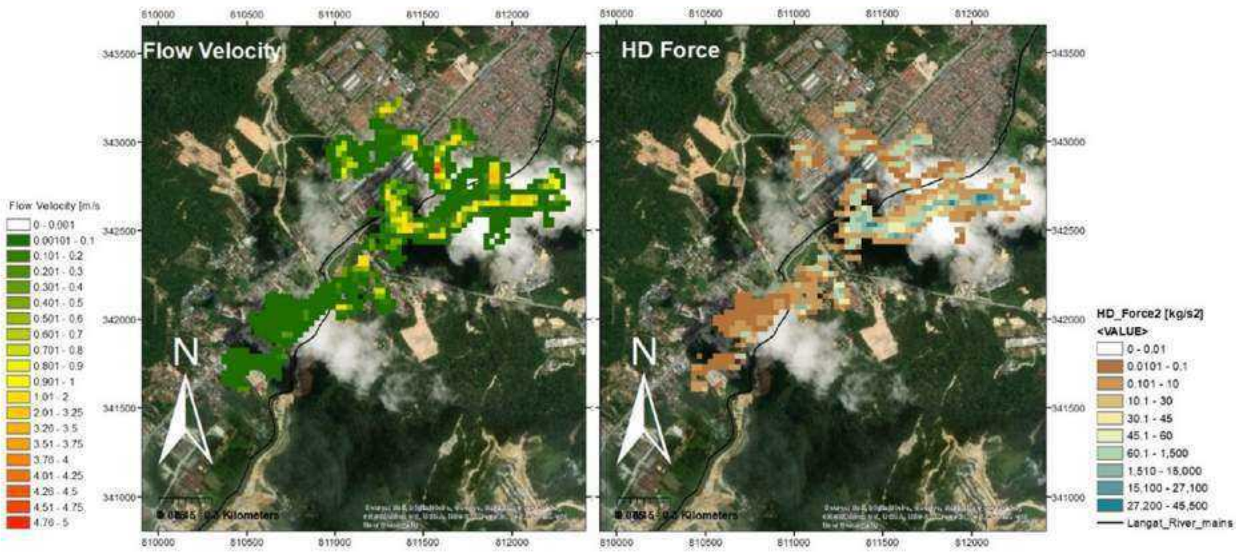


Figure 4. Simulated maximum flood flow velocity (left) and hydrodynamic force (right)

Floods - Site 4: Kampung Tok Muda, Kapar

The safety of Kampung Tok Muda from seawater flooding relies heavily on a stretch of coastal and river bunds between the village and the Kapar Besar River. The elevation of the area often first to be flooded is lower than the average high tides. The bunds are also subjected to erosion and need to be maintained consistently. DID has periodically done maintenance on the bund structure to maintain its height. However, it was reported by the locals and verified by DID that the bund integrity is compromised by the development of crab burrows through the bund over time. This then enabled water to seepage through and encouraged erosion as the tides fluctuates. While higher water levels contributed by higher tides and heavy rainfall might not necessarily lead to the bund overtopping, it creates larger pressure against the bund and contributes to the breaching/breakage.

Despite having the bund fixed after the flood, the risk of bund breaching remains in the future as such crab activity is a natural phenomenon beyond control and is impossible to be monitored. However, in the event of high tides, seepage of water through the bund could be observed and be identified as signs of possible bund breaching as shown in Figure 5. If the local leaders and community could act upon these seepage signs, possible failure and resultant flooding could be avoided.

From this observation, it can be deduced that the flooding in Kampung Tok Muda could be contributed by high water levels produced by the concurrence of heavy rainfall, high tides and strong waves which may not necessarily result to water overtopping but impose hydrodynamic forces that threatens the river bund structure that could already be compromised by crab activity. Thus, it is important to identify when is the highest chance for heavy rainfall and high tides to occur concurrently.

Figure 5. Seepage and small breaches during high tides as early signs of bund break

Observations in Addressing Disaster Risks

OBSERVATION 1. DATA AVAILABILITY

a. **Data needed for disaster risk analysis is limited.** Data for DRR purposes are not available either due to lack of resources for collection and compilation or cannot be sourced due to staff turnover. There is an urgent need to centralize data for easy retrieval, use and dissemination.

b. **Data collected but not being effectively used.** Data that are collected are sometimes not effectively used for DRR purposes. Vast amounts of data are collected and stored by the agencies, but are not leveraged for use in disaster risk reduction.

c. **Capacity development in understanding data and its importance.** Local governments and disaster management agencies will need to learn how to utilize hazard and risk maps for communicating risk to various stakeholders. This can be achieved through training, knowledge sharing, and collaborations with universities and research institutes with emphasis on using hazard and risk maps for disaster risk reduction.

d. **Investment in data acquisition.** There is a need for investment in data collection as well as the usage of data for spurring innovation. This calls for the use of high technology and advanced methods needed to collect good quality data for high-resolution mapping. This also requires the leveraging of data to create innovative solutions in communicating and reducing disaster risks.

e. **Need a platform for data sharing.** Access to data is a critical element for science-based communication tools such as hazard and risk maps. Data for modeling and visualization purposes needs to be made available to encourage disaster risk managers. A platform for data sharing is required.

OBSERVATION 2. NEED FOR CREATING HAZARD MAPS

a. **Hazard and risk maps help government prioritize high risk slopes for mitigation or rehabilitation.** Hazard and risk maps help identify areas that require priority works for rehabilitation. Government agencies can then develop measures and priorities for DRR.

b. **Federal and state governments have a responsibility to identify risk through science.** Both the federal and state governments have a strong responsibility to develop hazard and risk maps for landslide- and flood-prone rivers in the country, as this is not the responsibility of the local governments. Currently, hazard maps are predominantly created for mitigation measures. However, these maps should be created for the purpose of risk communication to the local leaders and communities.

c. **Hazard maps need to be updated due to changing land use and mitigation measures.** Local authorities and planners need to update hazard maps as hazard and risk profiles change as a result of changing land use and mitigation measures that may increase or decrease the level of risk. This should be done by local governments.

d. **Need for standardization of methodology for landslide and flood hazard and risk assessment.** There are many existing methodologies for carrying out risk assessment for floods and landslides. This may result in lack of interoperability and compatibility among the various methods and systems. There is a need for a standard methodology.

OBSERVATION 3. NEED FOR RISK COMMUNICATION

a. **Hazard experts to teach communities how to read and use hazard maps.** There is a huge knowledge gap between the hazard experts and local community members, and it is crucial that we consider how to use the hazard map and show the map to the people. The map should be easy enough for residents to understand, but the map needs to convey a strong enough message to make people evacuate and take action.

b. **Using hazard maps to dispel community misconceptions and assumptions about slopes.** It is also crucial for residents to understand that an area deemed as high hazard can be mitigated and even downgraded to medium or low hazard through mitigation measures or engineering. This is to counter assumptions and misconceptions by the communities about slopes that result from lack of information or understanding about slope risks.

c. **Early warning systems should be deployed in high-risk areas.** Hazard and risk maps help identify high-risk areas. In cases where high-risk areas cannot be rehabilitated due to budgetary or resource reasons, early warning systems can be effective.

d. **Government to share maps for DRR purposes.** Hazard and risks maps are useful for communicating disaster risks. They indicate potential hazards, help create awareness among stakeholders, and spur communities and local governments into preparedness mitigative measures. They can also indicate evacuation sites and routes to take in case of disaster-related emergencies. For such use in the interest of public safety, it is recommended that local and state authorities communicate risks using such maps in a way that is controlled and localized.

e. **Need for an industry platform for standardization of terms.** There are differences in terminology of disaster-related terms among the various technical and science fields. These differences in definitions of hazard and risk maps call for the need for a standard definition that can be applied across all disciplines. A possible platform for standardization is a multidisciplinary, government-level body called the Inter-Government Committee for Slope Management (ICSM), which comprises high-level government officials from various relevant departments and agencies to discuss, resolve and create standards in matters pertaining to slope management for the country.

1 Introduction

1.1 About the JPP SeDAR Program

The program "Strengthening the Disaster Risk Reduction to Improve the Safety and Security of Communities by Understanding Disaster Risks (SeDAR)" aims to equip local governments as well as community leaders with the skills and know-how to build a disaster risk reduction program at the grassroots level, from the bottom up. This program takes a unique approach to community by:

- Instilling a science-based understanding of disaster risks among the community leaders, member and local authorities, and
- Having them work together to develop DRR activities and programs that are best suited to their understanding and needs

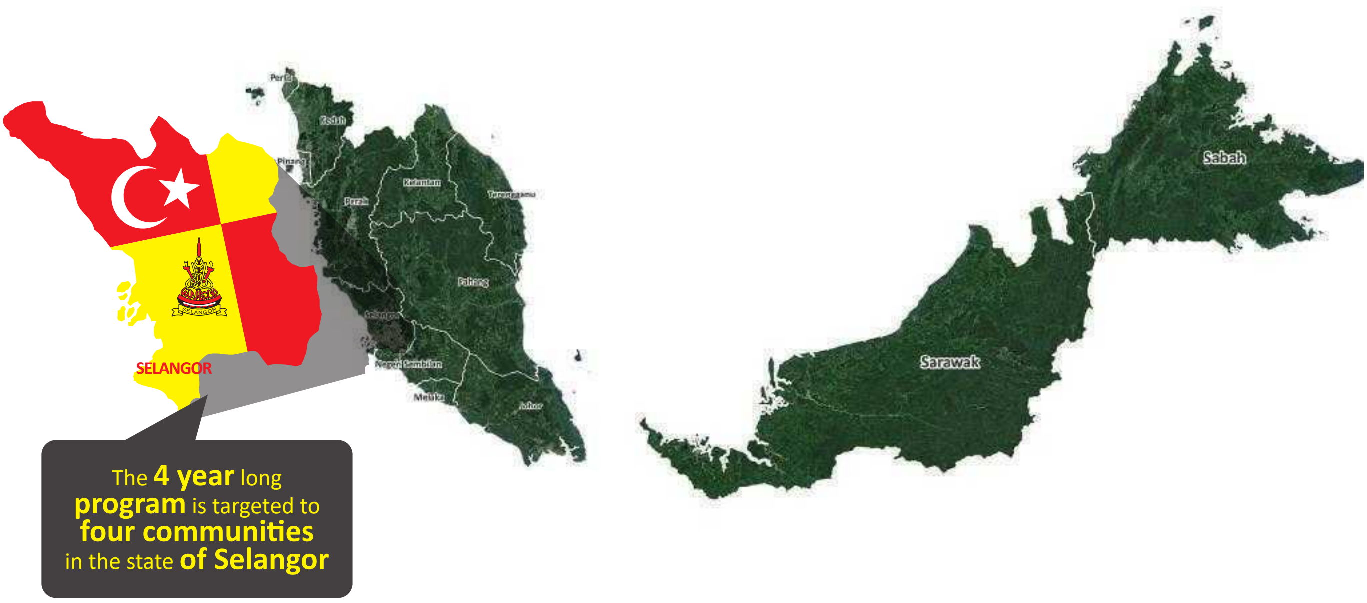
This community-oriented approach towards disaster risk reduction is an important step towards building disaster-resilient communities.

1.1.1 Main Players of the Program

- Local community leaders
- Local authorities and district officers
- Members of the communities

1.1.2 Program Details

The SeDAR project runs as a 4-year program targeted to four communities in the state of Selangor.



The communities selected as case studies in this report (Figure 6) are:

1. Ulu Klang, Gombak
2. Batu 14, Hulu Langat
3. Kampung Sg. Serai, Batu 11 1/2, Hulu Langat
4. Kampung Tok Muda and Kampung Sg. Serdang, Kapar

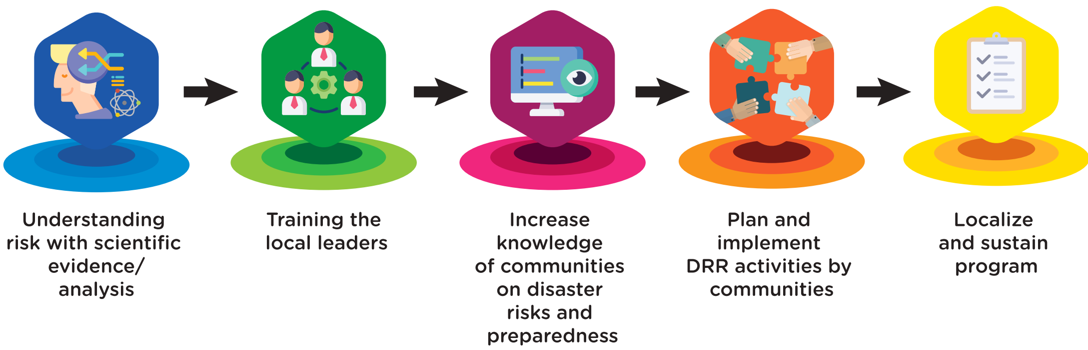
All of these areas have experienced major flooding or landslide incidents at some point in the past. However, their experiences are not unique to these locations. All of these sites have characteristics or conditions similar to those found throughout the country. Thus the lessons to be learned from running programs in these areas can be applied to other locations within Malaysia.

Figure 6. Location of selected communities

1.1.3 Key Concepts of the SeDAR Project

- Understanding of disaster risks by local government and community stakeholders
- Leadership and ownership by stakeholders to lead DRR projects
- Ensure sustained continuity of the programs

1.1.4 How the Project Runs



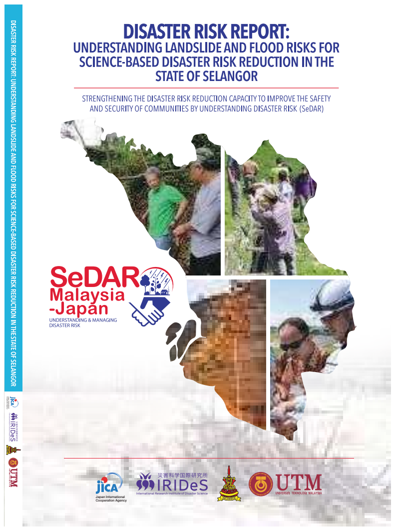
1.1.5 Program Partners

SeDAR is a collaboration between the International Research Institute of Disaster Science (IRIDeS) of Tohoku University, Selangor Disaster Management Unit (SDMU) of the Selangor State Government and the Disaster Preparedness and Prevention Centre (DPPC) of the Malaysia-Japan International Institute of Technology (MJIIT), Universiti Teknologi Malaysia, Kuala Lumpur (UTMKL).

- **IRIDeS** – is the project proponent that manages and provides direction in the implementation of the SeDAR project, as well as imparting skills and know-how that leverages on its vast experience in disaster management in Japan
- **DPPC** – is the local technical expert that transforms SeDAR objectives into local content for the communities, merging science and local knowledge for a more comprehensive approach to DRR
- **SDMU** – is the local implementer that serves as the link between the communities, government agencies and academia, thus ensuring smooth implementation

1.2 About the Disaster Risk Report

The Disaster Risk Report explains the risks of landslides and floods faced by communities in Selangor, in a way that can be easily understood by technical and non-technical readers alike. It serves as a communication tool for local and district authorities as well as government agencies at the district and state level to understand the hazards and risks of the project areas. The simplicity of the report belies the hard science behind the explanations and risk analysis of the four case studies shown in this report.



Each of the case studies showcase how science can help in identifying disaster risks. By taking a scientific approach in showing risks to community stakeholders, risk managers are better able to persuade residents to learn, design, implement and take ownership of proactive measures in safeguarding their homes, properties and lives on a long-term, sustainable basis.

The 'science' that is referred to in this report is derived from extensive studies conducted by Malaysian government agencies in the four project areas.

For landslide case studies: Data for risk analysis in this project is based on hazard data from the Department of Mineral and Geoscience Malaysia (JMG). From 2014 to 2016, JMG carried out the area-based mapping and hazard analysis by implementing the Slope Hazard and Risk Mapping Project (*Projek Penghasilan Peta Bahaya & Risiko Cerun - PBRC*) (Figure 7).

The project was carried out in Peninsular Malaysia in the Klang Valley in the state of Selangor, Cameron Highlands in the state of Pahang, and Ipoh in the state of Perak, covering 1,350km^2. It was also carried out in Kundasang and Kota Kinabalu in Sabah state. PBRC covers only some of the landslide-prone areas recorded throughout the country.

Figure 7. JMG's NATSIS portal for slope hazard and risk mapping information

The data produced by PBRC produces *hazard maps*, which identify areas that are subject to landslides and is measured from ‘low’ to ‘high’. The landslide hazard map takes into account where the landslides occur and what causes them (slope, soil type and the impact of the flow of water in an area) (Figure 8).[1]

Figure 8. JMG’s NATSIS portal and maps

From these, an analysis in the project areas was conducted by the Project Team’s landslide expert. With this approach, risk areas were identified to be used for risk communication and action planning by the residents in the implementation phase of the SeDAR program.

For flood case studies: River and coastal flood models had to be created by flood modelers within the Project Team at the sub-basin level. Hydrological input data were procured from the Department of Irrigation and Drainage, Malaysia, while digital elevation model development services were provided by Geomapping Technology Sdn. Bhd.

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Based on the models, flood maps were then created to be shown to community leaders and local authorities to explain how these floods occur and what could be done to mitigate the effects of these phenomena.

The Disaster Risk Report is the output from the first phase of the JPP SeDAR program and shall serve as the reference document during the activity planning and implementation phases of the program.

[1] *Geological Survey Ireland, https://www.gsi.ie/en-ie/programmes-and-projects/geohazards/projects/Pages/Landslide-Susceptibility-Mapping.aspx*

DISCLAIMER:

IRIDeS and UTM is furnishing data and analysis results in this publication with data as shared by Malaysian government agencies. Certain data, some of which was key in assuring accuracy and fidelity of the results, were not attainable. As such, the results may vary from studies conducted by other parties with greater access to input data. This publication is merely a demonstration of how science, through modeling and visualization, can be used to identify risk to relevant target audiences. While reasonably accurate, IRIDeS and UTM recommends that any modeling or visualization works be conducted with higher resolution data.

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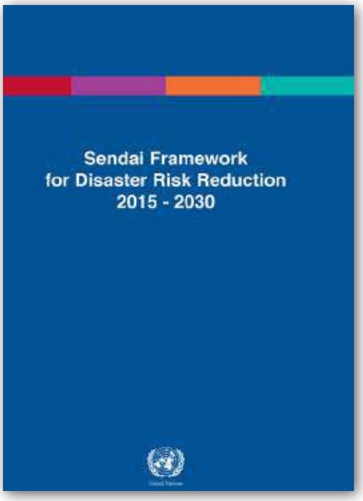
1.3 What is Science-Based Risk Analysis?



Simply put, risk is a combination of the possibility or probability that a disaster may occur and the negative consequences of such an incident[2]. Disaster managers carry out risk analysis to study hazards and evaluate how conditions of vulnerability could harm exposed people, property, services, livelihoods and the environment[3]. These results of risk analysis are used to make decisions on how best to prepare, respond and recover from disasters.

Science-based risk analysis is based on the concept of introducing science and technology in disaster risk reduction, which is highlighted in the Sendai Framework for Disaster Risk Reduction 2015-2030, in its first Priority of Action "Understanding Disaster Risk", where it emphasizes the role of science and technology in explaining disaster risk to various audiences[4].

The use of science and technology to show 'how and why disasters occur' can be useful in risk communication to policy makers and city planners in the development and dissemination of science-based risk knowledge, technology and innovation[5]. It is also a useful approach to communicate risks to communities, in that it provides a deeper understanding of the causes and mechanisms of disasters and enables communities to come up with meaningful and sustainable courses of action for preparation, mitigation and recovery.

As mentioned in the previous chapter, this report is targeted to local governments and local community leaders to get them to understand disaster risk through the lens of science and technology. This is done through the application of:

- Remotely sensed data
- Real-time digital data
- Evidence-based digital cum social data
- Geoinformation tools and techniques[6]

These tools and techniques are used in this report to demonstrate hazards and risks being faced by communities in four locations within the state of Selangor. These explanations are explained under the chapter "Science-Based Risk Identification".

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[2] *2009 UNISDR Terminology on Disaster Risk Reduction*

[3] *UNDP, Bureau for Crisis Prevention and Recovery, www.undp.org/cpr/we_do/disaster_global_risk_id.shtml, 2010*

[4] *Sendai Framework for Disaster Risk Reduction 2015-2030, UNISDR*

[5] *The Science and Technology Roadmap to Support the Implementation of the Sendai Framework for Disaster Risk Reduction 2015-2030, UNISDR, Revised draft February 2019*

[6] *Appraisal of gaps and challenges in Sendai Framework for Disaster Risk Reduction priority 1 through the lens of science, technology and innovation, Atta-ur Rahman, Chen Fang, Science Direct, Volume 1, May 2019*

2 About the State of Selangor

Selangor, also known by its Arabic honorific Darul Ehsan, or “Abode of Sincerity”, is one of the 13 states of Malaysia.

2.1 Location

Selangor is situated is on the west coast of Peninsular Malaysia and is bordered by Perak to the north, Pahang to the east, Negeri Sembilan to the south and the Straits of Malacca to the west. Selangor surrounds the federal territories of Kuala Lumpur and Putrajaya, both of which were once part of the state. The state capital of Selangor is Shah Alam, and its royal capital is Klang. There are nine districts and 12 local authorities within the state (Figure 9).

Figure 9. State of Selangor and its districts

2.2 Geography

Selangor is located to the west of Peninsular Malaysia, overlooking the Straits of Malacca. Selangor, with an area of approximately 8,000 km, extends to the west coast of Peninsular Malaysia to the north coast of Malacca. It is located at the heart of the Peninsular Malaysia on the west coast and surrounds the Federal Territory of Kuala Lumpur and Putrajaya. Selangor is bordered north by Bernam River from Perak, south by Sepang River from Negeri Sembilan, east by the Titiwangsa Mountains and Straits of Malacca on the west. Malaysia’s capital, Kuala Lumpur is located in the heart of Selangor. It was once a part of Selangor territory before it was separated from the state to form a Federal Territory.

2.3 Economy

The state of Selangor has the largest economy in Malaysia in terms of gross domestic product (GDP), with RM239.968 billion (roughly USD 55.5 billion) in 2015, comprising 22.6% of the country's GDP. It is the most developed state in the country, with good infrastructure such as highways and transport, the largest state population, high standard of living, and the lowest poverty rate in the country.

2.4 Population

With the Klang Valley within its perimeters, Selangor is most populous state in Malaysia. Selangor's geographical position in the centre of Peninsular Malaysia contributed to the state's rapid development as Malaysia's transportation and industrial hub. Selangor's population has increased considerably in recent decades, due mostly to the urban development of the Klang Valley. As of 2015, its population was almost 6 million people at 5,874,100.

As a commercial and industrial hub, people from other parts of the country migrate to Selangor for employment and business opportunities. The living standard in this state is high, with the poverty level relatively low. Selangor is said to be propelled by urban growth, making it a centre of commercialization and industrialization and subsequently, Malaysia's richest state.

3 Natural Hazards, Disasters and DRR in Malaysia

3.1 Natural Hazards and Disasters

Malaysia is located in Southeast Asia with an area of nearly 330,000 km^2. The average precipitation is between 2,000 mm to 4,000 mm with temperatures ranging from 26°C to 32°C. The Malaysian climate is characterized by uniform temperature, high humidity and heavy rainfall. While Malaysia is buffered from devastating disasters that frequently befall its neighbouring countries, it still experiences its share of natural disasters.

In Malaysia, the top disasters are floods, storms and landslides according to disaster management communities in the country.

3.1.1 Landslides

Landslides are a serious geologic hazard in Malaysia as well as many parts of the world. Landslides, which claim lives, damage properties and affect major transportation networks, have caused substantial economic losses to the nation. An updated list from another study under the Public Works Department Malaysia shows that there were 721 fatalities from the year 1961 to 2019 (see Table 1).

List of Major Landslide Events

Table 1. List of landslide events with fatalities in Malaysa
Sources: National Slope Master Plan 2009 (JKR); updated list in A Study on Determining "Acceptable Risk" and "Tolerable Risk" Criteria and Their Applications in Landslide Risk Assessment 2015 (JKR)

No	Date	Location	Fatalities
1	11-May-61	Ringlet, Cameron Highlands	16
2	10-Oct-66	PDRM Headquarters, Tanjong Rambutan, Ipoh, Perak	1
3	26-Jun-67	Government Agricultural Experimental Station (MARDI), Tanah Rata, Cameron Highlands	4
4	23-Sep-69	Jalan University, Petaling Jaya	2
5	18-Nov-72	New Lahat Tin Mine, Ipoh, Perak	1
6	22-Jun-73	Yew Meng Tin Mine, Gunong Rapat, Ipoh, Perak	7
7	18-Oct-73	Kampung Kachang Putih, Gunung Cheroh, Ipoh	42
8	3-May-74	Bharat Tea Estate, Cameron Highlands	2
9	5-Feb-75	Ho Pak Yew Tin Mine, Tronoh, Perak	4
10	9-Apr-78	Luen Seng Tin Mine, Gopeng, Perak	1
11	9-Nov-79	Asia Mining Sdn Bhd, Perak	1
12	4-Mar-81	Kampung Kandan, Puchong, Selangor	24
13	1-Jul-85	Jalan Pending, Kuching, Sarawak	2
14	22-May-87	Taman Yoon Seng, Seremban, Negeri Sembilan	1
15	14-Nov-89	Bukit Permai, Ampang, Selangor (Fatalities not confirmed)	3
16	24-Oct-93	KM 58, Kuala Lipis - Gua Musang	1
17	23-Nov-93	KM 25.5, Kuala Lumpur - Karak Highway	2
18	28-Nov-93	KM 63, Kuala Lumpur - Karak Highway	

No	Date	Location	Fatalities
19	11-Dec-93	Highland Towers, Ulu Klang	48
20	31-Dec-93	KM 59.5, Timur - Barat Highway	1
21	2-May-94	Puchong Perdana, Puchong, Selangor	3
22	9-Dec-94	Cameron Highlands, Pahang	1
23	30-Jun-95	KM 39, Genting Sempah, KL- Karak Highway	21
24	24-Oct-95	Kea Farm, Tringkap, Cameron Highlands	1
25	1-Dec-95	Cameron Highlands	7
26	20-Dec-95	Taman Chiap Aik, Seremban, Negri Sembilan	1
27	6-Jan-96	KM 303.8, PLUS Highway, Gua Tempurung, Ipoh	1
28	15-Jul-96	KM 1.5, KL-Karak Highway, Selangor	15
29	29-Aug-96	Perkampungan Orang Asli Pos Dipang, Perak	38
30	10-Oct-96	Kuala Terla, Cameron Highlands	3
31	17-Oct-96	Kampung Baru, Gelang Patah, Johor	1
32	26-Dec-96	Taufan Gregg, Keningau, Sabah	302
33	11-May-97	Jalan Pantai, Kuala Lumpur	1
34	25-Dec-97	KM 17 Lebuhraya Ampang - Ulu Klang, Selangor	3
35	8-Feb-99	Jalan Leila, Kg Gelam, Sandakan, Sabah	17
36	15-May-99	Jalan Wangsa 1, Bukit Antarabangsa, Selangor	1
37	28-Jan-02	Kg. Ruan Changkul, Simunjan, Sarawak	16
38	20-Nov-02	Taman Hillview, Ulu Klang, Selangor	8
39	5-Feb-03	Kg. Lanchang Sijo, Serian, Sarawak	1
40	24-Jan-04	Kg. Podam, Bau, Sarawak	1
41	5-Nov-04	Taman Sri Harmonis, Gombak, Selangor	1
42	29-Nov-04	KM 59, Kuala Lipis - Merapoh, Pahang	4
43	1-Dec-04	Damansara Century Heights, Tol Sg Penchala, Selangor	1
44	2-Dec-04	Taman Bercham Utama, Ipoh, Perak	2
45	1-Jan-06	Sungai Menson, Cameron Highlands (Agriculture, date and month not known)	1
46	8-Feb-06	Kg. Sundang Darat, Batu Sapi, Sandakan, Sabah	3
47	31-May-06	Kg. Pasir, Ulu Klang, Selangor	4
48	26-Jun-06	KM 8.5, FT606, Pelabuhan Sepanggar, Kota Kinabalu, Sabah	1
49	7-Nov-06	Kuari Gunung Jerai, Gurun, Kedah (Mining)	2
50	11-Nov-06	Kg. Bukit Sungai Seputeh, Lembah Jaya, Ampang, Selangor	1
51	26-Dec-07	Lorong 1, Kampung Baru Cina, Kapit, Sarawak	4
52	30-Nov-08	Ulu Yam Perdana, Kuala Selangor, Selangor	2
53	6-Dec-08	Taman Bukit Mewah, Bukit Antarabangsa, Ulu Klang, Selangor	5
54	16-Jan-09	Bukit Kanada, Miri, Sarawak	2
55	12-Feb-09	Bukit Ceylon, Kuala Lumpur	
56	29-Jan-11	Residential areas in Sandakan, Sabah	2
57	21-May-11	Rumah Anak Yatim At-Taqwa Hulu Langat, Selangor	16
58	7-Aug-11	Perkampungan Orang Asli Sg. Ruil, Cameron Highlands	7
59	29-Dec-12	Puncak Setiawangsa, Kuala Lumpur	
60	18-Feb-12	Kampung Terusan, Lahad Datu	2

No	Date	Location	Fatalities
61	4-Jan-13	Kingsley Hill housing project at Putra Height	
62	15-Jul-13	Kampung Masilou, Kundasang	1
63	18-May-14	Kampung Melayu Subang, Subang, Selangor	1
64	4-Jun-14	Ulu Temani, Tenom, Sabah	2
65	8-Sep-14	Quarry at Bukit Sagu 4, Kuantan, Pahang	3
66	5-Nov-14	Kg. Raja, Pekan Ringlet, Lembah Bertam, Cameron Highlands	5
67	30-Dec-14	KM 46, Jalan Brinchang-Tringkap, Cameron Highlands	2
68	1-Jan-15	Tapak Bintong, Tringkap, Cameron Highlands (Actual date and month not known)	3
69	1-Jan-15	Desan Corina, Cameron Highlands (Actual date and month not known)	1
70	5-Jun-15	Gunung Kinabalu, Sabah	18
71	11-Nov-15	Kuala Lumpur-Karak Expressway (between Lentang and Bukit Tinggi and Gombak Bentong Old Road)	
72	14-Jan-16	Terisu, Cameron Highlands	1
73	23-Feb-16	Ara Damansara, Selangor	1
74	28-Feb-16	Kuala Pilah, Negeri Sembilan	1
75	09-Apr-16	Lombong Pasir Linggiu, Bandar Tenggara, Kota Tinggi	1
76	06-Oct-16	Bukit Manggak, Padang Terap, Kedah	1
77	26-Nov-16	Serendah, Rawang, Selangor	
78	11-Dec-16	Hutan Matau, Jerantut, Pahang	2
79	25-Jan-17	Flower Orchard, Batu 49, Kuala Terla, Kampung Raja, Cameron Highlands	1
80	21-Sep-17	Jalan Tun Sardon-Bukit Baru Road, Paya Terubong (causing the main roads leading to Balik Pulau and George Town to blocked)	-
81	21-Oct-17	Housing project at Lengkok Lembah Permai, Tanjung Bunga (8.57am)	11
82	5-Oct-17	A total of over 100 landslides occurred in Bukit Bendera area	10
83	19-Oct-17	Bukit Kukus Project site for constructing twin road connecting Paya Terubong to Relau	-
84	20-Oct-17	Landslide of 0.4 hectare land at Telipok Residential Scheme, Kota Kinabalu which destroyed 12 houses	-
85	5-Jan-18	Ladang Lada, Tanjung Bungah	-
86	11-Oct-18	Heav rains with strong winds caused 14 concrete beams measuring 25m fell on the slopes at Bukit Kukus project	-
87	14-Oct-18	Batu 49, Kampung Tiga, Kuala Terla, Cameron Highlands	3
88	25-May-19	Jalan Ringlet-Blue Valley	-
89	25-May-19	Jalan Ulu Merah	-
90	12-Jun-19	Jalan 19 / 144A, Taman Bukit Cheras (wall failure caused by earthworks)	
91	26-Jun-19	Resort near the site of the landslide at Jalan Batu Ferringhi, Tanjung Bungah	4
		TOTAL	721

In Malaysia, major landslides are largely attributed to urban development on hillsides and the construction of roadworks in hilly terrain. Landslides can be due to natural, geological as well as anthropogenic factors such as land use, inadequate design, and bad construction practices.

Regardless of the factors, landslides in Malaysia are often triggered by intense or prolonged rainfall. It is expected that with the nation's ongoing development, coupled with the effects of global warming that will increase the volume of rainfall, the occurrence of landslides and its consequences will escalate.

From left: Highland Towers landslide (1994), Bukit Antarabangsa landslide (2008), Taman Hillview landslide (2012)

3.1.2 Floods

Floods top the list of disasters in Malaysia, with 1.2 million denizens affected, damages worth USD1.5 million and 290 deaths for the period 1970 to 2018.[7] In 2018, major floods in six states (Johor, Kelantan, Pahang, Perak, Selangor and Sabah) caused the evacuation of 4,000 families while in 2018 floods in Sarawak saw the evacuation of 4,859 people (Figure 10).[8]

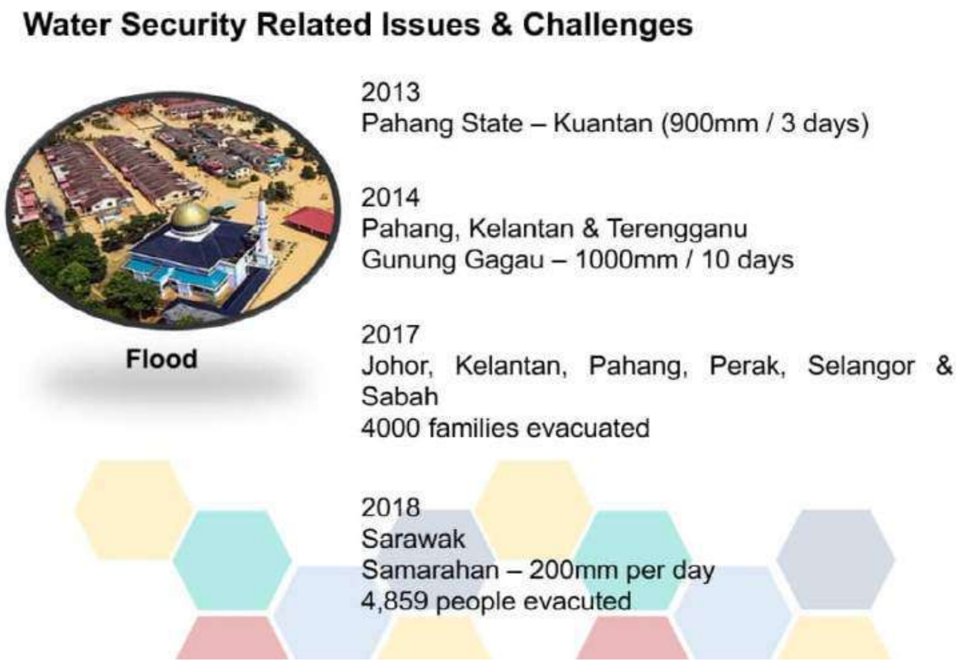


Figure 10. Flood issues highlighted by the Department of Irrigation and Drainage Malaysia
Source: Water Resources and Hydrology Division, DID Malaysia, 2019

In just 2017 alone, 498 flood incidents were reported nationwide, and states with the highest number of floods were Selangor (86 cases), Sarawak (64 cases), and Pahang (61 cases).[9]

[7] *Summary of Recorded Natural Disaster in Malaysia Year 1968 to 2018 (cut-off on February 12, 2018) (adopted from EM-DAT 2018)*

[8] *Water Resources and Hydrology Division, Department of Irrigation and Drainage Malaysia*

[9] *Water Resources and Hydrology Division, Department of Irrigation*

There are two kinds of floods that afflict the country:

- **Monsoon floods** are seasonal floods brought about by large amounts of precipitation. Such floods tend to occur during the Northeast monsoon season from October to March and the Southwest season from May to September.
- **Flash floods** can occur during periods of normal rainfall due to natural factors such as unusually heavy rainfall or man made ones such obstructions in the drainage channels.

Flash floods usually take only some hours to return to the normal water level, while monsoon flood can last for a month. Rapid and massive development in urban and suburban areas has led to increased surface runoff and siltation in the waterways that lead to more flash floods starting from the 1980s.

Clockwise from top left: Kampung Tok Muda coastal flood (2016), Cameron Highlands mud flow (2014), Cameron Highlands mud flow (2015)

3.2 Disaster Risk Reduction

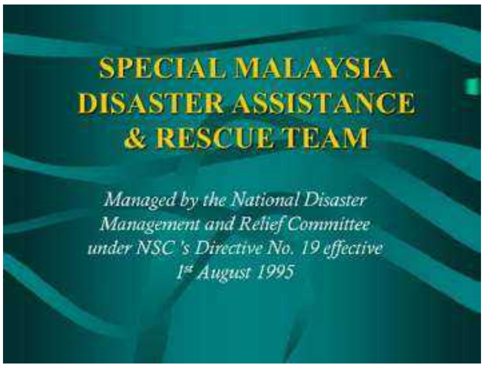
Massive and rapid urban development in the 1980s and 1990s saw the onset of man made as well as natural disasters. Widespread clear-cutting of trees, changes in land use, non-engineered slope cutting practices, heavily silted drain systems, and alterations in the river corridor resulted in flash and monsoon floods as well as slope failures.

With the onslaught of devastating flood and landslide disasters came the need for capacity and capability for disaster response, and until the late 2000s the government's focus has been centered on disaster response and recovery.

In recent years, focus has shifted more to disaster preparedness and management, introducing the concept of disaster risk reduction in various sectors of the government.

3.2.1 Policy - Directive 19 and 20

In the aftermath of the 1993 Highland Towers landslide disaster, two significant policies in disaster management materialized (Figure 11). Directive 19, which called for the establishment and set-up of the Special Malaysia Disaster Assistance and Rescue Team, was created in 1994. Directive 20, which laid the groundwork for standard operating procedures and organizational framework for disaster response, was established in 1997 and revised in 2012. These two directives are the main policies driving disaster response in Malaysia.



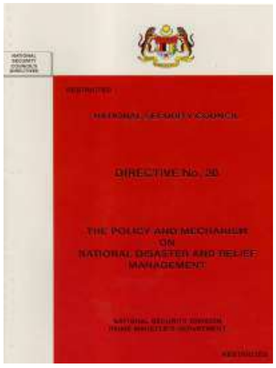


Figure 11. Directive 19 and Directive 20

3.2.2 Institutional - NADMA

The National Disaster Management Agency (NADMA) is Malaysia's national agency for crisis and disaster management. Established in 2015, it is the focal point of national disaster management at the federal, state, and district levels. Prior to NADMA, the disaster management was under the Malaysian National Security Council (NSC), which was established in 1995 (Figure 12).

NADMA has many functions in disaster management, including:

- Producing strategies, directions, action plans and policies
- Ensuring the implementation of these policies and action plans
- Providing secretarial services to Disaster Management Committees at all levels of disaster management
- Monitoring and ensuring implementation of disaster risk reduction measures by government agencies to prevent or mitigate the impact of disasters
- Planning, coordinating and overseeing the implementation of education, training and awareness programs by government agencies, statutory bodies, private and voluntary bodies, and the public in mitigating disaster risk

Evolution of Disaster Management in Malaysia

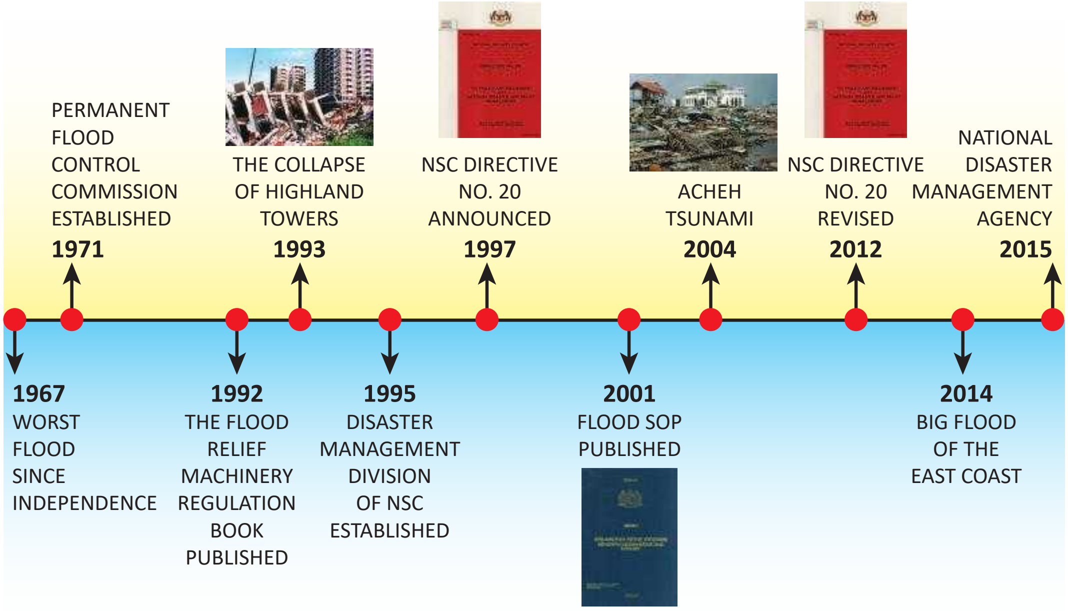


Figure 12. Evolution of disaster management in Malaysia
Source: Role and Mechanisms in Disaster Management, Disaster Management Unit, NADMA

3.2.3 Urban Planning

Urban planning plays a significant role in reducing disaster risks. Flood and landslide risks can be reduced through effective and efficient urban planning practices taken by the government and private sectors in Malaysia.

Various initiatives have been taken by the Federal Town and Country Planning Department of Peninsular Malaysia (Federal TCPD PM) to mainstream and incorporate disaster risk reduction agendas into existing urban planning practices such as preparation of guidelines and manuals.

There are four physical development plans that are prepared at different levels of the development planning, which are the National Physical Plan (NPP), the State Structure Plan (SS), the Local Plan (LP), and the Special Area Plan (SAP).

An example is shown in the National Physical Plan (the highest level of spatial development planning for the country) which requires the identification and preparation of disaster preparedness action plan against tsunami and floods in major tourism destinations (Figure 13).

Figure 13. National Physical Plan

4 Natural Hazards, Disasters and DRR in Selangor State

4.1 Natural Hazards and Disasters

With geographical terrain that covers mountains to the east, a coastline to the west and densely populated river basins, the state of Selangor has a long history of disasters. The natural disasters include monsoon floods, flash floods, storms, landslides, peatland fires and fire incidents in forest reserves.

From 2015 until May 2019, there were 2,248 disaster incidents in Selangor (see Table 2). At the top of the list, flash floods prevailed, followed by storms, forest fires, and floods.

DISASTER TYPE	2015	2016	2017	2018	2019	Total by Type
Flood	44	95	114	54	0	307
Flash Flood	0	160	159	266	49	634
Forest Fires	82	132	126	135	45	520
Illegal Dumpsite Fires	0	0	16	41	18	75
Landslides	3	8	48	23	4	86
Storms	105	176	85	140	55	561
Extreme High Tides	0	14	48	0	3	65
TOTAL (By Year)	**234**	**585**	**596**	**659**	**174**	2248

**2019 data until May*

Table 2. Number of disasters in Selangor by type
Source: Selangor Disaster Management Unit, Selangor State, 2019

4.1.1 Landslides

A total of 20 critical hillslopes in Selangor (Kajang, Ampang Jaya, Selayang and part of Hulu Selangor) have been identified to be at risk of landslides if no action is taken to properly maintain the hilly slopes (Figure 14).

Figure 14. Locations of the critical slope areas in Selangor

As of 2018, landslides account for 161 fatalities in Selangor as shown in the table.

No.	Date Occurred	Location	Fatalities
1.	23-Sep-69	Jalan University, Petaling Jaya	**2**
2.	24-Mar-81	Kampung Kandan, Puchong	**24**
3.	14-Nov-89	Bukit Permai, Ampang (fatalities not confirmed)	**3**
4.	11-Dec-93	Highland Towers, Ulu Klang	**48**
5.	31-Dec-93	KM 59.5, Timur - Barat Highway	**1**
6.	2-May-94	Puchong Perdana, Puchong	**3**
7.	30-Jun-95	KM 39, Genting Sempah, KL- Karak Highway	**21**
8.	15-Jul-96	KM 1.5, Lebuhraya KL-Karak	**15**
9.	25-Dec-97	KM 17 Lebuhraya Ampang - Ulu Klang	**3**
10.	15-May-99	Jalan Wangsa 1, Bukit Antarabangsa	**1**
11.	20-Nov-02	Taman Hillview, Hulu Klang	**8**
12.	5-Nov-04	Taman Sri Harmonis, Gombak	**1**
13.	1-Dec-04	Damansara Century Heights, Tol Sg Penchala	**1**
14.	31-May-06	Kg. Pasir, Ulu Klang	**4**
15.	11-Nov-06	Kg. Bukit Sungai Seputeh, Lembah Jaya, Ampang	**1**
16.	30-Nov-08	Ulu Yam Perdana, Kuala Selangor	**2**
17.	6-Dec-08	Taman Bukit Mewah, Bukit Antarabangsa, Ulu Klang	**5**
18.	21-May-11	Rumah Anak Yatim At Taqwa Hulu Langat	**16**
19.	18-May-14	One Sejati Perabut, Kampung Melayu Subang, Subang	**1**
20.	23-Feb-16	Ara Damansara	**1**
21.	26-Nov-16	Serendah, Rawang	**0**
TOTAL			**161**

Table 3. Landslides with Fatalities in Selangor
Source: Slope Engineering Branch, Public Works Department

Landslide at the orphanage in Batu 14 (2011) and Bukit Antarabangsa landslide (2008)

4.1.2 Floods

Due to extensive flood mitigation projects carried out within the major river basins by the Department of Irrigation and Drainage, Selangor no longer experiences major floods from river overtopping. However, the state continues to be afflicted with flash floods, particularly in areas where there is construction or sand mining activities. With the current increase in urban development and construction, flash floods occur frequently.

Listed below (Table 4) are the number of flood events in Selangor by district from the period 2014-2019.

DISTRICT	2014	2015	2016	2017	2018	2019
Petaling	17	35	13	11	32	4
Klang	17	45	33	25	10	5
Sepang	7	17	5	12	10	4
Hulu Langat	6	16	21	29	20	6
Hulu Selangor	15	8	4	10	8	2
Kuala Langat	7	7	3	2	6	2
Kuala Selangor	6	11	7	9	16	3
Gombak	11	30	12	20	26	3
Sabak Bernam	6	2	2	23	23	2
TOTAL	**92**	**171**	**100**	**151**	**151**	**31**

Table 4. List of flood events in Selangor by district
**2019 figures are until the month of May*

In addition to man-made activities, the State Government is also aware that increased flash floods and rising sea levels are effects brought about by climate change.

Scenes from coastal flooding at Kapar in the 2017 flood
Sources: New Straits Times

4.2 Disaster Risk Reduction

In Selangor, there are several initiatives that have been undertaken at the state and municipal government regarding disaster risk reduction. The first is the **Smart Selangor Blueprint**, the second is the setup of the **Selangor Disaster Management Unit**, and the third is the **Selangor GeoHazard Planning Study**.

4.2.1 Smart Selangor Blueprint

SMART SELANGOR

In 2016, the Selangor State Government introduced the Smart Selangor Blueprint, a strategic plan that leverages on smart infrastructure, services, systems and people for greater economic growth and resilience as well as better governance and efficient management of the state's key resources and economic sectors. In essence, it is the plan for making Selangor a hub of 'smart cities' (Figure 15).

Figure 15. SMART City branding for Selangor state

There are 12 domains in the blueprint (Figure 16), ranging from education to healthcare and well-being to energy, with all leveraging on IOT (Internet of Things) solutions under the umbrella term 'smart' solutions. One of these domains is Smart Disaster Management.

Figure 16. Twelve domains of the SMART Selangor Blueprint

Smart Disaster Management is an integrated crisis management system for better and more effective disaster management and coordination among the relevant state agencies. Its multi-hazard Smart Selangor Control Centre provides round-the-clock 24/7 monitoring early warning and fast responses to geo hazards (Figure 17).

Figure 17: SMART Selangor Control Centre in Shah Alam

4.2.2 Setup of the Selangor Disaster Management Unit

The implementing body of this domain is the **Selangor Smart Disaster Management Unit (SDMU).** Established in July 2014, SDMU is an initiative of the Selangor State Secretary that was especially set up to monitor and manage disaster events in Selangor.

This unit, which is the only such state agency in the country, functions as a coordinating body that responds to state and district level emergencies. It also gathers disaster-related data and disseminates it among local authorities and relevant agencies within Selangor to minimize risks.

4.2.3 GeoHazards and Urban Planning

As stated earlier, one of Federal TCPD's roles was to introduce and incorporate disaster risk reduction into urban planning documents at the federal, state, and district/ municipal levels. In line with this function, the TCPD has carried out the Selangor GeoHazard Planning Study (*Kajian Perancangan Geo Bencana Negeri Selangor*) (Figure 18).

The study, which commenced in April 2018 and was completed in November 2018, is a state government effort to identify areas vulnerable to catastrophic threats under each local authority, measure the level of resiliency of the local authority, assess the feasibility of planning policies, and present best management and planning approaches to achieve resilient cities within the state of Selangor. This study focused on five types of disasters: landslides, floods, sea level rise, coastal erosion, and forest fires.

The resulting Report:

- Identifies the issues, causes and impacts of disaster on planning and development
- Provides spatial risk inventories and delineate geo-risk zone by type of hazard
- Proposes the best urban planning practices based on international experience as reference for formulating planning controls and development plans according to classes of vulnerability within the disaster zones
- Provides specific planning guidelines for geo-hazard zones
- Presents management and implementation mechanisms to achieve resilient state goals

The output of the Study is a collection of risk inventories, disaster risk zoning plans, and guidelines for mitigating the various geohazards by the local authorities.

Figure 18. Selangor GeoHazard Plan, with hazard maps by local authority jurisdication

5 Site Selection

5.1 Site Selection of Communities for the Landslide Component

The selected project sites which serve as demonstration case studies for this report are (1) the sub-district of Ulu Klang in the Gombak district and (2) the township of Batu 14 in the Hulu Langat district.

The process of site selection for the landslide component of the SeDAR project was assisted by:

- the results of the Hazard and Risk Mapping Project (*Projek Pemetaan Bahaya dan Risiko Cerun*) which indicated areas of risk
- comprehensive historical records of major landslide and flood events within the state provided by the Selangor Disaster Management Unit (SDMU)
- site visits to candidate sites and discussions with community leaders

5.1.1 Site Selection Process

The process flow for the landslide community site selections is provided in Figure 19:

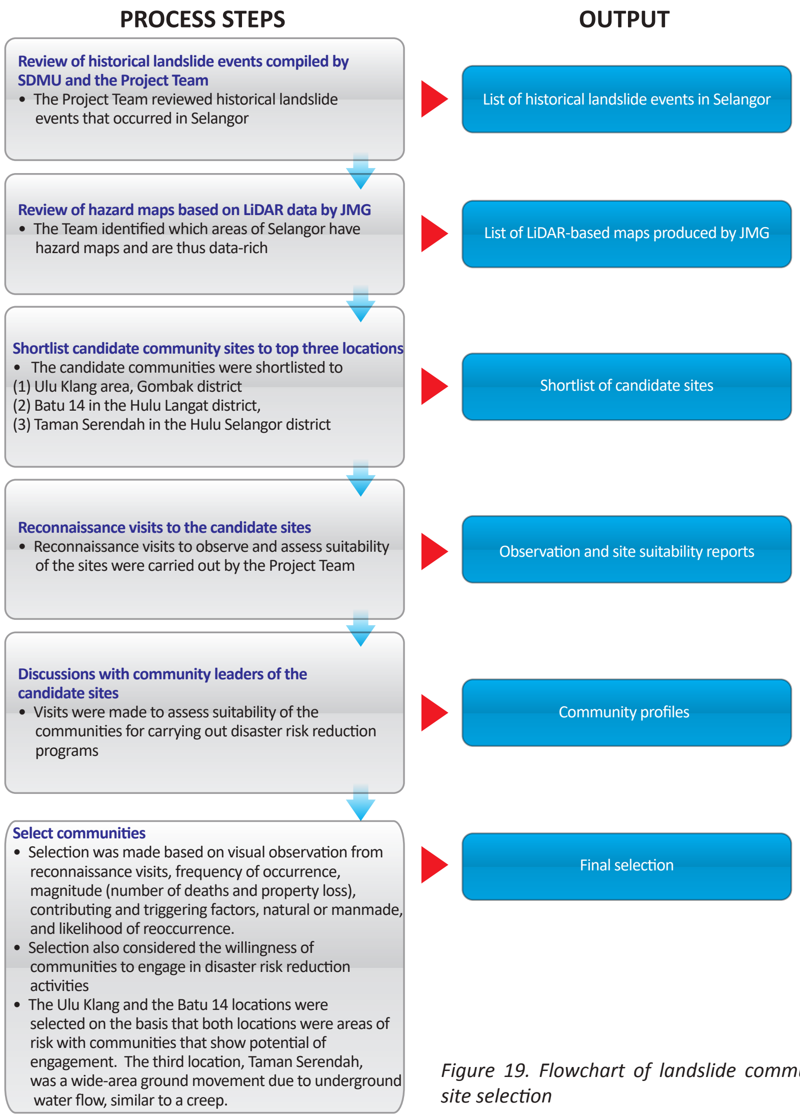


Figure 19. Flowchart of landslide community site selection

The Ulu Klang and the Batu 14 locations were selected on the basis that both locations were areas of risk with communities that show potential of engagement. The third location, Taman Serendah, was a wide-area ground movement due to underground water flow, similar to a creep and thus was not selected.

5.2 Site Selection of Communities for the Flood Component

Site selection for floods proved to be a bit more difficult than for landslides. This was mainly due to the fact that many of the floods in Selangor were flash floods or caused by tidal influences along the coast. The type of flooding desired by the Project Team was the overtopping of river banks.

After reviewing historical flood reports, visiting the candidate sites, and reading studies conducted in the candidate locations, the Project Team selected two locations: (1) Kampung Sungai Serai (in the Sg. Langat river basin) and (2) Kampung Tok Muda (in the district of Klang).

5.2.1 Site Selection Process

The process flow for the landslide community site selections is provided as in Figure 20:

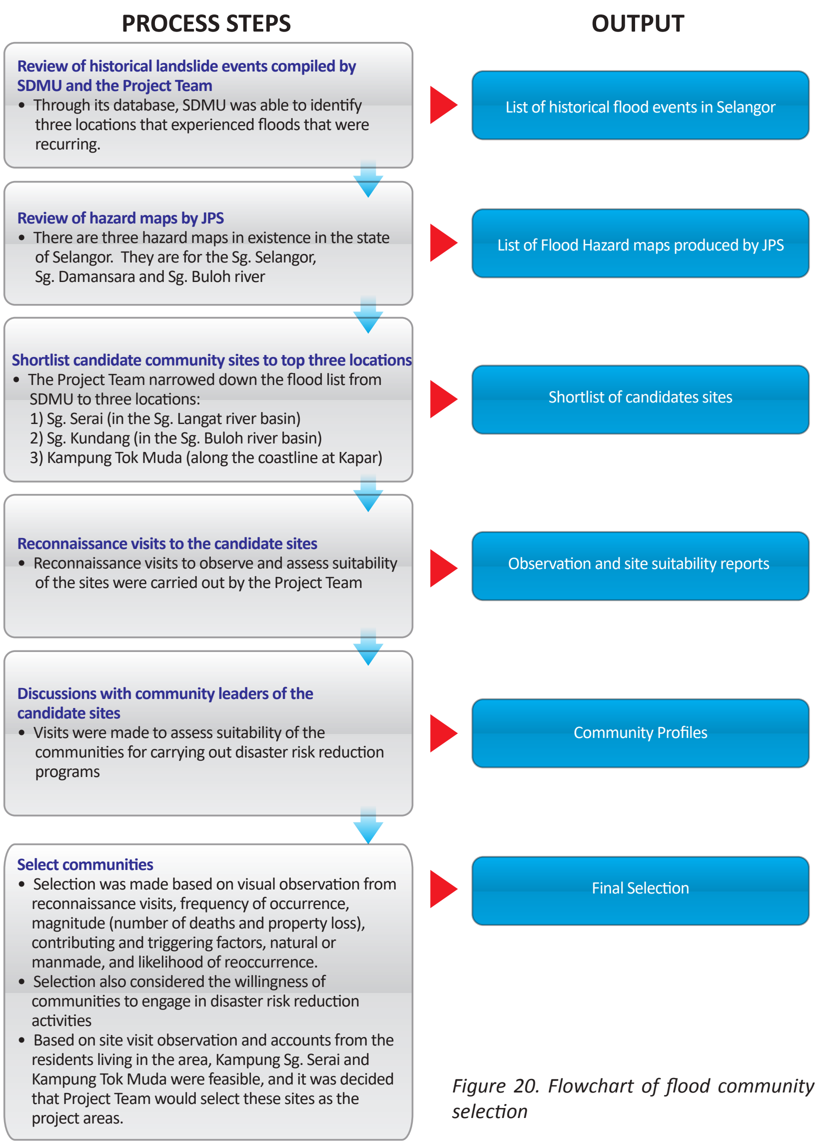


Figure 20. Flowchart of flood community site selection

There are some interesting notes to highlight in the selection process of flood project areas:

- There are three hazard maps in existence in the state of Selangor. They are for the Sg. Selangor, Sg. Damansara and Sg. Buloh river basins. Flood maps were created for the purpose of flood mitigation projects and have since been mitigated by the Department of Irrigation and Drainage. Thus, although these rivers were data-rich (hydrological and hydraulic data available through these risk map studies), they were no longer flood-prone and could not be considered as candidate project areas.
- There was one site within Sg. Selangor that was considered called Sg. Asahan, but discussions with the community leaders there said that there was recently a flood pump that was recently installed and the community was confident that the flood problems in the area were no longer an issue. Thus, they believed that a disaster risk reduction program was not relevant in this community.
- At the visit at Sg. Kundang, it was revealed that the river was in the middle of four urban development projects and drainage system upgrading was in the works. Similar to the Sg. Asahan case, once the physical drainage works were completed, floods would a thing of the past.
- The Tok Muda location visit showed that it was by the coastline, with the bund that has been raised to prevent seawater intrusion during high tide.
- During deliberations on choosing the sites for the Project, the Project Team was mindful not to select flood areas that were caused by man made factors—most predominantly being due to siltation from urban development and construction projects, bad or inadequate drainage systems, and solid waste pollution from residential areas that clogged up the waterways.

This left the need to identify one more site for the project. Kampung Tok Muda in the Klang district, north of Port Klang along the Selangor coast, proved to be an interesting candidate site for this project. Although it is located along the coast, the flooding events in 2016 and 2018 at Kampung Tok Muda and Kampung Sg. Serdang were triggered by the overtopping of a river bund and exacerbated by a combination of high tide and heavy rainfall.

Based on site visit observation and accounts from the residents living in the area, Kampung Tok Muda was feasible based on the fact that major infrastructural works was not planned any time in the future and the community was willing to engage in non-structural measures to mitigate the flood problems there. Thus, it was decided that Project Team would select this site as one of the project areas.

As a final note, it should be mentioned that the kind of floods experienced at Kapar and Hulu Langat are frequent but not fatal events. However, this does not negate the importance of these locations for disaster risk reduction, as disasters can come in the form of infrequent but fatal or non-fatal but frequent/chronic. The non-fatal but frequent type of disasters also have widespread consequences to communities: losses to property, losses in potential income (losses in agricultural yield), constant interruptions in the flow of businesses and daily life, lost productivity, and psychological and emotional stress. Therefore, the flood sites selected are suitable for this project.

6 Landslides: Science-Based Risk Identification

This section presents the four sites selected for the JPP project. The sites are:

1. Ulu Klang, Gombak
2. Batu 14, Hulu Langat
3. Kampung Sg. Serai, Hulu Langat
4. Kampung Tok Muda, Klang

For each site, the history of past events, profiles of the communities, and the risk analysis process and results are presented and explained.

6.1 Site 1: Ulu Klang Sub-District, Gombak District

6.1.1 About the Project Area

Ulu Klang is one of five state constituencies administered by the Ampang Jaya Local Authority (MPAJ). The sub-district of Hulu Kelang or Ulu Klang is located upstream of Klang River, northeast of Kuala Lumpur as shown in Figure 21.

The elevation is relatively high, 500 meters above sea level. Ulu Klang is a catchment area for Sungai Klang. Residential areas within the sub-district includes Taman Melawati, Taman Permata, Ukay Heights, Bukit Antarabangsa, Taman Sri Ukay, and Ukay Heights.

The area has an area of 16.94 km^2. The terrain is characterized by undulating land, with highland in the upper catchment.

Figure 21. Location of Ulu Klang, Gombak District

The area sits on a narrow ridge that extends in the northeast-southwest direction with a maximum elevation of 230 meters. The hill is underlain by granite whose characteristics are grey color, coarse grained particles and slightly porphyritic texture. Extensive weathering has transformed the granite into the residual soil (grade VI) and weathered material (grade V). The average thickness of the weathering profile is approximately 30 m. The weathered material is sandy and rapidly loses its consistency with increasing amounts of water.

Landslide Incidents in Ulu Klang

Ulu Klang has historically been known as a landslide-prone areas in Malaysia. The area has seen frequent incidents of landslides since the 1990's. Most of these landslides occurred on man-made slopes, and there are studies on analysis of rainfall effect to slope stability in Ulu Klang. The table below (see Table 5 and Table 6) shows the impacts of the landslide incident in Ulu Klang area with dates and location of the event.

DATE	LOCATION	CASUALTIES	LOSS of PROPERTIES
11-Dec-1993	Highland Towers	48 killed	Collapse of one block of 12-storey high apartment
15-May-1999	Bukit Antarabangsa	-	Closure of the main and only access road to the residential area
05-Oct-2000	Jalan Bukit Antarabangsa	-	Damage of road
20-Nov-2002	Taman Hillview	8 killed	Damage of 1 unit of bungalow
31-May-2006	Kampung Pasir	4 killed	Damage of 3 blocks of longhouses
24-Apr-2008	Condo Wangsa Height, Bukit Antarabangsa	-	Damage of 4 vehicles
6-Dec-2008	Taman Bukit Mewah, Bukit Antarabangsa	5 killed, 7 injured	Damage of 14 units of bungalow

Table 5. Impact of the landslide incidents in Ulu Klang area

NO	DATE	LOCATION
1	11.12.1993	Highland Towers
2	14.05.1999	Bukit Antarabangsa, Ulu Klang-Ampang
3	15.05.1999	Menara Athaneum, Ulu Klang
4	05.10.2000	Bukit Antarabangsa, Ulu Klang-Ampang
5	29.10.2001	Taman Zoo View, Ulu Klang
6	08.11.2001	Taman Zoo View, Ulu Klang
7	20.11.2002	Taman Hillview
8	02.11.2003	Kondominium Taman Oakleaf, Bukit Antarabangsa
9	07.11.2003	Jalan Bukit Mulia, Bukit Antarabangsa, Ulu Klang
10	31.01.2005	Jalan Tebrau, Dataran Ukay, Ulu Klang
11	01.02.2005	Jalan Tebrau, Dataran Ukay, Ulu Klang
12	31.05.2006	Taman Zoo View, Kampung pasir, Ulu Klang
13	06.12.2008	Bukit Antarabangsa, Ulu Klang
14	19.09.2009	Wangsa Height, Selangor
15	21.06.2011	Taman Bukit Jaya, Selangor

Table 6. Date and location of landslide events in Ulu Klang

Given the undulating topography, hilly terrain, weak geological materials, and densely populated area with elements-at-risk such as residential houses, public facilities, transportation and utilities, this area has been selected for strengthening disaster risk reduction capacity of the local communities.

6.1.2 About the Community

Communities along Ulu Klang stretch from the Melawati area to the Ukay Heights/Taman Hijau neighborhoods, before Taman Tun Abdul Razak. All these communities are situated at the foothills or on hillsides of the Titiwangsa Range, the chain of mountains that run along the length of the country from north to south. The residences are mixed, ranging from high-income to low-cost.

Population – The population of Ulu Klang is 112,956. There are six (6) villages or kampungs, and 79 housing developments.

Pre-Existing Knowledge – Most communities are aware of the risks of slope failure in the area based on actual landslide occurrences, visual signs and media reports. Some communities have an active slope monitoring and reporting system, while others do not have a formal structure.

Concerns – The residents' concerns are new hillside developments and how they impact adjacent terrain.

Social capital – Communities that have a mixture of lower, middle and upper income household groups have active social calendars and communal gatherings. However, for very high-income communities, residents tend to have direct line of contact and influence on local government heads and political figures. These groups rely less on social, community events and more on issues-driven one-on-one sessions with local government and town hall meetings.

Information network – All community members are heavy users of social media.

Community leadership – Each community has two levels of leadership: one is the Village Head Community Council (*Majlis Pengurusan Komuniti Kampung – MPKK*) shown in Figure 22. It is at the mukim or sub-district level, and is headed by the chairman, with various portfolios or bureaus. Slope safety falls under the 'Security' bureau.

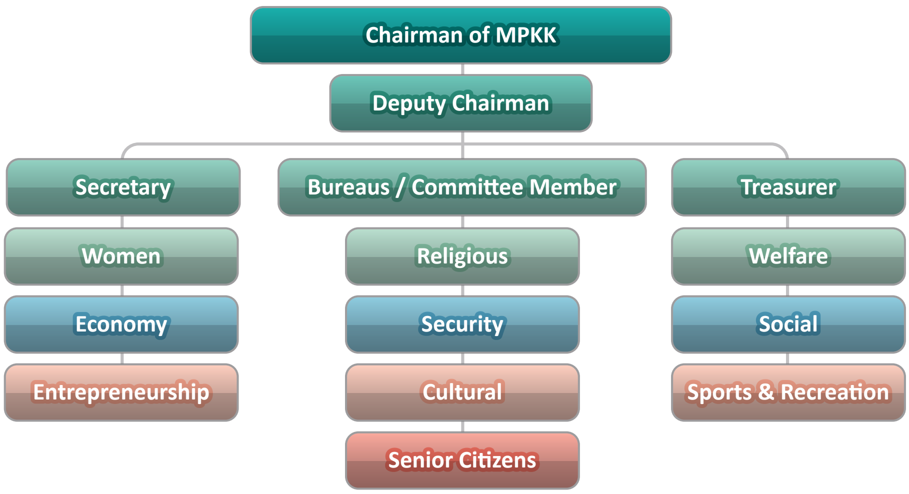


Figure 22. Community leadership structure in Ulu Klang

The other leadership structure is the local council committee or *jawatankuasa penduduk*. The local councilor is affiliated with the local authority and not with the district. Each committee is headed by the local councilor and is supported by portfolios or bureaus. Similar to the MPKK, the committee also has a Security bureau that oversees slope safety.

There is some uncertainty among the residents over which structure is in charge of slope safety within overlapping boundaries of jurisdiction.

6.1.3 Risk Analysis Using a Science-Based Approach

To identify risk in the Ulu Klang area, this study used the hazard maps created under the Slope Hazard and Risk Mapping (PBRC) project by the Department of Mineral and Geoscience (JMG) Malaysia. PBRC is a national initiative that maps and identifies landslide hazards and risks in urban, mountainous and tectonically active regions throughout the country for use by policy makers, planners and risk managers.

A brief explanation of how the hazard maps were generated under PBRC is provided below.

Methodology for Identifying Risk Zones

__LiDAR__, which stands for Light Detection and Ranging, is a technology that produces a georeferencing map by scanning the ground area using lasers from high-flying aircrafts.

In order to come up with hazard and risk maps, JMG used state-of-the-art airborne and terrestrial LiDAR technology and GPS surveys to capture data and then used specialized geoprocessing tools such as Geographical Information System (GIS) processing modules and 2D/3D visualization models. Figure 23 below shows the types of data capture and data processing methods used in creating high-resolution terrain models.

Figure 23. Data and processes used in the Slope Hazard and Risk Mapping (PBRC) project
Source: PBRC Project, JMG Malaysia

A __hazard map__ is used to depict danger from landslides of given magnitude.

It may use locations of old landslides to indicate potential in stability incorporating probabilities based on variables such as rainfall, earthquake, slope angle and soil type.

The workflow of the processes in PBRC are broken down into phases (see Figure 24) consisting of data acquisition and creating maps for landslide inventory (a collection of past and current landslides), analyzing susceptibility, identifying elements-at-risk, determining vulnerability, and assessing risk. The final step of this project is the development of a portal created by JMG called NaTSIS, which is a repository of geospatial information.

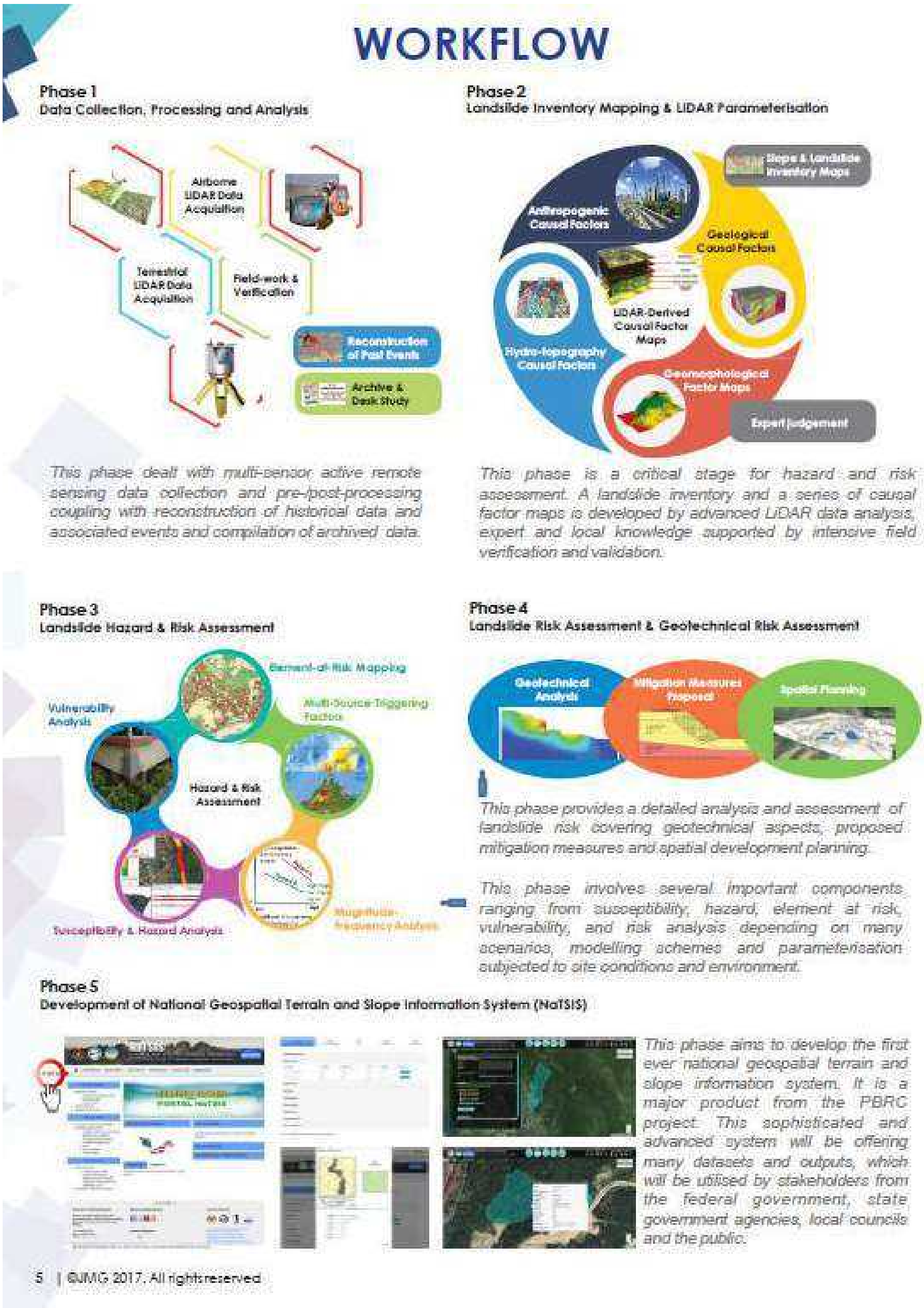


Figure 24. Workflow of the Slope Hazard and Risk Mapping (PBRC) project
Source: PBRC Project, JMG Malaysia

It is the output of these processes—the primary and secondary maps—that are of interest in this study. The significance of the slope maps and landslide hazard maps created under PBRC is that they allow us to better understand the root causes of future mass movements and slope failures.

Visual-Based Analysis

Let's take a look at maps in the Ulu Klang area.

Figure 25. Orthophoto of the project area in Ulu Klang (Gombak, Selangor) with indication of possible failure area

Analysis using orthophoto

Using a technique called *photogrammetry*, a particular type of aerial map—an orthophoto—was produced (see Figure 25). Orthophotos are different from ordinary aerial maps in that they are adjusted to provide a top-down view. In this map, we see built-up areas amidst a landscape of vegetation and trees.

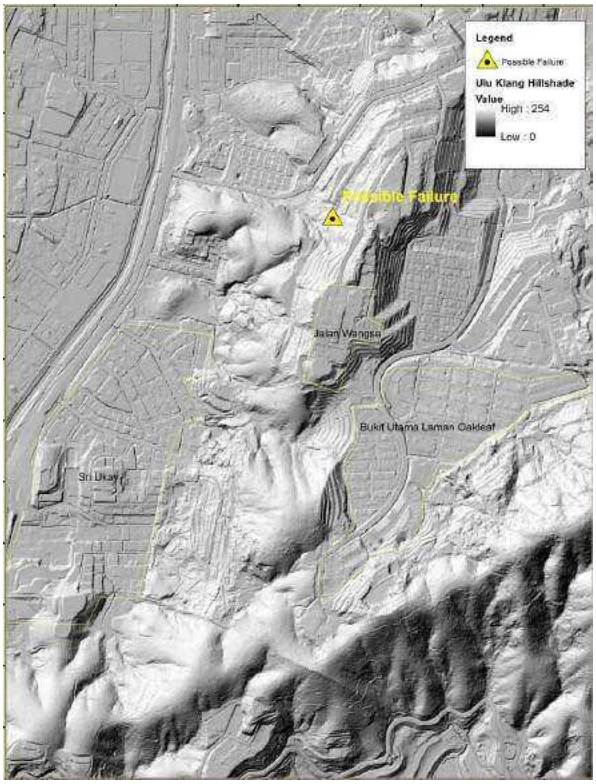


Figure 26. Shaded relief map derived from high resolution LiDAR-DEM for the project area with indication of possible failure
Source: PBRC Project, JMG Malaysia

Analysis using shaded relief map

In the following map, we now see the same area with the vegetation and built-up areas removed (Figure 26). This is a shaded relief map that was created using high-resolution LiDAR. With LiDAR, we can see the bare terrain beneath dense forest cover.

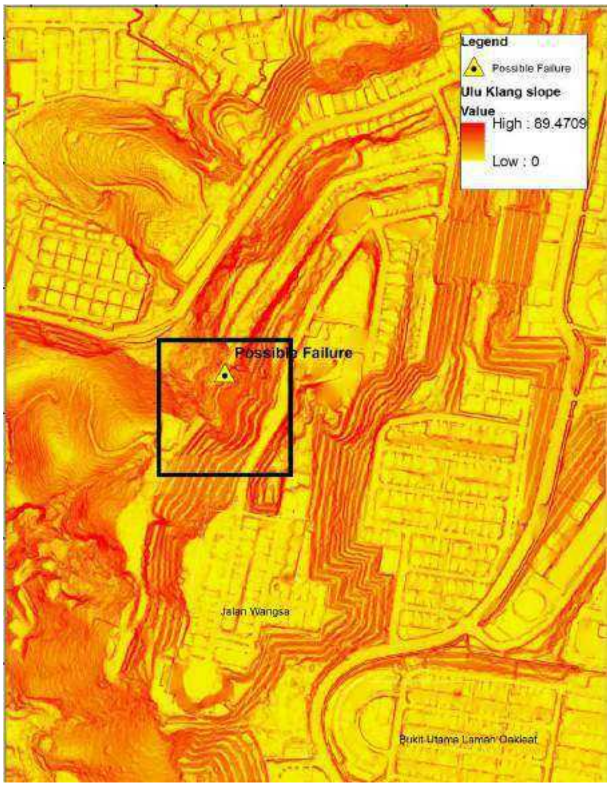


Figure 27. Slope map of the project area with indication of possible failure (black box) and slope of up to 89 degrees
Source: PBRC Project, JMG Malaysia

Analysis using slope map

Figure 27 shows a more accurate slope map, which can also be used to visualize slope gradient in a 3-dimensional model. This slope map provides clues to risk managers about topography (hilly and flat terrain) and proximity of slopes to any elements-at-risk (houses, buildings, structures). The map also identifies the level of susceptibility (probability of failure) and hazard (extent of possible damage).

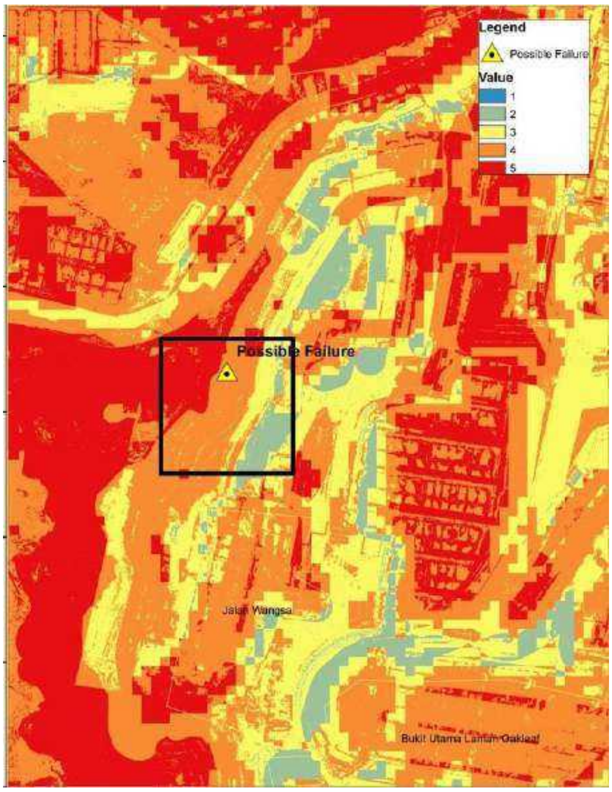


Figure 28. Landslide hazard map over the project area using GIS-based statistical landslide hazard assessment. Red color indicates a very high hazard for future landslide occurrence in the vicinity
Source: PBRC Project, JMG Malaysia

Analysis using landslide hazard map

When this slope map is combined with causal and triggering factor maps, a GIS-based landslide hazard map can be statistically produced (see Figure 28). In this landslide hazard map, we observe that the terrain is divided into zones of probability of landslides occurring according to intensity (high to low). We see that the area is largely dominated as high hazard (shown as red). A smaller portion of the map, in yellow, shows lower hazard levels. It should be noted that some of the residential areas that fall under the category of high hazard not only have slopes that are steep, but also consist of weak geological material, experience a high degree of 'weathering', and are subject to intense or prolonged rainfall. These causal and triggering factors are what makes this particular area 'high hazard'.

When we zoom in on a particular location within this area, we can see the difference between the orthophoto and the shaded relief map (Figure 29). In the shaded relief map, the topography of the terrain indicates that this location may be prone to landslides. There also appears to be an abandoned construction for a housing development downslope. As for the slope itself, there seems to be previous construction activity on terrain that seems to be deteriorating retrogressively, or eroding from the bottom up.

Figure 29. Possible failure was located in the vegetated terrain, with (A) orthophoto of the area and (B) digital terrain model viewed over the high susceptibility to landslides

What does the future hold for this area? Figures 30 and 31 present the current and future land use in the project area. The current land use map shows this area as largely an open area with some residential and commercial zones, whereas the future projected land use shows that the open area will be converted into residential and public facilities.

Based on this, development demand for residential area seems to be increasing in this area, even so in the forested and vegetated terrain (see the maps on the right that show the land use map overlaid on the orthophoto). In this way, risk profiles change over time. Thus, it is important for stakeholders such as local governments, private sector, civil societies and vulnerable communities to engage in disaster risk reduction activities to mitigate any landslide disasters.

Figure 30. Current land use over the project area

Figure 31. Current land use over the project area

6.1.4 What Did We Find Out?

The main findings for this project area are as follows:

In this section, we found out that hazard and risk maps are a powerful communication medium for identifying landslide hazards and risks. By stripping away vegetative cover, shaded relief maps derived from LiDAR digital elevation models expose the terrain beneath to show past or current human activities as well as natural geological or hydrological processes. In this project area, the shaded relief map or hillshade view shows that what appears to be a 'natural slope' to the naked eye is in fact ridden with potential failure features. Using maps derived from remote sensing, the 'signature marks' or signs of an impending slope failure can be detected.

The risks identified through the above methods are as follows:

- In this project area as a whole, we found out from the landslide hazard map that the area is largely dominated as high hazard (shown as red). A smaller portion of the map, in yellow, showed lower hazard levels.
- From the shaded relief map, we saw that a location within the vicinity may be prone to landslides.
- There also appears to be an abandoned construction for a housing development downslope.
- As for the slope itself, there seems to be previous construction activity on terrain that seems to be deteriorating retrogressively, or eroding from the bottom up.

Other Findings and Observations

It is important to note that other elements required for visual-based analysis are (1) the tools to carry out GIS processing for 3D modeling, (2) expert knowledge to identify and diagnose landslide features, and (3) an understanding of the root causes of potential failures based on knowledge of causal and triggering factors.

This requires a collaboration between the academia, government agencies, and community leaders. With hazardous areas identified and landslide risks clearly understood by slope managers, local authorities and the community members, they can take the next step in disaster risk reduction.

6.2 Site 2: Batu 14, Hulu Langat District

6.2.1 About the Project Area

The second landslide project area is located in Batu 14, Sg. Gahal, Mukim Hulu Langat, Hulu Langat District, Selangor. The project area, measuring about 300 hectares, falls under the jurisdiction of Kajang Local Authority (MPKj). This project area is located in the sub-urban area in the district of Hulu Langat, Selangor, with low population density but large tracts of land for plantation, farming, and agriculture activities.

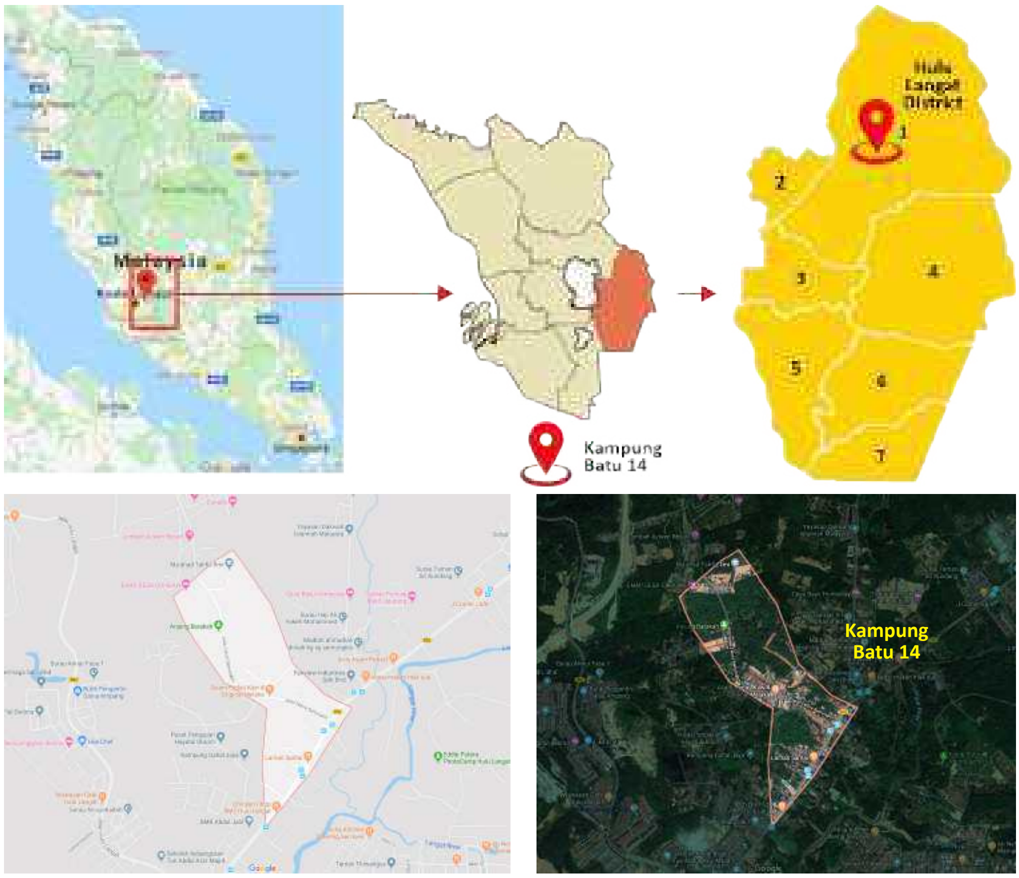


Figure 32. Location of Kampung Batu 14, Selangor

Source: adapted from Google map (accessed on 3 April 2019)

The area is situated approximately 12 km east of Kuala Lumpur and about 3.6 km to the northeast of Pekan Batu 14 (see Figure 32). It is in the catchment of Sg. Gahal, which is the main tributary of Sg.Langat.

The area was selected as a result of a 2011 landslide that occurred at an orphanage/religious school, Rumah Anak-Anak Yatim dan Kebajikan Madrasah At-Taqwa, situated on Lot 301 on Jalan Felcra Semungkis. The landslide, which occurred at 2:30 p.m on May 21, claimed a total of 25 victims (21 children and four school staff members). Sixteen lives were lost.

Based on the forensic investigation report by the Public Works Department, the failure was due to a non-engineered slope construction, which was cut as a single faced slope with an angle of up 60 degrees and a height of up 23 m. The landslide originated from a steeply cut slope located at the back of the 3-storey building that was built at the foot of the slope. It was reported about 2,300 m^3 of earth had been transported, with maximum run-out distance of 11 m. Continuous rainfall over a period of nine days had caused excessive infiltration of surface water into the ground and triggered the landslide.

Figure 33. Landslide area: Children's Hidayah Madrasah At-Taqwa orphanage

Landslide Incidents in Batu 14

According to the community leaders, there has been no large-scale landslides before 2011. Since then, there have been a number of minor incidents. In April 2019, there was a big landslide on a private land in Kampung Sg. Gahal near Jalan Felcra Semungkis. Rocks from the gabion wall fell into the river, and there were no reports of damages to adjacent houses despite being very close by. The slope owner engaged in repairs, but the slope integrity remained questionable as the site and the housing were too close to the river. The village head stated that developers tended to not maintain the buffer zone around the developed area for purposes of drainage and safety. The 2011 At-Taqwa landslide is along the same road on Jalan Felcra Semungkis (see Figure 33), about 1.4 km away from the recent landslide site.

Ten years ago, there was a slope around Sg. Semungkis, near Impian Resort, where the village leader observed cracks and signs of slope failure from above. But it has now been covered with vegetation. Community leaders acknowledge that local authorities are not involved in monitoring the site, as it is private property.

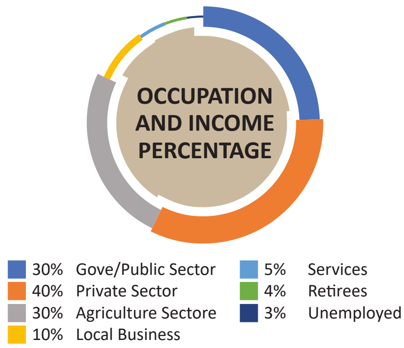
Field Observation of the Project Site

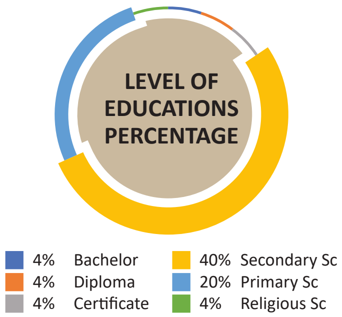
In addition to remote sensing observation of the overall project area, field observation of the 2011 landslide site was carried out. The orphanage building was built in 1997 on natural terrain with a slope gradient above 35 degrees. The natural slope was steeply cut to attain the desired platform level and maximize space for the orphanage facilities within the compound. An access road to the upper slope had been built at the left side of the orphanage building. No systematic drainage system was constructed. The steepness of the slope, compounded by inadequate and improper surface drainage system, were the primary causes of the landslide that took place 14 years after construction.

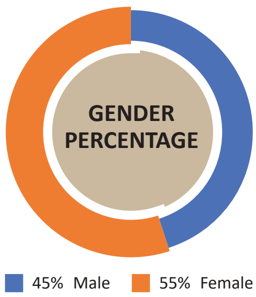
Based on aerial photos (1982, 1989, 1992, 1996, 2000, 2005) from the Department of Survey and Mapping (JUPEM) Malaysia, human activities of slope cutting and clearance of rubber trees at the upper slopes were observed. It is not clear what they were being developed for. An access road to the upper slope was built at the left side of the Madrasah. The area had been abandoned since then and later secondary forest was overgrown.

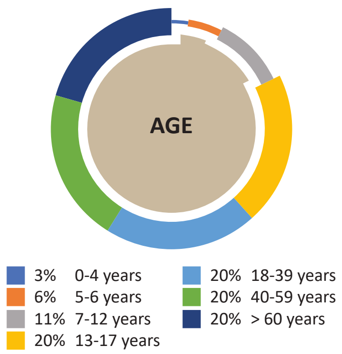
This slope characterization is not unique to the orphanage centre lot. A similar scenario and landscape can also be observed within the greater Batu 14 area.

6.2.2 About the Community









The Kampung Batu 14 village is a traditional village located in Mukim Hulu Langat, Hulu Langat District. The village is located about 2 km from the nearest town of Hulu Langat and 42 km from Shah Alam, the state capital of Selangor.

Located at the eastern fringes of Kuala Lumpur, Batu 14 is surrounded by forest and rolling hills. It offers many natural tourism and outdoor recreational attractions such as waterfalls, picnic areas, hot springs and hiking trails. The area attracts tourists and business entities for retreats and team-building activities, and there are a number of homestays. It is a rural area that is seeing rapid urban development, and private land belonging to absentee landowners are starting to be developed for residential homes as well as resorts.

Population – Total population including absentee land owners is 2,989. Permanent residents comprise 1,978 villagers (358 families) or 67% of the population. Other residents are from Indonesia, Bangladesh, Pakistan, Vietnam. Felcra has 75 settler houses. Some locals lease their land to foreigners, and they build squatter houses. There are no *orang asli* (aboriginal) people in Batu 14 (they are located mostly closer upstream of Sg. Langat near the dam).

Pre-existing Knowledge – No DRR programs have been recorded in the past.

Concern – Ongoing East Klang Valley Expressway (EKVE) construction runs along Sg. Gahal.

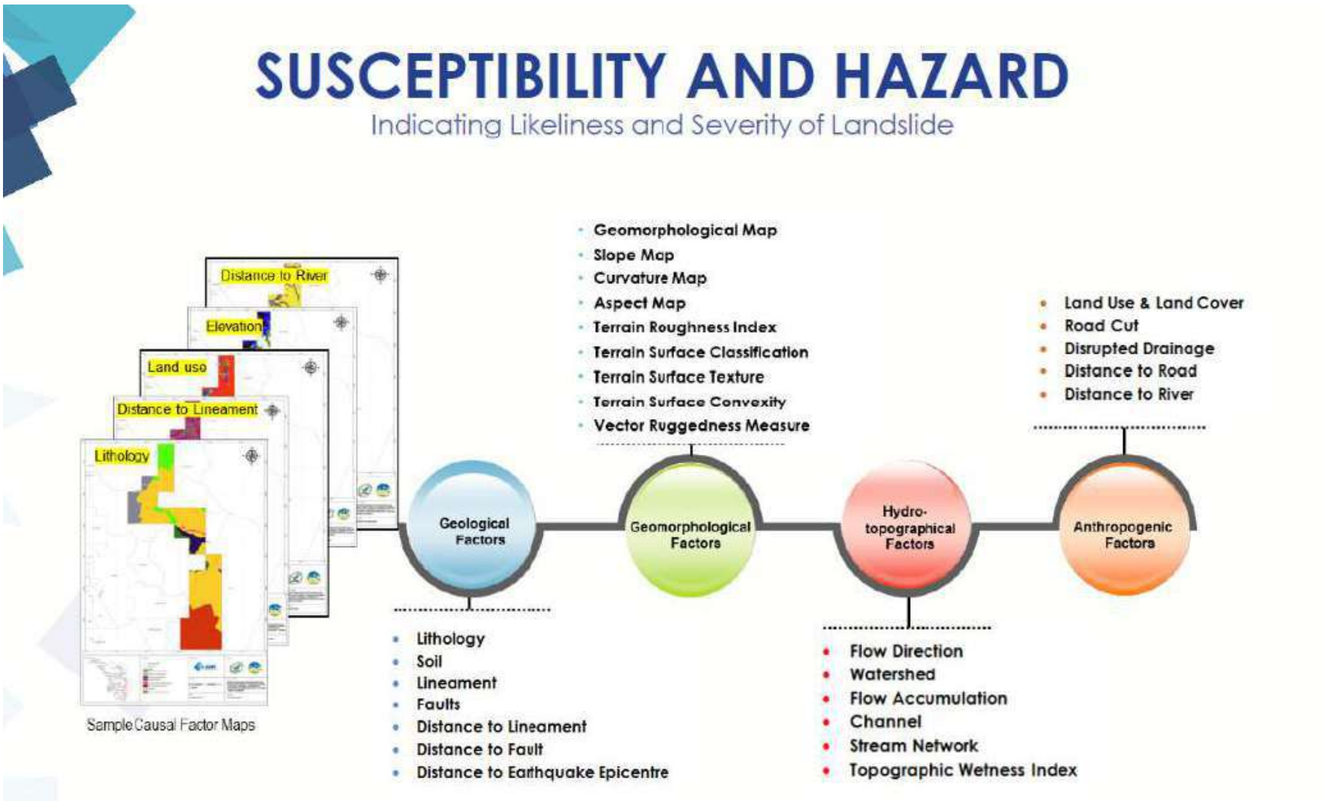
Social capital – Community get-togethers: *Rewang* activity (communal cooking) was common but has been reducing recently. Community clean-up (gotong-royong) activities are still going on, but most community programs are attended by the same people, who are mostly older generations. Sg. Semungkis has a *kompang* (traditional drums) band of up to 60 members. Kampung Batu 14 has futsal, takraw and badminton courts which are actively utilized by the community.

Information network – The community is familiar with Whatsapp. There is an established information network within the community between the leaders and the people.

Community leadership – The community leadership structure driven by the Village Head Community Council or Majlis Penduduk Ketua Kampung. The structure is the same as that described in the section on Ulu Klang.

6.2.3 Risk Analysis Using a Science-Based Approach

Analysis for this project site also is based on maps created under PBRC project under JMG. As explained in the previous section for Ulu Klang, these maps were generated using airborne and terrestrial LiDAR technology and GPS surveys to capture data and were processed through specialized geoprocessing tools.



Susceptibility and hazard maps produced under the PBRC project
Source: PBRC Project, JMG Malaysia

Visual-Based Analysis

A risk analysis of the Batu 14 project area is explained below.

Figure 34. Aerial view or orthophoto of the project area (300 ha) in Batu 14 with clear indication of anthropogenic activity particularly in east, and south part of the project area

Source: PBRC Project, JMG Malaysia

Analysis using high-resolution orthophoto

The Batu 14 area is characterized by cut and fill slopes that dot the project area. Visual investigation (see Figure 34 and Figure 35) indicates that original terrain in some areas have been excavated, most of the vegetation on the hills have been stripped, and building structures constructed very close to the foot of the slope to maximize the space within the designated lot. Some of these human activities appear to have taken place within the last few years, with the passage of time allowing secondary vegetation to grow and provide an appearance of undisturbed ground. Some of the slope cuttings created areas of temporary water accumulation zones, which allow water to infiltrate the soil during intense and prolonged rainfall.

Some areas appear to be ongoing new developments for residential construction and partially developed land in phases of construction, while some areas appear to be abandoned without proper drainage and slope maintenance.

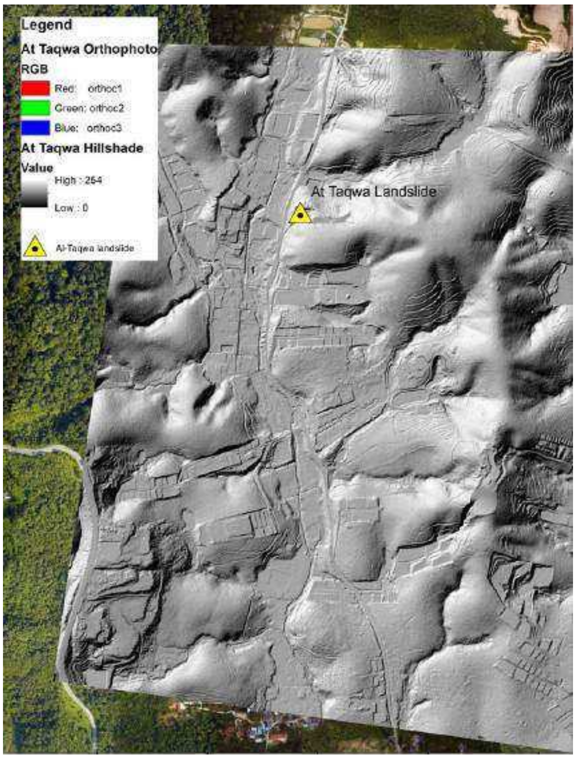


Figure 35. Shaded relief map derived from airborne LiDAR data over the project area with indication of 2011 At-Taqwa landslide at Batu 14

Source: PBRC Project, JMG Malaysia

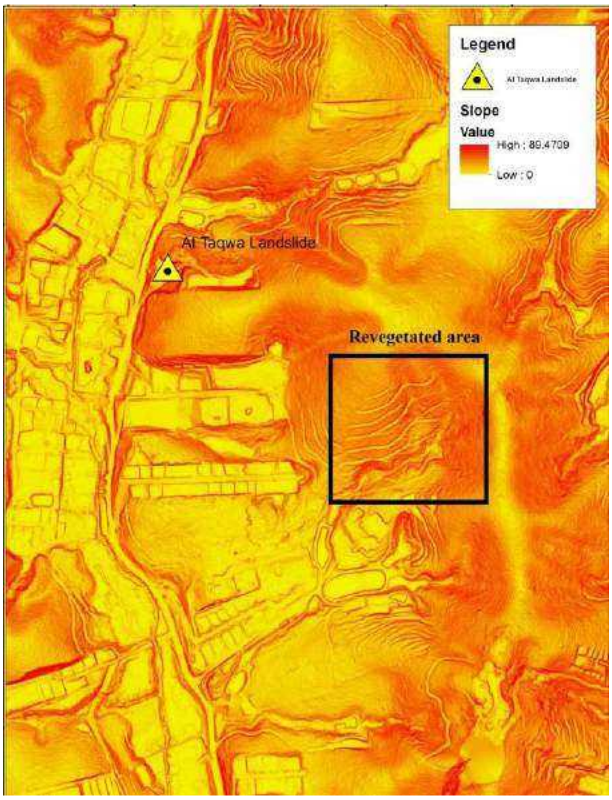


Figure 36. Slope map of the Batu 14 project area
Source: PBRC Project, JMG Malaysia

Analysis using high-resolution slope map

The main road, Jalan Felcra Semungkis, was constructed in the late 1970s for large-scale development of agriculture land. Disturbed terrain due to land clearing for large-scale agriculture and smallholder farming in the past are visible in the map. Gradually, slopes along both sides of the road began to be developed. The topography of this narrow valley is steep terrain with slope gradient ranging from 25 to 40 degrees. To the west of the project area is a forest reserve gazetted by the state of Selangor, while to the east the forest was cleared for urban and agricultural development.

In Figure 36, we see agricultural activity as well as past forest clearing (tracks are visible in the box). After time, areas like this are re-vegetated.

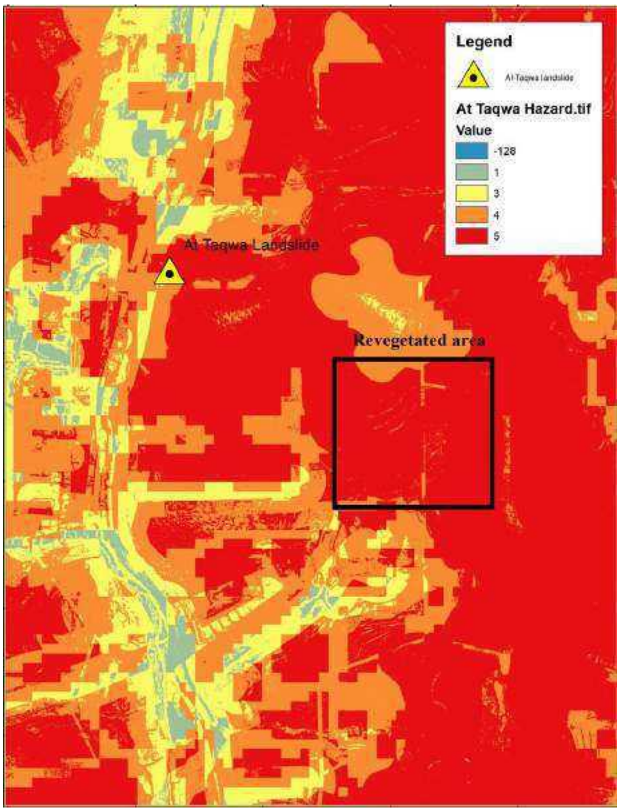


Figure 37. Landslide hazard map of the Batu 14 project area
Source: PBRC Project, JMG Malaysia

Analysis using the landslide hazard map

The landslide hazard map (see Figure 37) was produced using statistical-based landslide modeling. The map provides a visualization of the terrain in higher resolution than the slope map, at 0.5 m. Based on statistical-based landslide assessment using this map, we see that the area is predominantly categorized as high to very high level of hazard, particularly in the eastern part of the area.

The rugged topography of the project area reveals an area made up of steep terrain and narrow valley with gradient of between 25 degrees to 40 degrees and exposed to high degrees of vulnerability to future landslides. In most areas, the disturbed terrains are widely distributed in the form of cut slopes, platforms and filled areas. With climate change and environmental degradation, the probability of future occurrence of landslide is high.

Overlay of orthophoto, hillshade and land use

A comparison of the orthophoto and hillshade views (see Figure 38) show that massive agriculture activity and forest clearing have taken place in the past with the trace of track (see rectangle box). After several years, the areas have been re-vegetated.

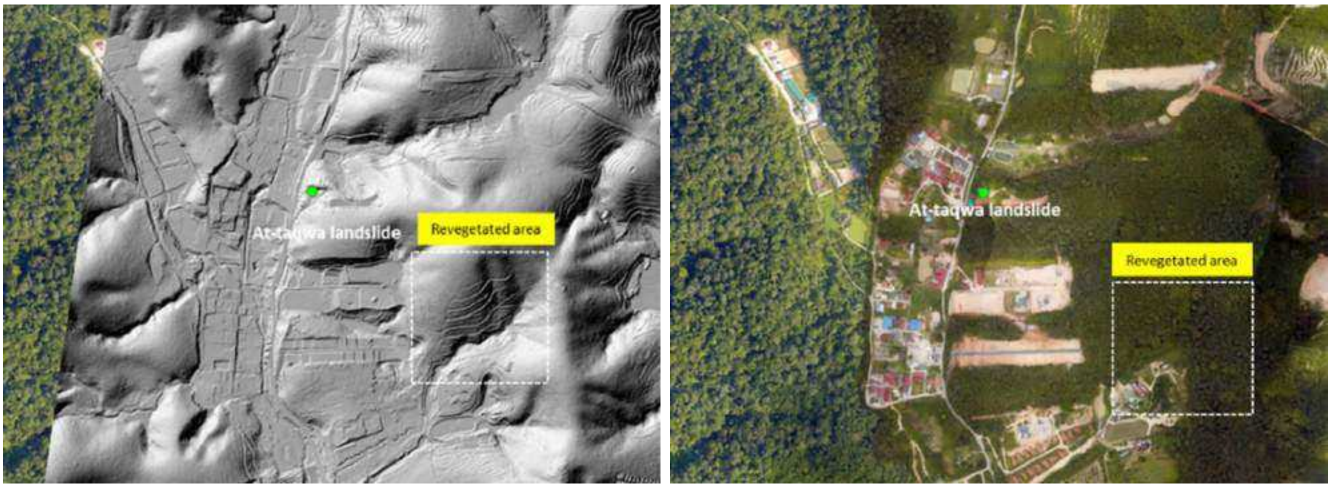


Figure 38. Orthophoto and hillshade showing some revegetated area with high degree of anthropogenic activity, e.g. slope cutting for new development in the project area in Hulu Langat

The current land use map (Figure 39) shows that the area is largely covered by agricultural activity, with only a small portion is dedicated to open area, forest, and residential zones. With an orthophoto overlay, it can be clearly seen that many agricultural activities had taken place, particularly in the southeastern area.

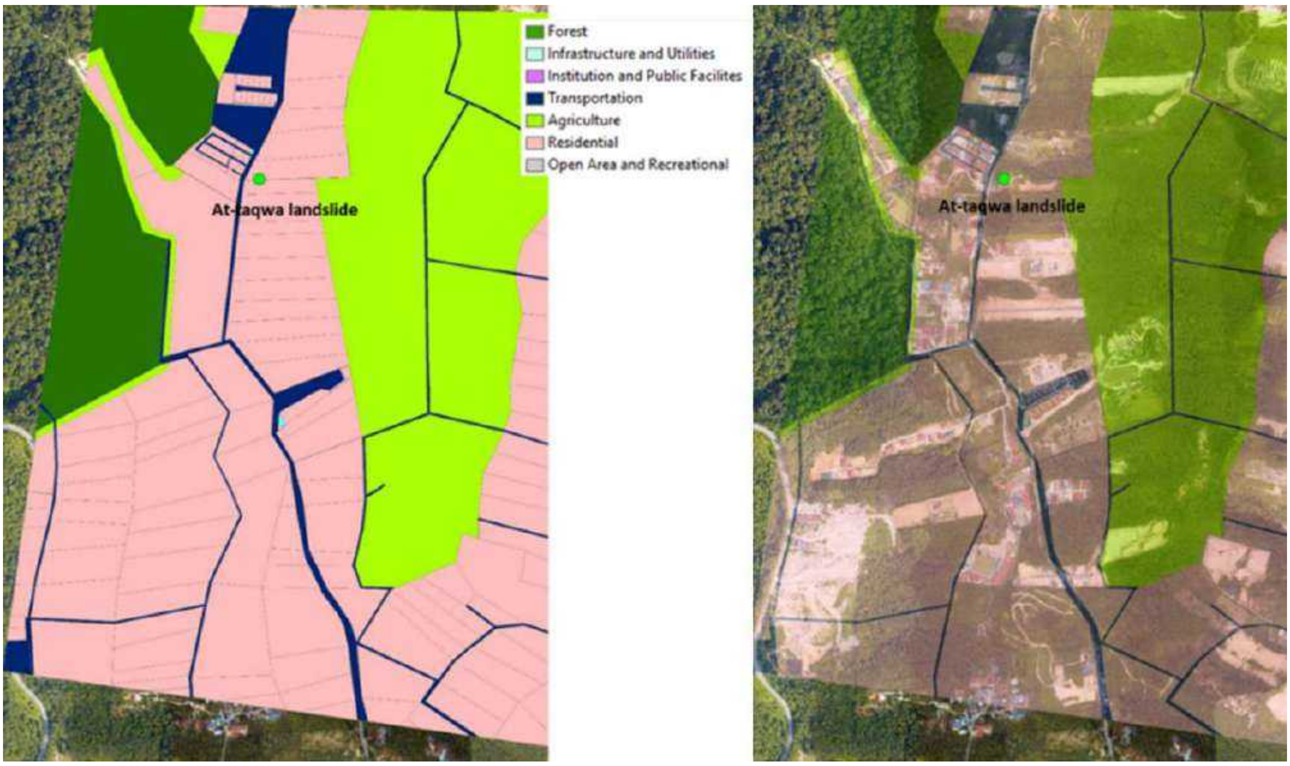


Figure 39. Current land use over the area

Looking forward, the future land use map (see Figure 40) shows that this area will become predominantly residential. With increased risk introduced by higher population and structural density, land conversion from open space and agriculture area into urban development mandates special attention by approving government agencies, developers, and local communities.

Figure 40. Future land use over the area

6.2.4 What Did We Find Out?

We saw from the various maps that:

- The use of orthophotos and landslide hazard maps make it possible to identify and analyze unseen topography beneath dense vegetation cover. In this project area, it appears that landslides are induced by small degrees of land disturbances, particularly at toe of the slopes, and the area is largely characterized by heavy rainfall.

The risks identified through the above methods are as follows:

- Original terrain in some areas have been excavated, most of the vegetation on the hills have been stripped, and building structures constructed very close to the foot of the slope to maximize the space within the designated lot.
- Some of these human activities appear to have taken place within the last few years, with the passage of time allowing secondary vegetation to grow and provide an appearance of undisturbed ground.
- Some of the slope cuttings created areas of temporary water accumulation zones, which allow water to pond during intense and prolonged rainfall.
- Hulu Langat is a popular recreational area that serves as a forest getaway close to the city. Nestled in greenery and shady hillside forests, Batu 14 and its neighboring areas are popular destinations for resort owners, homestays, team building operators, fishing ponds operators, and other tourism-oriented businesses. As tourism is a key industry in this area, construction on slopes need to be properly carried out to reduce the risk of failure.

Other Findings and Observations

The main factors of slope failures in this area are bad practices in slope cutting, ad-hoc renovation and construction of additional building structures on slopes without consideration of loading factors, and improper drainage systems without any maintenance.

Other factors include non-engineered hillside construction that led to slopes currently in service with low factors of safety and lack of adequate buffer zones between the toe of the slope and building structures.

Finally, phase-by-phase construction and development projects that are carried out over long periods of time as well as abandoned construction sites pose threats to slope stability, as they allow bare earth to be exposed to the natural elements.

This area is particularly sensitive as it comprises predominantly agricultural land and as such, are not subject to slope engineering guidelines and requirements stipulated for urban and other types of development. This is an issue plaguing not only this project area but in other places throughout the country. The exemption of agricultural land from regulations and requirements has resulted in uncontrolled land clearing on slopes. The lack of oversight on slopes in agricultural land has resulted in fatalities, and revisions on legislation would alleviate the risks being posed.

6.2.5 Simulation of the 2011 Hulu Langat Landslide

This section shows how the 2011 landslide at the At-Taqwa Madrasah occurred using numerical simulation. Numerical simulation is based on calculations that is run on a computer. It follows a program that implements a mathematical model for complex physical occurrences, including landslides.

The numerical simulation for the Hulu Langat landslide shows what happened to the slope and the house that was situated at the foot of the slope. To see the extent of the landslide being simulated, Figure 41 and Figure 42 show aerial photos taken before and after the landslide. Figure 43 shows a photo taken just after the landslide.

The numerical method used in this simulation has been developed by author's research group.[10]

Figure 41. An aerial photo taken before the landslide (Google map)

[10] *Moriguchi S., Borja R. I., Yashima A. and Sawada K., Estimating the impact force generated by granular flow on a rigid obstruction, Acta Geotechnica, Vol. 4, No. 1, pp.57-71, 2009*

Figure 42. An aerial photo taken after the landslide
Source: https://crisp.nus.edu.sg/coverages/HuluLangat_landslide/index.html

Figure 43. A photo of structural damage
http://edition.cnn.com/2011/WORLD/asiapcf/05/22/malaysia.landslide/index.html

Simulation of landslide

In this method, soil is assumed to be a Bingham fluid, and governing equations of fluids are solved to describe flowing soil. The flow behaviors of soil can be controlled by adjusting two key parameters, which are internal friction angle and cohesion.[11] Topography was modeled using real data. Figure 44 shows the simulated results of the numerical simulation. We can see flow behavior from the figures, and this information might be useful from an engineering viewpoint.

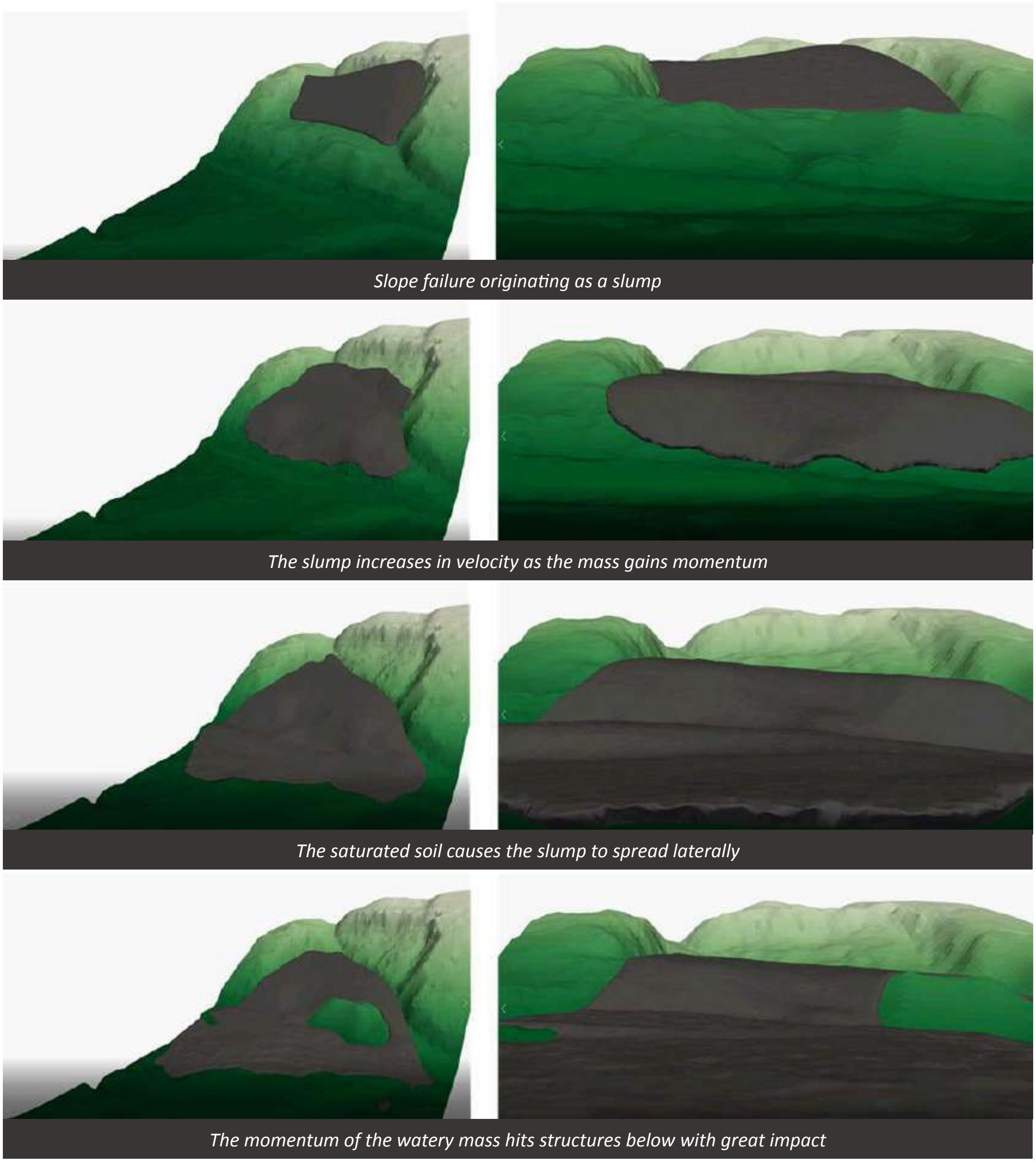
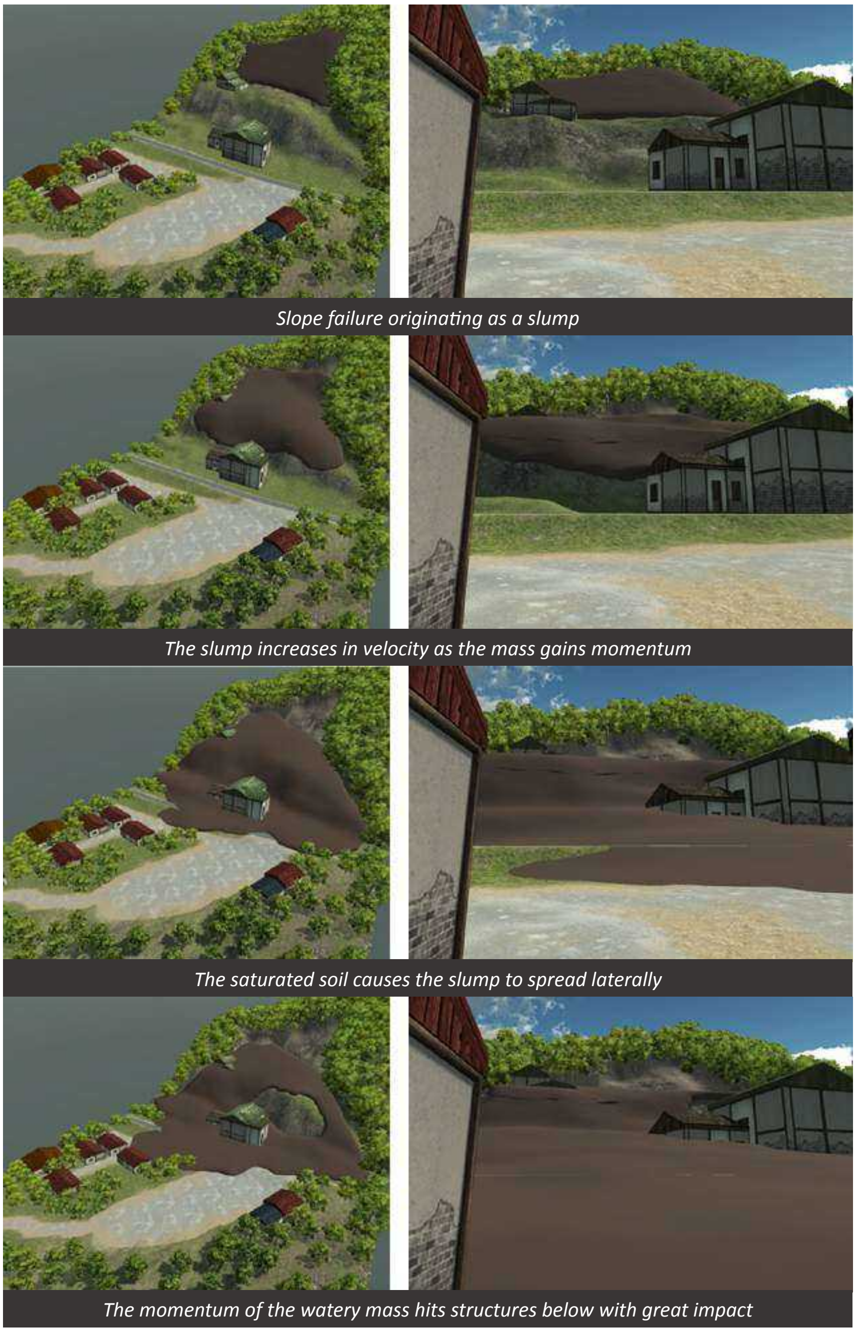


Figure 44. Simulated results of the numerical simulation

However, original results from numerical simulation do not communicate well as an education tool to non-technical audiences. Thus, to appeal to a mass audience, we tried to visualize the simulated results using Unity.[12] Unity is a game development platform that depicts 3D realistic visuals. Visualized results are shown in Figure 45.

[11] *Oda K., Moriguchi S., Kamiishi I., Yashima A., Sawada K. and Sato A., Simulation of snow avalanche model test using computational fluid dynamics, Annals of Glaciology, pp.57-64, Vol.52, No.58, pp.57-64, August 2011*

[12] *Unity Home page, https://unity.com/*



Slope failure originating as a slump

The slump increases in velocity as the mass gains momentum

The saturated soil causes the slump to spread laterally

The momentum of the watery mass hits structures below with great impact

Figure 45. Simulated results visualized using gaming application Unity

6.2.6 What Did We Find Out?

In this section, we found that:

- Simulation of disasters is a powerful communication tool in showing the consequences of a hazard. It is not used for risk identification, but for risk visualization during occurrence. The full impact of disaster events is not fully conveyed with maps, whereas simulations show just how dangerous these events can be. This is helpful for stakeholders when communicating disaster risk.
- The landslide simulation shows how the landslide moved in two retrogressive movements, meaning that the slope failed in two movements within minutes of each other. Because the slope was water-logged or saturated from previous rainfall events within the past nine days, the landslide moved rather quickly.

- This demonstrates to community members that with retrogressive landslides, it may be possible to evacuate or move out of harm's way if the interval between movements is long enough. However, we can also see that with saturated slopes, once the slope is displaced, movement occurs rather quickly due to the water-logged consistency of the soil.

Other Findings and Comments

The main reason for the damage caused by the landslide is that the houses were located too near the cut slope. This is a common scenario in rural areas, particularly on privately-owned agricultural land. Maximum usage of plot land is driven by financial considerations sometimes at the cost of slope safety. Building structures too close to steeply cut slopes or cutting slopes without engineering expertise increases the risk of landslides. Bad practices in slope construction and lack of slope guidelines for agricultural land are some of the main reasons for slope-related disasters throughout the country. Thus, residents and owners of hillside property must be made to understand the risk of landslides such that they can effectively take measures and actions to reduce the risks around them.

7 Floods: Science Based Risk Identification

7.1 Site 3: Kampung Sungai Serai, Hulu Langat District

7.1.1 About the Project Area

Sg. Serai is a tributary of the Sg. Langat river basin. The Sg. Langat basin is in southwestern Selangor and part of the neighboring state of Negeri Sembilan (see Figure 46). It is 200 km long and drains an area of 2,350 km^2.[13] Its headwaters are located to the east within Gunung Nuang, which is at the tri-point of Selangor-Pahang-Negeri Sembilan and the highest point in Selangor. The river flows through urban centers such as Bangi, Kajang, Dengkil and Putrajaya before draining into the Straits of Malacca.

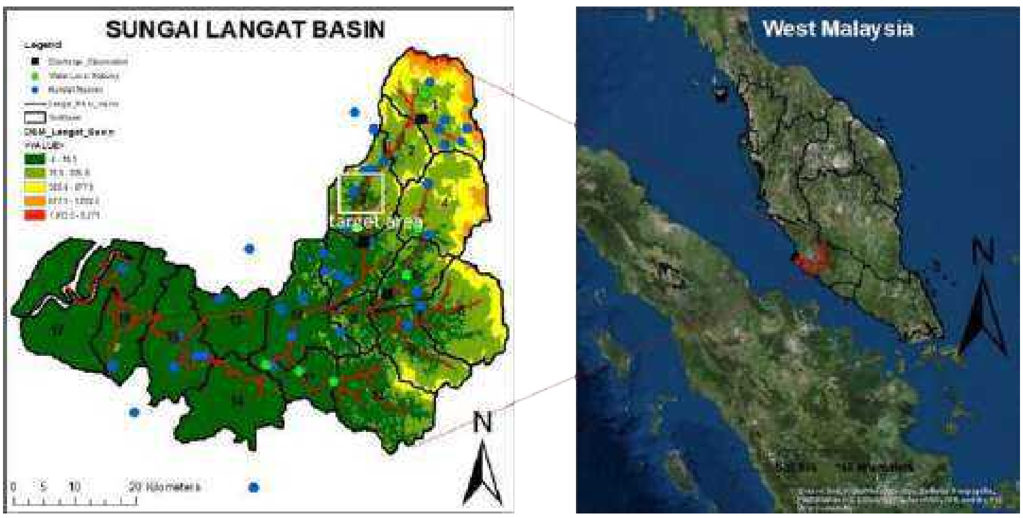


Figure 46. Location of the Langat River basin

[13] *Zakaria, 2008*

The basin is affected by two types of monsoon: the northeast monsoon, which occurs from November to March and the southeast monsoon from May to September.[14] The average rainfall is about 2,400 mm. The wettest months are April and November with average monthly rainfall exceeding 250 mm. From 1980 to 2012, there were 24 flood occurrences along Sg. Langat, which accounts for approximately 20% of the total 122 flood events in Malaysia. During this period Sg. Langat experienced flooding nearly every year. Especially affected are communities along the upper basin area in the Hulu Langat district.

Small-Scale Flooding - The small-scale flooding is concentrated in Kampung Sg. Serai and neighboring tributaries, which occurs several times a year, usually around June and July. The affected areas are approximately 50 m from the river banks. The duration of flooding is short and affects about ten houses. Due to the frequency of the flood events, Sg. Serai is considered a hotspot for floods in Hulu Langat. Also commonly flooded are Sg. Betung and Sg. Putih.

Large-Scale Flooding - Once every five years, there is large-scale flooding that affects all villages that stretches for 12 km, from Batu 18 near the Semenyih Dam to Batu 10 in Cheras. Past flood occurrences have been in 2009, 2012 and 2017. In the 2017 flood incident, the entire Hulu Langat area was flooded, affecting 1,000 houses and 50 to 60 houses within 100 m of the river banks were flooded. During flooding, a power substation was flooded, disrupting power supply.

Areas most commonly affected are Kampung Sg. Serai, Kampung Iman, Kampung Boyan, Kampung Sg. Serai Tambahan, Lorong 6, Lorong 7, Lorong 8 and Lorong 9. Regardless of the type of floods, according to accounts by DID and community leaders of Hulu Langat, the causes of flooding are overtopping of the Sg. Langat river.

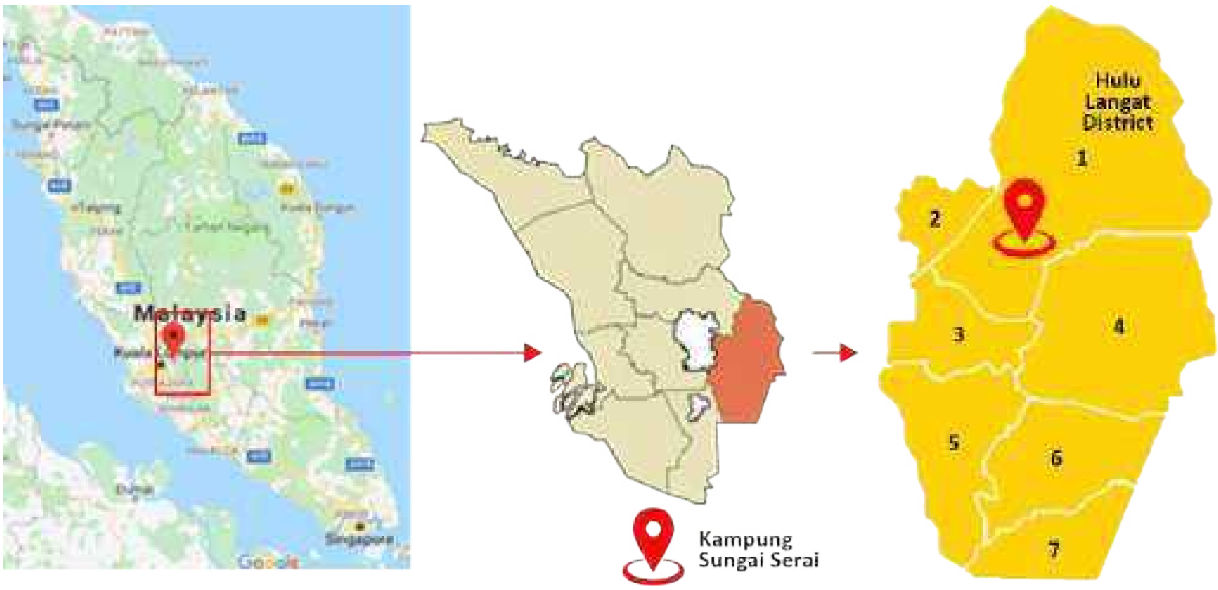


Figure 47. Location of Kampung Sungai Serai and upper Sg. Langat, Selangor
Source: adapted from Google map (accessed on 15 May 2019)

7.1.2 About the Community

Kampung Sungai Serai is a combination of traditional villages and modern suburban residences located in Mukim Hulu Langat in the Hulu Langat district (see Figure 47). The village is located about 2 km from the nearest town of Hulu Langat and 5 km from Kampung Batu 14.

Kampung Sungai Serai is considered the 'main village' (*kampung induk*) in the area, which is supported by 'linked villages' (*kampung rangkaian*) including Kampung Sungai Betong, Kampung Tengah, Kampung Hilir, Kampung Sungai Serai Tambahan and Kampung Lombong.

In addition, Kampung Sungai Serai also includes a few residential schemes such as Taman Desa Pelangi, Taman Perkasa Indah, Taman Perkasa, Taman Lagenda Surai, Taman Seri Mas and Taman Bukit Sekawan.

[14] *Faghih, M., Mirzaei, M., Adamowski, J., Lee, J., and El-Shafie, A. (2017) Uncertainty Estimation in Flood Inundation Mapping: An Application of Non-parametric Bootstrapping. River Res. Applic., 33: 611– 619.*

Population – The total population is 6,815, with gender distribution of 40% male and 60% female.

Race – Mostly Malay, although there are foreign workers involved in the construction of Langat 2 Water Transfer Pipeline and water treatment plant project and EKVE. There are also people from Myanmar and Aceh (Indonesia), and some of them run small businesses.

Social Capital – Community members volunteer in local clean-up programs. The most active are residents at Lorong 6 or 7, with attendance of 100 locals. The people joining the local surau (small mosque) programs are often the same as the ones join the community programs

Concerns – Village leaders highlight the water intake at Batu 10 as being a possible contributor to the flooding. The locals are also concerned that the EKVE project will destroy the natural landscape, resulting in flooding and landslide.

The locals question the responsibilities of Air Selangor in monitoring the floodgates

There is a general concern by the community of dam breakage. They also cite development problems, e.g. TNB power cable project. Residents also complain that some developers clear more land than they should.

Information Network – Information on floods and other communal matters are effectively relayed between villages via social media groups.

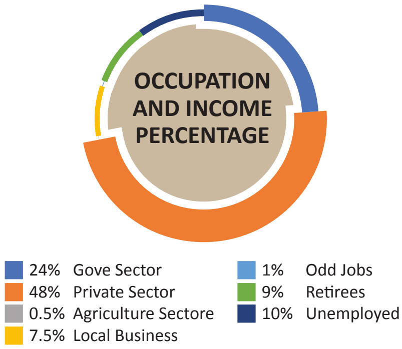
Pre-existing Knowledge and Perceptions – The locals understand based on experience that once Batu 16 is flooded, it will take 2 hours for Serai River to get flooded, followed by Batu 10.

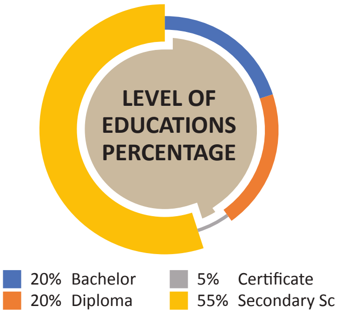
There has been an increase in demand for residential lots, thus increasing development activities around the area. Usually development follows a guideline for kampung development. They feel that developers no longer bother following these guidelines.

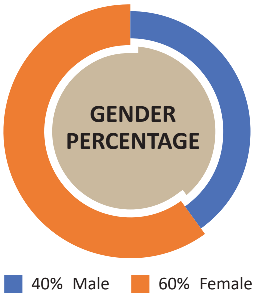
Residents are aware that the Department of Irrigation and Drainage (DID) has SCADA data. It would not prevent the floods, but the information helps to prepare for evacuation. Although village heads receive information about Pangsun Dam relayed by DID and the district community leader, they state that information on dam releases should be made public as they believe that releases also contribute to the flooding.

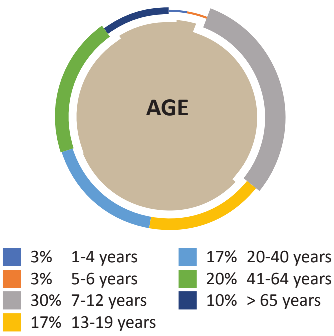
Awareness of Climate Change – the village leaders acknowledge that climate change and changes in rainfall pattern over the years are occurring.

Community Leadership Structure – The community leadership structure driven by the Village Head Community Council or *Majlis Penduduk Ketua Kampung*. The structure is the same as that described in the section on Ulu Klang.









7.1.3 Risk Analysis Using a Science-Based Approach

Previous Studies in this Area

Previous research on the evaluation of the hazard and risk in Sg. Langat basin was studied. Mirzaeii et al. (2016)[15] applied a rainfall-runoff model for regional-scale flood inundation mapping for the Sg. Langat basin.

The hydrodynamic modeling software (HEC-RAS) was used to compute the flood inundation depth and flow velocities considering different return periods. As an example, Figure 48 shows the simulated flood inundation depth for a 100-year return period and 120-minute duration in the upstream region of the Sg. Langat basin. Faghih et al. (2017) evaluated an uncertainty in flood inundation mapping based on the HEC-RAS application with a non-parametric bootstrapping. As an example, Figure 49 shows the location of urban area in probabilistic inundation maps.

As can be seen from these figures, the applications and results are based on a regional scale evaluation, and thus these results are not suitable for the hazard and risk evaluation in a local community level. Why did they analyze the river flood hazard at the regional scale? The answer is simple: **there are no sufficient spatial resolution data to evaluate the hazard at the local community level.** This crucial problem will be discussed in the next section.

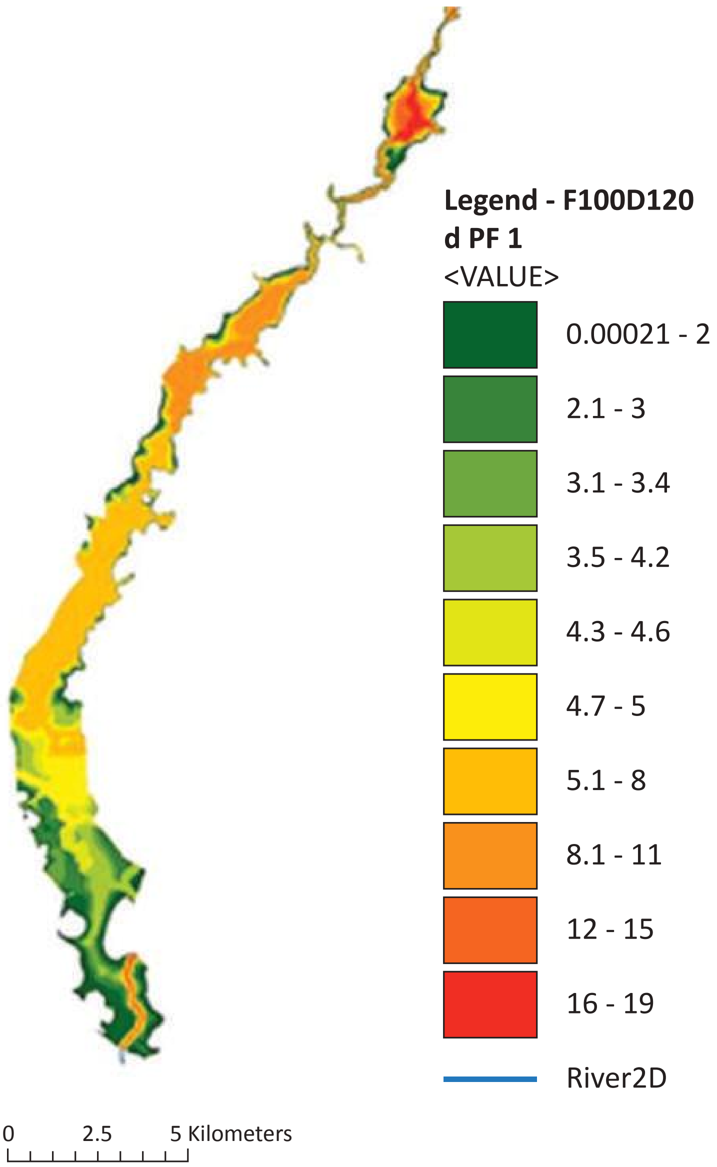


Figure 48. Flood depths for 100-year return period and 120 minute duration (Mirzaeii et al., 2016).

[15] *Mirzaei, M., M. Faghih, T. P. Ying, A. El-Shafie, Y. F. Huang, J. Lee; Application of a rainfall-runoff model for regional-scale flood inundation mapping for the Langat River Basin. Water Practice and Technology 1 June 2016; 11 (2): 373–383. doi:10.1002/rra.3108*

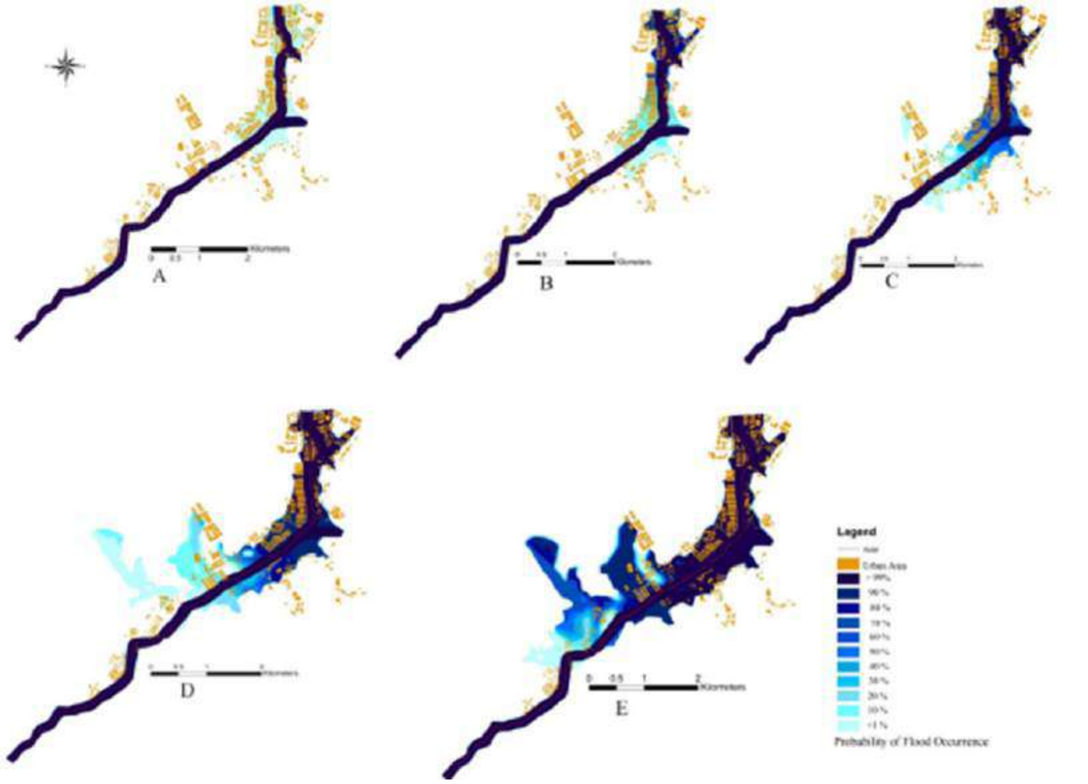


Figure 49. Location of urban areas in probabilistic inundation maps: (A) 25-year, (B) 50-year, (C) 75-year, (D) 100-year, and (E) 200-year return period flood event. (Faghih et al., 2017)

Methodology for Flood Modeling

Step 1. Establish GIS base map

In order to support river modeling, a geographic information system (GIS) was established for the project. The geo-referenced data, including spatially distributed data and point data from various sources, were downloaded and processed. The Universal Transverse Mercator (UTM) Coordinate System was selected as the standard GIS coordinate system for the project. The UTM Coordinate system divides the world into 60 zones, each being 6 degrees longitude wide, and extending from 80 degrees south latitude to 84 degrees north latitude. The UTM "ZONE 47" projection is used for the project. All the geo-referenced datasets in this project have been defined in this coordinate system.

Step 2. Generate digital elevation model

The digital elevation model (DEM) data at 1 arc second resolution, which corresponds to about 30-metre resolution, was downloaded from the HydroSHEDS dataset of USGS and processed for the target basins. It was re-projected into UTM ZONE 47 coordinates by utilising an ArcView software. The final processed DEM was also clipped in order to cover only the target area. A shapefile of the Sg. Langat river network system was provided by the Selangor Government while the river sub-basin data was downloaded from the HydroSHEDS website. Figure 50 shows the DEM and river networks and sub-basin in the target area.

Step 3. Gather hydrological data

Cross-section data of Sg. Langat was obtained from the Selangor State Government. Cross-section data is indispensable for flood inundation analysis, but as shown in the figure below, only three locations of the cross-section data were provided. This insufficient data for the cross section makes it difficult to apply the flood inundation model for an evaluation of the flood hazard because the relationship between water levels in the river and river bank height determine and dominate the overflow of the river flood water in the river.

Observed rainfall data from rain gauge as well as water level and river flow discharge data, as shown in the figure below, were provided by the state. Rainfall data was used as the input for the model, and the water level and flow discharge was used for the model parameter calibration and model output validation processes.

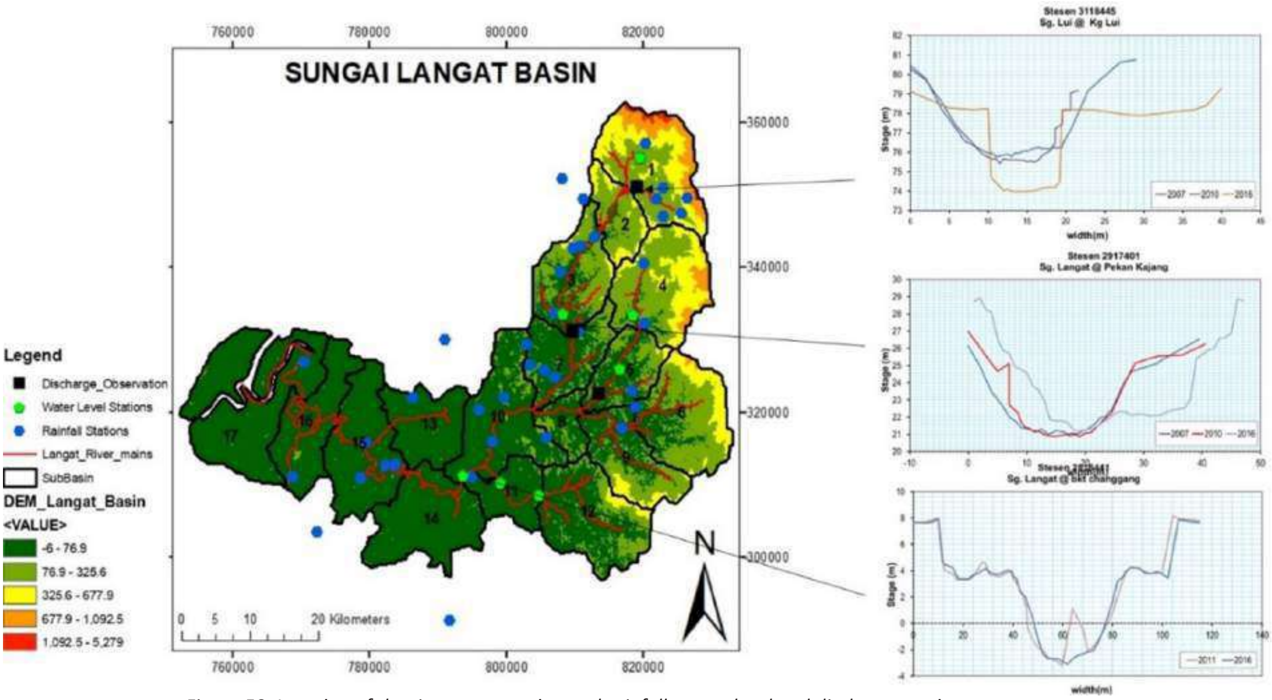


Figure 50. Location of the river cross section and rainfall, water level and discharge stations

Step 4. Run rainfall runoff and flood inundation model

A physical-based rainfall-runoff and flood inundation model was used to simulate the flood inundation scenario in the target area of the Sg. Langat basin. The model consisted of a rainfall-runoff module for each sub-basin, a one-dimensional hydrodynamic module for the river networks, and a two-dimensional flood inundation module for the floodplains. The computed runoffs from each sub-basin were used for lateral inflows of the hydrodynamic module. The hydrodynamic module and the flood inundation module were laterally linked based on a weir equation for simulating overflow from a river channel onto a flood plain. We used this model to compute flood inundation in the target area because it was previously applied to several basins around the world, and the model is applicable not only to mountainous regions, but also to highly urbanized areas.

Step 5. Calibrate with past rainfall data

Rainfall data observed at several stations were used as model input data, and then after the simulation, the river flow discharge and water level at each river section and flood inundation depth and velocity at each grid in the flood plain were computed. Details of the model are provided in Appendix B, Technical Notes.

Flood Modeling Analysis

For model validation, the rainfall-runoff simulation result was compared against observation. Figure 51 shows the observed and simulated river discharge at the Sg. Lui station. The simulated river discharge in the station matched the observed data reasonably well. Based on these results, flood inundation simulation was conducted.

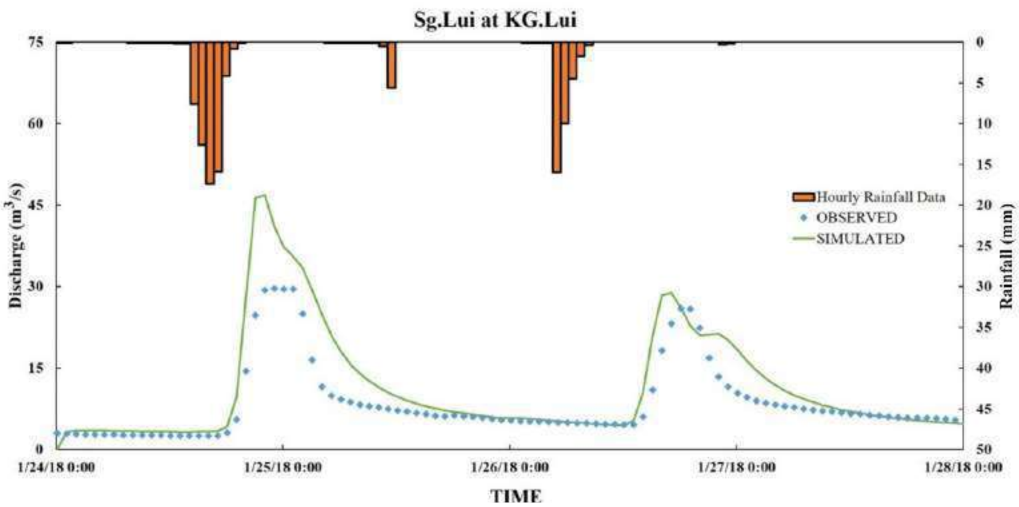


Figure 51. Simulated and observed flood discharge at Sg. Lui station

Figure 52 shows the simulated maximum flood inundation depth in the target area. It can be seen from the figure that many houses around target area were inundated. It should be emphasized that the flood inundation areas have strong correlation to the low elevation area because water always flow from high elevations to low elevations due to the gravity.

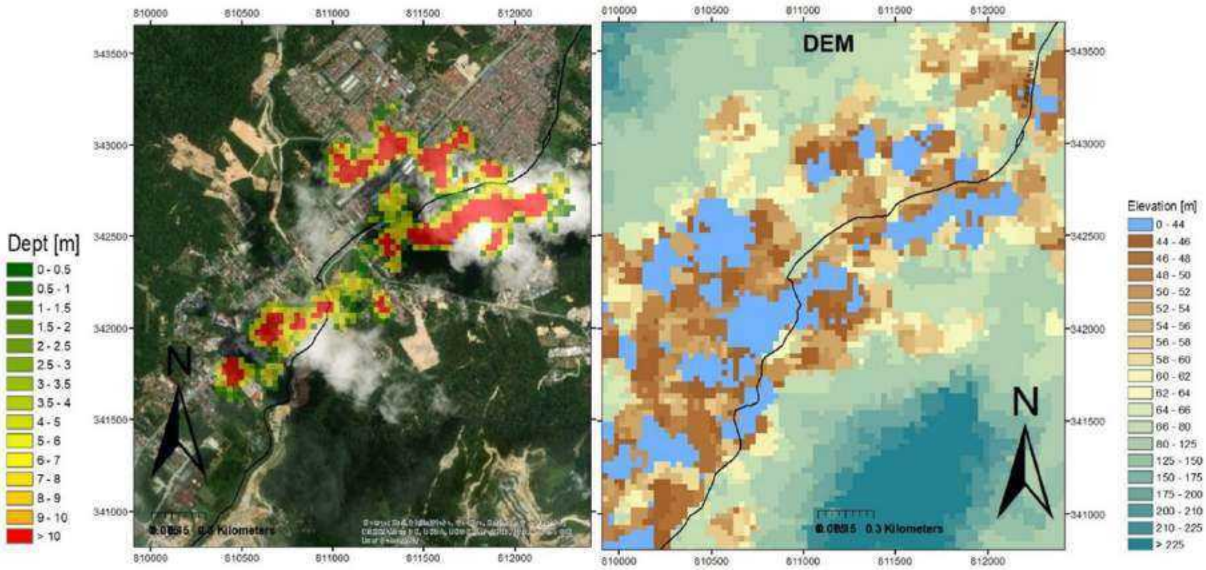


Figure 52. Simulated maximum flood inundation depth (left) and DEM elevation (right)

Also, Figure 53 shows the simulated maximum flood flow velocity and hydrodynamic force of the flood inundation. Not only flood inundation depth but also flow velocity should be evaluated as a hazard for the local communities because flow velocity may affect the ability of residents to evacuate.

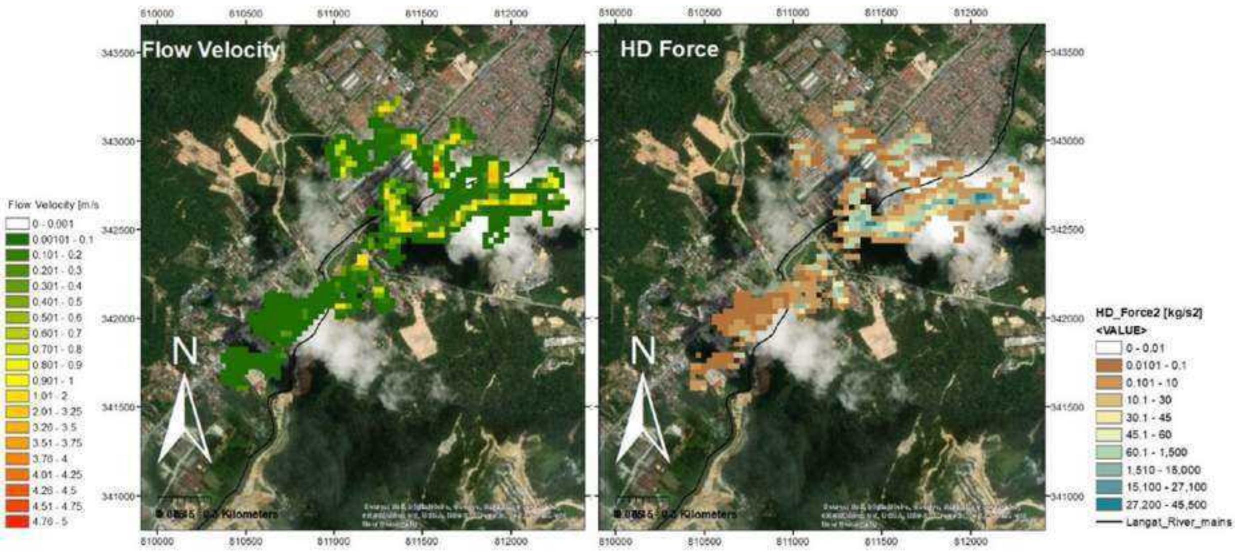


Figure 53. Simulated maximum flood flow velocity (left) and hydrodynamic force (right)

Strong hydrodynamic forces have the capacity to wash houses away; even weaker ones will make it difficult for residents to stay in their homes. High flow velocity and large hydrodynamic force can be found in the above figure because this target area is located in the upstream of the Sg. Langat basin where high elevation and steep gradient exist.

However, it should be emphasized that these simulation results are not good enough from the point of spatial resolution as a local community hazard evaluation. As discussed below sentences, we need much higher resolutions such as 5-metre DEM for local community hazard evaluation.

Also, several conditions related to the return periods of rainfall and inflow and scenarios related to the embankment breach should be analyzed and the flood risk in each grid location should be evaluated for the next steps.

7.1.4 What Did We Find Out?

- The simulated flood inundation analysis showed us that many houses in Kampung Sg. Serai experience flooding with rainfall events.
- In addition, the flood velocity analysis showed that there is potential for the force of flood waters to be strong enough to make it difficult for residents to stay in their houses during floods, particularly for flood events that occur in the upstream sections of the main Sg. Langat river. As such, residents need to be aware of the potential forces of flood water during extreme rain events.
- It is concluded from this study that the flood inundation and velocity modeling are suitable methods for simulating flood events to show flood risk. However, the lack of high-resolution DEM data constrained the modeling results. With higher resolution data, future modelers could develop hazard maps that are suitable for the local community to understand the risk and to evacuate before the disaster event.

Other Findings and Observations

It should be emphasized that there is no new technology in the methodology presented above, and free advanced software such as HEC-RAS, RRI and iRIC are available. These models can be downloaded through websites with an English manual and instruction, and these models are based on a Graphical User Interface and easy to use.

As such, it can be said that flood inundation simulation is not daunting as some may presume, and in fact is a common analysis tool within the science community. Future modelers, whether from the public or private sectors, can evaluate the flood risk at the local community level by considering the several return periods of the input rainfall and several scenarios of the embankment failure. A probable maximum flood inundation concept may be used as a hazard index for the local community.

However, it is impossible for local governments to do this analysis without support from experts, as vast modeling experience and hydrology and hydraulics knowledge are required to use these models. As such, universities as well as federal and state agencies should conduct this analysis for the support to the local community's risk reduction activities. Both the federal and state governments have a strong responsibility to develop hazard maps for all rivers in the country, as this is not the responsibility of the local communities. The residents should focus on how to use the hazard maps and not on how to develop them. Thus, we conclude that the presented method based on the numerical simulation in this report is not suitable for local governments to carry out, but that this responsibility falls under the state or federal government.

7.2 Site 4: Kampung Tok Muda, Kapar

7.2.1 About the Project Area

Kampung Tok Muda is a village located beside Sg. Kapar Besar near the town of Kapar in the district of Klang along the coast of Selangor about 12 km north of Port Klang. The area is on a coastal plain that lies between two major river basins in Selangor, the Sg. Buloh and Sg. Klang river basins.

This coastal plain has several small rivers along the coast where water flows through villages, towns, industrial areas, and palm oil plantations. One of the rivers is Sg. Kapar Besar which convey water from villages including Kampung Tok Muda and other upstream towns in Kapar. To its north is Kampung Sg. Serdang while Sg. Kapar Besar is to its south. Upstream of Sg. Kapar Besar are the towns of Kapar, Bukit Kapar and Meru (See Figure 54).

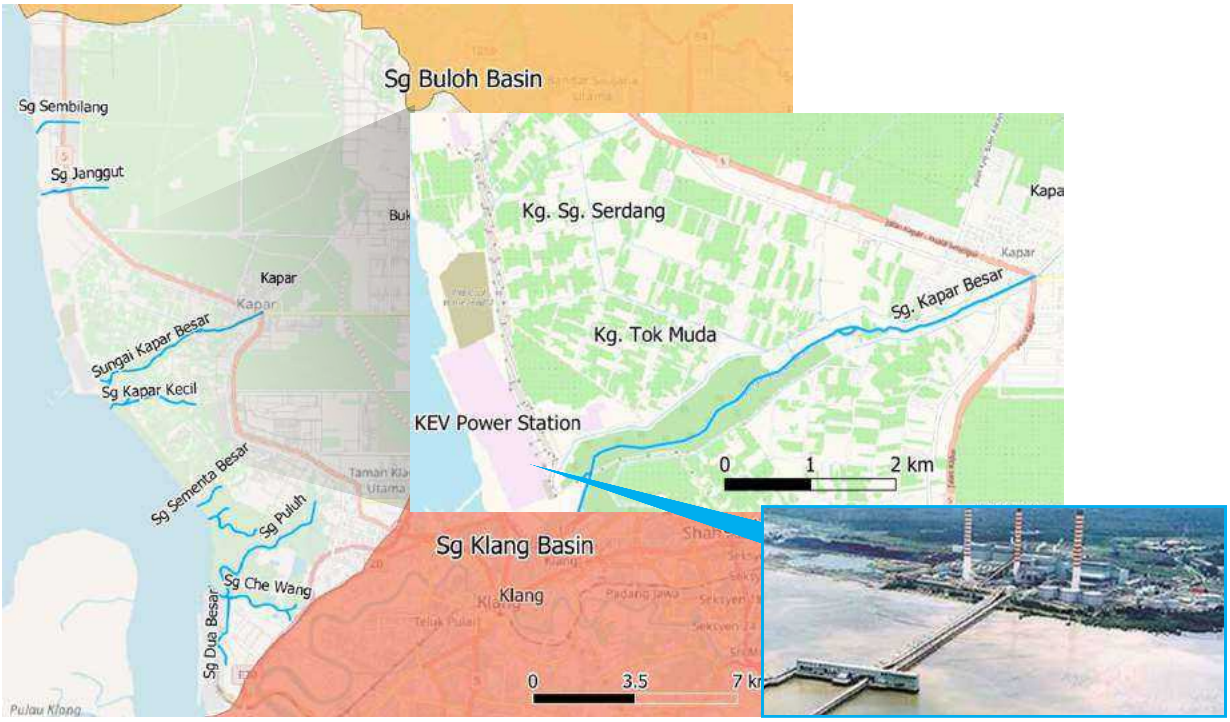


Figure 54. Location of KampungTok Muda and KEV in Kapar (Map by Openstreetmap)

Kapar Energy Ventures

A notable landmark of interest is the Kapar Energy Ventures (KEV), an independent power plant, which is the second largest power plant in Malaysia with a generating capacity of 2,420MW (Figure 54). KEV is the only power plant in Malaysia with triple fuel firing capability (gas, oil and coal). It is located west of Kampung Tok Muda and downstream of Sg. Kapar Besar. It is the largest employer for residents within Kampung Tok Muda and the neighboring village of Kampung Sg. Serdang.

Coastal Bund

Another feature of interest is a 3.5 km coastal bund made up of laterite soil that stretches along the Sg. Kapar Besar at the south end of the Kampung Tok Muda (Figure 55). As high tides intrude the river and flood the vast mangrove forest surrounding the river, the bund prevents seawater from inundating the villages, agricultural land, and the vicinity of the power station. The bund was built and is maintained by DID Negeri Selangor with a height of reduced level of 3.0 m to 3.5 m. It is only a small part of a 97 km-bund built by DID along the coastline in the Klang district that is crucial for the protection from high tides and waves as the land area is generally lower than the high tides.

Figure 55. The stretch of coastal and river bunds around Sg. Kapar Besar (map by Openstreetmap)

However, structural degradation of the bund is often accelerated due to land subsidence, intrusion by locals for illegal farming and cattle grazing, and the development of crab nests. Mangrove forests along the coast are also degrading as a result of illegal logging activity, consequently exposing the bund to coastal erosion and strong waves. The coastline is classified as Medium in terms of coastal erosion risk in the Third National Physical Plan (JPBD, 2016).

Past Flood Events

On 19th September 2016 the bund was overtopped and breached during high tides, with seawater gushing into the canals or borrow pits, consequently flooding the villages and palm plantations in Kampung Tok Muda and Kampung Sg. Serdang (Figure 56). While KEV was designed to withstand any possible flood and sea level rise (SLR) for 100 years, the roads at the flooded villages were the main routes to KEV, affecting accessibility for KEV employees to work. In Kampung Tok Muda itself, about 1,000 residents were affected in the flood due to its low-lying terrain.

Based on information and flood reports from DID Klang, Kampung Tok Muda and Kampung Sg. Serdang have been listed as flooding hotspot areas by DID since 2010 and up until 2015, 2016 and 2017 (see Figure 57). Kampung Tok Muda is the closest to the river bund north of Sg. Kapar Besar and has been inundated during high tides because of river bund breaching. Within the same sub-catchment, Kampung Sg. Serdang often gets flooded every time Kampung Tok Muda gets flooded.

Figure 56. Flooded areas in Kampung Tok Muda during the 2016 high tide phenomenon

Figure 57. Flood hotspot areas in subcatchment of KampungTok Muda (DID) (map by Google)

The flood on 19th September 2016 was analysed based on photos, newspaper reports, tidal records and rainfall records. Aerial photos taken during the flood event were obtained from SDMU. Observed tidal data for Port Klang was obtained from JUPEM while DID provided observed rainfall data from a station at Jalan Benteng. The bund breaching happened around 7:00 AM during high tides based on predicted tide schedule. There was also only 27 mm of rainfall which is very small and should not contribute to the flood.

Based on aerial images, Figure 58 shows that the houses were still flooded by 10:00 AM. It was observed that the tides were receding, but some areas in Kampung Tok Muda were still inundated at knee level. This area is comparable with the flood inundation visualization during mean high water (MHW) done by NAHRIM. Based on discussions with the locals, these houses have often been the first to get hit with any floods in the past and have been utilized as an early warning to the others in the community. These houses could represent the areas that are the first to be flooded and the last to recover from the flood.

The figure also shows the breach points along the bund on 20 September 2016 during high tides at 7:00 AM. By this time, the floodwaters had already receded. However, seawater was seen overtopping and breaching the bund at multiple points. This phenomenon should also represent the events that contributed to the flood on the previous day. As a result, the villages were flooded again that evening. It should be noted that there was no rainfall that day.

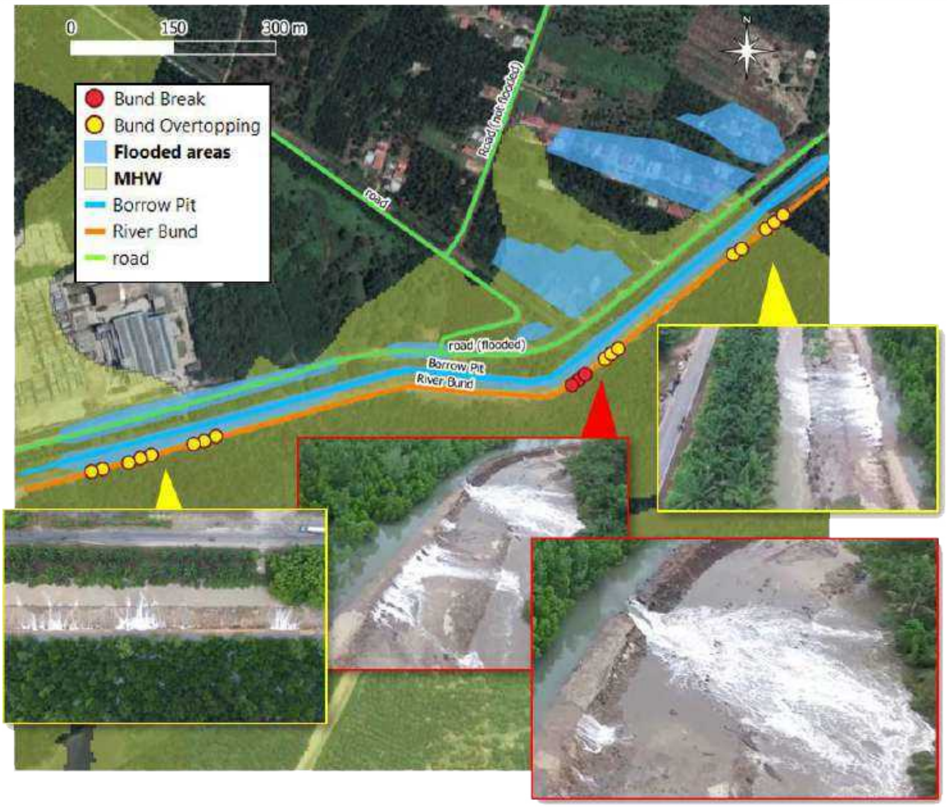


Figure 58. Multiple overtopping and bund breached points along the river bund in Kampung Tok Muda on 20 September 7:00AM. (Photos by SDMU, Map by Google Earth)

Sea Level Rise

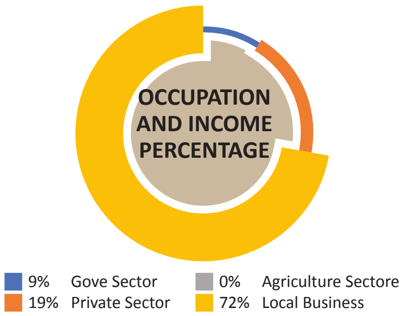
Sea level rise is also a continuous threat to coastal areas due to climate change. NAHRIM spearheads the study on sea level rise in Malaysia. Based on their study in 2010, the Malacca Straits has a sea level rise rate of about 3.87 mm/year. Kapar is represented by Port Klang, which is located only about 12 km to the south (see Table 7). Based on the projections for 2020, a part of Kampung Tok Muda and Kampung Sg. Serdang could already be inundated by sea water during mean high water (MHW). The risk of flooding would only increase with time as sea level continue to rise. This also shows how critical the bund is for protecting the community.

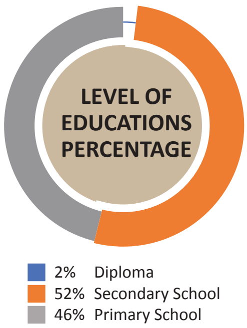
SEA LEVEL RISE PROJECTION IN PORT KLANG (NAHRIM)

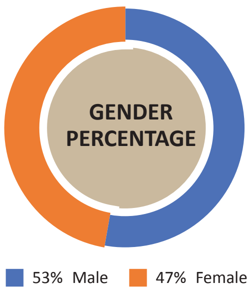
PROJECTED YEAR	2020	2040	2060	2080	2100
Meter (m)	0.057	0.134	0.238	0.358	0.495

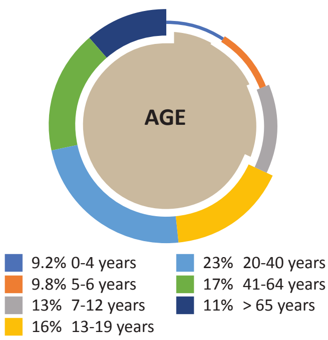
Table 7: Sea level rise projection

7.2.2 Community Profile









Occupation – About 50% oil palm plantation and farming, 20% fishing (full time and part time, for local consumption). Others work in KEV and in companies providing support to KEV. Still others work in various smaller companies and as contractors and vendors.

Population – Approximately 10,000 people live in Kampung Tok Muda, with 6,850 living in villages and the remainder in residential areas. Approximately 90% of the population is Malay with 10% others.

Communication Network – The locals are familiar with WhatsApp with good data reception in the area and have been using it for quick announcements.

Pre-Existing Knowledge – A Disaster Operation Centre is centralized in Kampung Tok Muda at the community hall. The community has never done any evacuation drills, but most people have experienced the flood firsthand and have some idea of what to do in the event of a flood. Some residents decline to be evacuated despite actual flooding. The community heads are aware of the importance of educating the community and increasing awareness of DRR.

Existing Practices – DID collaborates with the Fisheries Dept to provide the community leaders with information through talks on using high tide level charts as precautionary warnings.

Community-Private Company Relationship – KEV has no agreement to provide aid, but it is their policy to assist the local community. When the community hosts a program, KEV provides attendance support and sometimes some financial support as corporate social responsibility. KEV has provided aid by lending SUVs to evacuate through flooded roads, as well as distributing food and supplies. KEV has also helped in house clean-ups in the aftermath of floods.

Concerns – The residents are more worried about high tides than heavy rainfall.

7.2.3 Risk Analysis using a Science-Based Approach

The objective of this analysis is to produce a flood hazard map based on any available information and data at the proposed location. Data on past flood events, failure/breaching of the bund, visual evidence obtained during the flood, long-term tidal and rainfall data and the geographic features of the area were used to identify the possible scenarios of flood occurrences and visualize the flood event. Information about the floods was sourced from DID and SDMU. SDMU also provided aerial photographs taken during the flood. JUPEM provided observed tidal data while DID Selangor provided recorded rainfall and information about the bund. Geomapping Technology Sdn. Bhd. and SDMU provided high-resolution digital surface model (DSM) for key parts of the project area. QGIS software was used to establish GIS database and process spatial data. Base maps and satellite images were sources from Google Earth, Google Maps and Openstreetmap.

Step 1. Long-Term Rainfall

To identify the months that have higher rainfall, long-term rainfall data was analyzed. Data obtained was observed rainfall recorded by DID Station 3013002 at Jalan Benteng located near Kampung Tok Muda. The recorded rainfall data for 11 years (January 2008 to December 2018) were analyzed to obtain the rainfall pattern. Based on the data, average annual rainfall is about 1827 mm. Meanwhile the average monthly rainfall (Figure 59) shows more rainfall for November and December (wet period) and less rainfall on January-February and June-July (dry period).

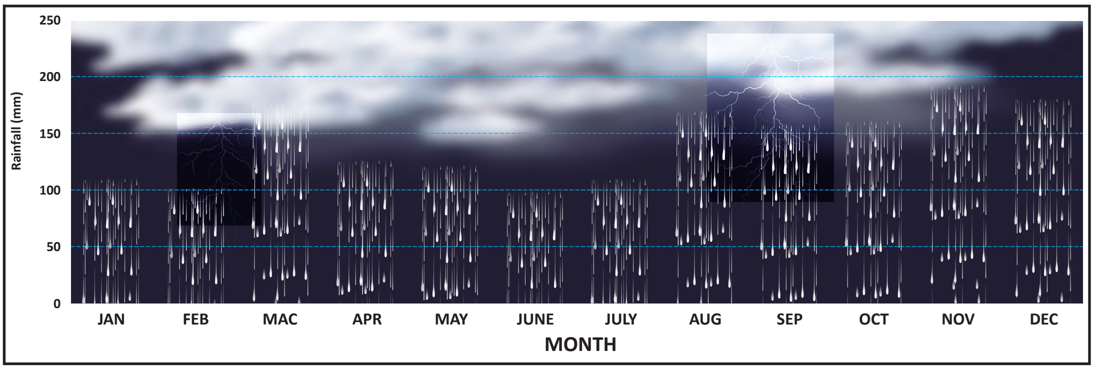


Figure 59. Average monthly rainfall for 2008 until 2018

Based on this result, the locals should be on alert during the months of November-December. While Kampung Tok Muda may not necessarily get flooded by heavy rainfall alone, it could worsen the flood situation in the event of a bund breach, which could happen at any time of the year.

Step 2. Geographical Visual Analysis

To understand the geography of the area, a spatial database was established with GIS. The UTM ZONE 47N projection was used for the project. Satellite images from Google provided a visual base map of the area, while maps from Google Maps and Openstreetmap enabled features such as roads and land use to be identified. Elevation contour lines from Openstreetmap provided information about the terrain for catchment demarcation. Aerial images by SDMU also provide an additional perspective to the geography.

The area around Kampung Tok Muda is a flat plain area consisting of mainly oil palm plantations and villages and is easily accessible through a network of roads. While main routes through villages and industries are paved with asphalt, service routes through the plantations are mostly elevated dirt roads that are also built as a perimeter around large patches of plantations. Some of these dirt roads run alongside rivers and the coastline and function as river and coastal bunds (Figure 60), which prevents inflow of water during high tides, while also keep the area accessible during floods.

Figure 60. Bund, borrow pits and roads run along the river beside Kampung Tok Muda (Photo by SDMU).

There are canals that stretch along the bunds called *borrow pits* to convey stormwater and serve as temporary storage in the event of bund overtopping or breaching during high tides. Being a flat coastal plain, the basin boundaries of these small rivers are strongly defined by the network of man-made drainage/irrigation canals and elevated roads. Figure 61 shows the possible catchment area of Sg. Kapar Besar based on drainage networks of Sg. Kapar Besar that stretches from Kampung Tok Muda through Bukit Kapar up to the edges of the neighboring basin boundary of Sg. Buloh upstream.

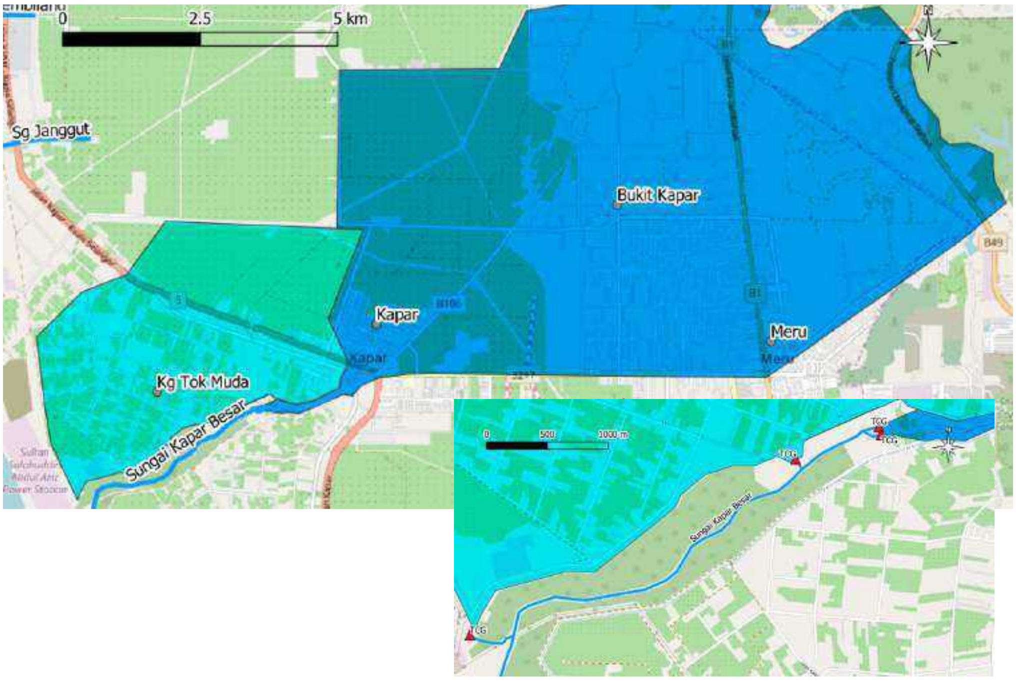


Figure 61. Sub-catchments of Sg. Kapar Besar and tidal control gates (Openstreetmap)

From this observation, it can be deduced that any extreme heavy rainfall activity from Bukit Kapar and Meru upstream of the river should not directly threaten Kampung Tok Muda with stormwater flooding but could only influence the flow and water level of Sg. Kapar Besar.

Step 3. Identify Flooding Scenarios

During low tides, it is impossible to have floods in Kampung Tok Muda. In the event of high tides, there are several scenarios that would result in flooding in Kampung Tok Muda. However, flood by bund breaching and overtopping are the main concern as it has happened twice within two years, in 2016 and 2018.

Scenario 1: Tidal Control Gate Failure

During high tides, tidal control gates (TCG) managed by DID is closed to prevent inflow of seawater. With the TCG closed, the village is protected by the bund. If the TCG fails to be closed, seawater will flood the village because the ground elevation of the village is lower than the average high tides, especially during extreme high tides. Hence the existence of the bund is to prevent flooding. Heavy rainfall will also reduce the water storage capacity in the area and increase the possibilities of flooding.

Scenario 2: Bund Breach/Breaking

Even if the TCG is closed, a breach in the bund would result in flooding by seawater, especially after heavy rainfall or extreme high tides. It was breached at multiple points along the bund on 19th September 2016 during a spring tide. Seawater gushed in, rapidly filling up the borrow pits and overtopped the side banks and roads, consequently flooding Kampung Tok Muda and Kampung Sg. Serdang.

__Spring tide__ – also known as a "King Tide" – refers to the 'springing forth' of the tide during new and full moon when high tides are a little higher and low tides are a little lower than average.

Scenario 3: Bund Overtopping

Even if the TCG and the bund is able to hold against the high tides, extreme high tides might exceed the height limit of the bund. It is crucial for the bund to be continuously monitored and maintain its maximum height against extreme high tides.

Scenario 4: Heavy Rainfall and Pump Failure

Since the TCGs are needed to be closed during high tides, heavy rainfall at Kampung Tok Muda would produce excessive stormwater and accumulate behind the gate and result in flooding by ponding. Hence, each TCG is equipped with pumps to convey out water into the river and flow to the sea. Most pumps at the TCG are functioning as either automated by sensors or local operators. It is important for the pumps to be capable during heavy rainfall and high tides.

__Extreme High Water (EHW)__ is the highest level reached during the year, while Extreme Low Water (ELW) is the lowest level reached during the year.

Flood Visualization Analysis

To obtain information on the general land elevation, the area was surveyed using Real-time Kinematic System (RTK) with a connection to a Global Navigation Satellite System (GNSS) through MyRTKnet, which is maintained by JUPEM. Elevation data and coordinates were acquired from multiple points over the area mainly on roadsides on flat land. These points represent the general elevation of nearby villages and plantations considering the area as mainly low-lying flat plain. A method called *interpolation* was used to get an average/representative sample of the elevation between the available points. A more detailed explanation of how the DEM was created is provided in **Appendix B, Technical Notes**. Based on tidal data from JUPEM, the highest recorded tide or extreme high water (EHW) was 2.89 m NGVD while for mean high water springs (MHWS) was 2.146 m NGVD. These values represent the highest possible tide level and the highest common tides, respectively.

__Mean High Water Springs (MHWS)__ is the average, throughout a year when the moon phase is at full or new, of the heights of two successive high waters during those period of 24 hours when the range of the tide is greatest.

Based on the DEM produced from interpolated elevation values, a flood hazard map was produced using GIS visualization in Figure 62 and Figure 63. Based on the tidal values of MHWS, the DEM values were calculated to produce a flood depth map that visualize any area of the DEM that is inundated by 0.3m of water or more. However, this comes with the assumption that the tides had a lot of time to flow through a bund that breached. In the event of a bund breaching and seawater intrusion, having the storage capacities filled up with prior heavy rain would accelerate the flooding.

This flood map is also based solely on the interpolated DEM which does not account for the irrigation and drainage systems that could distribute flood water further away and reduce the inundation. The depth of 0.3 m was selected as the threshold of flooding because there are various structures that could be within the height of 0.2 m such as elevated roads, ground level of housing, or simply bumps and potholes on the ground.

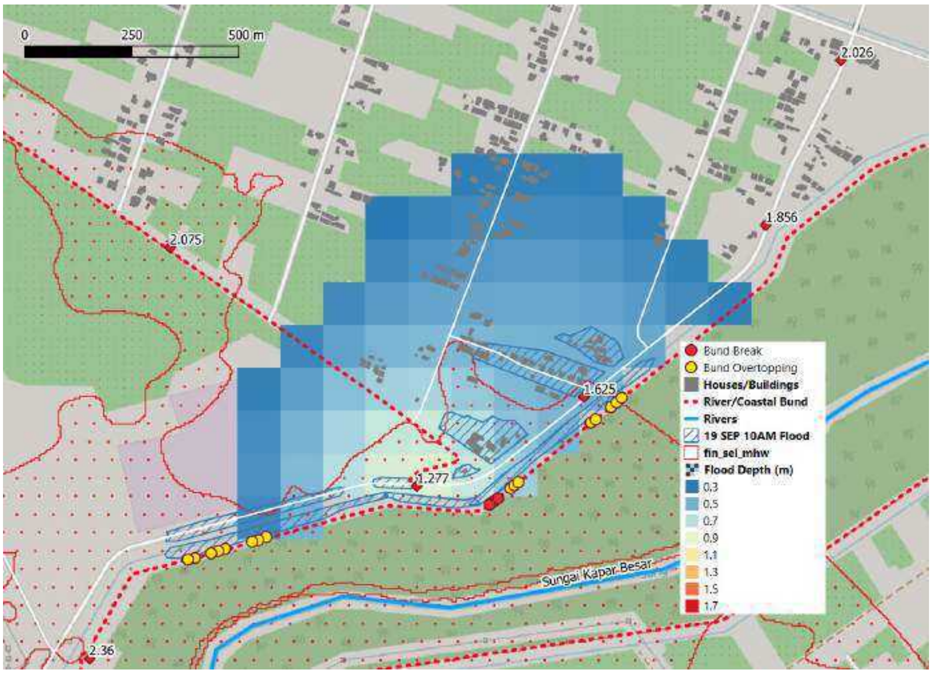


Figure 62. Visualization of areas could be inundated with 0.3 m of water or more during MHWS in the event of a bund breaching.

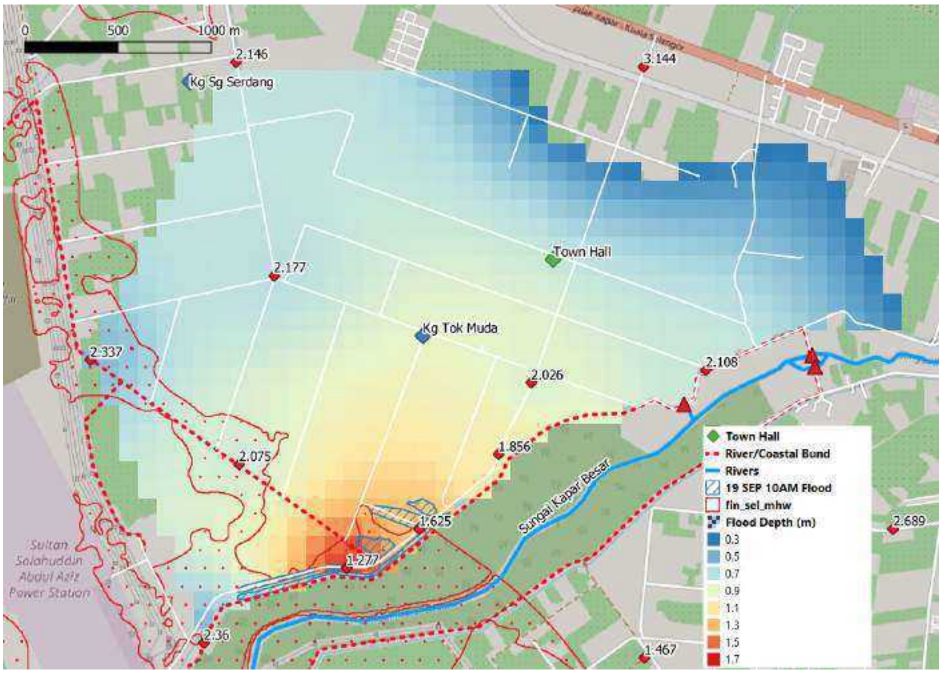


Figure 63. Visualization of areas could be inundated with 0.3 m of water or more during EHW in the event of a bund breaching.

Figure 63 is the visualized flood hazard map based on EHW tide level which shows a larger inundation area that reaches Kampung Sg. Serdang. Despite that, such flooding is also with the assumption that tide water had infinite time to flow past the failure/breached bund. The DEM used for this visualization is also only a rough presentation of the area. The area covered by DEM is also limited. However, based on community interviews, we know that Kampung Sg. Serdang has also flooded previously together with Kampung Tok Muda. The town hall of Kampung Tok Muda is deemed safe from floods and is designated as an evacuation centre for the affected community. There is also not enough information on a flood event that occurred exactly during EHW to verify such flooding possibility.

7.2.4 What Did We Find Out?

The main findings for this project area are as follows:

- The bunds are also subjected to erosion and need to be maintained consistently. DID has periodically done maintenance on the bund structure to maintain its height. However, it was reported by the locals and verified by DID that the bund integrity is compromised by the development of crab burrows through the bund over time. This then enabled water to seepage through and encouraged erosion as the tides fluctuates. While higher water levels contributed by higher tides and heavy rainfall might not necessarily lead to the bund overtopping, it creates larger pressure against the bund and contributes to the breaching/breakage.
- Despite having the bund fixed after the flood, the risk of bund breaching remains a strong possibility as crab activity is a natural phenomenon beyond human control and is impossible to be monitored. However, in the event of high tides, seepage of water through the bund could be observed and be identified as signs of possible bund breaching as shown in Figure 64. If the local leaders and community could act upon these seepage signs, possible failure and resultant flooding could be avoided.
- From this observation, it can be deduced that the flooding in Kampung Tok Muda could be contributed by high water levels produced by the concurrence of heavy rainfall, high tides and strong waves which may not necessarily result to water overtopping but impose hydrodynamic forces that threatens the river bund structure that could already be compromised by crab activity. Thus, it is important to identify when is the highest chance for heavy rainfall and high tides to occur concurrently.
- Three-dimensional maps provide good visualization to communicate the flood hazard in this area. However, high resolution DEM is required in order to conduct analysis with higher confidence level.
- Data required to carry out the visual analysis of the project site were:
  - Past flood events
  - Failure or Breaching of the bund
  - Visual Evidence obtained during the flood
  - Long-term tidal and rainfall data
  - Geographic features of the area
  - Aerial Photographs
  - Bund Information
  - High-resolution digital surface model (DSM)
- Software used were:
  - Google Earth
  - QGIS/ArcGIS

Figure 64. Seepage and small breaches during high tides as early signs of bund break

Other Findings and Comments

This study would like to highlight how scientific study relies heavily on the availability of data and information. Flood events at Kampung Tok Muda have never been thoroughly investigated in the past. For that matter, scientific data within the area has been scarce. Moreover, there is a need for advance scientific studies to be done to highlight areas with higher risks. While studies are important for structural mitigations, non-structural mitigations are also important and it is crucial to investigate such options with the hopes of being implemented by the community.

There are several types of studies that can be done in Kampung Tok Muda in the future that could help visualize floods to the community to raise awareness and promote action. For detailed flood visualization, high-resolution DEM is crucial to identify houses or areas that have risks of flooding. While drone photogrammetry used in this study could only cover small portions of land with high resolution, having a fixed-wing drone or LiDAR for elevation capturing methods could enable DEM to be produced at a larger scale.

Hydrodynamic flood modeling can also be done but requires actual recorded data such as rainfall data, tidal data, and river flow data especially during flood events. Sea level rise studies are also important to be advanced further inland to see the effect on the surrounding area. Despite that, the absence of advance scientific studies should not stop non-structural mitigation and awareness to be developed among the community.

Summary of Risk Areas

ULU KLANG, GOMBAK DISTRICT

DATA USED:
High-resolution LiDAR data, high quality orthophotos

SOURCE:
NATSIS Portal, Department of Mineral and Geoscience (National Slope Hazard and Risk Mapping Project [PBRC])

METHOD:
Visual-based analysis based on remote sensing and GIS provides a spatial clue to future landslides, with clearly indicated geodynamic features and diagnostic landslide features.

FINDINGS:
The topographic terrain, when stripped of vegetation and forest cover, is prone to landslides with housing lots visible (left abandoned) downslope. It also shows previous slope design and construction was partly deteriorated in a retrogressive manner.

BATU 14, HULU LANGAT DISTRICT

DATA USED:
Airborne LiDAR data, high resolution satellite images

SOURCE:
NATSIS Portal, Department of Mineral and Geoscience (National Slope Hazard and Risk Mapping Project [PBRC])

METHOD:
Visual-based analysis based on remote sensing and GIS diagnostic landslide features

FINDINGS:
The rugged topography of the project area reveals an area exposed to high degrees of vulnerability to future landslides. In most areas, the disturbed terrains are widely distributed in the form of cut slopes, platforms and filled areas.

Over time, these may degrade and contribute to future occurrence of landslides.

KAMPUNG SG. SERAI, HULU LANGAT DISTRICT

DATA USED:
Base GIS map, DEM layer, river network overlay, hydrological data (water level, river flow, rainfall data, cross-sections)

SOURCE:
DID for hydrological data, HydroSHEDs (USGS) for DEM, Universal Transverse Mercator Coordinate System for GIS

METHOD:
Physical based rainfall-runoff and flood inundation model

FINDINGS:
Many houses around target area was inundated, showing strong correlation of flood inundation to low elevation area because water always flow from high elevations to low elevations due to gravity.

Hydrodynamic forces (river flow) if strong may pose threat to residents.

Low resolution DEM used in physical-based, hydrodynamic model is not ideal for community purposes.

KAMPUNG TOK MUDA, KLANG DISTRICT

DATA USED:
Base GIS map, RTK ground survey, high resolution DSM around bund, river network, rainfall data, tidal data, aerial images

SOURCE:
DID for rainfall and bund information, JUPEM for tide, SDMU for aerial images, GMT for DSM, NAHRIM for SLR projection

METHOD:
Field and photo observation, geographical observation, rainfall and tidal analysis, GIS based visualization

FINDINGS:
The first area to be flooded is the area closest to the bund that is lower than the average high tides. Flood prevention is highly dependent on a bund that is structurally compromised due to crab activity with the risk of breaching during high tide. Seepage of water during high tides is visually detectable and could be the early signs of bund breaching.

Observations in Addressing Disaster Risks

Observations were made during the course of development of the Disaster Risk Report, which should be shared with stakeholders engaged in science-based risk communication activities with communities, in particular local authorities, district and state-level government agencies, and community leaders. These pertain to activities related to the Sendai Framework's Priority for Action 1: Understanding Disaster Risk. These observations highlight gaps and challenges in carrying out the various activities.

OBSERVATION 1. DATA AVAILABILITY

a. **Data needed for disaster risk analysis is limited.** Data for DRR purposes are not available either due to lack of resources for collection and compilation or cannot be sourced due to staff turnover. There is an urgent need to centralize data for easy retrieval, use and dissemination.

b. **Data collected but not being effectively used.** Data that are collected is sometimes not effectively used for DRR purposes. Vast amounts of data are collected and stored by the agencies, but are not leveraged for use in disaster risk reduction.

c. **Capacity development in understanding data and its importance.** Local governments and disaster management agencies will need to learn how to utilize hazard and risk maps for communicating risk to various stakeholders. This can be achieved through training, knowledge sharing, and collaborations with universities and research institutes with emphasis on using hazard and risk maps for disaster risk reduction.

d. **Investment in data acquisition.** There is a need for investment in data collection as well as the usage of data for spurring innovation. This calls for the use of high technology and advanced methods needed to collect good quality data for high-resolution mapping. This also requires the leveraging of data to create innovative solutions in communicating and reducing disaster risks.

e. **Need a platform for data sharing.** Access to data is a critical element for science-based communication tools such as hazard and risk maps. Data for modeling and visualization purposes needs to be made available to encourage disaster risk managers. A platform for data sharing is required.

OBSERVATION 2. NEED FOR CREATING HAZARD MAPS

a. **Hazard and risk maps help government prioritize high risk slopes for mitigation or rehabilitation.** Hazard and risk maps help identify areas that require priority works for rehabilitation. Government agencies can then develop measures and priorities for DRR.

b. **Federal and state governments have a responsibility to identify risk through science.** Both the federal and state governments have a strong responsibility to develop hazard and risk maps for landslide- and flood-prone rivers in the country, as this is not the responsibility of the local governments. Currently, hazard maps are predominantly created for mitigation measures. However, these maps should be created for the purpose of risk communication to the local leaders and communities.

c. **Hazard maps need to be updated due to changing land use and mitigation measures.** Local authorities and planners need to update hazard maps as hazard and risk profiles change as a result of changing land use and mitigation measures that may increase or decrease the level of risk. This should be done by local governments.

d. **Need for standardization of methodology for landslide and flood hazard and risk assessment.** There are many existing methodologies for carrying out risk assessment for floods and landslides. This may result in lack of interoperability and compatibility among the various methods and systems. There is a need for a standard methodology.

OBSERVATION 3. NEED FOR RISK COMMUNICATION

a. **Hazard experts to teach communities how to read and use hazard maps.** There is a huge knowledge gap between the hazard experts and local community members, and it is crucial that we consider how to use the hazard map and show the map to the people. The map should be easy enough for residents to understand, but the map needs to convey a strong enough message to make people evacuate and take action.

b. **Using hazard maps to dispel community misconceptions and assumptions about slopes.** It is also crucial for residents to understand that an area deemed as high hazard can be mitigated and even downgraded to medium or low hazard through mitigation measures or engineering. This is to counter assumptions and misconceptions by the communities about slopes that result from lack of information or understanding about slope risks.

c. **Early warning systems should be deployed in high-risk areas.** Hazard and risk maps help identify high-risk areas. In cases where high-risk areas cannot be rehabilitated due to budgetary or resource reasons, early warning systems can be effective.

d. **Government to share maps for DRR purposes.** Hazard and risks maps are useful for communicating disaster risks. They indicate potential hazards, help create awareness among stakeholders, and spur communities and local governments into preparedness mitigative measures. They can also indicate evacuation sites and routes to take in case of disaster-related emergencies. In such cases, it is recommended that local and state authorities communicate risks using such maps in a way that is controlled and localized.

e. **Need for an industry platform for standardization of terms.** There are differences in terminology of disaster-related terms among the various technical and science fields. These differences in definitions of hazard and risk maps call for the need for a standard definition that can be applied across all disciplines. A possible platform for standardization is a multidisciplinary, government-level body called the Inter-Government Committee for Slope Management (ICSM), which comprises high-level government officials from various relevant departments and agencies to discuss, resolve and create standards in matters pertaining to slope management for the country.

APPENDICES

Appendix A. Disaster Risk Report Team Members

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Appendix B. Technical Notes

Serai River, Hulu Langat District

Flood Inundation Model

The flood inundation model includes a rainfall-runoff module for each sub-basin, a hydrodynamic module for the river and canal networks, and a flood inundation module for the floodplains. This model has been applied to several basins in Japan, as well as to Southeast Asian countries (Kure et al., 2008; Moe et al., 2016).

Rainfall-runoff module (Kure et al., 2008)

This rainfall-runoff model simulates multilayer flows related to overland flow, vertical infiltration flow, and saturated and unsaturated seepage flows on a hillslope of the basin. The model generates Horton overland flows in urban areas, and subsurface and saturation overland flows in mountainous areas depending on the relationship between the soil, geological characteristics and rainfall intensity on the hillslope. The equations describe overland flow, subsurface flow, vertical infiltration flow, and the water depth of overland flow, as follows:

$$\frac{dq_s}{dt} = a_s q_s^{\beta_s}\left(r(t) - q_0 - q_s\right) \qquad \text{Surface flow (1)}$$

$$\frac{dq_*}{dt} = a_0 q_*^{\beta}\left(q_0 - q_*\right) \qquad \text{Subsurface flow (2)}$$

$$\frac{dq_0}{dt} = \left(r(t) - q_0\right)\frac{q_0 - K_s}{h + h_k} - \frac{q_0}{\left(\theta_s - \theta_i\right)}\frac{\left(q_0 - K_s\right)^2}{K_s\left(h + h_k\right)} \qquad \text{Vertical infiltration flow (3)}$$

$$\frac{dh}{dt} = r(t) - q_0 - q_s \qquad \text{Surface water depth (4)}$$

where q_0 is the vertical infiltration rate (mm h^{-1}), q_s is the surface runoff (mm h^{-1}), q_* is the subsurface runoff (mm h^{-1}), r(t) is the effective rainfall (mm h^{-1}), h is the water depth of overland flow (mm), K_s is the saturated hydraulic conductivity (mm h^{-1}), h_k is the capillary negative pressure of the wet line (cm), θ_s is the saturated water content of the soil, θ_i is the residual water content of the soil, and a_0, a_s, β, and β_s are runoff parameters. For more information, see Kure et al. (2008).

Hydrodynamics module

Flood routing in the rivers and canal networks was calculated using the following continuous equation, and a momentum equation of unsteady flow (Saint-Venant equation).

$$\frac{\partial A}{\partial t}+\frac{\partial Q}{\partial x}=q_l \tag{5}$$

$$\frac{\partial Q}{\partial t}+\frac{\partial\left(\alpha\frac{Q^2}{A}\right)}{\partial x}+gA\frac{\partial h}{\partial x}+\frac{n^2gQ|Q|}{AR^{4/3}}=0 \tag{6}$$

where Q is the discharge ($m^3\ s^{-1}$), A is the cross-sectional area (m^2), q_l is the lateral inflow or outflow distributed along the x-axis of the watercourse ($m^2\ s^{-1}$), n is Manning's roughness coefficient, α is the momentum distribution coefficient, g is the acceleration of gravity ($m\ s^{-2}$), R is the hydraulic radius (m), and h is the water level (m).

Flood inundation module

Unsteady two-dimensional flow equations, consisting of the following continuity equation and momentum equations, were solved numerically for the flood inundation simulation of the floodplains.

where C (x,y) is the Chézy resistance ($m^{1/2}\ s^{-1}$), ρ_w is the density of water ($kg\ m^{-3}$), ζ (x,y,t) is the water elevation (m), τxx, τxy, and τyy are the components of effective shear stress ($kg\ m^{-1}\ s^{-2}$), p (x,y,t), q (x,y,t) are the flux densities ($m^3\ s^{-1}\ m^{-1}$) in the x- and y-directions, respectively and h (x,y,t) is the water depth (m). g is the acceleration of gravity ($m\ s^{-2}$).

$$\frac{\partial h}{\partial t}+\frac{\partial p}{\partial x}+\frac{\partial q}{\partial y}=0 \tag{7}$$

$$\frac{\partial p}{\partial t}+\frac{\partial}{\partial x}\left(\frac{p^2}{h}\right)+\frac{\partial}{\partial y}\left(\frac{pq}{h}\right)+gh\frac{\partial \zeta}{\partial x}+\frac{gp\sqrt{p^2+q^2}}{C^2-h^2}-\frac{1}{\rho_w}\left[\frac{\partial}{\partial x}(h\tau_{xx})+\frac{\partial}{\partial y}(h\tau_{xy})\right]=0 \tag{8}$$

$$\frac{\partial q}{\partial t}+\frac{\partial}{\partial y}\left(\frac{q^2}{h}\right)+\frac{\partial}{\partial x}\left(\frac{pq}{h}\right)+gh\frac{\partial \zeta}{\partial y}+\frac{gq\sqrt{p^2+q^2}}{C^2-h^2}-\frac{1}{\rho_w}\left[\frac{\partial}{\partial y}(h\tau_{yy})+\frac{\partial}{\partial x}(h\tau_{xy})\right]=0 \tag{9}$$

Kampung Tok Muda, Kapar

Flood Visualization

To obtain an estimated digital elevation model (DEM) of the area, the points were interpolated with inverse-distant weighting (IDW) with QGIS Software with a resolution of 100 m cell size. The vertical resolution was captured in 0.001 m but was rounded down to 0.01 m for analysis to account for the generalization of the spatial resolution. The DEM was also cropped to remove the part beyond the bund as it is a flooded mangrove forest, which is not representable by the interpolated values.

The points closest to the bund also serve as Ground Control Points (GCP) for elevation capture with a drone using photogrammetry techniques (Figure 65) and produce high resolution digital surface model (DSM) to obtain cross sectional profile of the bund and borrow pits (Figure 66). Drone elevation capture was done by Geomapping Technology Sdn Bhd (GMT) and SDMU to produce the DSM.

Figure 65. Scatter of surveyed elevation points with IDW interpolated DEM.

Long-term observed tidal data was provided by JUPEM. The closest tidal station is located at Port Klang. The distance between the coastline of Kapar and Port Klang is only about 12 km. Ten years of observed tidal data was obtained starting from January 2008 to December 2017. The long term mean sea level is 3.646 m from the zero of tide gauge or 0.022 m NGVD, which account for 33 years of observation from 1984 to 2016 (JUPEM, 2016).

Based on tidal data, the highest recorded tide or extreme high water (EHW) was 2.89 m NGVD while mean high water spring (MHWS) was 2.146 m NGVD. These values represent the highest possible tide level and the highest common tides, respectively. Based on these values, the cross-section profiles of the bund was analysed to compare the elevation of the bund and road with tide levels during EHW and MHWS (Figure 66). If the bunds are lower than the tide level, there will be overtopping. The roads nearby each GCP should represent the elevation of the surrounding area, including nearby settlements which are mostly only within 200 m away. If the road is lower than the tide levels, it can be assumed that there is a chance of flooding during breaching/overtopping.

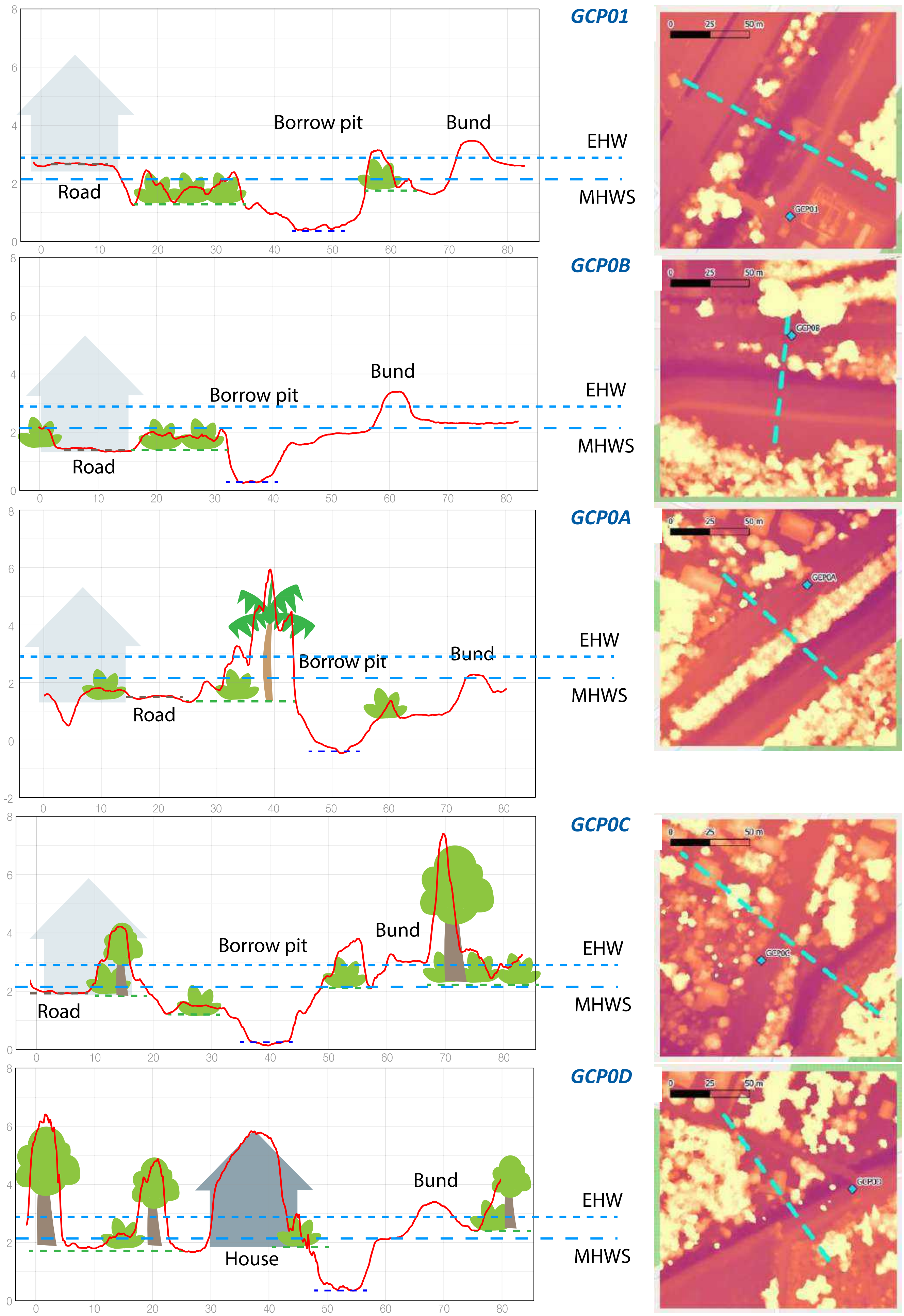

Figure 66. Cross-sectional profiles of the bund and nearby features

The area around GCP01 is the closest to KEV. It can be deduced that there is no chance of overtopping during EHW. The area is possibly developed with higher elevation for the nearby gas supply station for KEV and a concrete industry across the road. The roads are also higher than MHWS, thus a lower risk of getting inundated during a bund breach.

For GCP0B, EHW is still below the bund height with no chance of overtopping. However, the roads are lower than MHWS, which is verified by the flooding of roads observed during the last flood event in Figure 58 during a bund breach. A house located nearby was also flooded around this area.

GCP0A is the lowest area in terms of elevation, both for the land and the bund. Unlike industrial areas, this area was probably not developed with flooding in mind. The bund height suggests high possible overtopping even for MHWS. This was the area where the bund was highly damaged that resulted to rapid water flow to the land area during the flood event. This area is also the location of most houses flooded and the worse area. During EHW, this area could be completely flooded to about 1 m high.

The area around GCP0C should have low possibility of bund overtopping during MHWS and EHW. However, EHW could still pose a threat of bund failure. The area might have risk of flooding only for tides on par with EHW. GCP0D is the furthest area from the coast, but still has a chance of flooding in the event of a bund breaching during EHW albeit a rare event.

Overall, all five areas have risk of flooding during EHW, especially in the event of a bund breach. In the event of overtopping or bund breach, flooding will also take time depending on the water storage capacity of the area. The time period of a high tide is also limited (about 1-2 hours). However, it can be deduced that the area around GCP0A has the highest chance of flooding even on MHWS and is often the first place to get flooded.

Figure 67 shows a longitudinal section of the bund to compare the bund elevation and road level from each cross-sectional profile. The longitudinal section also shows the elevation of EHW and MHWS. The results highlight the lower elevation of GCP0A where several groups of houses are close by, including the houses often the first to get flooded. The results also show the roads and nearby houses along the bund are generally either the same or lower than MHWS.

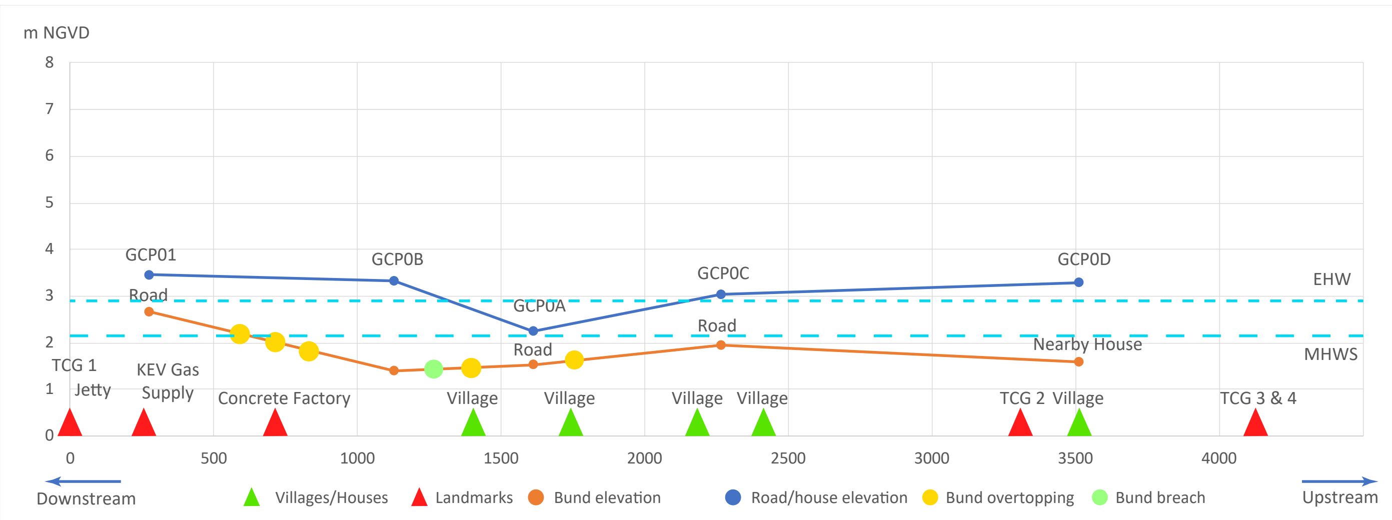

Figure 67. Longitudinal profile of the bund and nearby features

Conclusion

Based on the geographical profile of the area, the ground level around Kampung Tok Muda is generally lower than the average high tides in the area, especially at the village closest to the bund which is usually the first to be affected by the past flood events. The safety of the area against seawater intrusion/inundation is heavily dependent on a stretch of river bund that is susceptible to degradation due to crab activity that is impossible to be controlled. Rising sea level due to climate change will also increase the chances of coastal flooding.

It is critical to maintain the function of the bund in terms of its structural integrity and height to avoid overtopping and breaching during high tides, especially when there are chances of extreme high tides up to 2.89 m NGVD which is about 2.87 m above the mean sea level of Port Klang. While the bund continues to be maintained by DID, the community could help decelerate the degradation by keeping the bund clear of any agricultural activity. Crab activity burrowing through the bund is a natural phenomenon and may not be able to be mitigated. However, during high tides, seepage of water could be seen and could be an indicator of possible breaches.

Appendix C. Terminology on Disaster Risk Reduction

Terminology relating to disaster risk reduction is sourced from the 2009 UNISDR Terminology on Disaster Risk Reduction, unless otherwise stated in the definition entry.

Capacity

The combination of all the strengths, attributes and resources available within a community, society or organization that can be used to achieve agreed goals.

> *Comment: Capacity may include infrastructure and physical means, institutions, societal coping abilities, as well as human knowledge, skills and collective attributes such as social relationships, leadership and management. Capacity also may be described as capability. Capacity assessment is a term for the process by which the capacity of a group is reviewed against desired goals, and the capacity gaps are identified for further action.*

Capacity development

The process by which people, organizations and society systematically stimulate and develop their capacities over time to achieve social and economic goals, including through improvement of knowledge, skills, systems, and institutions.

Comment: Capacity development is a concept that extends the term of capacity building to encompass all aspects of creating and sustaining capacity growth over time. It involves learning and various types of training, but also continuous efforts to develop institutions, political awareness, financial resources, technology systems, and the wider social and cultural enabling environment

Climate change

The Inter-governmental Panel on Climate Change (IPCC) defines climate change as: "a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forces, or to persistent anthropogenic changes in the composition of the atmosphere or in land use".

The United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods".

> *Comment: For disaster risk reduction purposes, either of these definitions may be suitable, depending on the particular context. The UNFCCC definition is the more restricted one as it excludes climate changes attributable to natural causes. The IPCC definition can be paraphrased for popular communications as "A change in the climate that persists for decades or longer, arising from either natural causes or human activity."*

Coping capacity

The ability of people, organizations and systems, using available skills and resources, to face and manage adverse conditions, emergencies or disasters.

> *Comment: The capacity to cope requires continuing awareness, resources and good management, both in normal times as well as during crises or adverse conditions. Coping capacities contribute to the reduction of disaster risks.*

Disaster

A serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources.

> *Comment: Disasters are often described as a result of the combination of: the exposure to a hazard; the conditions of vulnerability that are present; and insufficient capacity or measures to reduce or cope with the potential negative consequences. Disaster impacts may include loss of life, injury, disease and other negative effects on human physical, mental and social well-being, together with damage to property, destruction of assets, loss of services, social and economic disruption and environmental degradation.*

Disaster risk management

The systematic process of using administrative directives, organizations, and operational skills and capacities to implement strategies, policies and improved coping capacities in order to lessen the adverse impacts of hazards and the possibility of disaster.

> *Comment: This term is an extension of the more general term "risk management" to address the specific issue of disaster risks. Disaster risk management aims to avoid, lessen or transfer the adverse effects of hazards through activities and measures for prevention, mitigation and preparedness.*

Disaster risk reduction

The concept and practice of reducing disaster risks through systematic efforts to analyse and manage the causal factors of disasters, including through reduced exposure to 11 hazards, lessened vulnerability of people and property, wise management of land and the environment, and improved preparedness for adverse events.

> *Comment: A comprehensive approach to reduce disaster risks is set out in the United Nations-endorsed Hyogo Framework for Action, adopted in 2005, whose expected outcome is "The substantial reduction of disaster losses, in lives and the social, economic and environmental assets of communities and countries." The International Strategy for Disaster Reduction (ISDR) system provides a vehicle for cooperation among Governments, organisations and civil society actors to assist in the implementation of the Framework. Note that while the term "disaster reduction" is sometimes used, the term "disaster risk reduction" provides a better recognition of the ongoing nature of disaster risks and the ongoing potential to reduce these risks.*

Early warning

The set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by a hazard to prepare and to act appropriately and in sufficient time to reduce the possibility of harm or loss.

> *Comment: This definition encompasses the range of factors necessary to achieve effective responses to warnings. A people-center early warning system necessarily comprises four key elements: knowledge of the risks; monitoring, analysis and forecasting of the hazards; communication or dissemination of alerts and warnings; and local capabilities to respond to the warnings received. The expression "end-to end warning system" is also used to emphasize that warning systems need to span all steps from hazard detection through to community response.*

El Niño-southern oscillation (ENSO)

A complex interaction of the tropical Pacific Ocean and the global atmosphere that results in irregularly occurring episodes of changed ocean and weather patterns in many parts of the world, often with significant impacts over many months, such as altered marine habitats, rainfall changes, floods, droughts, and changes in storm patterns.

Comment: The El Niño part of the El Niño-Southern Oscillation (ENSO) phenomenon refers to the well above-average ocean temperatures that occur along the coasts of Ecuador, Peru and northern Chile and across the eastern equatorial Pacific Ocean, while La Niña part refers to the opposite circumstances when well-below-average ocean temperatures occur. The Southern Oscillation refers to the accompanying changes in the global air pressure patterns that are associated with the changed weather patterns experienced in different parts of the world.

Emergency management

The organization and management of resources and responsibilities for addressing all aspects of emergencies, in particular preparedness, response and initial recovery steps.

Comment: A crisis or emergency is a threatening condition that requires urgent action. Effective emergency action can avoid the escalation of an event into a disaster. Emergency management involves plans and institutional arrangements to engage and guide the efforts of government, non-government, voluntary and private agencies in comprehensive and coordinated ways to respond to the entire 14 spectrum of emergency needs. The expression "disaster management" is sometimes used instead of emergency management.

Environmental impact assessment (EIA)

Process by which the environmental consequences of a proposed project or program are evaluated, undertaken as an integral part of planning and decision making processes with a view to limiting or reducing the adverse impacts of the project or program.

Comment: Environmental impact assessment is a policy tool that provides evidence and analysis of environmental impacts of activities from conception to decision-making. It is utilized extensively in national programming and project approval processes and for international development assistance projects. Environmental impact assessments should include detailed risk assessments and provide alternatives, solutions or options to deal with identified problems.

Environmental degradation

The reduction of the capacity of the environment to meet social and ecological objectives and needs.

Comment: Degradation of the environment can alter the frequency and intensity of natural hazards and increase the vulnerability of communities. The types of human-induced degradation are varied and include land misuse, soil erosion and loss, desertification, wildland fires, loss of biodiversity, deforestation, mangrove destruction, land, water and air pollution, climate change, sea level rise and ozone depletion.

Forecast

Definite statement or statistical estimate of the likely occurrence of a future event or conditions for a specific area.

Comment: In meteorology a forecast refers to a future condition, whereas a warning refers to a potentially dangerous future condition.

Geological hazard

Geological process or phenomenon that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage.

> *Comment: Geological hazards include internal earth processes, such as earthquakes, volcanic activity and emissions, and related geophysical processes such as mass movements, landslides, rockslides, surface collapses, and debris or mud flows. Hydrometeorological factors are important contributors to some of these processes. Tsunamis are difficult to categorize; although they are triggered by undersea earthquakes and other geological 17 events, they are essentially an oceanic process that is manifested as a coastal water-related hazard.*

Geographic information systems (GIS)

Analysis that combine relational databases with spatial interpretation and outputs often in form of maps. A more elaborate definition is that of computer programmers for capturing, storing, checking, integrating, analyzing and displaying data about the earth that is spatially referenced.

> *Comment: Geographical information systems are increasingly being utilized for hazard and vulnerability mapping and analysis, as well as for the application of disaster risk management measures.*

Greenhouse gas (GHG)

Gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation of thermal infrared radiation emitted by the Earth's surface, the atmosphere itself, and by clouds.

> *Comment: This is the definition of the Intergovernmental Panel on Climate Change (IPCC). The main greenhouse gases (GHG) are water vapour, carbon dioxide, nitrous oxide, methane and ozone.*

Hazard

A dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage.

> *Comment: The hazards of concern to disaster risk reduction as stated in footnote 3 of the Hyogo Framework are "… hazards of natural origin and related environmental and technological hazards and risks." Such hazards arise from a variety of geological, meteorological, hydrological, oceanic, biological, and technological sources, sometimes acting in combination. In technical settings, hazards are described quantitatively by the likely frequency of occurrence of different intensities for different areas, as determined from historical data or scientific analysis.*

Hydrometeorological hazards

Process or phenomenon of atmospheric, hydrological or oceanographic nature that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage.

> *Comment: Hydrometeorological hazards include tropical cyclones (also known as typhoons and hurricanes), thunderstorms, hailstorms, tornados, blizzards, heavy snowfall, avalanches, coastal storm surges, floods including flash floods, drought, heatwaves and cold spells. Hydrometeorological conditions also can be a factor in other hazards such as landslides, wildland fires, locust plagues, epidemics, and in the transport and dispersal of toxic substances and volcanic eruption material.*

Land-use planning

The process undertaken by public authorities to identify, evaluate and decide on different options for the use of land, including consideration of long term economic, social and environmental objectives and the implications for different communities and interest groups, and the subsequent formulation and promulgation of plans that describe the permitted or acceptable uses.

Comment: Land-use planning is an important contributor to sustainable development. It involves studies and mapping; analysis of economic, environmental and hazard data; formulation of alternative land-use decisions; and design of long-range plans for different geographical and administrative scales. Land-use planning can help to mitigate disasters and reduce risks by discouraging settlements and construction of key installations in hazard-prone areas, including consideration of service routes for transport, power, water, sewage and other critical facilities.

Mitigation

The lessening or limitation of the adverse impacts of hazards and related disasters.

Comment: The adverse impacts of hazards often cannot be prevented fully, but their scale or severity can be substantially lessened by various strategies and actions. Mitigation measures encompass engineering techniques and hazard-resistant construction as 20 well as improved environmental policies and public awareness. It should be noted that in climate change policy, "mitigation" is defined differently, being the term used for the reduction of greenhouse gas emissions that are the source of climate change.

Natural hazards

Natural process or phenomenon that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage.

Comment: Natural hazards are a sub-set of all hazards. The term is used to describe actual hazard events as well as the latent hazard conditions that may give rise to future events. Natural hazard events can be characterized by their magnitude or intensity, speed of onset, duration, and area of extent. For example, earthquakes have short durations and usually affect a relatively small region, whereas droughts are slow to develop and fade away and often affect large regions. In some cases hazards may be coupled, as in the flood caused by a hurricane or the tsunami that is created by an earthquake.

Preparedness

The knowledge and capacities developed by governments, professional response and recovery organizations, communities and individuals to effectively anticipate, respond to, and recover from, the impacts of likely, imminent or current hazard events or conditions.

Comment: Preparedness action is carried out within the context of disaster risk management and aims to build the capacities needed to efficiently manage all types of emergencies and achieve orderly transitions from response through to sustained recovery. Preparedness is based on a sound analysis of disaster risks and good linkages with early warning systems, and includes such activities as contingency planning, stockpiling of equipment and supplies, the development of arrangements for coordination, evacuation and public information, and associated training and field exercises. These must be supported by formal institutional, legal and budgetary capacities. The related term "readiness" describes the ability to quickly and appropriately respond when required.

Prevention

The outright avoidance of adverse impacts of hazards and related disasters.

Comment: Prevention (i.e. disaster prevention) expresses the concept and intention to completely avoid potential adverse impacts through action taken in advance. Examples include dams or embankments that eliminate flood risks, land-use regulations that do not permit any settlement in high risk zones, and seismic engineering designs that ensure the survival and function of a critical building in any likely earthquake. Very often the complete avoidance of losses is not feasible and the task transforms to that of mitigation. Partly for this reason, the terms prevention and mitigation are sometimes used interchangeably in casual use.

Public awareness

The extent of common knowledge about disaster risks, the factors that lead to disasters and the actions that can be taken individually and collectively to reduce exposure and vulnerability to hazards.

Comment: Public awareness is a key factor in effective disaster risk reduction. Its development is pursued, for example, through the development and dissemination of information through media and educational channels, the establishment of information centres, networks, and community or participation actions, and advocacy by senior public officials and community leaders.

Recovery

The restoration, and improvement where appropriate, of facilities, livelihoods and living conditions of disaster-affected communities, including efforts to reduce disaster risk factors.

Comment: The recovery task of rehabilitation and reconstruction begins soon after the emergency phase has ended, and should be based on pre-existing strategies and policies that facilitate clear institutional responsibilities for recovery action and enable public participation. Recovery program, coupled with the heightened public awareness and engagement after a disaster, afford a valuable opportunity to develop and implement disaster risk reduction measures and to apply the "build back better" principle.

Relief/Response

The provision of emergency services and public assistance during or immediately after a disaster in order to save lives, reduce health impacts, ensure public safety and meet the basic subsistence needs of the people affected.

Comment: Disaster response is predominantly focused on immediate and short-term needs and is sometimes called "disaster relief". The division between this response stage and the subsequent recovery stage 25 is not clear-cut. Some response actions, such as the supply of temporary housing and water supplies, may extend well into the recovery stage.

Resilience

The ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions.

Comment: Resilience means the ability to "resile from" or "spring back from" a shock. The resilience of a community in respect to potential hazard events is determined by the degree to which the community has the necessary resources and is capable of organizing itself both prior to and during times of need.

Retrofitting (or upgrading)

Reinforcement or upgrading of existing structures to become more resistant and resilient to the damaging effects of hazards.

> *Comment: Retrofitting requires consideration of the design and function of the structure, the stresses that the structure may be subject to from particular hazards or hazard scenarios, and the practicality and costs of different retrofitting options. Examples of retrofitting include adding bracing to stiffen walls, reinforcing pillars, adding steel ties between walls and roofs, installing shutters on windows, and improving the protection of important facilities and equipment.*

Risk

The combination of the probability of an event and its negative consequences.

> *Comment: This definition closely follows the definition of the ISO/IEC Guide 73. The word "risk" has two distinctive connotations: in popular usage the emphasis is usually placed on the concept of chance or possibility, such as in "the risk of an accident"; whereas in technical settings the emphasis is usually placed on the consequences, in terms of "potential losses" for some particular cause, place and period. It can be noted that people do not necessarily share the same perceptions of the significance and underlying causes of different risks.*

Risk assessment

A methodology to determine the nature and extent of risk by analyzing potential hazards and evaluating existing conditions of vulnerability that together could potentially harm exposed people, property, services, livelihoods and the environment on which they depend.

> *Comment: Risk assessments (and associated risk mapping) include: a review of the technical characteristics of hazards such as their location, intensity, frequency and probability; the analysis of exposure and vulnerability including the physical social, health, economic and environmental dimensions; and the evaluation of the effectiveness of prevailing and alternative coping capacities in respect to likely risk scenarios. This series of activities is sometimes known as a risk analysis process.*

Structural and non-structural measures

Structural measures: Any physical construction to reduce or avoid possible impacts of hazards, or application of engineering techniques to achieve hazard resistance and resilience in structures or systems.

Non-structural measures: Any measure not involving physical construction that uses knowledge, practice or agreement to reduce risks and impacts, in particular through policies and laws, public awareness raising, training and education.

> *Comment: Common structural measures for disaster risk reduction include dams, flood levies, ocean wave barriers, earthquake-resistant construction, and evacuation shelters. Common non-structural measures include building codes, land use planning laws and their enforcement, research and assessment, information resources, and public awareness 29 programmes. Note that in civil and structural engineering, the term "structural" is used in a more restricted sense to mean just the load-bearing structure, with other parts such as wall cladding and interior fittings being termed non-structural.*

Sustainable development

Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

Comment: This definition coined by the 1987 Brundtland Commission is very succinct but it leaves unanswered many questions regarding the meaning of the word development and the social, economic and environmental processes involved. Disaster risk is associated with unsustainable elements of development such as environmental degradation, while conversely disaster risk reduction can contribute to the achievement of sustainable development, through reduced losses and improved development practices.

Vulnerability

The characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard.

Comment: There are many aspects of vulnerability, arising from various physical, social, economic, and environmental factors. Examples may include poor design and construction of buildings, inadequate protection of assets, lack of public information and awareness, limited official recognition of risks and preparedness measures, and disregard for wise environmental management. Vulnerability varies significantly within a community and over time. This definition identifies vulnerability as a characteristic of the element of interest (community, system or asset) which is independent of its exposure. However, in common use the word is often used more broadly to include the element's exposure.

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