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Flood Hazard Information Map Using Geographical Information System (GIS) for Residential Community Resilience

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Abstract
The purpose of this research is to develop the residential flood hazard information map using Geographical Information System (GIS) for residential community resilience. The review approach is based on related literature contributing to identifying themes such as "flood hazard information map" and "geographical information system". Integration of data will be sourced from Department of Irrigation and Drainage (DID), National Property Information Centre (NAPIC) and Jabatan Ukur dan Pemetaan Malaysia (JUPEM) using Unique Parcel Identifier (UPI) for respective residential land parcels. An extensive review of previous studies of flood hazard information map of residential community resilience for different flood disaster studies is considered to be the main restrictive factor resulting in a lack of empirical studies in this field. The development of residential property needs to be imposed with the elements for building specifications and materials that have flood resistance and resilience to protect the community life and property.

Keywords: Community resilience, Floods, Geographical Information System (GIS), Residential property

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1.0 Introduction

Flooding has been more significant in recent years due to increased urban development, with subsequent increases in water run-off and changes in world weather patterns (Eves & Brown 2002). The occurrence of such heavy rainfall (Syafrina 2015) and subsequent flooding has not only raised issues of climatic change and the effect on the environment, but also more local issues of the ecological impact , health risks (Veronesi 2014), residential property development, residential property prices (Lamond et al. 2007) and the ability for the residential property owners to gain both finance and insurance for their properties (Daniel et al. 2009).

Malaysia is a country very prone to flood risk (refer to Figure 1), mostly by the nature of its physical and human geography as land use patterns of settlements (Chan 2015). Compared to other types of disasters in Malaysia, flooding is the most frequent and causes the greatest damage to properties annually. Floods have been divided into three (3) types: river flooding, flash flooding and coastal flooding (Shafapour Tehrany et al. 2017).

The frequent occurrence of flooding in Peninsular Malaysia and the damage caused can be significant in relation to both property damage and service disruption. Property with physical damage (Jonkman et al. 2008) requires a higher operating cost of repair and

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maintenance which might directly affect the value of the property. Besides that, flood causes disruption to amenities and facilities provided to the community, especially road transport infrastructure (Pregnolato et al. 2017).

GIS provides a powerful and effective tool to strengthen the integration of flood risk mapping (Muhamad 2015). By providing better information and analysis in property valuation using GIS (Bohari 2015), it helps relevant stakeholders and property players to make better decisions and governance (Latif et al. 2015). GIS is able to provide a model which can be used to map the residential parcels and the flood's historical reviews (Diya et al. 2014), and predict flood areas base on certain parameters (Tam 2014).

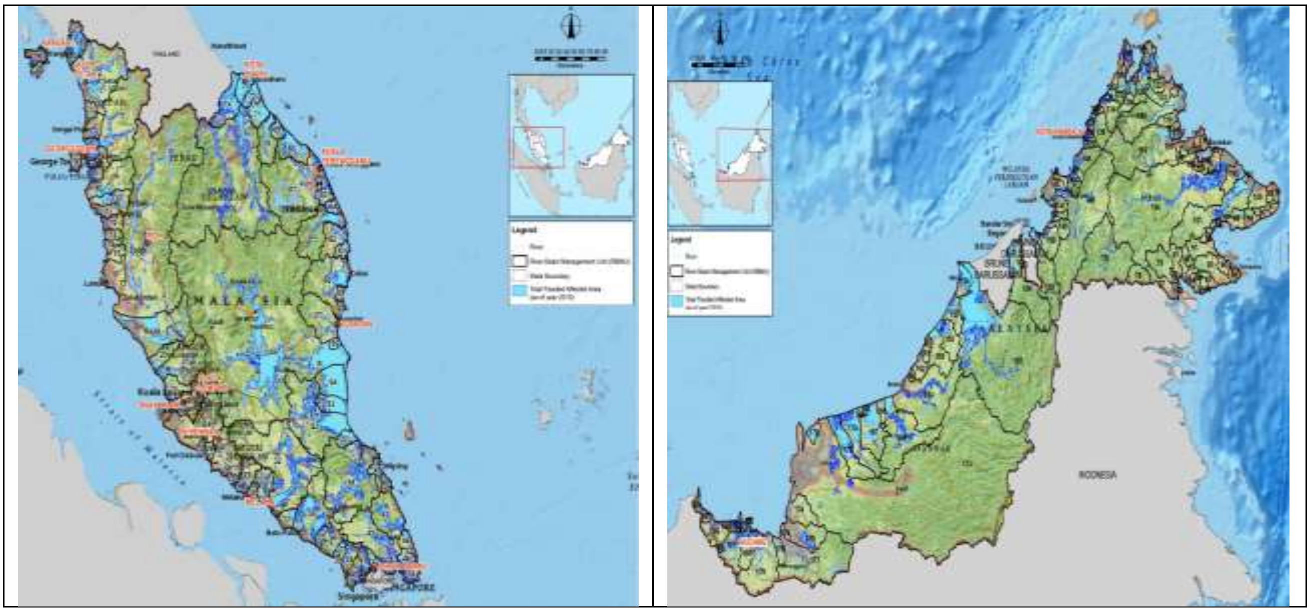

Fig. 1: Flood-prone areas in Malaysia
(Source: Department of Irrigation and Drainage Malaysia)

1.1 Purpose of the Study

The purpose of this research is to develop a residential flood hazard information map using GIS for residential community resilience. The review approach is based on related literature contributing to identifying themes such as "flood hazard information map" and "geographical information system". Integration of data was sourced from DID, NAPIC and JUPEM using UPI for respective residential land parcels.

1.2 The Objectives of the Study

In line with the purpose, the objectives of the study are to identify the flood characteristics and parameters in a residential area, to determine the significant approach for the development of residential property with the specification and material that have flood resistance and resilience at the respective flood-prone areas.

2.0 Literature Review

From the previous literature study, flood resilience for residential property can be integrated with building fabric, fixtures and fittings to reduce the impact and damage of flood water to the residential property. This allows easier drying and cleaning, ensures that the structural integrity of the building is not compromised and reduces the amount of time until the building can be re-occupied.

2.1 Flood Resilience Construction for Residential Community

In designing a residential property for community resilience purposes towards floods, architects and property development players need to have knowledge of basic flood parameters (Bowkerm et al. 2007), and they are as follows:

(1) *Flood depth:* the main parameter in the design strategy, as this will dictate whether it is feasible to try to exclude and/or delay floodwater from entering the property. Flood depth can be quantified based on meter heights of the water level.

(2) *Flood frequency:* In areas where flooding is frequent but shallow, an effective strategy may be to consider avoidance or resistant measures to restrict water reaching or entering the property. If avoidance or resistance is not possible, or the flood depth is significant, then incorporation of resilient measures may be the only option. Flood frequency can be quantified based on the flood occurrences per year in flood respective areas.

(3) *Flood duration:* Flooding from large rivers which exceed their capacity or from rising groundwater can often be of long duration, sometimes taking several days/weeks (or months, in the case of groundwater) to drain away, so that pumping may be required. Inundation of a building by floodwater for long periods could damage the building fabric and lead to structural problems. For long duration flooding, a strategy to keep water out at the building level may not be a viable option. Flood duration can be quantified based on the duration per hours of flood events.

For a strategy of promoting safe and eco-friendly development to the residential community, developers and property development players need to construct a residential unit with appropriate flood resistant and resilient measures in areas that have a residual risk of flooding, as shown in Figure 2. The residential community needs to be protected by the government by providing the best and safe residential area to live. The aim is to manage flood risk and reduce the threat to people and property (Grahn & Nyberg 2017), delivering the greatest environmental, social and economic benefit to the community.

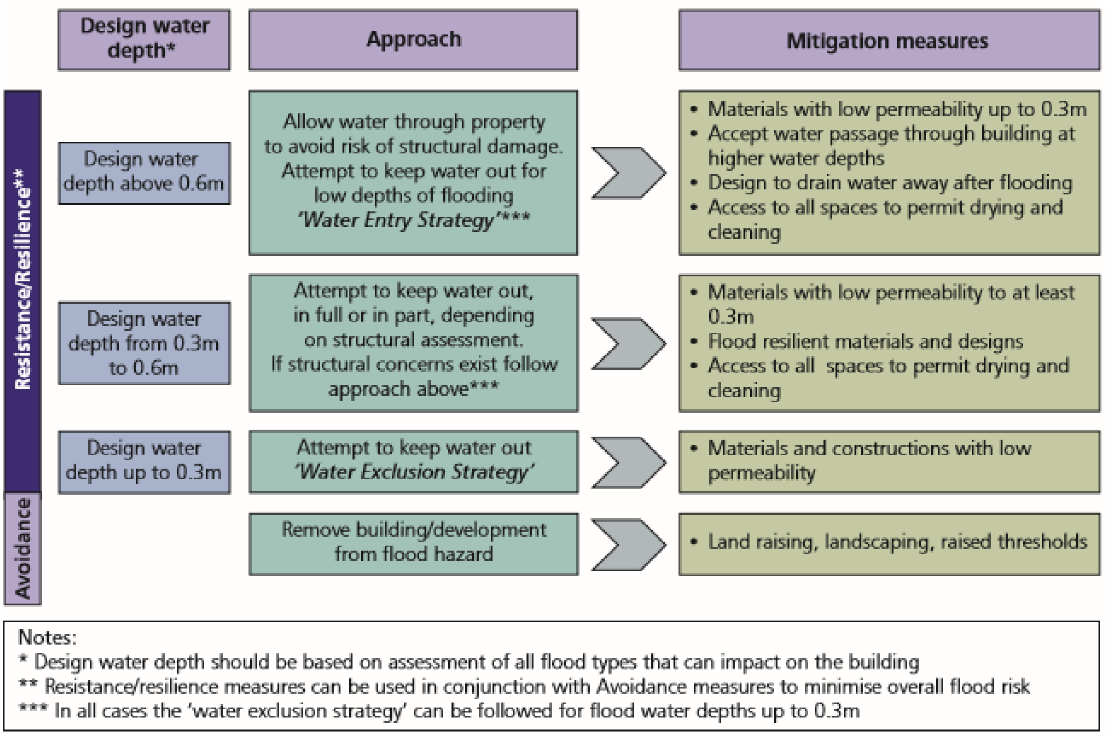

Fig. 2: Design approaches and flood resilient design and construction
(Source: Bowkerm et al. 2007)

A flash flood that occurs in a major urban area is swift flooding in response to intense rainfall over a small area. Inundation over dry land occurs within minutes to a few hours of the rainfall event, potentially having a tremendous impact on the community and infrastructure (de Brito et al. 2017). In constructing residential property within a flood-prone area, there are various flood characteristic (see Table 1) to be considered to prevent the floodwater from entering and damaging (Merz et al. 2010) property.

Table 1: Flood categories for building construction

Flood Categories	Description
Flood avoidance	Constructing a building and its surrounds (at the site level) in such a way to avoid it being flooded (e.g. by raising it above flood level, re-siting outside flood risk area etc.).
Flood resistance	Constructing a building in such a way to prevent floodwater from entering the building and damaging its fabric.
Flood resilience	Constructing a building in such a way that although flood water may enter the building its impact is reduced (i.e. no permanent damage is caused, structural integrity is maintained and drying and cleaning are facilitated).
Flood repairable	Constructing a building in such a way that although flood water enters a building, elements that are damaged by flood water can be easily repaired or replaced. This is also a form of flood resilience.

(Source: Bowkerm et al. 2007)

2.2 Assessing Flood Hazard

Assessing flood hazard needs an indication by looking at how often floods have occurred historically (de Moel 2009) and assess the information of floods such as the flood depth, duration, and frequency. Flood hazard components (Ahmadisharaf et al. 2017) can be divided into three (3) types: (i) Economic Hazard (ii) Social Hazard and (iii) Environmental Hazard. Figure 3 shows the hierarchy of each type of hazard component.

The impact of each hazard components will be varied, depending on the land use and types of property affected by floods. This research focuses on the damage factor for structures and property that refer to the adjustment to be made on the base damage value, and the fact that the magnitude of damage per unit is a function of the severity and duration of flood (Glas 2016), as well as the value of structures and properties that vary by location.

Analysis and assessment for each component and indicator of flood hazard need to be determined and classified based on the flood parameter and class. The damage assessment and survey for the property needs to be scored based on the real flood condition and situation as shown in Table 2.

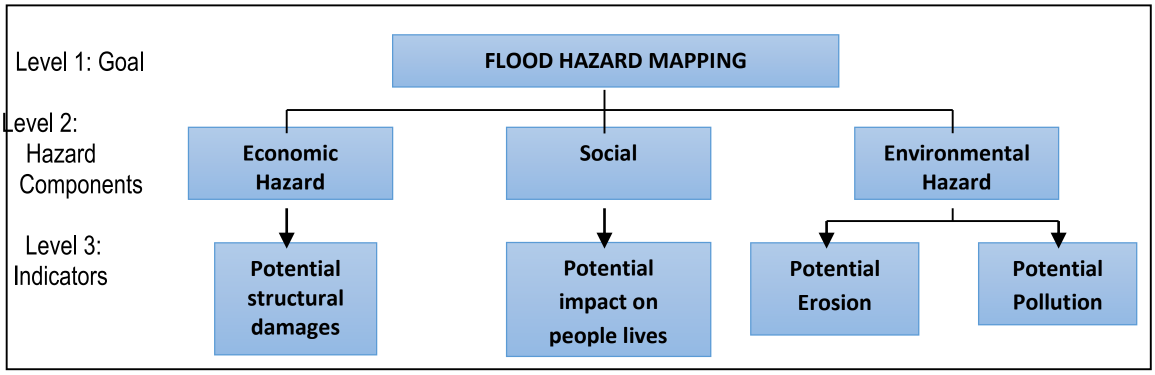

Fig. 3: Hierarchical structure of flood hazard mapping framework
(Source: Ahmadisharaf et al. 2017)

Table 2: Flood hazard components, indicators and corresponding scores

Flood Hazard Component	Indicator	Flood parameter	Class	Score
Economic Hazard	Structural damages	Depth	< 0.5m	0.1
			0.5m – 1m	0.3
			1.0m – 2.0m	0.5
			2.0m – 3.0m	0.7
			> 3.0m	0.9
Social Hazard	Peoples' lives	Depth & Velocity	Low Danger	0.1
			Judgement Zone	0.5
			High Danger	0.9
Environmental Hazard	Potential erosion	Impulse	< $1m^2/s$	0.1
			$1m^2/s$ – $2m^2/s$	0.3
			$2m^2/s$ -$3m^2/s$	0.5
			$3m^2/s$ – $7m^2/s$	0.7
			> $7m^2/s$	0.9
	Pollution	Duration	< 1 day	0.1
			1 day – 2 days	0.3
			2 days – 3 days	0.5
			3 days – 5 days	0.7
			> 5 days	0.9

(Source: Ahmadisharaf et al. 2017)

3.0 Research Methodology

The research methodology is presented in Figure 4. The research objectives are achieved through a literature review and analysis from the previous research from local and international studies. The methodology is designed by separating this research works into four (4) main stages as shown below.

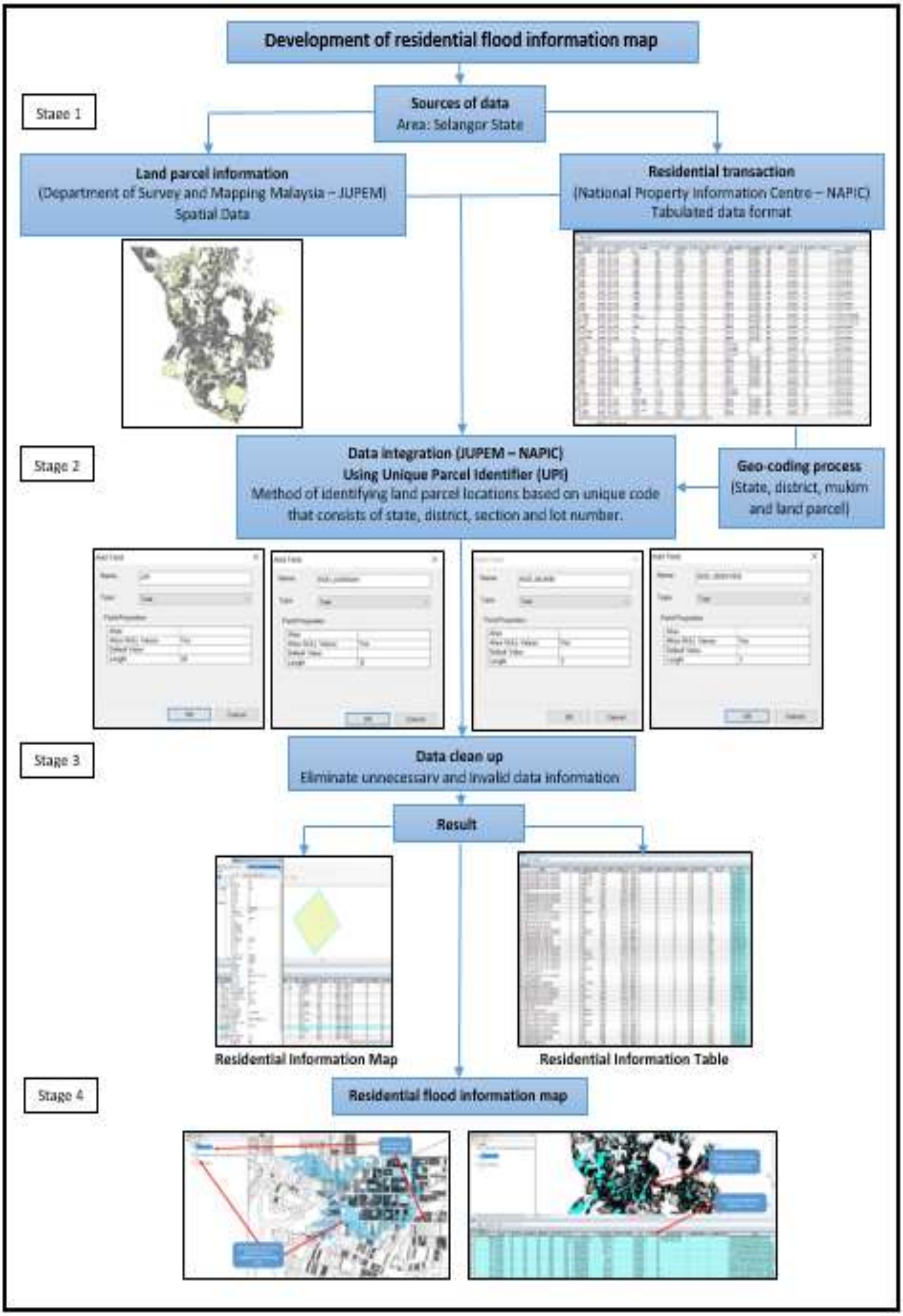

Fig. 4: Research Methodology Flowchart

Based on Figure 4, there are four (4) stages involved in completing the research as follows:

Stage 1:
The research begins with a literature review relating to flood-risk and residential areas, examining previous research journals and reports. The literature review covers overseas and local experience and focused on flood and community resilience. At this stage, data collection such as flood parameter data from DID, property information data from NAPIC and digitised maps from JUPEM were gathered to be integrated using GIS software.

Stage 2:
At this stage, the flood hazard area and the residential land parcel map are integrated using UPI. Besides that, all data needs to be encoded based on the criteria of state, district, region and land parcel.

Stage 3:
Residential community areas that have been affected by a flood have been integrated with GIS. The data needs to be cleaned up to make sure only the significant data is used in this research. The elimination process needs to be aligned with the spatial data from JUPEM.

Stage 4:
As the final stage, the results from the research are the residential flood hazard information map as a combination of all information on the land parcel for each residential community area, together with the flood information as highlighted in blue. These findings are very useful as benchmarks to residents and government agencies related to community resilience in assessing the flood risk for residential property.

4.0 Findings

4.1. Development of Residential Flood Hazard Information Map

The prediction of flood-prone areas for a residential property using a GIS approach allows the property players in the real estate industry to assess their objectives for property development and valuation. The implementation of valuation using a GIS database has opened opportunities for the deployment of valuation tasks at low cost, and easily maintained and operational effective systems (Kershaw & Rossini 2014).

All map layers need to be established and are stored in the GIS database, accompanied by feature and attribute codes in which the method for encoding the geospatial data provides a description of the features and their attributes for the exchange of digital geographic information as seen in Figure 5.

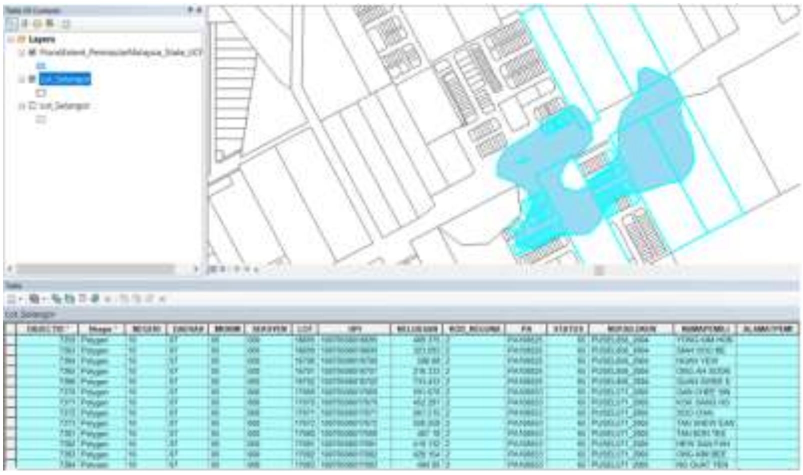

Fig. 5: Recognition of map layers

Geospatial database determines whether a GIS application is successful. The major task involves data entry, error cleaning and coordinated registration for each land parcel as per Figure 6. These maps are structured to accommodate certain attributes required for future queries and analysis. Other attributes may be added from time to time depending on the requirements.

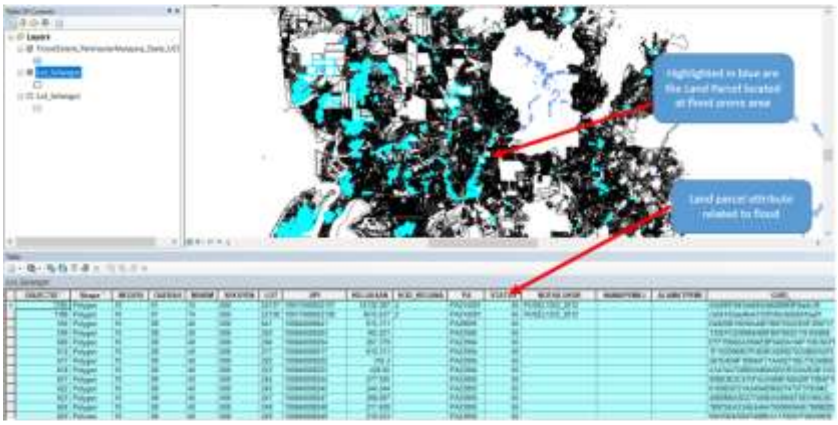

Fig. 6: Structuring the feature and attribute codes

Prior to mapping digital technology, the geospatial information is stored and portrayed on hard copy maps as seen in Figure 7. The finding of maps contains information for the land parcel of residential properties together with the information of flood-prone areas.

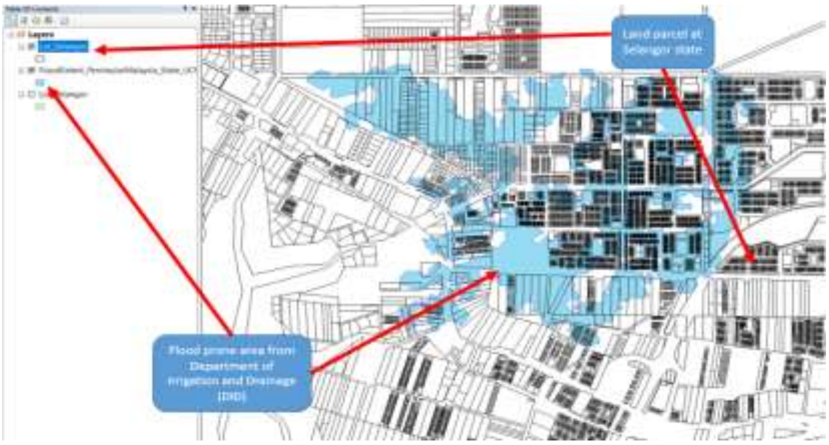

Fig. 7: Residential Flood Information Map

5.0 Discussion

Description of Flood Hazard Degree Map

The flood hazard degree map (see Figure 8) generated from the GIS is very useful for community resilience and resistance purposes for residential development. The flood-prone area is shown in the blue colour and can be divided into three (3) types based on the flood depth range information (see Figure 8a).

The hazard degree map is an indicator of the Emergency Response Unit that will be incorporated with the community affected by the flood. At the area of flood depth more than 3.0m (see Table 3); the community needs to be compulsorily evacuated to the evacuation centre at the nearest and safest area. While for the communities living at a flood depth area within 0.5 – 3.0m, they only are evacuated when necessary if the flood water flow increases. For communities living at a flood depth area below 0.5m are considered at caution stage and need monitoring from the respective agencies.

Any impact of damage to the properties can be foreseen and mitigated against by relatively simple design and construction techniques. Residential property for the community needs to be constructed using materials which are flood resilient construction. The assessment of flood risk, building design and community awareness to adapt and respond to floods may reduce the social and economic vulnerability index to the flood area. The flood hazard map is considered as one tool to provide information for the evaluation of floods using the GIS for community resilience. The hazard map should be produced and distributed to the community prior to the flood, and guide them to fastest and safety places when the flooding occurs (Sukeri et al. 2015).

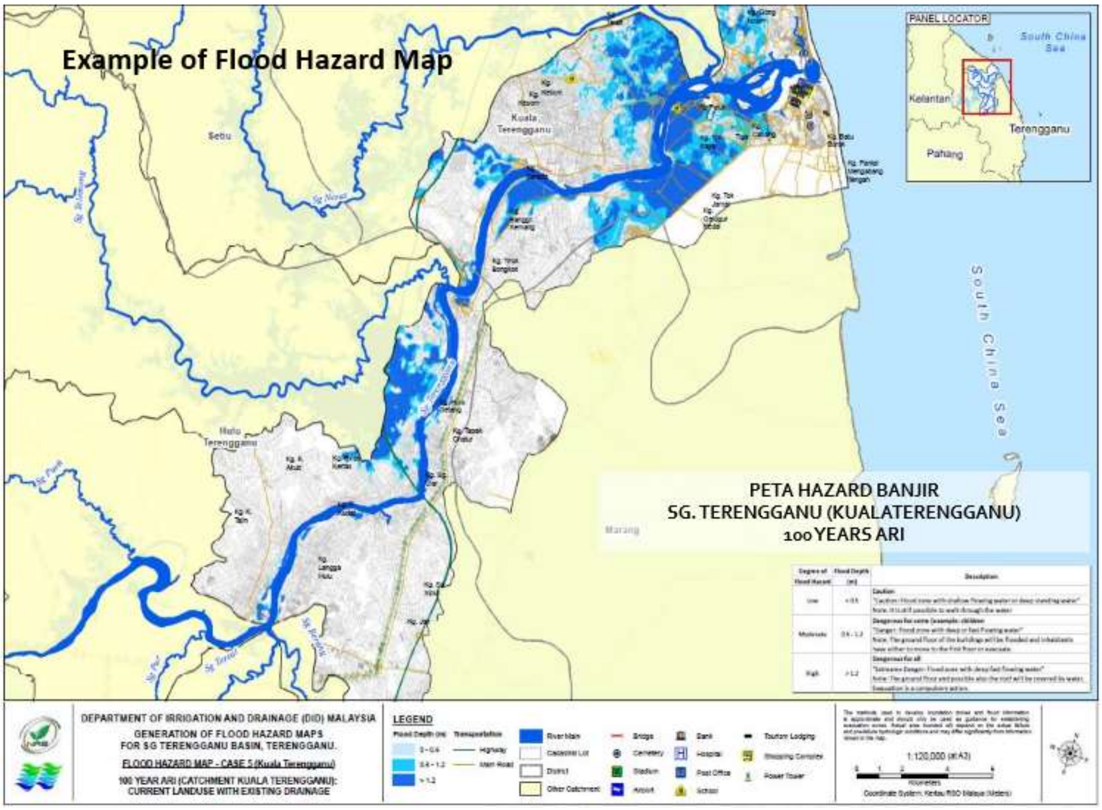

Fig. 8: Flood Hazard Degree Map
(Source: Department of Irrigation and Drainage)

Colour	Flood Depth	Colour Name	R	G	B
	0 – 0.5m	Sodalite Blue	190	232	255
	0.5 – 1.2m	Big Sky Blue	0	197	255
	Above 1.2m	Lapis Lazuli	0	92	230

Fig. 8(a): Flood depth range

Table 3: Description of Flood Hazard Degree

The Degree of Flood Hazard	Flood Hazard Value	Indicative Depth Range (m)	Description
Low	< 0.75	Up to 0.25m	***Caution*** "Caution: Flood zone with shallow flowing water or deep standing water" Note: It is still possible to walk through the water.
Moderate	0.75 – 1.25	Up to 0.5m	***Danger for some (i.e. children)*** "Danger: Flood zone with deep or fast flowing water" Note: The ground floor of the building will be flooded and inhabitants have to either move to the first floor or evacuate.
Severe	1.25 – 2.0	0.5 – 3m	***Danger for most*** "Extreme Danger: Flood zone with deep fast flowing water" Note: The ground floor and possibly also the roof will be covered by water. Evacuation is a compulsory action.
Extreme	> 2.0	0.5 to over 3m	***Danger for all*** "Extreme Danger: flood zone with deep fast flowing water"

(Source: Dwelling et al. 2017)

6.0 Conclusion

These findings are very useful as benchmarks for property players and agencies related to the flood emergency response team while assessing the flood risk for residential property and community resilience. The characteristics of flood events in several places are varied and critical in determining the impact of flooding on the residential area. The residential flood hazard information map is an important outcome of the research which will encourage further research in this area of study.

The finding from this research will provide information to the residential community regarding the impact of the flood on residential community resilience. The flood hazard information map is very useful and can provide information related to flood parameters for the duration, frequency and depth in flood respective areas.

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e) Universiti Teknologi MARA (UiTM)

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