

# 3D GIS Visualisation for Urban Flood Risk Assessment in Taman Sri Muda, Shah Alam

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## Abstract

*Flooding has become a major urban issue in Malaysia, especially in high-density areas like Taman Sri Muda, Shah Alam, which faced severe inundation during the 2021 monsoon. The recurring nature of such events has highlighted critical weaknesses in traditional flood management strategies. Conventional flood maps often lack the spatial resolution needed to assess the impacts on individual buildings, limiting their utility for emergency preparedness and planning. This study addresses these limitations by proposing a framework for 3D flood visualisation utilising Geographic Information Systems (GIS) technology, enhanced by intelligent spatial analysis tools embedded within modern platforms such as ArcGIS Pro. The aim is to identify buildings most at risk from rising floodwaters by integration of Digital Surface Model (DSM) and Digital Elevation Model (DEM) data for flood simulation and building height analysis. A 3D interactive dashboard was created to visualise flood risks using extruded building footprints and simulated flood levels. While AI was not explicitly implemented in this study, the approach leveraged intelligent GIS functions such as automated rendering and spatial analysis available within ArcGIS Pro. AI serves a supportive, embedded component rather than a standalone feature. Preliminary results demonstrate the effectiveness of 3D visualisation in identifying vulnerable structures and supporting data-driven, timely decision-making. The findings indicate that low-rise residential buildings are significantly more affected compared to mid-rise structures. This research offers a practical approach aligned with the next generation of geospatial intelligence, highlighting the role of intelligent GIS in enhancing flood awareness, guiding infrastructure planning and improving disaster response preparedness in flood-prone urban environments.*

**Keywords:** 3D Visualisation, GIS, Flood Simulation, Flood Impact Assessment, Taman Sri Muda

## 1. Introduction

Urban flooding has become a major concern, as it is influenced by two phenomena: climate change and the high rate of urbanisation [1]. This problem is especially acute in Malaysian cities with the population high density and the low-lying topography, like Taman Sri Muda, Shah Alam. What is more, the aging or ineffective infrastructure contributes to this situation by substantially increasing flood risks, especially in the case of the monsoon season [2]. The disastrous flood incident of 2021 revealed the inadequacy of traditional two-dimensional (2D) mapping approaches that do not properly represent ground grade changes and the effects on the building level. This study, as a reaction, suggests the mathematical development of a 3D

Flood Impact Visualisation Framework, which intends to use Geographic Information Systems (GIS), and therefore be more detailed and spatially precise as to the detrimental effects that floods have on existing buildings [3] and [4].

Specifically referring to Taman Sri Muda, the framework seeks to determine the most vulnerable 3D buildings to floods during the rising of water levels by combining Digital Surface Models (DSM), Digital Elevation Models (DEM) and the data of building footprint [5]. Although it is not applied directly to the study, the research makes use of AI-integrated functionality to perform spatial modelling, flood simulation, and automatic data processing on ArcGIS Pro [6]. This is not something that is coded

individually but rather forms of in-built automation and geospatial intelligence apps. The area of concern is efficient processing and visualisation based on available GIS functionalities. These tools enable the construction of elevation-based flood models that enhance both analytical accuracy and visualisation quality.

Ultimately, this research culminates in the development of an interactive dashboard that enhances risk communication and supports informed decision-making and preparedness among planners and local communities. Within this framework, artificial intelligence (AI) functions as a supportive technology embedded in a broader geospatial analysis system, facilitating the transition toward smarter urban flood management. Although the study does not involve the creation or deployment of standalone AI algorithms, it positions AI as a vital component of next-generation geospatial technologies. In particular, AI operates as an enabling mechanism that enhances spatial modelling, automates analytical processes, and supports real-time visualisation through the built-in functionalities of ArcGIS Pro. The term *AI* in this context refers to the software's embedded intelligent features such as automated spatial analysis, surface extraction, and hydrological modelling that collectively improve the accuracy of geospatial flood simulations. These capabilities are intrinsic to the software's internal architecture and should be understood as metaphorical representations of AI, rather than explicit, trainable machine learning models.

## 2. Material and Methods

The research focuses on Taman Sri Muda in Section 25 of Shah Alam, Malaysia an area prone to repeated flooding due to its low-lying topography and rapid development. This location represents a typical urban flood-prone site where high-resolution flood simulation is crucial. By integrating building footprint data, elevation models, and rainfall records, it provides a spatial assessment of flood vulnerability. The research followed a four-stage methodology:

### 2.1 Data Acquisition

The success of the spatial analysis and 3D modelling process in this study heavily depended on the acquisition of high-quality geospatial datasets [7]. The major datasets were Digital Surface Model (DSM) and the building footprint data in the shapefile (.shp) format were obtained in the Department of Survey and Mapping Malaysia (JUPEM) and Digital Elevation Model (DEM) that was obtained in the Malaysian Space Agency (MYSA). Drawing on the DSM, which records elevation to the roof level of buildings plus any

vegetation, the extraction of building heights and provision of the required spatial accuracy in high resolution that is important in a corrective urban modelling was immensely possible [8]. To go together with this, the DEM gave vital information on elevation that was used to support hydrological studies like slope, flow direction modelling, and flood depth investigation [9].

Spatial analysis tools in ArcGIS Pro were applied to estimate what the flood extents, depth grids, and flow velocities would be to simulate flooding, and the results were based on the rainfall which were used to predict the potential depth of the flood in any scenario [10]. Building footprint data, the basic shape of the extrusion in 3D were obtained using both the official governmental sources along with the open data repositories like the OpenStreetMap (OSM), depending on the data availability and completeness [11]. Such impressions allowed the generation of volumetric models of buildings, without which a precise model of the flood impact would not be possible.

Additionally, the past level of water in the Taman Sri Muda locality was obtained by referring to the Department of Irrigation and Drainage (JPS) and also to the Infobanjir platform. These data were useful in simulating several flood scenarios, that were varied in intensity and duration, integrating the spatial datasets with temporal dynamics. All the obtained datasets were properly pre-processed by coordinate system matching (usually to WGS 84 or the corresponding local UTM mesh), the resampling, and validation with the aim of spatial consistency and accuracy. The resolution of the high DEM and DSM data was of great essence in the area of credible 3D modelling and hydrological simulations. Furthermore, the accuracy of the building footprint data also played a tremendous role in determination of the precision of the flood impact estimates, warranting the relevance of the presence and accuracy of the geospatial input at every stage of the modelling process.

### 2.2 3D Building Modelling

The ArcGIS pro software was used to extrude the height of buildings using the Digital Surface Model (DSM) data, which can convert the two-dimensional building footprints into the three-dimensional ones [12]. This process was done using the software's 3D Analyst extension, which incorporates AI-driven spatial recognition and modelling capabilities, allowed for accurate urban topography visualisation [13]. Extrusion gave each building footprint a vertical dimension which basically translates to its elevation above ground [14]. Automated scripts like the ones named as: Surface Information and Layer

3D to Feature Class were used to define building height which reduced the level of manual intervention hence increased method accuracy and efficiency in the topographic modelling process. It should be noted that building extrusion was not an extraction of zonal statistics, but the direct extraction of building heights by the DSM (ArcGIS pro tools, "Surface Information" and "Layer 3D to Feature Class" made it possible to perform precise modelling in the vertical direction, based on the values of the elevation). While these tools are not classified as standalone AI, intelligent automation features are included to improve the efficiency and accuracy of spatial analysis.

This approach enabled accurate urban topography modelling with minimal manual input, enhancing the overall quality and speed of the 3D visualisation workflow. Following the extrusion of 3D buildings, the workflow proceeded with flood level visualisation through a series of spatial analysis steps [15]. The process began with the preprocessing of the Digital Elevation Model (DEM) and Digital Terrain Model (DTM) datasets using the "Extract by Mask" tool in ArcGIS Pro, which confined the analysis strictly to the delineated study area. Subsequently, flood levels were modelled using a multi-stage raster calculation approach. First, water level masks were generated (Equation 1) to simulate varying flood scenarios. Then, flood depth raster's were derived by subtracting the DEM values from the simulated water surface elevations (Equation 2), effectively capturing the inundation depth across the terrain. These flood depth raster's were overlaid on the previously extruded 3D building models to identify and assess the structures most vulnerable to inundation. The flood extent simulations were performed using the Raster Calculator tool, which allowed for dynamic modelling of water level variations in relation to urban infrastructure [16].

*Con (elevation raster < water level value water level value, 0)*

Equation 1

Equation 1 of the flood water level needs to be created first before the depth raster and make sure to replace the water level value with a constant value, for example, 1 meter using  $DEM + 1$ . Then, continue to calculate the flood depth raster by using the same raster calculator in ArcGIS Pro.

*Depth Raster = Water level raster - DEM*

Equation 2

Equation 2 uses a subtract elevation model from the water level raster to calculate the flood depth raster.

The resulting flood mask was overlaid with 3D building footprints to assess structural vulnerability. Impacted buildings were categorised and colour-coded based on height and usage (e.g., residential, commercial, industrial).

Finally, Buildings were categorised and colour-coded by type and height, allowing clear visualisation of flood impact [17]. The resulting detailed 3D urban model supported further analysis and was integrated into an interactive dashboard to help users explore flood effects at various water levels [18]. However, the current 3D visualisation framework is limited to extruded building models overlaid with simulated water depth and does not incorporate dynamic hydrological processes such as terrain-based flow direction, water routing, or temporal flood propagation.

### 2.3 Flood Simulation

ArcGIS Pro was used to simulate the effects of the flood by processing a pre-processed Digital Elevation Model

(DEM) using hydrology tools to generate peer review-level information on the terrain profile that influences flood dynamics. The important characteristics of flow direction, slope, and catchment boundaries were obtained to simulate hydrological processes and know how water would be deposited and flow across the surface.

Rainfall data were combined with elevation surfaces then to estimate flood depths, with estimates based on raster-based calculations of inundation under different scenarios, a widely adopted approach in GIS-based flood modelling. The modelling workflow utilised AI-assisted GIS functionalities, including automated catchment delineation and surface interpolation, which have been shown to enhance modelling efficiency and reliability without the development of standalone artificial intelligence algorithms. The resulting flood simulation maps were overlaid with extruded 3D building models, providing a detailed spatial representation of building-level vulnerability to flooding, consistent with recent urban flood risk assessment studies [19].

The intersection of the 3D visualisation and the spatial analysis revealed not only the vulnerable buildings but also the impacts percentage, which could prove helpful in reducing flood risks and aid in planning urban environments. The study is based on use of AI-integrated features in ArcGIS Pro, including automated catchment delineation, intelligent terrain analysis, and pattern-based layer rendering; nevertheless, no standalone AI algorithms were custom-created directly related to the study. These characteristics enhanced speed, minimised

hand involvement and also enhanced accuracy of the flood depth and building impact estimations [20].

#### 2.4 Dashboard Development

The creation of the 3D dashboard was able to show simulated flood levels on urban structures, giving interactive ability to visualise the extent to which the structures are encased by flooding and its eventual consequences. The dashboard was constructed on ArcGIS Online and ArcGIS Dashboard so that 3D scenes created in ArcGIS Pro merged with it easily. Although no explicit AI coding was implemented, the application leveraged intelligent GIS functionalities such as real-time layer rendering and automated data integration to enhance responsiveness and accuracy [21]. These features allowed the user to interactively traverse the spatial projection of the assigned flood effects in various simulation conditions. Important characteristics comprised the availability of zoom, state switching, and details of the scene, such as building height and estimate of the flood level by structure. The design of the interface made it easy to use and understand particularly to the urban planners, the emergency authorities and other members of the society. Sliders and filters were interactive elements that allowed the exploration of different flood scenarios and enabled users to develop the knowledge about their possible vulnerability. With the help of in-built AI-empowered visualisation abilities found in the ArcGIS environment, the dashboard was able to transform the complicated spatial information set into productive knowledge.

This design is used to show how ingenious GIS applications will democratise access to the spatial information and evidence-based decision-making during the environmental crisis. The dashboard is an effective tool upon which the flood awareness of the population, as well as planning can be effective through the visualisation of the potential effects of flooding at the building level. Nevertheless, the research lacked usability testing and the opinion of stakeholders to determine how well the dashboard conveys the risks of floods to the intended audience. Other studies are needed to evaluate how useful it is in practice to decision-makers and to the local communities [22].

### 3. Result and Discussion

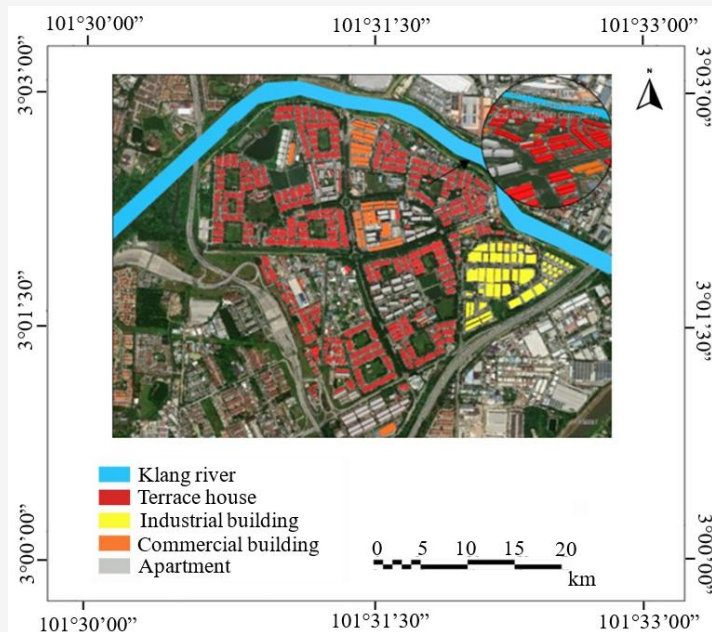
In this section, the results of 3D building footprint extrusion and flood model will be displayed and will demonstrate the impact of an increase in water levels on buildings in the Taman Sri Muda, Shah Alam. The results emphasise spatial distribution of buildings, the flood area and accuracy of use of 3D visualisation

in determining the impact of floods. These findings entail understanding the accuracy, limitation and potential application in managing the urban city floods.

#### 3.1 3D Building Visualisation

The 3D visualisation helped in offering key insights on flood vulnerability in Taman Sri Muda. The classification of buildings was based on the height and the distance to the pathways of drainage, and it was revealed that the low-rise buildings that included residential buildings were the greatest victims of flooding compared to the mid and high-rise buildings [23]. To be more precise, the exposure of low-rise houses was higher at flood depths between 0.5 and 1.5 meters. On the contrary, most of the taller commercial buildings and apartments were generally beyond the critical levels of inundation, but their infrastructural facilities and access pathways along the ground level were still endangered [24]. The study was able to generate precise representations of the structure and full detail of the heights of each building by extruding the building footprints of DSM data and hence approach a superior level of perception of the city space as a whole.

Furthermore, AI-assisted spatial tools within ArcGIS Pro streamlined the process by automatically detecting elevation variations, computing flood depths, and generating 3D models without requiring manual geometric input [25]. The automation significantly contributed to efficiency in terms of processing and reduced chances of making errors. The visualisation clearly shows terrace houses as the most affected structures, highlighting spatial patterns of flood vulnerability across the urban landscape. The 3D visualisation not only depicts variations in building height but also enables users to assess how different structures interact with simulated flood levels under various scenarios [26]. Figure 1 illustrates the 3D building footprints of Taman Sri Muda, Shah Alam, displayed at a scale of 1:5000. The footprints were extruded in ArcGIS Pro based on the mean building heights to generate block-shaped representations of individual structures. Variations in building heights across the study area are clearly discernible, reflecting distinct urban patterns such as low-rise residential zones in suburban neighbourhoods, mid-rise apartment complexes that support higher population densities, and clusters of commercial and industrial buildings. Industrial zones, characterised by larger yet generally low-rise structures, are notably situated away from residential areas a spatial arrangement that reflects deliberate planning to minimise environmental impacts on inhabitants.



**Figure 1:** 3D building footprint in Taman Sri Muda, Shah Alam

Overall, the 3D building footprint dataset effectively captures both the spatial distribution and vertical dimensions of the built environment in Taman Sri Muda. It offers valuable insights into land use patterns, potential flood risks associated with building types and elevations, and the broader structure of urban development in the area.

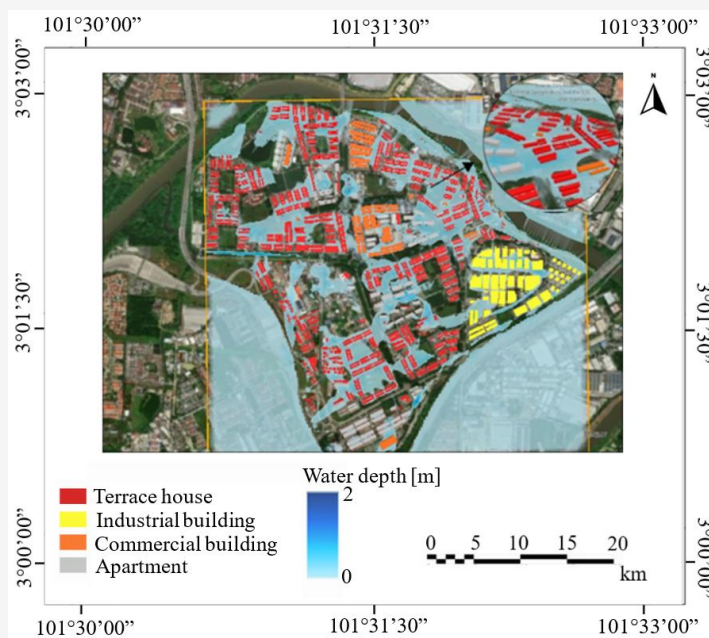
### 3.2 Flood Simulation Output

Flood simulations conducted at varying water levels effectively illustrated the progression of inundation across the urban landscape. Structures located on flat terrain and in close proximity to water accumulation zones were found to be at greater risk of flooding. The simulation results revealed that even moderate rainfall events could inundate more than 60% of ground-level buildings in the study area. Flow direction and water accumulation maps further indicated that floodwaters consistently converged within central residential zones, aligning closely with historical flood records. This alignment not only validated the accuracy and realism of the simulation model but also demonstrated that the integration of topographic and building data can reliably predict actual flood impacts [27].

Figure 2 illustrates the flood simulation conducted for Taman Sri Muda, displayed at a scale of 1:5000 using ArcGIS Pro's hydrological modelling tools. The simulation incorporated rainfall intensity and temporal parameters to assess spatial flood distribution and identify vulnerable structures within the urban landscape. This approach is particularly relevant in densely built environments, where water

sources and surrounding topography significantly influence flood behaviour. The model was based on rainfall data indicating a peak intensity of 141 mm over 20 minutes, representing the highest observed flood depth. It is important to note that the rainfall input of 141 mm in 20 minutes was applied in a simplified, deterministic manner within the raster-based simulation, without incorporating a full hydrological or hydraulic model such as HEC-RAS or SWMM. As such, the simulation does not represent dynamic water flow, drainage system performance, or temporal flood evolution.

The simulation, visualised at a scale of 1:5000, highlights the most severely affected areas, particularly those in close proximity to the Klang River, which contributes to the region's heightened flood risk. Based on the 3D flood simulation, approximately 62% of low-rise residential buildings in Taman Sri Muda were found to be inundated at a flood depth of 1.5 meters. In contrast, less than 20% of mid-rise structures experienced similar impact. These figures provide a clearer understanding of structural exposure at different water levels and help quantify the severity of flood risk across building categories. Table 1 outlines key factors influencing flood simulation, including water movement [28], infrastructure impact, rainfall intensity [29], upstream flow [30] and catchment characteristics [31]. These interconnected elements determine flood behaviour, damage extent, and water accumulation, providing a comprehensive understanding of flood dynamics.



**Figure 2:** Flood simulation through Taman Sri Muda

**Table 1:** Key factors of flood simulation [32]

| Factors                           | Description   |
|-----------------------------------|---|
| Water Movement                    | Tracks how floodwaters spread across the terrain and interact with buildings.                                 |
| Impact on Infrastructure          | Assesses damage to buildings, roads, and utilities based on flood depth and duration.                         |
| Rainfall Intensity                | Measures the impact of heavy rainfall on water accumulation and runoff.                                       |
| Upstream to Downstream Water Flow | Analyse how excess water moves through the river system, affecting flood-prone areas.                         |
| Catchment Area                    | Evaluates how water is collected, stored, and discharged within a drainage basin, influencing flood severity. |

### 3.3 Flood Simulation Validation

To evaluate the simulation's accuracy, the simulated flood results are compared with real-world observed data. The validation reference for this study is the EOS-RS Flood Proxy Map obtained from Copernicus Sentinel-1 on December 21, 2021. An overview of the actual flood extent during Taman Sri Muda's December 2021 flooding event is given by this satellite-derived map, which is commonly used for rapid flood extent mapping and validation purposes.

Based on Figure 3, in general, Taman Sri Muda's flood simulation in ArcGIS Pro matches the EOS-RS Flood Proxy Map from Copernicus Sentinel-1, which was created on December 21, 2021. Particularly in the center, southern and eastern regions of Taman Sri Muda, the simulated flood extent closely resembles the real flooded areas observed in the satellite data. These areas, as shown in both Figures 2 and 3, experienced significant inundations, affecting

various building types including terrace houses, commercial buildings, and industrial zones. Nevertheless, several discrepancies between the satellite-derived flood proxy and the simulated flood extent are evident. For instance, scattered flood patches in some industrial zones and the western low-lying areas appear in the simulation results but are not detected in the satellite-based flood map. These differences may be attributed to factors such as inaccuracies in the digital surface model (DSM), limitations in representing rainfall intensity and duration, and inherent uncertainties in SAR-based flood detection. Additionally, it is important to note that the simulation represents flood conditions on 18 December 2021, whereas the Sentinel-1 flood proxy map reflects conditions on 21 December 2021, when floodwater may have already begun to recede, potentially resulting in reduced visible flood extent in the validation dataset.

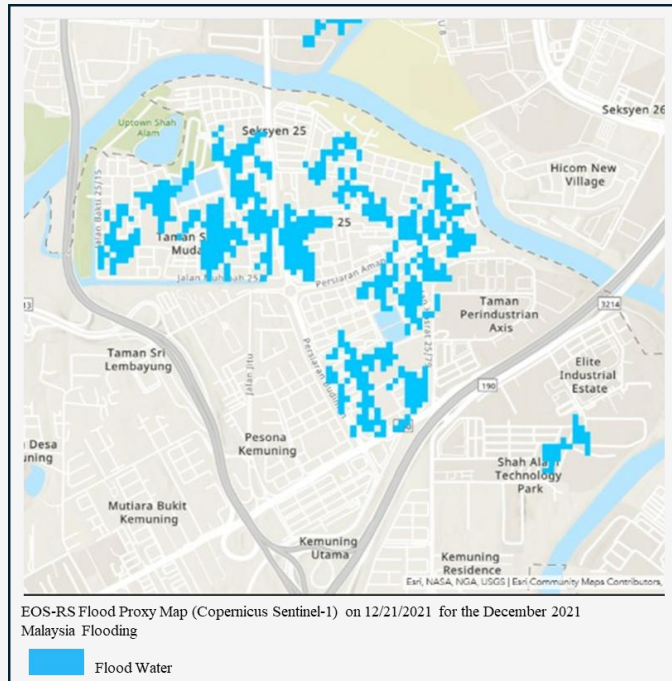


Figure 3: Flood proxy map [33]

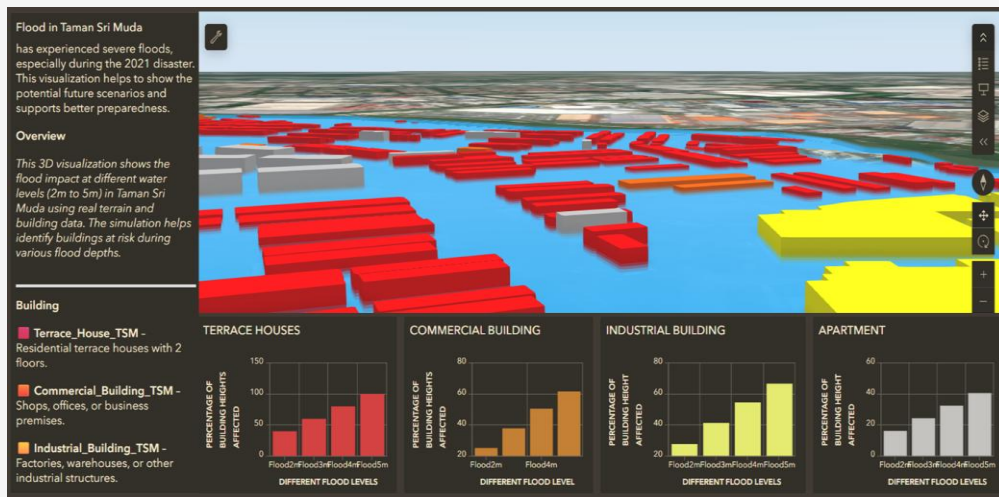
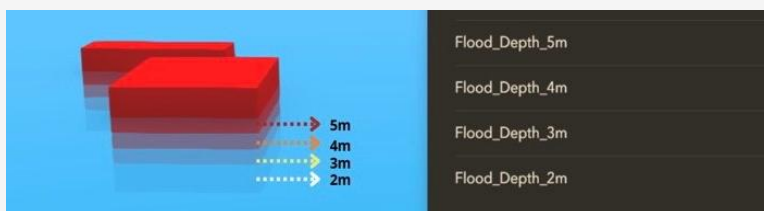


Figure 4: Dashboard of 3D building with flood level at different heights

### 3.4 Dashboard of 3D Building with Flood Level at Different Heights

The dashboard interface, underpinned by intelligent geovisualisation dashboard enables users to interactively assess flood impacts by adjusting flood height parameters. By allowing users particularly urban planners can visualise corresponding changes in building exposure, the dashboard enhancing situational awareness and risk assessment. Powered by AI-integrated ArcGIS, it effectively combines real-time visualisation with spatial hydrological modelling to support data-driven decision-making in flood management and urban resilience Planning

[34]. Figure 4 presents a dashboard that provides a 3D visualisation representing various flood depths and their impacts on different building types, highlighting which structures are most affected. The study area has experienced severe flooding in recent years, particularly during the 2021 event, and this dashboard serves as a proactive tool for disaster risk assessment and preparedness by illustrating the consequences of flood depths ranging from two to five metres. The left panel of the dashboard provides an overview of the study area and outlines the objectives of analysing rising flood levels in Taman Sri Muda.



**Figure 5:** Flood depth in different heights

It demonstrates variations in exposure according to building type and average height by visualising interactions between floodwaters at different depths and the existing built environment. By identifying the most at-risk structures during different flood scenarios, the dashboard supports informed planning and mitigation strategies.

Figure 5 shows that terrace houses (red) are the most affected by flooding, with water depths shown using shades of blue light blue for shallower and dark blue for deeper areas (2 to 5 meters). The interactive 3D GIS dashboard lets users turn the depth layer on or off, helping them better visualise how different structures are impacted. This tool enhances understanding of structural vulnerability and supports stakeholders such as emergency responders, urban planners, and policy makers by providing them with the capacity to assess flood risks, mitigation planning and communicate building specific vulnerabilities to the public and external agencies. However, this study does not incorporate quantitative indicators such as inundation volume, exposure statistics, or estimated economic losses, which would provide a more comprehensive assessment of flood impacts. Future research should integrate these metrics to strengthen flood risk evaluation and planning-oriented decision support applications.

### 3.5 The Role of AI-Enabled GIS Tools

This study highlights the potential of incorporating AI-ready GIS platforms in enhancing risk communication and spatial decision-making. Although no custom AI models were developed or deployed, the research leveraged embedded AI-driven functionalities within ArcGIS Pro such as data-driven symbology, automated terrain classification, and pattern recognition which are now integral to contemporary GIS workflows. These tools enhanced fine spatial inference, live streaming spatial extraction, real-time 3D rendering to enhance the accuracy and communicability of flood risk visualisations. The reliance on these built-in AI capabilities illustrates the growing integration of artificial intelligence within geospatial technologies, underscoring its significance in disaster simulation and risk management strategies.

## 4. Conclusions

The concept established in this study is making a feasible and expandable method with which to assess the effect of urban floods through 3D Geographic Information System (GIS) visualisation. It was also possible to create a complete system in ArcGIS Pro to display flood scenarios in three dimensions and make flood risks interpretable at the building level. While the research did not directly implement standalone artificial intelligence (AI) algorithms, employed AI-based spatial analysis capabilities deployed in GIS platform. These tools contributed to improved simulation accuracy, reduce the amount of manual data processing, and create an interactive dashboard to increase flood risk awareness.

By integrating elevation models, hydrological simulation, and interactive visualised parts, the framework optimally determined the high-risk buildings within the Taman Sri Muda area. Use of simulated flood conditions at different water depths yielded concrete results on the susceptibility of the buildings of different types on the basis of height and space [35]. The method will provide the planners, emergency responders and the population with an easier comprehension of flood exposure guiding more effective preparedness and emergency response plans. As the end result of this project, a 3D dashboard in ArcGIS Online will depict the 2, 3, 4, and 5-metres flood depths in an approachable and manipulative manner. This tool enables users to have visualisation of the scope of inundation with reference to certain buildings and terrain features irrespective of their technical savviness. The integration of AI-driven spatial, elevation, and hydrological tools within modern GIS platforms represents a significant advancement in data-driven disaster risk reduction and urban resilience planning.

However, this study did not include a comparative or sensitivity analysis of different DEM resolutions or rainfall intensities, which could affect the accuracy and generalisability of flood simulation outcomes. Future research should explore how varying spatial resolutions and rainfall scenarios influence model sensitivity and flood impact predictions. This study did not include validation against real flood data from the 2021 Taman Sri Muda event or official hydrological models such as

HEC-RAS or SWMM, which would be valuable for assessing simulation accuracy and is recommended for future research.

In the future, it is advisable that a more advanced hydrological modelling tool such as HEC-RAS 2D and SWMM be adopted in order to model the interaction of models with time in flooding and to provide a more accurate measurement of the works drainage system performance. Furthermore, incorporating explicit AI techniques such as machine learning for predictive flood modelling and deep learning for automated structure detection from satellite imagery could further enhance the precision, scalability, and utility of 3D visualisation frameworks in flood risk analysis. To design future study, to analyse the behaviour of water flow and the functioning of a drainage system, flood simulation, over a period of time could be done using hydrological modelling tools like HEC-RAS 2D and SWMM. Additionally, future studies could incorporate explicit AI models, such as machine learning to predict flood occurrence, or deep learning to automatically detect structures in satellite images, in the future studies, bringing even further precision and scope to visualisation frameworks [36].

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