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Research paper

Emphasizing Grid Feature as Flood Zonal Identification to Support Flood Relief Mechanism

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Abstract

Grid in Geographic Information System [GIS] mapping is used to determine specific location. This is a study to highlight the utilization of square grids network with flood forecast map modelling for regional identification of inundated zones focusing on Pekan sub-district. Satellite information, raster and digital elevation model [DEM] are used to produce a flood prediction map model to simulate inundation of the study area. Vertical elevation has been converted to match between WMGEOID04 with EGM96 ellipsoidal height for the multiple offsets of water layers in inundation simulation process because geoid and mean seal level values are set to be the same. Inundated zones are populated based on selected readings of Sungai Pahang gauging station located at Department of Irrigation and Drainage [DID] Pulau Jawa station, Bandar Pekan [Station ID: 3434401]. Flood spreads are monitored based on the 1.0m layer offsets starting from 2.5m [alert level] until 5.5m. Finally, square grids tessellation of the whole area within the boundary is generated and the affected zones are projected in different color code to indicate danger zones. The graphical output that are produced are able to be used to assess the rate of accessibility, habitability, and affected infrastructures which have the potential to act as flood relief center. Integrating these information with disaster web provider like 'InfoBanjir' [DID] and 'disaster portal' [NADMA] should be emphasized to ensure systematic flood management in the future.

Keywords: *Digital elevation model; ellipsoidal height; geoid; tessellation; infobanjir*

1. Introduction

Most recorded deaths caused by flood happened in 2013 with 45.4% share from global natural disaster fatalities [1]. Flood should not be taken lightly as it can also deal a great blow to economic loss. There have been many studies conducted that manipulate the use of modern technologies but flood cannot be simply avoided. Providing better risk assessments coupled with mitigation procedures are seen to bring the best solution to respond to this issue. In Malaysia, seasonal flood pattern annually comes around November to March during monsoon season which brings along major, long-term precipitation over large area specifically at the East Coast region of Peninsular Malaysia. Several key elements that have been identified as the factors of flood which are: localized continuous rainfall, tidal backwater effect, inadequate river capacity and poor drainage systems [2] During flood disaster event, the government through Natural Disaster Relief Committee were given task to coordinate flood relief operations at national, states, and district levels with a focus to prevent loss of human lives and to reduce flood damage. Thus, systematic countermeasures are highly needed to plan both works and peoples. This will ensure a great coordination between each tasks especially during the emergency situation.

GIS mapping procedures are well-known methods used in flood disaster studies. Researchers integrates it with other information on meteorological, hydrological, and physical characteristics of a study area. It will produce a comprehensive map model that will be able to guide the target audience. Combination of multiple datasets is important for the monitoring, prevention, protection, preparation, and response strategy by flood relief committee members. Flood prediction mapping studies provides information that are necessary to assist in mitigating, preparing, recovering, and responding to flood disaster [Department of Natural Resources and Mines, 2014] It also make measurement of the extent of inundation to the study area possible.

Method to be highlighted in this study is grid integration in inundation mapping. In most cases which involves mapping, grid method serve its purpose in identifying and determining any specific location manually. Grids are similar to the pixels of a photo or graphic. They are digital raster datasets in form of arrays of equally sized square cells arranged in rows and columns that defines specific geographic space [FEMA, 2014]. Tiling off networks of identical shape and size are useful in spatial grid zoning. This study will focus on using square shaped grid feature [250m^2] to indicate areas affected by flood within the boundary of Pekan sub-district. It will use a 3-Dimensional flood inundation map as model reference to perform flood simulation based on the gauge reading of Pahang River located at DID station, Pulau Jawa, Bandar Pekan.

This method is useful in simplifying the complex map produced by flood forecasting model raw simulations. Projected visuals combining with additional spatial information of flood affected zones are expected to raise flood awareness by any level of viewers. Grid assisted flood model will help flood committee members easily focus and assess flood zones. Early preparation and planning can be carried out before the next wave occurs in which the severity is still unknown.

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2. Study Area

Pekan sub-district have a total area of 182.74km which is located in Pekan district of Pahang. This region is located in one of the four East Coast states of Peninsular Malaysia which is susceptible to flood during monsoon season. It covers most part of the Pahang river estuary, the longest river [477.97km] in Peninsular Malaysia, which originates from the Main Range of Titiwangsa.

Malaysia has an equatorial climate with uniform air temperature throughout the year, varying from 24ºC to 28ºC with an average relative humidity approximately 80%. Almost every year during Northeast wind season from November to March, East Coast area of Peninsular Malaysia is exposed to flood, as precipitation quantities for these months are abnormal. The flood that caused by heavy rainfall during this period is termed as monsoon flood.

This area was selected because it is prone to flood considering its topography, monsoon season, river overflow, and tidal behavior as the natural cause of flood. The normal level of Pahang River [Pekan DID station] is reported to be at 1m reading while 3.66m is the dangerous level as observed at river cross-section[3]. Therefore, inundation behavior of Pekan sub-district is set to be observed starting from 2.44m [alert level] followed by other additional offsets layers that indicates the periodical rise of water level during simulation.

3. Methodology/Materials

This research consist of three main processes: 3-dimensional modelling; flood inundation simulation, and grid zoning. Figure 1 shows the simplified flowchart of the method involved. Shuttle Radar Topography Mission digital elevation model [SRTM DEM] and Landsat-8 satellite raster are used as the primary data for 3-dimensional map development while Department of Irrigation [DID] gauging station data are used as secondary data for inundation simulation. The final product is intended to be able to specify flood zones through tessellations of square grids. Appreciable assets of Pekan sub-district consists of selected infrastructures and industrial parks that might be inundated through flood simulation are monitored and identified.

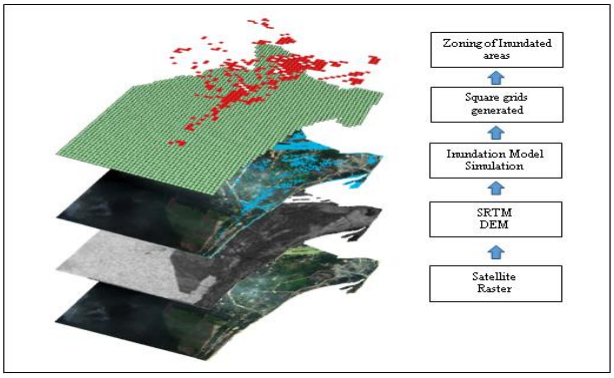


Fig. 1: Graphical explanation of simplified sequence of work for this research

3.1. Dimensional Map Model

3D map models are produced from combination between satellite raster and DEM [topographic datasets]. Enhancing it with the integration with water level simulations afterwards could work as inundation map model. This method are currently popular as part of non-structural approach in initiation to tackle flood issue. The modeled surface will provide multidimensional visualization of flood prone areas and its effect on public utilities. These information are necessary to be discussed among local authorities and flood committees especially in risk assessments and management for an effective flood solution.

Initially, the boundary of Pekan sub-district was specified from the shapefiles that contains districts of Pahang obtained from Department of Survey and Mapping Malaysia [JUPEM]. This process produced a specific feature class and was used as reference model boundary for data gathered afterwards in clipping and image subsetting. Pekan sub-district will be sorted out from the original raster image and DEM. 3-Dimensional map model is then generated locking on the focused study boundary specified from earlier processing based on the clipped 'area of interest' shapefile data. SRTM DEM and Landsat-8 satellite raster were both originally obtained from United States Geological Survey [USGS] Earth Explorer. These data which have similar resolution of 30m were transformed together to combine necessary spatial information of both layers through ArcGIS software.

A raster surface processing was performed to generate contours from the map model. Each contour intervals were set at 5.0m elevation to minimize unnecessary visuals from the color reclassification that separates contour lines due to height difference. ArcScene software was used to process raster data in 3D format. It allows stereo viewing in which model can be turned around in 360º for an optimal viewing angles. Visuals provided in ArcScene enable users to check and compare thoroughly between original topography data, contour model and 3D map model directly.

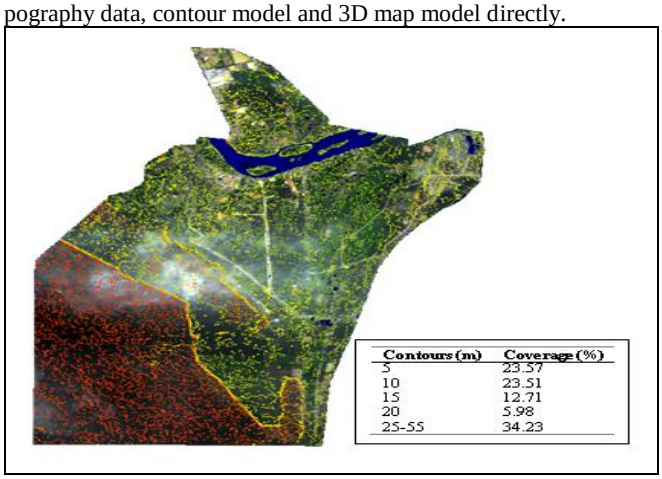


Fig. 2: Contours generated for initial understanding of topography of Pekan sub-district and comparison with 3D generated map model

3.2. Flood Inundation Simulation

Initially, mean sea level height is converted to match with the EGM96 elevation. It is because mean sea level of Peninsular Malaysia uses local geoid elevation WMGEOID04 [JUPEM, 2005], while the elevation used in the GIS program is different. It was set automatically in EGM96 format from the original SRTM DEM data. Thus, conversion from mean sea level to EGM96 was requested directly to JUPEM using the C0369 benchmark [nearest point to DID Pulau Jawa station] as height reference. Based on the ellipsoidal height provided, adjustment of elevation were conducted using normal mathematical ratio calculation to ensure inundated areas to be correctly projected during computer simulation process.

To observe the extent of inundation of the study area, multiple blank layers representing water level of Pahang River gauging station readings were integrated into the 3-Dimensional map model. The water layers created to simulate inundation is represented by the river water level of Sungai Pahang based on the degree of danger reading from DID guidelines. Gauging station readings [station ID 3434401] which is located at Pulau Jawa, DID station [GPS location; N 387667.46m, E 321625.07m] was used as reference benchmark to estimate inundation behavior within the boundary of study area. Published river level readings at the reference station are supposedly at 1.0m – normal, 2.44m – alert, and 3.66m – danger.

In ArcScene, multiple layers of different elevation acting as waterbody were set at 2.5m, 3.5m, 4.5m, and 5.5m to simulate flood. The constant layer offsets with 1.0m gradual increase in water level were intended to distinguish flood spread between each layers over the boundary of Pekan sub-district. The inundation pat-

tern are determined from the simulation and reclassified in the zoning process.

3.3. Grid Processing and Flood Zoning

A vulnerability type mapping should be guided by theoretical framework[4]. This study wanted to proof that low-laying ground areas are more susceptible to flood which is the common understanding on topography. The previous procedures conducted which simulate flood based on 3D terrain model have proven such inferential idea. Gridding process were chosen to precisely locate areas that are vulnerable to flooding. In order to be able to properly orient each grid with one another, and to more accurately compare one flood risk data to another at a given location, grids should be set to use the same origins, coordinates system, and cell size [FEMA, 2014]. Thus, square grids of 250m x 250m squares network is generated in the ArcMap based on the boundary shapefile prepared earlier. To analyze and classify flood affected zones, square grids feature class is loaded together in the flood simulation for flood zoning process.

Monitoring the flood spread from simulation, square grids focusing on the land area that is observed to be affected are reclassified into a new feature class and marked with different color code [red] from wholly generated grids [green]. The process is repeated for each water body layer offsets due to theincrease in flood affected zones from the rise of river level.

Main routes of access in Pekan sub-district including important public infrastructures namely schools, mosques, community halls, rescue stations, and hospitals were classified into a new feature class and also monitored throughout flood simulation process. The extent of river spillage and coastal flood were not observed through this method and is left as unaffected zones.

4. Results and Discussion

4.1. Flood Zoning

Results of inundated zones were presented based on the flood simulation from selected water body layer offsets. Square grids used to indicate flood zones are very significant from the provided visuals. Figure 3 below shows how severe flood can appear from observation at 2.5m gauge reading until 5.5m.

At 2.5m gauge reading, flood affected zones are very minimal. Some areas at the east side of Pekan sub-district are recognized to be aquaculture farms from field checking. In fact, the danger level as described by DID is a first alarm to indicate that Pahang River has rose onto the warning level. The first alert is actually the most important as a notice to local residents and flood committee that situation might become worse. During this period, coordination of work and rescue preparation should be put on standby. Locals might start to save their belongings to a higher ground or move to a safer place.

Flood zones starts to look significant from the visuals as water rise to 3.5m which is to be expected because at this range, water level is at an equal height with the river banks within the area. From the visuals of flood zoning, inundation starts to accumulate more on the east side of the Pekan sub-district which consists of lowest lying areas based on the topographical and contour monitoring done earlier.

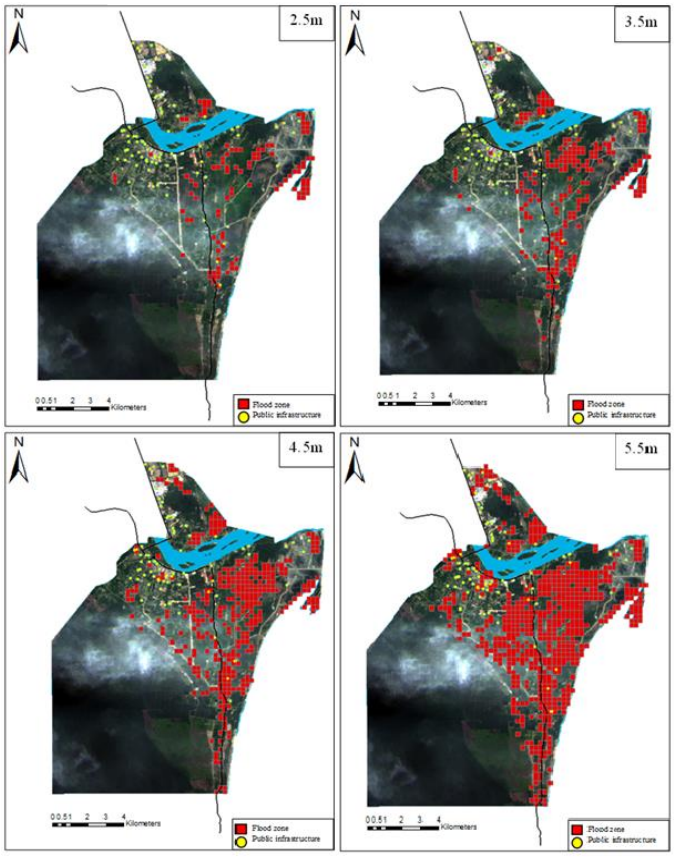


Fig. 3: Flood affected zones at 2.5m, 3.5m, 4.5m, and 5.5m gauge reading at DID station 3434401 Pulau Jawa, Bandar Pekan

Observation of flood continues at 4.5m and 5.5m gauge reading which resulted for Pekan sub-district to be nearly uninhabitable according to the simulation prediction. The inundation modelling has shown us that any gauge reading that is forecasted to pass the 4.5m mark of gauge reading either from precipitation data or river discharge data would extremely harm the residents of this area. With the availability of flood zoning prediction visuals from this study, flood relief and emergency committee members should be able to plan ahead with more organized preparations to respond to the upcoming flood scenarios.

4.2. Observation on Affected Routes and Infrastructures

Observing the access routes, some important infrastructures and industrial park is also an important task in support of flood relief mechanism. Pekan sub-district routes of access are represented by three main access which are Batu balik road [West path], Pekan-Rompin road [South path], and Pekan-Kuantan road [North path]. This information should be able to guide locals, flood victims and emergency response committee for a better selection of access.

Public infrastructures that are observed from simulation are emphasized on buildings that could work as flood relief center, command center, rescue center, and supply center during the hazards. The listings include community halls, schools, government office, mosques, hospitals and clinics which are chosen to be given attention within this study. Industrial sites were also included as they are the main appreciable assets in economic value of Pekan sub-district. Information on these places which will be inundated based on the inundation model with zoning capabilities will help various parties to act with more systematic coordination during the emergency situation. Table 1 below listed out the affected infrastructures following the gradual increment of Pahang River water level at reference DID station.

Table 1: Range of flood affected infrastructures at each gauge reading [DID station 3434401]

Gauge Readings [m]	Affected Appreciable Infrastructures	Affected Routes of Access
2.5	Masjid Ahmad Agro Capital Management Bhd	-
3.5	Masjid Ahmad Agro Capital Management Bhd	Jalan Pekan – Rompin
4.5	RELA Office Hospital Pekan Masjid Ahmad Surau Kg. Parit Tengah Tg. Agas Oil&Gas Surau Taman Permata SMK Tengku Abdullah Agro Capital Management Bhd	Jalan Pekan – Rompin
5.5	RELA Office Hospital Pekan Masjid Sultan Ahmad Shah Al-Hajj2 Masjid Ahmad Surau Kg. Parit Tengah Surau Taman Permata SMK Seri Pekan SK Sri Maulana Tg. Agas Oil&Gas SMK Tengku Abdullah SK Sinar Mutiara Kg. Parit Tengah Community Hall Kg Pasir Panjang Community Hall Puspakom Pekan Isuzu Hicom Malaysia Sdn Bhd Agro Capital Management Bhd	Jalan Pekan – Kuantan Jalan Pekan – Rompin Jalan Balik Batu

Masjid Ahmad and an agriculture farm [Agro Capital Management Bhd] were seen to be affected by flood at a slightly above normal river level. All roads are still intact and safe for access. Pekan-Rompin road starts to be inundated at 3.5m gauge reading which is to be expected because it is situated at the most vulnerable part of Pekan sub-district. Affected appreciable infrastructures remain the same with the previous river level. At 4.5m, the amount of affected grids increased gradually which also explained the number of observed inundated infrastructures. While at 5.5m gauge reading, the area has become totally inaccessible because including Balik Batu road and Pekan – Kuantan road, all three main routes are predicted to be inundated. Buildings that could work as flood relief center are also observed to decrease gradually. At this level, Pekan main hospital are also included in the flood hazard zone and thus evacuation of patients should be prepared earlier if river gauge reading were predicted to reach such level.

5. Discussion

The final visualization of flood zones from the flood model simulation produced an exceptional result that should be easily perceived and understood by any level of users. Some improvement can also be done by providing additional spatial information to enhance the viability of the produced map model. Pairing with other source of data especially meteorology and hydrology will greatly improve the model accuracy as this research is more focused on elevation difference study.

In the map generated, flood zones classification can be improved to be much more organized. During the process of zoning, any percentage within one shape of square grids that is inundated are marked in red colors. Improvement can be done through calculation of percentage affected areas per square grid. This will also open the capability of map to be reclassified into more variable color codes. This method could allow viewers to estimate the level of hazard on the already affected zones based on the assigned color difference. Controlling the depth of colors can deliver extra information especially flood depth, its probability to happen, and other flooding characteristics [FEMA, 2014].

Gridding procedure in this study can only classify inundated zones of land areas. This is a major weakness with this method because sizing of grid matters the most. Using 250m² grid tiles is not possible to be used to monitor river spillage at river banks areas or flood at coastal zones due to the edge effect from the square grids network. The natural meandering effect in river watercourse which resulted to smooth irregular curve lines [as well as coastal lines] goes against the working environment which focused on tessellation of squares network. It should be possible with a crisper [smaller] grids but it also defeat the purpose of providing a simple map model with ease in workability.

6. Conclusion

Computer simulation flood forecast is one of the most definite non-structural approach as flood control measures. Combining GIS mapping with various elements related to flood can provide models that can easily perceive the behavior of flood in different places with various conditions. The gridding method was introduced to be assimilated together within the flood forecast modelling to determine the distribution of flood affected zones based on the gradual increment of Pahang River water level. The use of square shaped tessellations with 250m resolution within this study shows its capability to separate between hazard and safe zones. This method is also found to be practical because the extra feature class generated can be adopted into another software components. For example, these information will enhance the graphical user interface [GUI] of 'infobanjir' web application by DID.

Transformation from impact-led approach to vulnerability-led approach is reasonable considering that people still lives in the flood prone areas despite the known consequences [5]. Integration with GIS mapping technology to investigate the extent of flood damage has become crucial nowadays. Additional features through combination with other computer tools allow manipulation of various source of data which also improve the quality and authenticity of the flood simulation processing.

An effective final product of flood inundation map system have to be able to deliver flood status and information in a more accurate manner. Building a system that is simple but packed with necessary information should be encouraged to the researchers to accommodate various level of audience. The main intention is to increase flood awareness among people which is the key point to mitigate hazards from flood disaster in the future.

Acknowledgement

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