

International Conference on Urban and Regional Planning, 2014

Open Source Web GIS Application for Flood Emergency and Evacuation Planning

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ABSTRACT:

Open Source Geographic Information System (OSGIS) has brought a tremendous change to the traditional approaches in digital mapping which has led to the new age of collaboration and provides benefits to the users in term of low cost and tailored made, particularly for those who are in great demand for enhanced decision making support tools. This paper discusses the use of OSGIS software in term of flood emergency response for decision makers. Digital mapping by means of OSGIS offers the potential to contribute to disaster management, specifically in term of the evacuation plan. GIS database was built based on data collected and analyzed from a survey of 390 households which are randomly selected in Segamat flood-prone areas. Evacuation time profiling and conflict point analysis was carried out through QGIS an OSGIS software which is later published using OS cloud computing web mapping browser (QGIS Cloud). Thematic maps showing categories of flood risk and evacuation time can easily be accessed by stakeholders through the web. This will enable decision makers, including the public, to plan for better evacuation planning and emergency response.

KEY WORDS: Open Source Web GIS, Flood Management, Evacuation Planning, Emergency Response.

INTRODUCTION

In global disaster sphere, flood occurrences are the most common natural disaster among all catastrophes leading to economic losses and destruction (Sharma and Priya, 2001). Disaster risk statistics 1970 – 2009 by the UN, it is apparent that flood disasters are the dominant disasters occur in ASEAN countries with 1085 events occurred per year which resulted in 17800 deaths in total. In disaster management the four phase's cycles for emergency management widely accepted in many countries in term of reducing damages and losses. Four phase cycle defined by US Federal Emergency Management Agency (FEMA) as mitigation, preparedness, response, and recovery which is to be pre-analytic vision in disaster and emergency management(Hans Günter Brauch et al, 2011). One of the most effective response strategies available to emergency managers during a disaster is evacuation planning. A risk assessment should be conducted from responsible agencies effectively for emergency and evacuation situations towards flooding. The emergency responders must then effectively do the evacuation “using Standard Operating Procedures (SOP's) for evacuations, which are some of the most demanding procedures community (will) undertake (Tresemer, 2007). Thus, emergency managers can conduct a comprehensive evacuation strategy and planning that more systematically with their capacity and resources. For this understanding, there is great interest in developing evacuation plans for many residential districts subject to known hazards have utilized GIS to address several problems in this setting (Dunn 1992; Cova and Church,1997; Silva et al 1993).

One of the best possible approaches for identifying flood vulnerable areas is to apply spatial analysis tools available in Open Sources geographic information systems (OSGIS). Open sources in GIS industry has led to the new age of collaboration and provides many benefits to the users in term of low cost, tailored to user needs and web-based in digital mapping, particularly to those who are greatly demanding for enhanced decisions making assistants and powerful information providers. GIS role in the preparedness and response phases relates to hazard modeling, which differs slightly from the hazard modeling in flood risk assessment. Spatial analysis is prepared to analyze spatially and temporal patterns and to find connections between various geographical factors (Mitchell, 1999). It is possible to gather several of the societal parameters on flood evacuation aspect to aid in short-term prediction(Cova, 1996). This application will allow the user to handle, make out and analyze the spatial data sets to see which factors have what effect and to envision the resulting effects for spatial decision making (Melesse and Shih, 2000; Baban and Kantarsingh, 2005; Ramlal & Baban, 2008). Utilizing OSGIS for flood risk assessment is a pre planning for evacuation process; it offers real time data sharing and predicts an accurate result. It can be a platform to execute one of governments' programs in flood management that resolve evacuation problem in local management. It can be interpreted as an example of predictability and consistency in providing adequate resources to the stakeholders in disaster relief works (Roosli, 2010).

In Malaysia, flood disaster management is handled by the National Security Council (NSC) working mutually with multi-disciplinary agencies on federal level. Problematic local government is a government that relegates them to a low priority in disaster response, adopts responses in a way coherent with other government uses and obligations (without trying to suit the local atmosphere) and leaves private interests to reach conclusions (Roosli, 2010). Moreover, local governments receive a deep impact in implementing federal government programs in disaster preparation but there is no particular attempt yet in Malaysia to provide accurate flood risk assessment and proper risk mapping (Sinnakaudan, Ab Ghani, Ahmad, & Zakaria, 2003). This does not meet the emergency management goal to protect local communities from flooding, thus putting lives at risk.

This paper provides new insights by utilizing a dynamic of the Open Sources GIS process, which is converted into a mapping function, appraisal for emergency and evacuation response by multi agencies and stakeholders. It also presents a computer-based visualisation that simulates the evacuation profiling (community level of evacuation status) during flood emergency. Nevertheless, this paper will determine the weight based on several listed critical points as mention by Chief Tresemer's article Exit Strategy 2007, for a successful evacuation, which is a clear egress routes (traffic circulation plan) and receiving area (shelter). Interpolation analysis in Open Sources GIS conducted in this research revealed a number of significant topics for emergency managers in Segamat Johor. Thus, priorities for evacuation can be addressed based on flood risk assessment that predicts the community level of capacity on evacuations (Ramlal & Baban, 2008). Emergency managers can establishment time for response team for an evacuation order in clearly GIS mapping. Under flood assessment, residents have relatively ample time to get prepare for evacuation It is because, people take different time periods to play through the sufferance of the evacuation order, get a decision, and prepare to leave (Rufener, 2008)

METOHDOLOGY

Cutter et al stress that the social data needed to indicate if community left their homes during a crisis, evacuation information sought included; time of departure, specifies cue leading to evacuation, destinations and the reason for destination selections and lastly the date of restoration. In terms of the evacuation mapping, OSGIS can be utilized to identify trends, both visually and statistically, resulting from the different community measure. The two important issue that need to consider as assessment in this paper are 1) the evacuation timing; is the most important variable that affects human behaviour during the flood emergency in the Segamat case study. The second significant subject is determining the residents conflicts points, as they associating with different modes of accessibility in order to prepare the evacuation process to be more effective (Ramlal & Baban, 2008). Segamat case study is selected to be studied area due topographical factors that contains two major river drainage basins in the area as shown in Figure 1. Moreover, the worst flood disaster in 100 years happened in this studied area on January 2007 and since then;

the event occur at almost each year especially during monsoon season and this has caused lots of damages including death. Based on previous floods occurrence data, field survey and interviewed, it is potential to analyze and prediction in OSGIS for flood assessment in term of evacuation planning. 390 households from Segamat case study were randomly chosen and interviewed (Figure 2) which is data that being be tested in the “flood evacuation profiling” of preparation and mitigation (Chovan, 1994;Rufener, 2008).

The information requirements and method for an flood assessment for evacuation study of this nature is minimal, hence the information that's been identified as table below:

Table 1: Data requirement for Segamat case study

Analysis	Data	Parameters
Community evacuation Profiling	A preparation period (time) before leaving their house for safety.	<ul style="list-style-type: none"> an evacuation was identified as critical more than 24 hours (Leonard, 1991)
Conflict points analysis	Intersection of road network and length of that road.	<ul style="list-style-type: none"> Where people are assigned to their nearest intersection (node). A valid evacuation is any contiguous subset of nodes (intersection centroids) in the road network (Thomas J Cova & Church, 1997)
Standard distance & Overlay (Community evacuation Profiling)	Location of Shelter (Supporting data for interpretation of analysis)	<ul style="list-style-type: none"> Policy is to ensure the safety of controlled hospital for victims and the school became the centre of disaster victims automatically amendment (National Security Council Directive No. 20) Shelter > 30m above sea level.
Overlay (Conflict points analysis)	Land use (Supporting data for interpretation of analysis)	<ul style="list-style-type: none"> Determination of built-area, the higher population the higher risk towards flood. (Cutter et al., 2003)

An assessment was performed by using spatial interpolation; it is the cognitive operation of using points with known values to estimate values at other levels. Spatial interpolation is available in OSGIS application for performing analysis for flood risk assessment. Inverse Distance Weighting (IDW) analysis in Geographic Information System (GIS) is used for interpolation, analysis which is one of regression methods to research the spatial correlation that determines if the values of the community perceptions are related. IDW determines cell value using a linear weight combination set of sample points. The weight assigned is a function of the distance of an input point from the output cell location.

The greater the distance, the less influence cell on the output value. Based on equation below

$$z_0 = \frac{\sum_{i=1}^s z_i \frac{1}{d_i^k}}{\sum_{i=1}^s \frac{1}{d_i^k}}$$

Where Z is estimate value at point 0, Z is the Z value at known point i , d_i is the distance point i and point 0, S is the number of known points used in estimation, and K is specified powers. The power controls the degree of local influences. A power of 1.0 means a constant rate of change in a value between points (linear interpolation). A power of 2.0 or higher suggests that the rate of change in values is higher near a known points and level off away from it. An important characteristic of IDW interpolation is that all predicted values are within the range of maximum and minimum values of the known points.

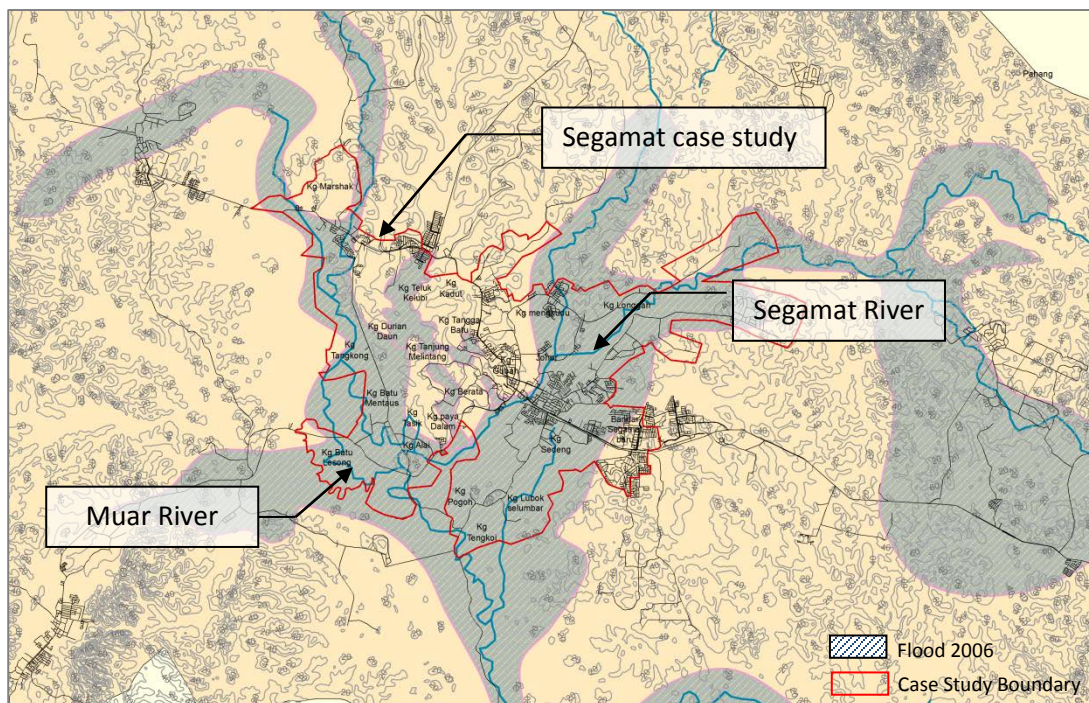


Figure 1: Segamat location and two major river drainage basins

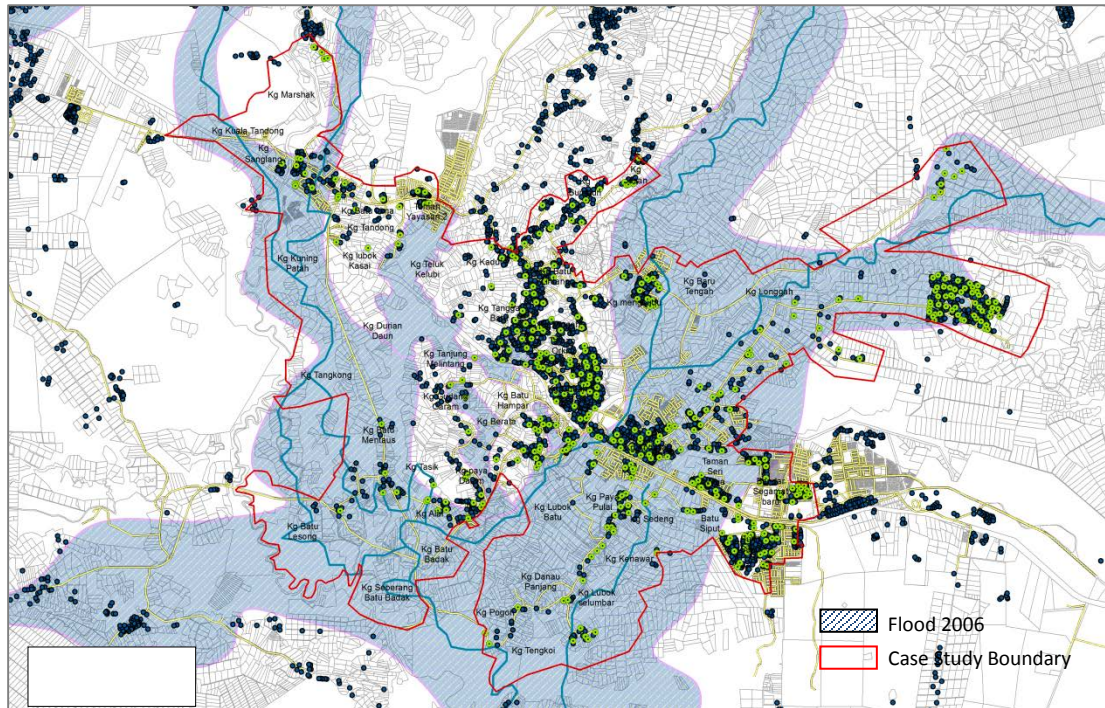


Figure 2: Point (green) indicates community that selected for interview and others (black points) were overall households in studied area.

ANALYSIS AND RESULT

The data requirements for an evacuation study of this nature are minimal. Survey data provide the evacuation information and a representation of the road network can normally be acquired. Moreover, a significant surface interpolation can be forecast and simulate remains in mapping the evacuation data. The analysis takes up with defined conflict points around the intersection in the road network as shown in figure 3. Conflict points are analyzed by converting network features vertices to points in order to identify community exit points for evacuees. More than 6 intersections in flooded area identified as critical conflicts points for evacuees. These conflicts points initiates 700m - 2.2km distance from one points to another points of intersection. In term of evacuation interpretation, the higher of value of conflicts points indicate the higher vulnerability for evacuees in flood event. However, if conflicts points indicate less than 200m with high population, it will generate chaos as well on evacuation. Identifying conflicts point is beneficial for emergency response authorities for simulating and predicts human behavior on evacuation based on result an inordinate number of people utilizing potential points or exits. As Cova mention future study can be sufficed with a set of parameters such as how many vehicles are there in these neighborhoods? Does the neighborhood have an evacuation plan?

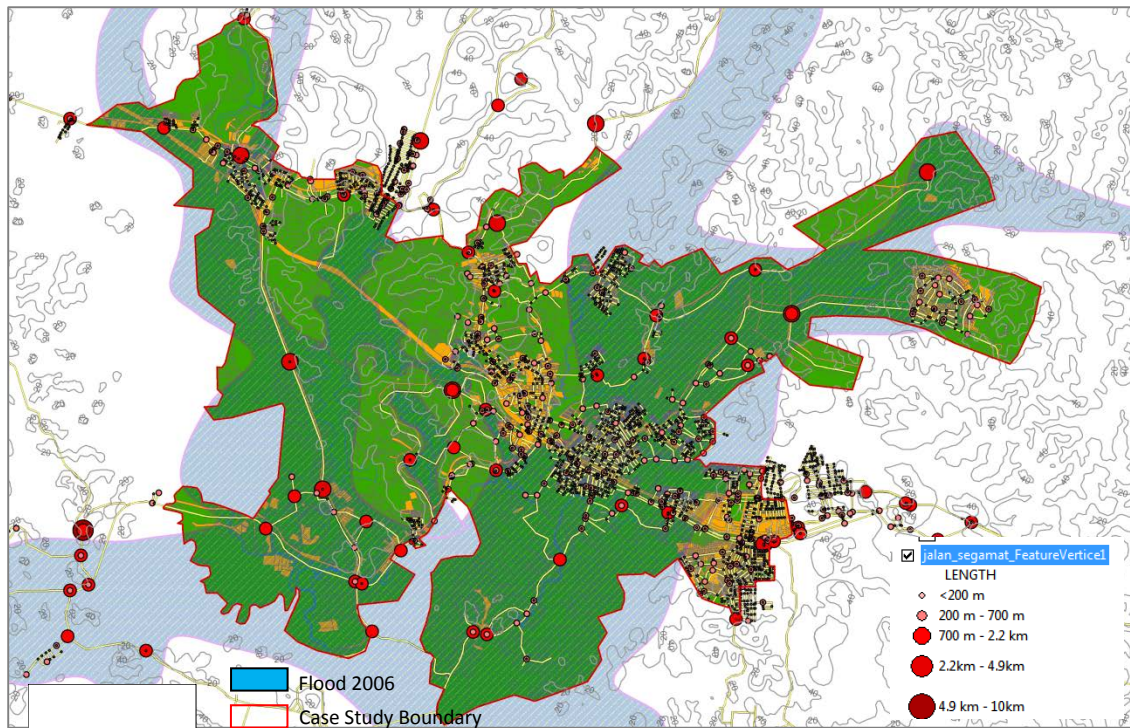


Figure 3: Identifying conflicts point (intersection) analysis

The thematic map in figure 4 shows a community evacuation profiling mapping for the studied area. IDW statistical result is predicted based on root-means square equation 0.5649. The yellow surface in particular neighborhoods predicted an average in a worst case evacuation with average spatial evacuation vulnerability values. However the worst event of evacuation action is anticipated to be in the red surface.

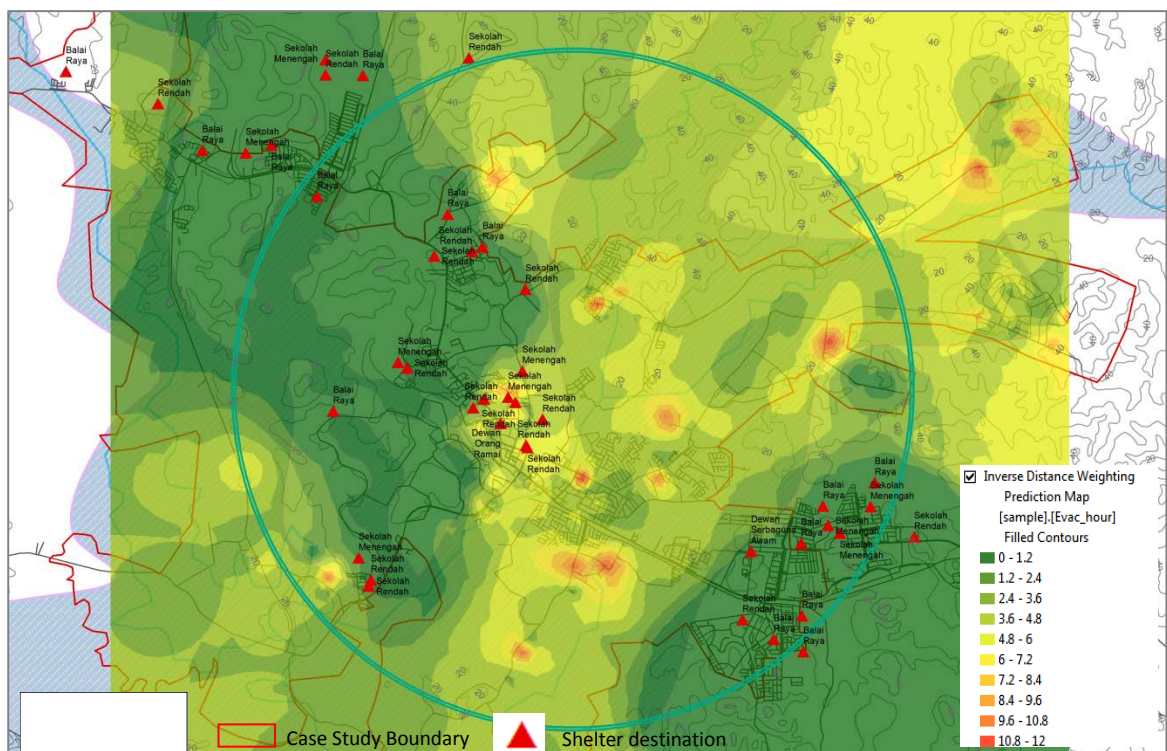


Figure 4: Evacuation hotspots resulted based on Inverse Distance Weighting (IDW).

For this understanding, these neighborhoods represent evacuation 'hot spots' and should be probed further for better preparation and development such as early warning system and mitigation project. A green line indicates standard distance for emergency shelter. A simple overlay mapping between shelter location, conflicts point data and evacuation hotspots can be related to decision makers' priorities for better evacuation planning. Supporting information such as land use map, socio economic maps, can be used for local planners for development control, avoiding human losses and physiological impact due to flood occurrences.

CONCLUSION AND RECOMMENDATION

Open Sources GIS application increasing the level of GIS activity in flood evacuation and emergency management. Human behavior during the emergency is hard to control and predict. However, Open Sources GIS can predict and simulate clear information for emergency response in term of evacuation. It helps the emergency managers to identify vulnerable community to meet their needs in term of efficiency of evacuation and towards flood occurrences.

Nevertheless, this research belief that, there numerous challenges still exist in the application of OSGIS in this area such as the deficiency of existing information and failure to take the demands of end-users adequately. With limited data this application is able to ensure that the occupiers of the community under threat are predicting around the flood emergency situation and may make evacuation process more efficient and the task of emergency managers much easier.

ACKNOWLEDGEMENT

The authors would like to thank Ministry of Higher Education (MOHE), Universiti Teknologi Malaysia (UTM) in vote project no: Q.J130000.2421.00G11

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