# FLOOD DAMAGE ESTIMATION AND MODELING

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UNIVERSITI TEKNOLOGI PETRONAS
JANUARY 2009

# FLOOD DAMAGE ESTIMATION AND MODELING

by

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Dissertation submitted in partial fulfillment of

the requirements for the

Bachelor of Engineering (Hons)

(Civil Engineering)

JANUARY 2009

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# CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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# ABSTRACT

To model the flooding over the area, the author uses data gathered from various sources, which are then compiled and matched with areas on the GIS map. The attribute tables are exported out of ArcMap as *.dbf files and opened in Excel. Then it is saved as a comma-delimited file (*.csv). The affected flood areas are extracted using Merge tool in the ET GeoWizards and separated on its own layer. Its attribute table is then exported as *.dbf files into Excel and saved as a worksheet. The damages are then summed, so do the total number of dwellings. The study found out that 64% of the total area is affected by flood, putting in into a high flood risk area.

# ACKNOWLEDGEMENT

I would like to express my gratitude to Allah the Lord Almighty for his blessings and guidance. I would also like to thank my supervisor, Assoc. Prof. Dr. Abdul Nasir Bin Matori for his help in guiding me to complete this work, and also for supplying me with the required software. A million thanks also go out to my parents Mr. Zainorin Su'ud and Mrs. Yon bt Salem for always believing in me, and always being there when I needed them. This appreciation also goes out to my housemates of V5D-L5.2 for giving me the required assistance and support in completing this work. Last but not least, I would also like to thank fellow civilians classmates, especially those under the supervision of Assoc. Prof. Dr. Abdul Nasir bin Matori; Ahmad Taqiyuddin, Muhammad Zahied and Mohammad Nasir.

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# ABBREVIATIONS

| | |
|---|---|
| ANUDEM | Australian National University's Digital Elevation Model |
| DEM | Digital Elevation Model |
| DID | Department of Irrigation and Drainage |
| DSM | Digital Surface Model |
| DSN | Database Source Name |
| EGM96 | Earth Gravitational Model 1996 |
| GIS | Geographical Information System |
| HEC-HMS | Hydrology Engineering Center - Hydrologic Modeling Software |
| HEC-RAS | Hydrology Engineering Center – River Analysis System |
| KML | Keyhole Markup Languange |
| NEXRAD | Next-Generation Radar |
| ODBC | Open Database Connectivity |
| OLE DB | Object Linking and Embedding, Database |
| TIN | Triangulated irregular network |
| USGS | United States Geological Survey |
| WGS84 | World Geodetic System 84 |
| XML | Extensible Markup Language |

# CHAPTER 1
# INTRODUCTION

## 1.1 Background of Study

A major flood event occurred earlier this year in the city of Kuching, Sarawak. From 8th to 11th January, the residents of Kuching was shocked after Sungai Sarawak swelled tremendously, causing a overspill onto the riverbanks and its major tributaries. The whole week, the city was hit with continuous torrent of rain. When this torrent was mixed together with seasonal king tide, the whole city suffered the wrath of Mother Nature. Many major areas in the city center were submerged under the murky water from Sarawak River. One by one major road was inundated, making it impossible for small vehicles to pass. The Sunday Post reported that access to Bau was cut off when flood water reached four feet at Batu Kawa, Batu Kitang and Matang. Therefore it is of importance to identify flood prone areas. Flood prediction is done on the area and the extent of inundation is identified.

To illustrate the severity of a flood event, it is usually easy to base it on an economic scale. The monetary loss of the inhabitants of the area is a good measure of flood severity. As reported in a Sunday Post article dated 18 January, Sara-Besi Hardware and Engineering Sdn Bhd proprietor, Ching Eng Kwang reported that he had lost RM10000 in faulty electrical items due to the flood entering his shop. This high monetary loss corresponds to the amount of things destroyed in a flood. More things are destroyed in a severe flood compared to a mild flood.

The estimation of damage is a good way for the local authorities to assess their preparation level against a flood threat. This will enable them to plan the mitigation process, either structurally by building monsoon drains or via land use zoning to prevent development from encroaching into the flood prone zones. The estimation can also be used to benchmark several proposed solutions to the flood problem. A before-after situation is an excellent way to see and evaluate each proposed solution. Both before-development and after-development flood maps are scrutinized to assess the probable performance of the proposed solution. (Dutta & Hearth, 2003)

## 1.2 Problem Statement

An area is selected by considering how frequent flooding happens in the area and the severity of the flood event. Flood model is then made and overlaid on top of the map of the area to determine the areas affected by the flood before damage estimation can be done in GIS software.

## 1.3 Objectives and Scope of the Study

There are two objectives that were identified for this study. The objectives are:

1. To model floods map the extent as a Geographical Information System (GIS) layer; and
2. To estimate the total damage to an area due to the aforementioned flood.

The study will be limited to the selected areas and the effect of the flood to the nearby catchment is omitted. For the area affected, this study will be helpful for the authority to plan proper mitigation options. The study will cover mostly on the usage of GIS technology in estimating damages incurred by floods.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Flood Modeling

The first step in doing the study is to select the area of study, preferably an area with frequent and major flooding. In Germany perspective, the requirements and features of the flood hazard maps include representation of present flood-relevant conditions, representations of inundation zones for flood events of different recurrence intervals up to generally 100 years, representative of inundation depths, potentially low velocities, representative of extreme, historical events with high recurrence intervals, representation of flood-protection measures, potentially hazard sources and level of detail for local analyses and planning purposes (Buchele, et al., 2006).

Hydrological science had developed several models to predict the flood. The humble beginnings started with Sherman's unit hydrograph model in 1932 and Horton's simplistic infiltration approach a year later (Pasche, 2007). Theoretically, these two models state that a catchment is a system where the precipitation is considered an input and transferred via the unit hydrograph. The end result would be a runoff hydrograph at the outlet of the catchment. This basic concept serves as a theoretical basis of the conceptual models, and also called "lumped models" (Pasche, 2007).

From a regional perspective, the modeling is usually done for the whole river since it considers the catchment contributing to the said river. In a paper by Knebl et al., a regional scale flood modeling was done to model the flooding at the San Antonio River Basin which has a frequent occurrence of flash flooding. In this model, NEXRAD Level III rainfall, GIS and hydrological models based on HEC-HMS/RAS were used and integrated. NEXRAD precipitation was used over traditional rain gages since it provides a finer resolution to calculate runoff accurately (Ahrens and Maidment, 1999; Bedient et al., 2003). For the study NEXRAD Level III datasets were obtained from Texas' West Gulf River Forecast Center for the calibration period and processed for compatibility with the hydrological model. Topography data with a resolution of 30 m was downloaded from USGS National Elevation Dataset (NED) and resampled to a 10 m grid. Streamflow observation data was also obtained from USGS to derive parameters and calibrate the model. Soil information was obtained from the National Conservation Service and land use cover data was obtained from the National Land Cover Dataset by USGS. River geometry was formed by combining data obtained from field survey with cross-section delineated from Digital Elevation Model. HEC-HMS was used to convert the rainfall to runoff based on the catchment conditions. Hydraulic model was done using HEC-HMS which can calculate one-dimension steady and unsteady flow using the output hydrographs from HMS. All this data was stored inside a geodatabase using ArcGIS. For the result, it was found that the shape of the hydrograph generated from modeling was the same with the observed one but overestimated the volume of runoff. To overcome this, finer calibration was done. Basin time of concentration, initial abstraction and the gridded curve number was found to be the most sensitive parameters. The modeling showed that different subbasins showed several disagreements between modeled and observed discharge. The flood polygons were overlain over the basin to show the inundated areas. It was then compared with satellite data (Landsat) corresponding to the day of flooding.

In modeling the urban flooding in Dhaka, Ole Mark et al. generated a Digital Elevation Model (DEM) by digitizing the alignment off and elevation for the road network in the Segunbagicha Khal catchment area from the map. Land elevation area data were also collected since they were important to estimate the storage capacity of the streets. For the study done by Dutta and Hearth (2003) in the Ichinomiya river basin in Japan, grid elevation data were obtained from the Japan Map Center and used to generate the DEM. Since the Segunbagicha Khal catchment was located entirely in the built-up area, it is mostly impervious. Water will travel fast from the ground towards the street. For the Ichinomiya river basin, there were different land covers for the area. Hence for the study purpose the land cover is divided into six types: forest, paddy, light grass, vegetable, water body and urban (Dutta & Hearth, 2003). In a study by Rahman and Alkema, the Digital Terrain Model and DSM for development plan in Naga City, Philippines by integrating multiple elevation data from different sources (Abdul Rahman & Alkema, 2007). Data sources are obtained from contour lines, spot heights and field observation with different accuracy levels. Interpolation of surface was done using Kringing, TIN, polynomial trend surface and ANUDEM methods. The interpolations also produces different accuracy, with ordinary Kringing producing an error of 1.00 m at 80$^{th}$ percentile and able to accurately represent the real study area. Thus it was used to construct the surface model.

The purpose of the Dhaka City urban drainage modeling is to improve the old pilot model since the more updated data were available. This model would also be used to simulate various alleviation schemes in the field of flood mitigation and optimize future development. The aim of the research on the Ichinomiya river basin is to show the estimation of flood loss using GIS methods, which expanded the current methodology to include both flood inundation simulation and flood loss simulation.

A real time flood modeling can also be done as a method of flood forecasting. This is essential in early flood warning systems in which an area is provided with enough time to evacuate or move themselves or their properties to a safer place. With flood warning, some last minutes actions can be done to prevent or minimize flooding; for example when flood warning is activated, river control structures such as river barrage can be operated or flood fighting activities such as erecting temporary flood barriers can be mobilized. (Sene, 2008). In chapter 5 of the book by Sene (2008), he states that a flood forecasting model for flood warning systems may include:

1. the forecasting requirement
2. the real time data available to support operation of the model
3. the forecasting system on which the model will be operated
4. the required model performance
5. The time, budget and skills available for model implementation.

## 2.2 Flood Damage Estimation

Damage during flood can be divided into two types: direct and indirect (Smith & Ward, 1998). These two can be further classified into tangible and intangible which measure how much money the damage is worth. The classifications of the damages are shown in table below (University of New South Wales, 1981). In case of damage to private dwellings, most of the damage were to the building structure itself while in the manufacturing sector the damage were mostly to the machinery operated by the industry (Merz, Kreibich, Thieken, & Schmidtke, 2004).

**Table 1: Flood Damage Classification**

| | Tangible | | Intangible |
| --- | --- | --- | --- |
| | Primary | Secondary | |
| Direct | Building structures, contents and agriculture | Land and environment recovery | Health, mental damage |
| indirect | Business interruptions | Impact on regional and national economy | |

In determining the damage estimation, there are two main methods used. One is through a questionnaire survey on the affected population asking them about their losses. The other frequently used method is the stage-damage function which relates the damage extent to a particular inundation depth and duration. Usually these are derived from past flood data analysis or by considering possible damage corresponding to a particular depth and period. One way to determine the direct damages was suggested by James in 1972:

$$C_d = K_d U M_s h A$$

Where $C_d$ is the flood damage cost for an event, $K_d$ is the flood damage per flood depth per dollar of market value of the structure, $U$ is the fraction of floodplain in urban development, $M_s$ is the market value of the structure inundated in dollars per developed acre, $h$ is the average flood depth over the inundated area in feet and $A$ is the area flooded, expressed in acres.

Stage-damage curve is constructed by plotting historical damages of flood against the flood stage, as presented by Eckstein in 1958. It requires a survey on property values of the flood plain and also the effect on structures such as structures, roads, crops and so on. The figure below shows an example of a stage-damage curve.

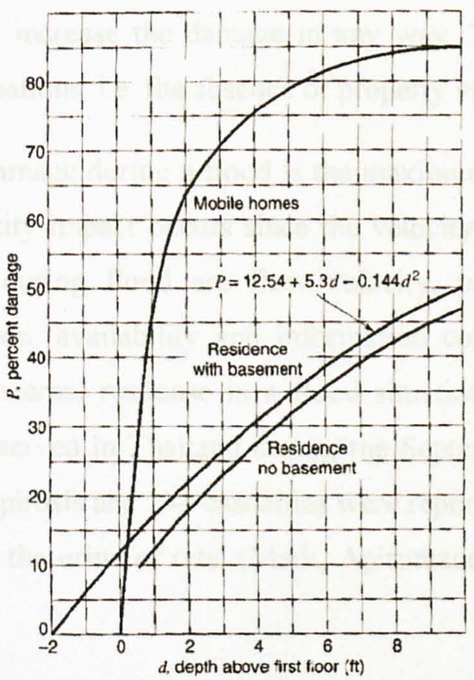



**Figure 1: Stage-Damage Curve**

From this figure, it is possible to determine the annual expected damage by integrating the functions, meaning to determine the area below the curve. By using this function, a study by Merz et al. found that large uncertainties will also occur. To reduce the uncertainty presented by the stage-damage curve, Buck and Merkel suggested that specific adjustments are made according to the area of interest.

Damage analysis can also be done using Geographical Information System (GIS). For the study done by Buchele et al., specific GIS-based tools were developed for damage estimation purposes. Three types of different functions were developed;

Linear-Based Polygon Function, Square-Root Function and Point-based Power Function. Linear polygon function relates the variables water depth and the damage. Then it is interpolated with linear functions, giving the output of estimated damage. Square-root function relates two parameters; the square root of the water depth and a user-defined parameter. Usually the user defined parameter represents the damage for a water depth of 1 meter. For point-based power function, it considers that damage only occurs when the water depth reaches a threshold level in the structure. An increase of water level after full submersion does not increase the damage in any way. The three functions are used for different situations, i.e. the absence of property values etc.

The main cause of damage during a flood is the maximum water level; hence no damage due to velocity impact occurs since the velocity is small. Other factors that cause damage during flood are flow velocity, period of submergence, sediment concentration, availability and information content of flood warning and the quality of external response in a flood situation. An interesting effect after a flood was observed in Thailand during the September 2000 flood where 6921 cases of Leptospirosis and 244 casualties were reported. This was due to the spread of bacteria in the urine of rats. (Mark, Apirumanekil, Kamal, & Praydal, 2001)

However in estimating future floods it is also important to estimate extreme events. Extreme event is defined as events having large recurrence intervals, usually more than 100 years. Study done by Buchele et al. took the flood analyses frequency from 335 gauges which cover catchment areas from 10 to 1000 square kilometers. The analyses were conducted using statistical methods to determine the probability of high recurrence interval events. The method used was linear regression equation to determine the mean annual peak discharge and peak discharge especially for ungauged sites. The study using statistical methods identified that the mean annual precipitation depth and landscape factor were significant for the peak discharge.

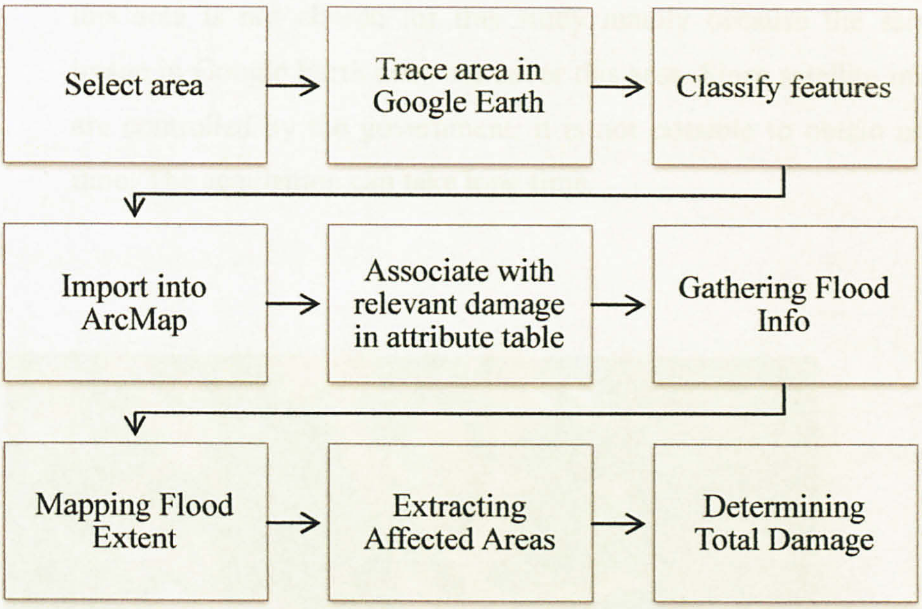
A research by Grelot suggested that floods are classified by their infrequency rather by their physical intensity or consequences. A classification based on physical properties is good to describe a natural event at a given location. Its drawback is that the ranking of the event is partly subjective. When classifying according to flood consequences, it is easy to understand by the common people however their impacts are described in non-directly comparable measures. The classification based on infrequency uses the stochastic properties of flood. Using this criterion we are able to know the probability of an event with certain physical characteristics above a given threshold

# CHAPTER 3

# METHODOLOGY/PROJECT WORK

The modeling of the study area and the flood map in GIS software can be summarized in the flow chart below:

Figure 2: Methodology Flow Chart




### 3.1 Select Area

Firstly, the study area was determined. The main factor for the consideration of the study area is that it must be prone to flooding and major flood events had occurred in recent years. Several areas in the Kuching city had been identified which matches the required criteria. The areas are as follows:

### 3.1.1 Batu Kawa

Batu Kawa is an urban sprawl of Kuching city. It is located near a bend on the Sarawak River and subjected to regular flooding especially during heavy rain periods. This is due to the location of the shop houses which is located on low grounds. The flooding here is severe and several measures had been suggested to alleviate the problem, one is to build bunds or levees around the town area. Unfortunately, the economic costs are too high and according to a report by the Department of Irrigation and Drainage, the most cost effective method is to invest in flood emergency centers. However, this area is not chosen for this study mainly because the satellite image in Google Earth does not cover this area. Since satellite images are controlled by the government, it is not possible to obtain one in time. The acquisition can take long time.


**Figure 3: Satellite Image of Batu Kawa Area**

### 3.1.2 Gita

Gita is an area located not far from the Satok Bridge crossing over the Sarawak River. It is also an urban sprawl of Kuching City where many housing estates are built and being built. The area also comprises of some villages, which are located near the river. The terrain is getting higher as it moves away from the river, which means the lowest point of the area are located near the river bank.

This area was considered because in the past six years, three major flood events had hit this area. In 2003, the river bank was overtopped due to heavy rains and king tide events causing floods depths of 2 feet. In 2004, the flood was more severe and affected the areas that were once assumed as safe from flood. The latest event was in early 2009, where heavy continuous rain for 4 days combined with king tide events raised the water level in the river, affecting more area than the previous floods. The area seems like the most probable candidate for use in this study.

However, from checking the satellite image in Google Earth, it was known that there are satellite image available for that area in perfectly clear resolution. So it had been decided that the area be selected for the purpose of this study.

**Figure 4: Satellite Image of Gita Area**

### 3.2 Tracing Area in Google Earth

Google Earth is chosen for the source image since the data is available freely online. In Google Earth, polygons can be drawn using the Polygon tool. The area of interest is outlined using the polygon tools. Usually these areas consist of a row of residential areas (terrace houses) and detached houses. In this image, the residential areas are outlined using the polygon tool while the road alignments are drawn using line tool. For residential areas belonging to the same roads, they are stored inside a folder name according to the nearest street.

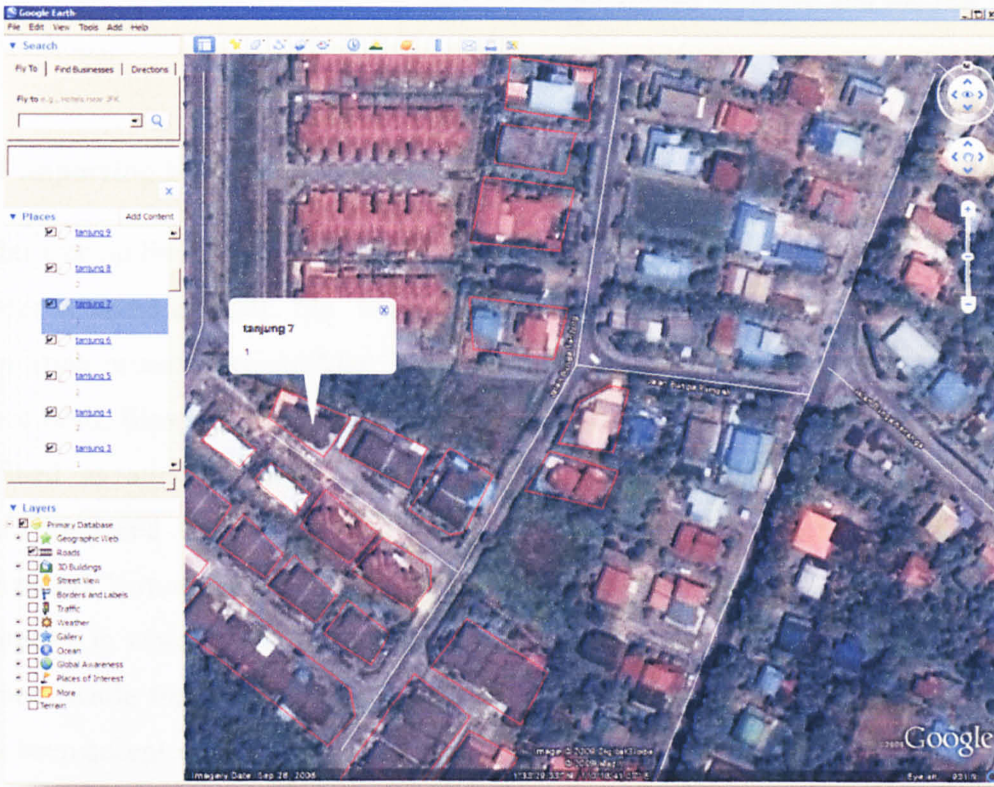



**Figure 5: Polygon Outlining and Classifying**

### 3.3 Classifying Features

During the tracing process, the types of the features are saved as the names of the polygons and lines. For example, for Jalan Merak, the layer is given the name Jalan Merak. For residential areas, the polygons are named according to the street that they are on. This is for easy reference later on. For example, the first residential on Jalan Tanjung is labeled tanjung 1. For residential areas that are connected in a row, they are lumped together to form a single polygon. The numbers of residential areas in each polygon are saved inside the description of the features.

In this study area, there were four major types of functional land use. One is residential, where housing estates and kampong house are also included in this type. The second one is prayer house, since there is a Muslim prayer house located in the study area. Groceries are also one type of the functional land use and the last one is workshops.

### 3.4 Importing KML Files into Arcmap

After tracing lines and polygons inside Google Earth is complete, the every resulting folder is saved as KML file. The purpose of saving it as KML file is to enable the importing process into ArcMap. Directly, ArcMap cannot accept KML files directly since KML files are not supported as the input files. From Wikipedia, KML files are defined as an XML-based language used to display and express geographical annotation and features inside software such as Google Earth, Google Maps and Microsoft Virtual Earth. It uses the 3D coordinate system (latitude, longitude and altitude), in which the latitude and longitude components uses the WGS84 geodetic system while the altitude uses the WGS84 EGM96 Geoid Vertical Datum. Now it has been accepted as one of the official Open Geospatial Consortium standards.

Since there is no way to import KML files directly into ArcMap, an extension is required. This extension, ET GeoWizards version 9.8 is used as an ArcMap extension. It is developed by ET SpatialTechniques in January 2002. It enables user to manipulate data easily and also do 3D analysis without the need for 3D Analyst. It is available in free and registered version. For the purpose of this study, the free version is good enough, making it the choice for the task.

First, in ArcMap, the ET GeoWizards wizard box is invoked by clicking it on the toolbar. Then, In/Out tab on the bottom of the wizard box is selected. To import the KML files, the Import From Google Earth is selected.

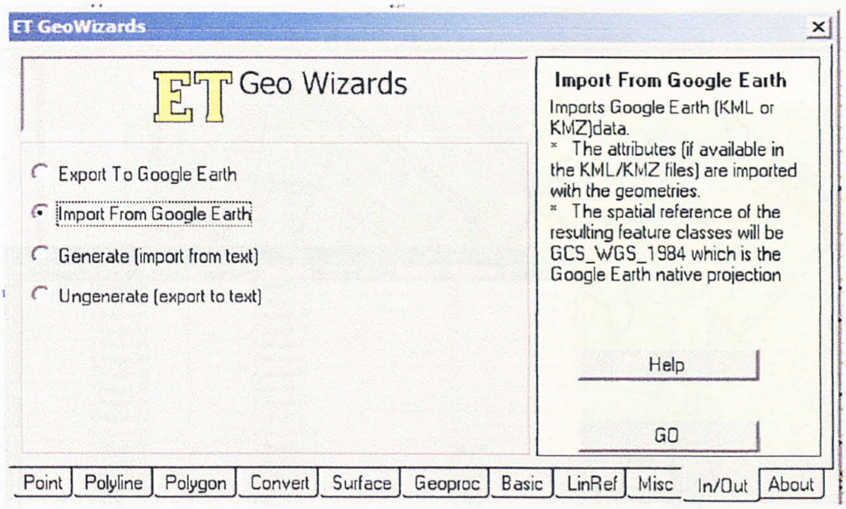



**Figure 6: Importing Google Earth Images into ArcMap using ET GeoWizards**

Next, the extension will ask for the location of the KML file as input and to specify an output folder. By specifying those and clicking finish, the extension will automatically import the polygons and transfer it to shapes format. The extension will also automatically create layers for each KML files imported. The same step is repeated for each KML files generated inside Google Earth. The end result is the replication of the sketched area inside Google Earth in ArcMap software. This replication follows exactly the projection in Google Earth (WGS1984) with minimal user modification.

### 3.5 Associate with Relevant Damage in Attribute Table

Each layer has its own attribute table. The attribute table lists down all polygons and features in the layer. Each polygons and features has its own data that can be attributed to it, just like an ordinary table.

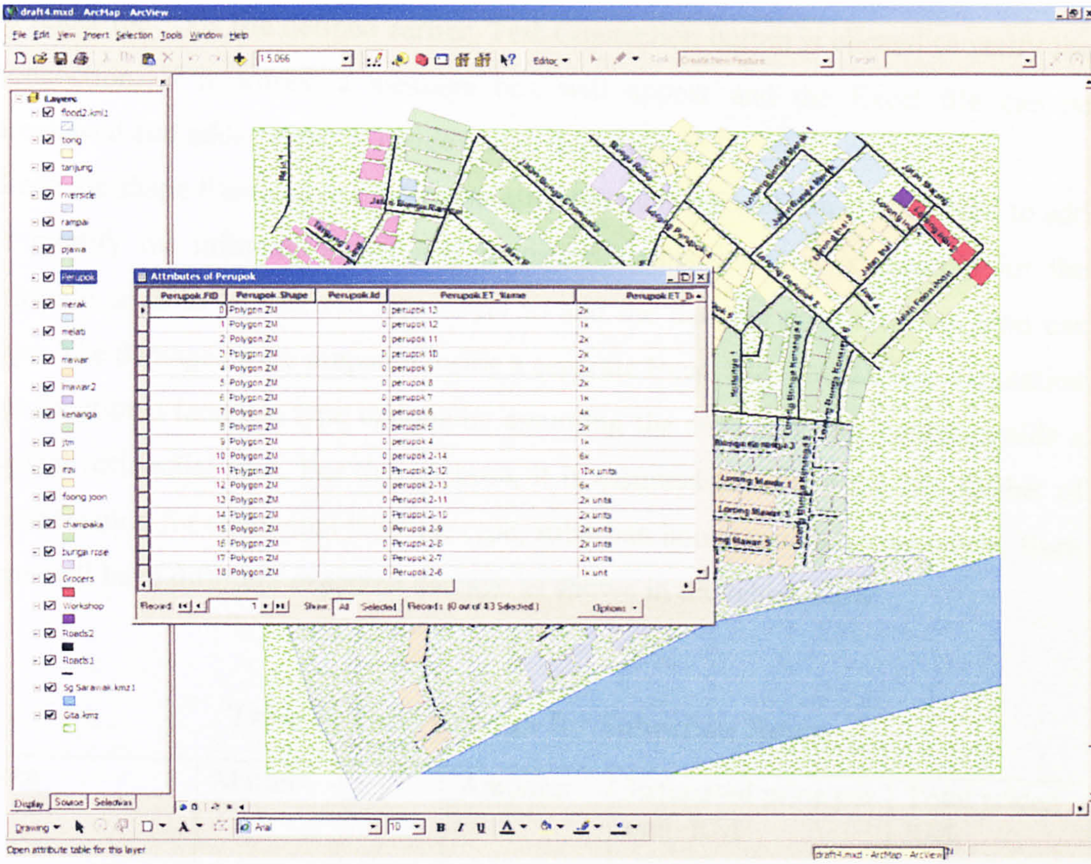


**Figure 7: Attribute Table for Perupok Polygon**

One wonderful thing about ArcGIS is that it can be used together with Microsoft Excel files, as if it natively understood the content of the Excel files. An Excel file can be used as a data source for ArcGIS via Microsoft ODBC Text Driver (Pratt, 2004). To do this, one should first create an ODBC data source inside Windows. First, inside Administrative Tools in Control Panel, Data Source is selected. Then, User DSN tab inside ODBC Data Source Administrator dialog box is selected and Add button is clicked. Microsoft Excel Driver (*.xls; *.xlsx) is selected. In the Data Source text box, a name for the database is created together with its description. To navigate to the Excel file, Select Workbook is clicked.

To edit the data inside Excel, the data that is required to be displayed inside ArcGIS is selected. The selected cells is then defined by going to Insert > Name > Define in Excel menu and this name will appear in the tables list inside ArcCatalog or ArcMap. To ensure the connection to the Excel file is working, in ArcCatalog, Database Connection is expanded and Add OLE DB Connection is selected. Microsoft OLE DB Provider for ODBC Driver is selected and the User Data Source Name is clicked to select the *.xls file defined earlier. Test Connection button is clicked to verify the connection. If it works, a message box will appear and the Excel file can be previewed and added directly inside a map document.

Since the shape files also has their own attribute tables, Excel can also be used to add or modify the information for map features. In this study, it is required for the attribute table to be inserted into Excel to add the damage per functional land use type. The damages were prepared inside a separate Excel file. The damage estimation per functional land use type is done by assuming the most probable content inside a typical residential area. For this purpose, it is assumed that there are two further of classification for residential land use type; suburban house and kampong house. Each type will have different expected damage as shown in the table below:

**Table 2: Total Damage for Suburban House**

| Area | Matter | Amount | Estimated price per unit, RM | Total price, RM |
|---|---|---|---|---|
| Porch | Car | 2 | 60,000 | 120000 |
| | Motorbike | 1 | 5000 | 5000 |
| Living room | Sitting sofa | 1 | 2200 | 2200 |
| | Coffee table | 1 | 500 | 500 |
| | television | 1 | 1200 | 1200 |
| | TV rack | 1 | 500 | 500 |
| | Satellite decoder | 1 | 300 | 300 |
| Kitchen | Dining table | 1 | 2000 | 2000 |
| | Refrigerator | 1 | 1500 | 1500 |
| | Gas stove | 1 | 230 | 230 |
| Bedroom | Sleeping bed | 3 | 1100 | 3300 |
| | Closet | 3 | 1300 | 5400 |
| | Dresser | 3 | 800 | 2400 |
| | | | Total | RM 144,530 |

**Table 3: Total Damage for Kampong House**

| Area | Matter | Amount | Estimated price per unit, RM | Total price, RM |
|---|---|---|---|---|
| Porch | Car | 1 | 30,000 | 30000 |
| | Motorbike | 1 | 5000 | 5000 |
| Living room | sitting chair | 1 | 1000 | 1000 |
| | Coffee table | 1 | 300 | 300 |
| | television | 1 | 800 | 800 |
| | TV rack | 1 | 250 | 250 |
| | Satellite decoder | 1 | 300 | 300 |
| Kitchen | Dining table | 1 | 500 | 500 |
| | Refrigerator | 1 | 800 | 800 |
| | Gas stove | 1 | 120 | 120 |
| Bedroom | Sleeping bed | 3 | 500 | 1500 |
| | Closet | 3 | 800 | 2400 |
| | Dresser | 3 | 200 | 600 |
| | | | Total | RM43570 |

To enter the total damage value for each polygon type, the attribute table from each layer is exported using the export tool into dBASE (*.dbf) format. The attribute table for each layer is opened and the tools button is clicked to export it. The *.dbf file is then opened in Excel. All fields except for FID field are deleted and the corresponding damage value is inserted next to it. This edited file is then saved as a comma-delimited text with an extension *.csv.

Next step is to join the edited file with the attribute table inside ArcMap. Before that, it must be ensured that the first row of the spreadsheet is made up of field headings with no more than 10 characters and no spaces, dashes or brackets. The edited Excel file is checked to ensure it shares a common field with the attribute table. In this study, the common field is the FID field.

Firstly, to join the fields the *.csv file must be added to the Table of Contents by clicking the Add Data button. The *.csv file will be displayed in the Sources tab in the Table of Contents. On the layer, Join and Relate is selected in the context menu (right-click) and then Join Attributes from a Table is chosen in the dialog box.

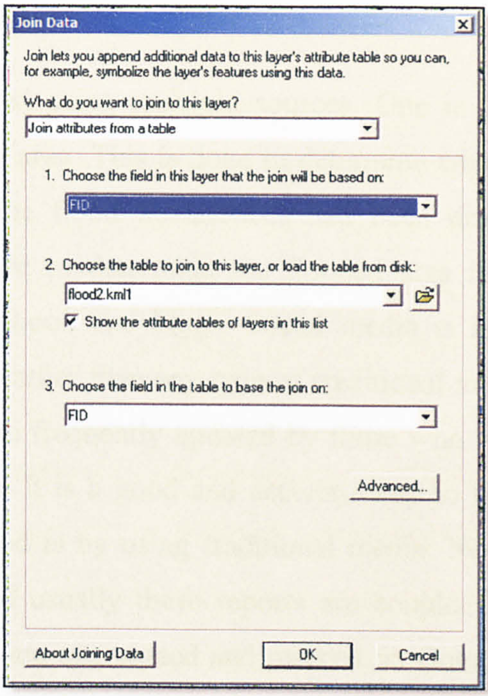



**Figure 8: Join and Relate Dialog Box**

In the first drop-down box, the field in the attribute table that the join will be based on is selected. For this study, the specific field is the FID field. To point the software to the excel file with the damages and FID field, Browse button is selected and the *.csv file is selected in its directory. In the third drop-down box, the field in the table on which the join will be based on is selected, and in this case, it is also the FID field. After clicking OK, the fields will be joined and the results can be seen by viewing the attribute table. This is done for every layer also.

### 3.6 Gathering Flood Info

Flood info was gathered using multiple sources. One is by interviewing several people who lived in the area. This is done to determine which area was affected by the previous floods. The flood occurrences had been discussed in the previous chapter. Another method to determine the flooded area is by researching online media such as on Facebook and blogs. Social media is increasingly effective in dispersing information earlier than any type of traditional media. Online discussions on Twitter or forums are frequently updated by those who were affected by natural disasters (Miller, 2009). It is a good and accurate way to find out which area was affected. Another method is by using traditional media. Newspapers published the event in its reports, and usually these reports are coupled with the areas that are affected. These sources are aggregated and marked on Google Earth as placemarks. The placemarks are then connected using the polygon tool producing a polygon which shows the flood affected areas.

### 3.7 Mapping Flood Events

As stated in the previous step, the placemarks are joined together inside Google Earth to produce an approximation of the flooded area. As with tracing the area, the resulting polygon representing the flooding area is exported into ArcMap using ET GeoWizards. The steps are still the same with the previous step. The resulting layer is ensured to be put on the topmost layer to ensure it covers much of the study area.

### 3.8 Determining Total Damage

After the flood layer has been overlain with the study area layer, it is time to separate the affected features from the unaffected ones. In ArcMaps, again the extension ET GeoWizards is used. Basically, since the flood layer had been overlaid on the top of the other polygons, the intersection of the flood layer with the other polygon layers are taken as the affected areas and the resulting damage is extracted from the attributes table.

To intersect the polygons, the extension ET GeoWizards is used. Here, ET GeoWizards is invoked from the toolbar. The polygon tab is selected and the Advanced Merge option is selected.

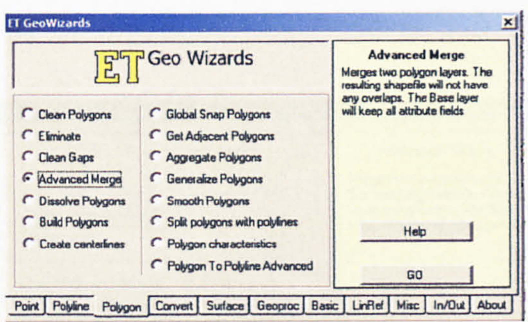



**Figure 9: Advanced Merge Dialog Box**

Next the extension asks for the base polygon layer. This is the layer which is the damages is to be determined. In this case, it is the layer containing the residential features. It also asks for the output class feature or shapefile, basically another polygon resulting from the merge. Here the output folder and the name of the new layer of polygon are entered.

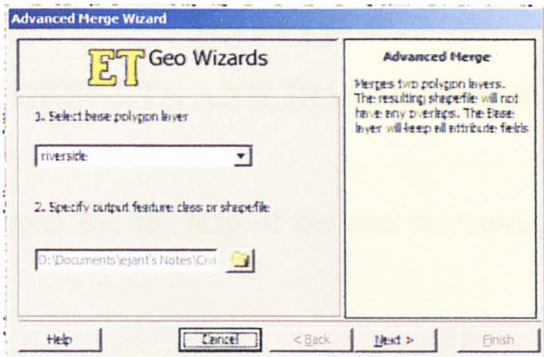



**Figure 10: Selecting Output Folder and New Polygon Layer**

Then the flood layer is selected as the layer to be merged. The fuzzy tolerance need not to be changed since the default values work most of the time. Then the third option is selected to include the intersection in the finished layer.

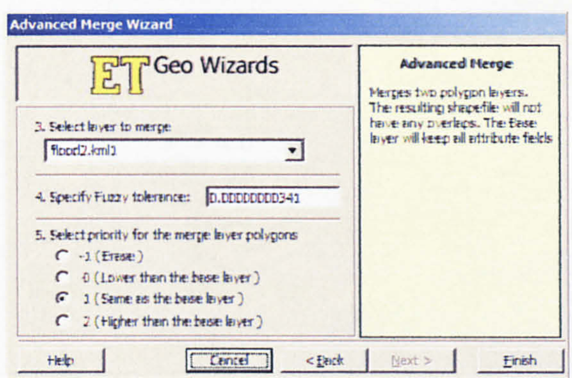



**Figure 11: Merging Options**

The new layers resulting from the merge is joined again with the damage *.csv file to enter the damages into a new attribute field. The steps of joining two tables had been explained in the previous step. After the join is finished, the new attributes table are then exported into Excel as *.dbf, converted into Excel spreadsheet and summed together to obtain the total damage.

# CHAPTER 4
# RESULTS AND DISCUSSIONS

The completed flood map and the map of the area in ArcMap are as in the figure below:

**Figure 12: Completed Flood Map**

The transfer of data from Google Earth to ArcMap also brings the properties saved in Google Earth into the attribute tables in ArcMap. From that the attribute table for each layer is exported into *.dbf and the information about the number of polygons and total dwellings are obtained. Here is the summary table for the whole area:

**Table 4: Zones and Their Attributes**

| Area | Total Polygons | Total Dwellings | Dwellings Per Polygon |
|---|---|---|---|
| tiong | 8 | 9 | 1.125 |
| tanjung | 22 | 50 | 2.272727 |
| rampai | 2 | 2 | 1 |
| perupok | 43 | 180 | 4.186047 |
| merak | 19 | 39 | 2.052632 |
| inai | 19 | 30 | 1.578947 |
| champaka | 9 | 25 | 2.777778 |
| bunga rose | 8 | 15 | 1.875 |
| lmawar | 26 | 175 | 6.730769 |
| melati | 18 | 23 | 1.277778 |
| riverside | 10 | 70 | 7 |
| jtm | 12 | 51 | 4.25 |
| kenanga | 71 | 176 | 2.478873 |
| mawar | 25 | 170 | 6.8 |
| pjawa | 23 | 80 | 3.478261 |
| | 315 | 1095 | 3.47619 |

The zone with the maximum number of dwellings is perupok with 180 residential dwellings. The zone with the least number of dwellings is rampai with only 2 dwellings. For the average number of dwellings per zone, it equals to 73 dwellings per zone. This indicates that the zoning is more or less random and taking account of larger areas. This simply means that the zones should be divided into smaller slices to ensure a more accurate average per zone.

The average dwelling per polygon is 3.476. This means that for every polygon drawn on the Google Map image, it accommodates almost four dwellings. However, for some areas with large grouping of houses, particularly in terraced houses, it is hard to individually contain a residential within a polygon. To do that would take more time, and contributing to more probable error since each single house is taken care for. This will create more data points from what is needed.

After conducting the intersection analysis, it was found out that a total of 701 dwellings were affected by the flood. The number of affected dwellings and the damages incurred are detailed in the table below:

**Table 5: Flooded Zones and Their Attributes**

| Zone | Total polygons | Total dwellings | Total damage (RM) |
|---|---|---|---|
| lmawar | 26 | 175 | 25,292,750 |
| melati | 18 | 23 | 3,324,190 |
| riverside | 10 | 70 | 3,049,900 |
| jtm | 12 | 51 | 7,371,030 |
| kenanga | 71 | 176 | 25,437,280 |
| mawar | 25 | 170 | 24,570,100 |
| pjawa | 9 | 36 | 5203080 |
| | 171 | 701 | 94,248,330 |

For each landuse type, the flooded area will be divided with the total area to obtain the fraction of the flooding (Kafle, Hazarika, Shrestha, Prathumchai, & Samarakoon, 2006). In the study area, it only consists of residential land use type, so the total flood percentage also equals to the percentage of residential zones affected; thus

Flood percentage = (flooded area / total area) x 100

This percentage will be interpreted as the hazard ranking of the area. Next a threshold value of hazard is selected to classify the flood into hazard level. A low hazard level is determined to have 20% of flood percentage. A high hazard level will endure 60% of flood percentage.

**Table 6: Hazard Level According to Inundation Percentage**

| Hazard Level | Percentage |
|---|---|
| Low | < 20 % |
| Medium | >20 %, < 60% |
| High | > 60 % |

From the table 5 above, there are seven areas that are affected by the flood. The percentage of flooded area is 64%, which amounts to about two thirds of the whole residential area. Comparing the percentage of flooded area with the values in Table 6, the Gita area can be classified as a high hazard for flooding area. However this has not taken into consideration of free space, which might also be flooded but for this case is being neglected because free space usually does not contribute to any physical damage.

From the map generated above, we can see that some of the areas are only semi-flooded. This is apparent in the zone pjawa, where 36 out of 80 dwellings were affected. This is mainly due to the topology of the ground level, in which as it goes north, it gets higher. Most of the northern part of the area is safe from the flood. This is also a proof that as it goes north, it is higher. Most of the flooded zones have their dwellings fully affected by the flood.

The damage costs per dwelling were obtained by assuming each residential type for suburban dwelling is a single-story terrace house with five members in the family. The typical possession that one residential dwelling might have is also assumed based on the assumption that each house has 3 bedrooms, a typical sitting room with coffee table and television sets with satellite receiver, 2 cars, 1 motorcycle and typical appliances inside kitchen. For the kampong house type of dwelling, the types of possession are the same but the values are different, considering different purchasing power of those living in villages.

The values obtained here are pretty conservative and seem superfluous. This is because the damage estimates take account that once flooding occur at an area, the full damage also occur. This is why the values obtained are very large. In the event of a flood, it might be or might not be the exact damage that occurs in the structure. In this way also, it is assumed that once water level rise in the study area, the full damage effect will happen i.e. all the possession in the house will be destroyed.

By using Google Earth and ArcMap, it is possible for people or organization to build a Geographical Information System without requiring official remote sensing sources from commercial vendors. It is proven by this study that for an area, the concept of constructing an information system for an area is feasible. It is also applicable to other types of information such as recording crime data, income level or number of population. By using the satellite images provided in the public domain, no charges whatsoever are required. However, according to Google copyrights of the images produced by Google Earth software must be preserved.

There is also a concern with the accuracy of the location of features as obtained from Google Earth. Comparing points from site survey and obtained from Google Earth, the position may vary by as much as 30 feet in some cases (Pawlowicz, 2007). This is due to the improper alignment of the aerial image over the spherical projection of the Earth, causing some place to distort out of place.

# CHAPTER 5
# CONCLUSION AND RECOMMENDATION

## 5.1 Conclusion

In this study, a flood prone area is selected according to specified characteristics. It must have major flood event occurring in close duration. For the purpose of this study, Gita area in Kuching, Sarawak is selected because in the past six years, three major flood events had happened in the area, giving an average of two years per flood event. The flood event also gets more severe year by year, so that strengthens the decision to choose this particular area for the purpose of the study. The study aims to estimate the damages incurred by a flood event. This flood event is modeled and inserted into the GIS software as a layer. The flood layer is overlaid on top of the other features layers and intersection analysis is done to extract those affected areas. From intersection analysis, it is found that 701 dwellings are affected from seven zones designated earlier in the study. The 701 dwellings incurred a total damage of RM 94,248,330. However it is important to remind that the value obtained is very conservative since it considers total damage occurs once the area is inundated with water. The area also has a high flood hazard ranking, with 64%, exceeding the threshold set for high flood hazard.

## 5.2 Recommendations

For a more detailed flood model, it is suggested that a digital elevation model is constructed for the area. A DEM can be used to accurately model the surface of the area, with pits and contours are properly defined. A time-scale meteorological model can be coupled with this DEM to provide an accurate flood inundation level. By having the flood depth, the proper stage-damage curve, stage-discharge curve, can discharge-damage curve can be developed and also can be the model for another regional empirical curve.

For estimating the direct damages, the aggregate formula suggested by (James, 1972) can be used. This formula aggregates the flood damage cost for a particular event, flood damage per foot per market value of structure, fraction of floodplain in the urban development, market value of the structure, flood depth and also the area of the inundated zone to determine a total direct damage to a building. Of course by using this aggregate formula, only the damage to the structure can be determined. To provide a more comprehensive flood damage estimation system, surveys or questionnaires can be given out to residents of affected area asking them what possession of theirs was destroyed by previous floods to create the stage-damage function. The stage-damage function is interesting in that one model created in a country may not necessarily apply to another because of the differences in market values of structure and so on. Even different countries have different kinds of houses and how they set up their possession in the house. In the event that these data are not available, it is suggested that data from completed studies are used as the basis of damage estimation. For example, damage data for each type of dwellings from existing flood damage studies in Malaysia can be used here.

A high hazard ranking area means that the area is prone to flooding, in case of equal or greater intensity of rain happening compared to the early year flood event (2009). For future mitigation effort, it is suggested that a comprehensive flood warning system being utilized. Currently, the monitoring of upper catchments and water levels by the DID had helped greatly in warning the population that a flood may happen. During the last flood event, the announcement of the probable time of water rising was done in the radio, which reached most of the population. It can help the residents to plan when to evacuate and move their things to safety. It can be improved more by having the information being relayed to the public gathering place such as mosques or markets as soon as a fast water level rise is detected by the water level station. The warnings can also be sent by text messages to those who are near the place.

Tighter integration of GIS software packages with flood forecasting/modeling can also be done. Geocoding can be done to classify zones according to their functional land use type. It is done to assign a coordinate values to an address by comparing the location element in the address to referenced materials (Crosier, 2004). By doing this it will be easier to extract land use type data just by referencing the address of a structure with reference material in the software. For example, the street at which a business central is located is used as a query word to find what functional land use type may exist there. It saves a lot of time compared to manually checking in the database or going to the location itself.

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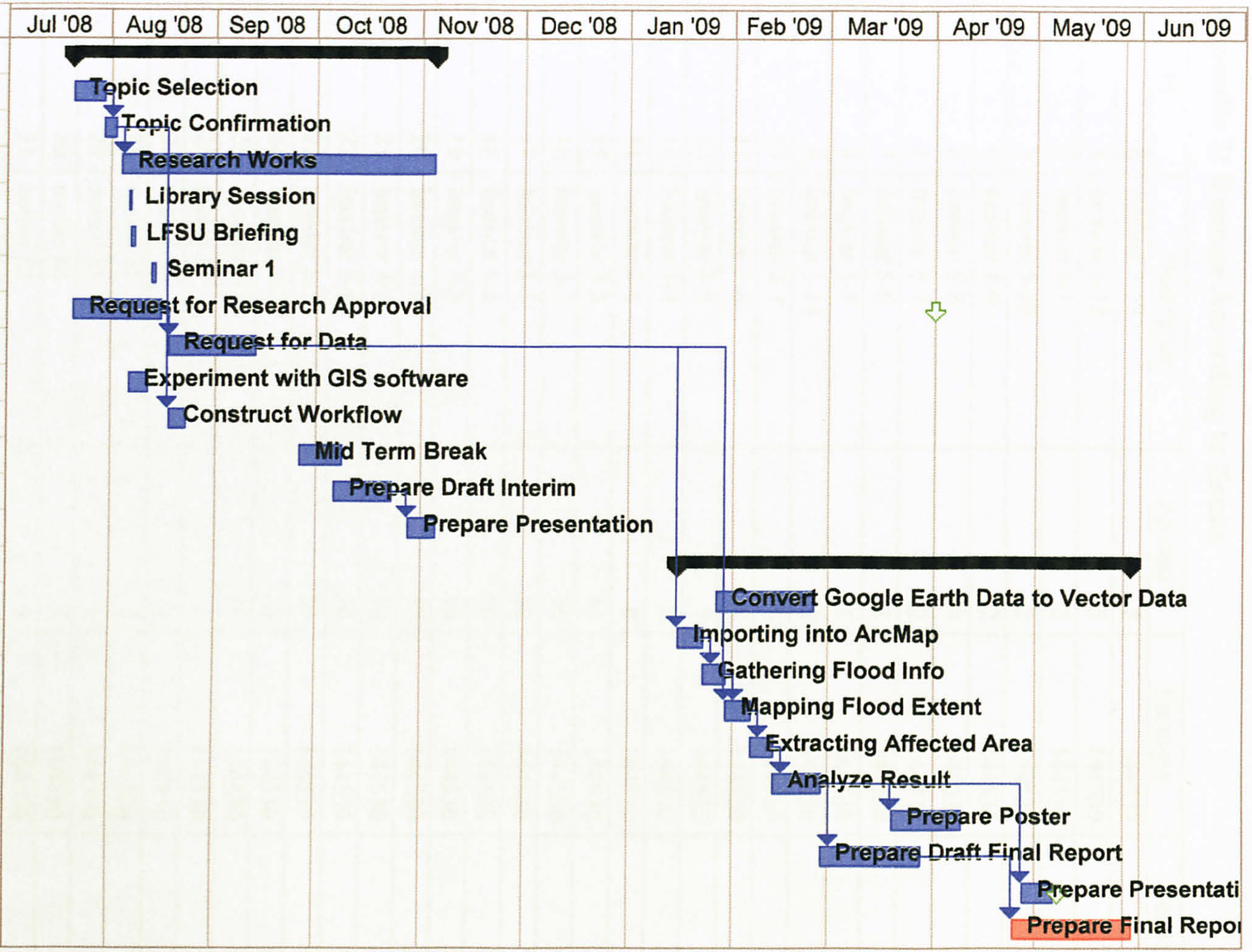
# APPENDIX

## Appendix 1: Gantt chart

| ID | Task Name |
|---|---|
| 1 | **FYP1** |
| 2 | Topic Selection |
| 3 | Topic Confirmation |
| 4 | Research Works |
| 5 | Library Session |
| 6 | LFSU Briefing |
| 7 | Seminar 1 |
| 8 | Request for Research Approval |
| 9 | Request for Data |
| 10 | Experiment with GIS software |
| 11 | Construct Workflow |
| 12 | Mid Term Break |
| 13 | Prepare Draft Interim |
| 14 | Prepare Presentation |
| 15 | **FYP2** |
| 16 | Convert Google Earth Data to Vector Data |
| 17 | Importing into ArcMap |
| 18 | Gathering Flood Info |
| 19 | Mapping Flood Extent |
| 20 | Extracting Affected Area |
| 21 | Analyze Result |
| 22 | Prepare Poster |
| 23 | Prepare Draft Final Report |
| 24 | Prepare Presentation |
| 25 | Prepare Final Report |



## Appendix 2: Damage According to Zones

| Id | Description | Amount | Damages | Total (RM) |
|---|---|---|---|---|
| 0 | lmawar 5-13 | 5 | 144530 | 722650 |
| 1 | lmawar 5-12 | 5 | 144530 | 722650 |
| 2 | lmawar 5-11 | 2 | 144530 | 289060 |
| 3 | lmawar 5-10 | 2 | 144530 | 289060 |
| 4 | lmawar 5-9 | 2 | 144530 | 289060 |
| 5 | lmawar 5-8 | 8 | 144530 | 1156240 |
| 6 | lmawar 5-7 | 2 | 144530 | 289060 |
| 7 | lmawar 5-6 | 1 | 144530 | 144530 |
| 8 | lmawar 5-5 | 1 | 144530 | 144530 |
| 9 | lmawar 5-14 | 10 | 144530 | 1445300 |
| 10 | lmawar 3-7 | 6 | 144530 | 867180 |
| 11 | lmawar 3-6 | 4 | 144530 | 578120 |
| 12 | lmawar 3-5 | 7 | 144530 | 1011710 |
| 13 | lmawar 3-4 | 4 | 144530 | 578120 |
| 14 | lmawar 3-4 | 6 | 144530 | 867180 |
| 15 | lmawar 3-3 | 10 | 144530 | 1445300 |
| 16 | lmawar 3-2 | 10 | 144530 | 1445300 |
| 17 | lmawar 3-1 | 10 | 144530 | 1445300 |
| 18 | lmawar 4-4 | 10 | 144530 | 1445300 |
| 19 | lmawar 4-3 | 10 | 144530 | 1445300 |
| 20 | lmawar 4-2 | 10 | 144530 | 1445300 |
| 21 | lmawar 4-1 | 10 | 144530 | 1445300 |
| 22 | lmawar 5-4 | 10 | 144530 | 1445300 |
| 23 | lmawar 5-3 | 10 | 144530 | 1445300 |
| 24 | lmawar 5-2 | 10 | 144530 | 1445300 |
| 25 | lmawar 5-1 | 10 | 144530 | 1445300 |
| 26 | melati 17 | 1 | 144530 | 144530 |
| 27 | melati 16 | 1 | 144530 | 144530 |
| 28 | melati 15 | 1 | 144530 | 144530 |
| 29 | melati 15 | 1 | 144530 | 144530 |
| 30 | melati 14 | 2 | 144530 | 289060 |
| 31 | melati 13 | 4 | 144530 | 578120 |
| 32 | melati 12 | 1 | 144530 | 144530 |
| 33 | melati 11 | 1 | 144530 | 144530 |
| 34 | melati 10 | 1 | 144530 | 144530 |
| 35 | melati 9 | 1 | 144530 | 144530 |
| 36 | melati 8 | 1 | 144530 | 144530 |
| 37 | melati 7 | 1 | 144530 | 144530 |
| 38 | melati 6 | 1 | 144530 | 144530 |
| 39 | melati 5 | 2 | 144530 | 289060 |
| 40 | melati 4 | 1 | 144530 | 144530 |
| 41 | melati 3 | 1 | 144530 | 144530 |
| 42 | melati 2 | 1 | 144530 | 144530 |
| 43 | melati 1 | 1 | 144530 | 144530 |
| 44 | riverside 1 | 12 | 43570 | 522840 |
| 45 | riverside 2 | 12 | 43570 | 522840 |
| 46 | riverside 3 | 8 | 43570 | 348560 |

| | | | | |
|---|---|---|---|---|
| 47 | riverside 4 | 4 | 43570 | 174280 |
| 48 | riverside 5 | 5 | 43570 | 217850 |
| 49 | riverside 7 | 6 | 43570 | 261420 |
| 50 | riverside 8 | 7 | 43570 | 304990 |
| 51 | riverside 9 | 5 | 43570 | 217850 |
| 52 | riverside 10 | 5 | 43570 | 217850 |
| 53 | riverside 11 | 6 | 43570 | 261420 |
| 54 | mawar 5.1-5 | 4 | 144530 | 578120 |
| 55 | mawar 5.1-4 | 4 | 144530 | 578120 |
| 56 | mawar 5.1-3 | 4 | 144530 | 578120 |
| 57 | mawar 5.1-2 | 9 | 144530 | 1300770 |
| 58 | mawar 5-5 | 4 | 144530 | 578120 |
| 59 | mawar 5-4 | 6 | 144530 | 867180 |
| 60 | Mawar 1-3 | 10 | 144530 | 1445300 |
| 61 | mawar 5-3 | 2 | 144530 | 289060 |
| 62 | mawar 5-2 | 2 | 144530 | 289060 |
| 63 | mawar 5-1 | 4 | 144530 | 578120 |
| 64 | mawar 5-5 | 2 | 144530 | 289060 |
| 65 | mawar 5-4 | 10 | 144530 | 1445300 |
| 66 | mawar 5-3 | 6 | 144530 | 867180 |
| 67 | mawar 5-2 | 10 | 144530 | 1445300 |
| 68 | mawar 5-1 | 4 | 144530 | 578120 |
| 69 | mawar 3-5 | 6 | 144530 | 867180 |
| 70 | mawar 3-4 | 8 | 144530 | 1156240 |
| 71 | mawar 3-3 | 5 | 144530 | 722650 |
| 72 | Mawar 1-2 | 10 | 144530 | 1445300 |
| 73 | mawar 3-2 | 10 | 144530 | 1445300 |
| 74 | mawar 3-1 | 10 | 144530 | 1445300 |
| 75 | mawar 1-5 | 10 | 144530 | 1445300 |
| 76 | mawar 1-4 | 10 | 144530 | 1445300 |
| 77 | mawar 5.1-1 | 14 | 144530 | 2023420 |
| 78 | Mawar 1-1 | 6 | 144530 | 867180 |
| 79 | kenanga 15 | 1 | 144530 | 144530 |
| 80 | kenanga 14 | 1 | 144530 | 144530 |
| 81 | kenanga 13 | 2 | 144530 | 289060 |
| 82 | kenanga 12 | 1 | 144530 | 144530 |
| 83 | kenanga 11 | 1 | 144530 | 144530 |
| 84 | kenanga 11 | 3 | 144530 | 433590 |
| 85 | kenanga 10 | 1 | 144530 | 144530 |
| 86 | kenanga 9 | 2 | 144530 | 289060 |
| 87 | kenanga 8 | 1 | 144530 | 144530 |
| 88 | kenanga 7 | 2 | 144530 | 289060 |
| 89 | kenanga 6 | 5 | 144530 | 722650 |
| 90 | kenanga 5 | 4 | 144530 | 578120 |
| 91 | kenanga 4 | 2 | 144530 | 289060 |
| 92 | kenanga 3 | 1 | 144530 | 144530 |
| 93 | kenanga 2 | 1 | 144530 | 144530 |
| 94 | kenanga 1a-8 | 2 | 144530 | 289060 |
| 95 | kenanga 1a-7 | 2 | 144530 | 289060 |

| | | | | |
|---|---|---|---|---|
| 96 | kenanga 1a-6 | 6 | 144530 | 867180 |
| 97 | kenanga 1a-5 | 6 | 144530 | 867180 |
| 98 | kenanga 1a-4 | | 144530 | 0 |
| 99 | kenanga 1a-3 | 2 | 144530 | 289060 |
| 100 | kenanga 1a-2 | 2 | 144530 | 289060 |
| 101 | kenanga 1a-1 | 2 | 144530 | 289060 |
| 102 | kenanga 1-3 | 2 | 144530 | 289060 |
| 103 | kenanga 1-2 | 1 | 144530 | 144530 |
| 104 | kenanga 1-1 | 2 | 144530 | 289060 |
| 105 | Kenanga 3-12 | 2 | 144530 | 289060 |
| 106 | Kenanga 3-11 | 2 | 144530 | 289060 |
| 107 | kenanga 3-9 | 1 | 144530 | 144530 |
| 108 | Kenanga 3-8 | 1 | 144530 | 144530 |
| 109 | Kenanga 3-7 | 6 | 144530 | 867180 |
| 110 | Kenanga 3-6 | 1 | 144530 | 144530 |
| 111 | Kenanga 3-5 | 1 | 144530 | 144530 |
| 112 | Kenanga 3-4 | 1 | 144530 | 144530 |
| 113 | Kenanga 3-3 | 2 | 144530 | 289060 |
| 114 | Kenanga 3-2 | 1 | 144530 | 144530 |
| 115 | Kenanga 3-1 | 1 | 144530 | 144530 |
| 116 | Kenanga 5-7 | 1 | 144530 | 144530 |
| 117 | Kenanga 5-6 | 1 | 144530 | 144530 |
| 118 | Kenanga 5-5 | 2 | 144530 | 289060 |
| 119 | Kenanga 1-1 | 2 | 144530 | 289060 |
| 120 | Kenanga 1 | 2 | 144530 | 289060 |
| 121 | Kenanga 1-7 | 10 | 144530 | 1445300 |
| 122 | Kenanga 1-6 | 2 | 144530 | 289060 |
| 123 | Kenanga 1-5 | 2 | 144530 | 289060 |
| 124 | Kenanga 1-4 | 2 | 144530 | 289060 |
| 125 | Kenanga 1-3 | 6 | 144530 | 867180 |
| 126 | Kenanga 1-2 | 4 | 144530 | 578120 |
| 127 | Kenanga 1-1 | 2 | 144530 | 289060 |
| 128 | Kenanga 4-8 | 1 | 144530 | 144530 |
| 129 | Kenanga 4-7 | 8 | 144530 | 1156240 |
| 130 | Kenanga 4-6 | 7 | 144530 | 1011710 |
| 131 | Kenanga 4-5 | 1 | 144530 | 144530 |
| 132 | Kenanga 4-4 | 2 | 144530 | 289060 |
| 133 | Kenanga 4-3 | 2 | 144530 | 289060 |
| 134 | Kenanga 4-2 | 2 | 144530 | 289060 |
| 135 | Kenanga 4-1 | 1 | 144530 | 144530 |
| 136 | Kenanga 6-5 | 5 | 144530 | 722650 |
| 137 | Kenanga 6.3 | 2 | 144530 | 289060 |
| 138 | Kenanga 6-2 | 2 | 144530 | 289060 |
| 139 | Kenanga 6-1 | 2 | 144530 | 289060 |
| 140 | Kenanga 5.1-2 | 2 | 144530 | 289060 |
| 141 | Kenanga 5.1-2 | 2 | 144530 | 289060 |
| 142 | Kenanga 5.1-1 | 6 | 144530 | 867180 |
| 143 | Kenanga 5.3-3 | 4 | 144530 | 578120 |
| 144 | Kenanga 5.2-2 | 2 | 144530 | 289060 |

| | | | | |
|---|---|---|---|---|
| 145 | Kenanga 5-4 | 2 | 144530 | 289060 |
| 146 | Kenanga 5-3 | 2 | 144530 | 289060 |
| 147 | Kenanga 5-2 | 2 | 144530 | 289060 |
| 148 | Kenanga 5.2-1 | 2 | 144530 | 289060 |
| 149 | Kenanga 6-4 | 5 | 144530 | 722650 |
| 150 | Kenanga 5-1 | 2 | 144530 | 289060 |
| 151 | jtmawar 1 | 6 | 144530 | 867180 |
| 152 | jtm 11 | 10 | 144530 | 1445300 |
| 153 | jtm 10 | 2 | 144530 | 289060 |
| 154 | jtm 9 | 4 | 144530 | 578120 |
| 155 | jtm 8 | 8 | 144530 | 1156240 |
| 156 | jtm 7 | 2 | 144530 | 289060 |
| 157 | jtm 6 | 2 | 144530 | 289060 |
| 158 | jtm 5 | 2 | 144530 | 289060 |
| 159 | jtm 4 | 1 | 144530 | 144530 |
| 160 | jtm 3 | 4 | 144530 | 578120 |
| 161 | jtm 2 | 8 | 144530 | 1156240 |
| 162 | jtm 1 | 2 | 144530 | 289060 |
| 163 | pjwa 5-4 | 1 | 144530 | 144530 |
| 164 | pjawa 5-3 | 2 | 144530 | 289060 |
| 165 | pjawa 5-2 | 2 | 144530 | 289060 |
| 166 | pjawa 5-1 | 5 | 144530 | 722650 |
| 167 | pjawa 8-1 | 6 | 144530 | 867180 |
| 168 | pjawa 6-2 | 6 | 144530 | 867180 |
| 169 | pjwa 6-1 | 6 | 144530 | 867180 |
| 171 | pjawa 15 | 4 | 144530 | 578120 |
| 176 | pjawa 1 | 4 | 144530 | 578120 |
| | | 701 | | 94248330 |

## Appendix 3: Outlining Features in Google Earth


Here the Google Earth image has been outlined and is prepared to be exported into ArcMap.