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ENVISIONING GIS BASED INFILTRATION EXCESS OVERLAND FLOW MODELLING

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ABSTRACT

The spatially distributed infiltration modelling serves an efficient method to identify and visualize hazardous impact towards rate of stormwater infiltrated into soil due to rapid population growth, urbanization and industrialization on land cover. The infiltration process occupies the earth surface and dealt with calculation of its infiltrability volume, occurrence of overland flow, channelizing and its area. Implementation of GIS technique may adequate for storing, manipulating and analysing geographical datasets of soil information on a projected coordinate system. Due to impossible of representing

mechanism using GIS based hydrologic modeling by stressing on map projections and grid resolutions are explained in Section 1 and 2. The experiment of determining infiltration and overland flow volume within IEOF boundary are highlighted in Section 3. The outlook of IEOF infiltration and overland flow volume are explained in Section 4 and 5, while the conclusion and further development of IEOF process are stated in Section 6.

2.0 GIS FOR IEOF

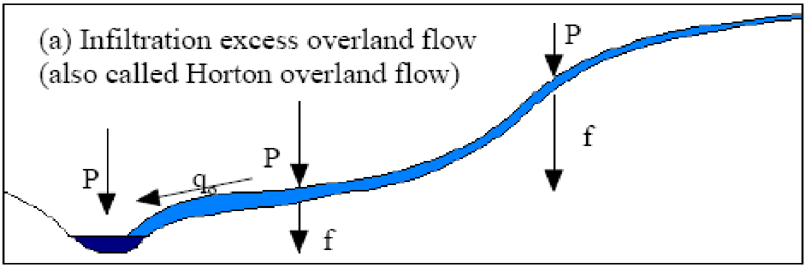
Soils and soil properties are fundamental to the partitioning of water inputs at the earth surface. There is a maximum limiting rate at which a soil in a given condition can absorb surface water input (Horton, 1939). Important factors of infiltrations include soil surface conditions, subsurface conditions, hydrophobicity, flow characteristics of fluid and factors that influence surface and subsurface conditions (Ward and Trimble, 2004). GIS is capable to serve hydrologic modellers to input data and present the output of hydrological process and impacts. GIS has been applied in various water management based application such as rainfall runoff modelling, water quality monitoring, assessing non-point source pollution and urban/rural stormwater management (Wilson *et al.*, 2000).

GIS have embedded new integration techniques to develop and run fully distributed model efficiently. The development of IEOF and NPS models such as *Agricultural Nonpoint Source Pollution Model*

(AGNPS), *Soil and Water Assessment Tool* – SWAT, *Kinematic Runoff and Erosion Model* – KINEROS (Semmens *et al*., 2002), *Storm Water Management Model* (SWMM) and *Long-Term Hydrologic Impact Assessment* – L-THIA successfully implemented GIS techniques in terms of spatial extent. Moreover, GIS has also allowed users to run more traditional lumped models more efficiently and to include at least some level of spatial effects by partitioning entire watersheds into smaller sub-watersheds. For example, HEC-HMS, SWAT and L-THIA have been linked to GIS, incorporates Soil Conservation Service (SCS) techniques to predict surface water flows. Nevertheless, the physical characteristics of map projection that deforms spatial objects are less focused while developing models mentioned above.

2.1 IEOF Mechanism

Freeze and Cherry (1979) stated two conditions must be fulfilled for distribution of IEOF flow; the delivery of surface water input in excess of the hydraulic conductivity on the soil surface and duration of precipitation must be longer than the time required saturating the soil surface. Due to spatial variability of the soil properties affecting infiltration capacity and surface water inputs, IEOF does not necessarily occur over a whole drainage basin during rainfall event (Tarboton, 2003). Moreover, the exception to localized Horton flow in temperate areas occurs on exposed bedrock (Allan and Routlet, 1994), anthropogenic effects such as urban development (Dunne and Leopold, 1978), agriculture (Dingman, 2002) and removal of vegetation due to air pollution. IEOF produced on catchment ridges and extended downslope until the entire catchment generated runoff, low slope angle and high saturated hydraulic conductivity (Bonell and Williams, 1986) as illustrated in Figure 1.



Source : Following Beven, (2000)

Figure 1: Generation of Infiltration Excess Overland Flow mechanism

2.2 Mathematical Horton and Green-Ampt Equation

Horton equation is one of the most widely used infiltration models developed by Robert E. Horton in 1939. MSMA (2000) also suggested the usage of Horton equation in Malaysian urban drainage situations. The method usually gives a good fit to a measured data because it depends on three parameters, but it has no physical significance and field data are required to calibrate the equation. Horton's equation has been implemented widely in watershed models, such as the Storm Water Management Model - SWMM. Ward and Trimble (2004) identified one of the most widely infiltration models used is the three parameter empirical equation developed by Horton (1939) :

$$f = f_c + (f_o - f_c)e^{-\gamma t}$$

(1)

where f is the infiltration rate at time t, f_o is the infiltration rate at time zero, f_c is the final constant infiltration capacity and γ is a best-fit empirical parameter. According to MSMA (2000), recommended value for γ is 4/hour. Total volume of infiltration, F after time t is calculated as :

$$F(t) = f_c + (f_o - f_c / k) (1 - e^{-\gamma t}) \qquad \mathbf{(2)}$$

This equation assumes that the rainfall intensity is greater than the infiltration capacity at all time and infiltration rate decrease with time.

Green and Ampt (1911) developed the Green-Ampt method of determining the amount of precipitation that infiltrates into the soil during a precipitation event. The Green-Ampt infiltration model is a physical model which relates the rate of infiltration to measurable soil properties such as the porosity, hydraulic conductivity and the moisture content of a particular soil based on simplified solutions to the Richards equation. The equation for infiltration under constant rainfall based on Darcy's law and assumes a capillary tube analogy for flow in a porous soil as follows:

$$f = K(H_o + S_w + L)/L \qquad \mathbf{(3)}$$

where K is the hydraulic conductivity of the transmission zone, H_o is the depth of flow ponded at the surface, S_w is the effective suction at the wetting front, and L is the depth from the surface to the wetting front. The method assumes piston flow (water moving down as a front with no mixing) and a distinct wetting front between the infiltration zone and soil at the initial water content. Smemoe (1999) stated basic Green and Ampt equation for calculating soil infiltration rate as follows :

$$f = K_s (1 + [\Psi\theta / F]) \qquad \mathbf{(4)}$$

where Ks is the saturated hydraulic conductivity, Ψ is average capillary suction in the wetted zone, θ is soil moisture deficit (dimensionless), equal to the effective soil porosity times the difference in final and initial volumetric soil saturations and F = depth of rainfall that has infiltrated into the soil since the beginning of rainfall.

Proper information delivery and prediction capabilities of both Horton and Green-Ampt equation would be vital to integrate GIS mapping procedures in terms of map projection and grid resolution to compute amount of infiltrated stormwater rate and overland flow. The capability of GIS techniques to analyze IEOF as its characteristics mentioned by Allan and Routlet (1994), Dunne and Leopold (1978), Dingman (1993) and Bonell (1989) may produce certain features on each layer to perform overlay, buffering, intersect, union and merge analysis to produce a new layer, which is the determined IEOF area.

2.3 Georeference: Map Projection, Scale and Resolution

Projections of a map are crucial for specific applications, such as determining infiltration rate of soils and runoff volume of entire catchments. The generalization process would greatly affect the detail information of catchment area. Topographic map with the small and medium scale (e.g. 1:100 000, 1:50 000) would display low accuracy of land use and soil description such as the impervious area, industrial, commercial, residential area, soil type, soil pervious / imperviousness and soil hydraulic properties such as hydraulic conductivity, soil moisture deficit, capillary suction and soil porosity. Such condition may produce incorrect infiltration rate and runoff volume when IEOF modeling is performed.

Aspects of scales are focused in three ways; (1) extent : the area covered by a map, (2) resolution : commonly used to refer to grid data fixed by pixel size; and (3) operational scale : the distance or area over which a phenomenon operates or varies (Jessen, 2004). Rainfall and soil hydraulic conductivity are heterogeneous over relatively small areas. At this point, measuring infiltration at one point would not be identified at nearby down-slope area. Furthermore, hydrophobic areas on the soil surface may not be continuous and initial runoff generated from these areas may re-infiltrate (Ward and Trimble, 2004).

In Malaysia, there are two types of projections used to display spatial data; the Conformal based Malaysian Rectified Skew Orthomorphic (MRSO) and Equidistant based Cassini-Soldner. Topographic layers are displayed in MRSO projections, while cadastral lot layers are projected in Cassini-Soldner. The Malayan Revised Triangulation (MRT) is the coordinate system used for mapping Peninsular Malaysia based on the old Repsold Triangulation datum and computed using data collected mainly in the period 1948 to 1966 using the Modified Everest ellipsoid. Coordinates in this system are known as MRT48 coordinates which represent a unified datum and albeit distorted (Kadir *et al.,* 2003). The Mercator projection is one of the most common cylindrical projections, and the equator is usually its line of tangency (Wan Abdul Aziz *et al.,* 2000). The physical characteristics of MRSO and Cassini-Soldner are explained in Table 1.

Table 1: Description and major properties of current map projections in Malaysia

Projection	Spatial Features
Malaysian Rectified Skew Orthomorphic Origin : Kertau, Pahang (804671.29977,0.000)	**Shape** Conformal. Local shapes are true. **Area** Increases with distance from the center line. **Direction** Local angles are correct. **Distance** True along the chosen central line.
Cassini-Soldner Origin : Fort Cornwallis, Penang (0.000, 0.0(	**Shape** Shape along the standard parallels is accurate and minimally distorted in the region between the standard parallels and those regions just beyond. The 90 degree angles between meridians and parallels are preserved, but because the scale along the lines of longitude does not match the scale along the lines of latitude, the final projection is not conformal. **Area** All areas are proportional to the same areas on **Direction** Locally true along the standard parallels. **Distance** Distances are best in the middle latitudes. Along parallels, scale is reduced between the standard parallels and increased beyond them. Along meridians, scale follows an opposite pattern.

Source : Wan Abdul Aziz et al, (2000) and Kadir et al., (2003)

2.4 Transformation between RSO and Cassini projections

The RSO is an oblique Mercator projection. This projection is orthomorphic (conformal) and cylindrical. All meridians and parallel are complex curves. The RSO provide an optimum solution in the sense of minimizing distortion whilst remaining conformal for Malaysia (Kadir *et al.,* 2003). Cassini projection system for the Peninsular is based on several local datums and realized by their published equations and coordinate of their respective State origin. The existing Cassini projection for cadastral mapping is based on the MRT system referenced to the Modified Everest ellipsoid. It is useful for mapping areas with limited longitudinal extent. it has a straight central meridian along which the scale is true, all other meridians and parallels are curved, and the scale distortion increases rapidly with increasing distance from the central meridian.

Transformation of coordinate system between RSO and Cassini are done in two methods; the general way or the polynomial equation. General transformation is done by changing a coordinate in its existing projection to the geographical coordinates as in (5); and recomputes them to the coordinate grid into the targeted map projection.

$$(X,Y) \dashrightarrow (Q,L)P \dashrightarrow (x,y)p \quad (5)$$

The polynomial solution is used when the numbers of coordinate points are high. In this method, a relationship is established as follows :

$$X = C_1 + x.C_2 + y.C_3 + xy.C_4 + x^2.C_5 + y^2.C_6 + ... \quad (6)$$

$$Y = D_1 + x.D_2 + y.D_3 + xy.D_4 + x^2.D_5 + y^2.D_6 + ... \quad (7)$$

where x,y is the coordinates in the existing map projection; X,Y is the coordinates in the targeted map projection and C_i,D_i is the parameters of the transformation of the projections. Transformation of RSO into Cassini coordinate system is done by using the equation in (8) and (9). The reverse process of coordinate system transformation from Cassini to RSO is performed using the equation in (10) and (11).

$$N_{cs} = N_0cs + X - (R_1 + xA_1 + yA_2 + xyA_3 + x^2A_4 + y^2A_5) \quad (8)$$

$$E_{cs} = E_0cs + Y - (R_2 + xB_1 + yB_2 + xyB_3 + x^2B_4 + y^2B_5) \quad (9)$$

where X = N_{rso} - N_{0rso}; Y = E_{rso} - E_{0rso}; x = X/10000, y = Y/10000; N_{rso}, E_{rso} is state coordinate in RSO; N_{0rso}, $E_{0rso}$is the state origin coordinate in RSO; $N_o$cs, E_0cs is state origin coordinate in Cassini; R_i, A_i, B_i where i = 1,2,..5 are the transformation parameters.

$$N_{RSO} = N_0RSO + X + R_1 + xA_1 + yA_2 + xyA_3 + x^2A_4 + y^2A_5 \quad (10)$$

$$E_{RSO} = E_0RSO + Y + R_2 + xB_1 + yB_2 + xyB_3 + x^2B_4 + y^2B_5 \quad (11)$$

where X = N_{cs} - N_{0cs}; Y = E_{cs} - E_{0cs} ; x = X/10000, y = Y/10000; N_{cs}, E_{cs} is state coordinate in Cassini; N_{0cs}, $E_{0cs}$is the state origin coordinate in Cassini; N_oRSO, E_0RSO is state origin coordinate in RSO; R_i, A_i, B_i where i = 1,2,..5 are the transformation parameters.

The IEOF process depends significantly with soil properties and land use. Performing transformation between MRSO and Cassini-Soldner projection by using equation (8), (9), (10) and (11) causes distortion on the shape, areas, distance and direction of the original position (Wan Abdul Aziz *et al.*, 1998) of each soil and land use properties. The MRSO projection is characterized as conformal based system, where shape of each feature in the map are preserved, but other physical parts such as area, distance and direction are distorted. The Cassini-Soldner projection is equidistance based system, where distance between each features on the map are maintained, while the shape, area and angle of those features are distorted.

3.0 THE IEOF EXPERIMENT

3.1 Study Area

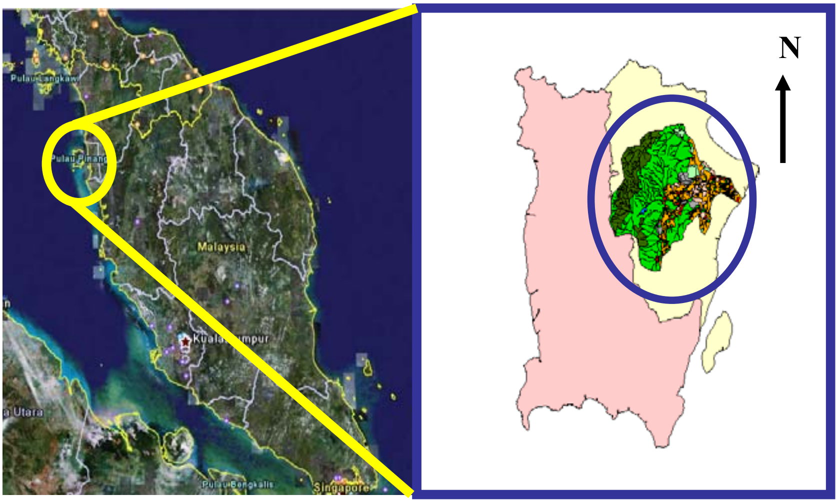
The Pinang River basin is located between Latitude from 5° 21’ 32” to 5° 26’ 48” and Longitude from 100° 14’ 26” to 100° 19’ 42”. Pinang River is the main river system in the Penang Island with the catchment size approximated 52 km^2, as illustrated in Figure 2. Pinang River basin has been selected to determine area and volume of IEOF process due to continuity of development that had affected the physical characteristics of land use and soils; degrading and increase the water quality and water quantity respectively of the entire basin (Mohamad Zaki Abdullah, 1999; WQI Report, 2006). Moreover, flash flood and water pollution are the main problems occurred in highly urbanized area such as Georgetown, Jelutong and Air Hitam (WQI Report, 2006). The hill terrains, which are mainly located in the central and northern part of the Island are generally rugged and steep with an average slope of more than 30 percents. The low or flat alluvial lands basically occupy the coastal side of the island. The elevations of these floodplains merely exceed than elevation of more than few meters while many areas near the estuary of Sg. Pinang are just 1 meter above the sea level.

In this study, the procedure for linking GIS and infiltration model parameter components results involves the following steps: (1)

acquisition and development of GIS map data layers of Sungai Pinang basin; (2) preprocessing of model input data and parameters and computation of Horton and Green-Ampt model results and (3) postprocessing of all infiltration components results to the GIS for spatial display and analysis of IEOF area, volume of infiltrated stormwater and overland flow. The Horton and Green-Ampt model parameters are linked into PC-based GIS package called ArcView GIS to storing, analyzing and displaying GIS based IEOF hydrologic modeling results.

Digital topography maps with 1 : 25 000 scale are used to extract layers of Buildings, Contours, Road network and River network. The latest landuse maps are obtained from Department of Agricultural. Soil map, published in the year 1968 is obtained to evaluate the soil condition at the place of interests. In this study, the rainfall data on 18th of June, 2006 with duration of 70 minutes is used to determine infiltration rate and overland flow generated from IEOF using both Horton and Green-Ampt equation. Grid data layers of 20 meter and 5 meter resolution are obtained through conversion of vector data using Spatial Analyst extension within ArcView GIS 3.3 software. Further derivation of Rainfall data and slope for entire basin is obtained through interpolation process. Topographic information such as slope, aspect, flow length, contributing area, drainage divides and channel network can be reliably extracted from Digital Elevation Model (DEMs). DEM is a digital representation of the elevation of a land surface. Square-grid DEMs are used in the hydrologic modelling because of their simplicity, processing ease and computational efficiency.

(a)



(b)

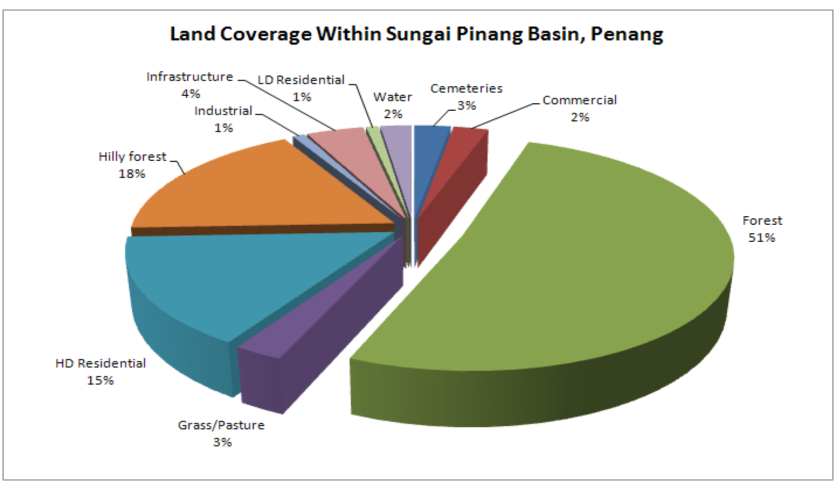


Figure 2: Location of Sungai Pinang Basin (a) and its landuse for 2006 (b)

3.2 Determining potential area of IEOF using Conformal RSO and Equidistant Cassini-Soldner Projection

In order to obtain potential IEOF areas, each vector data layers are converted into raster based layers with resolution of 20 meter and 5 meter grid cell respectively within RSO and Cassini projections. Analysis is performed into two phases. The first phase is to model spatial data layers by overlaying raster layers of Precipitation, Landuse, Slope, Soils, Buildings and Road network based on criteria mentioned by Freeze (1980), Dunne (1978), Dingman (1993) and Bonell (1989) to map potential IEOF area. The second phase is to intersect mentioned raster layers to map potential location of IEOF and its area. Schematic diagram for determining IEOF area is illustrated in Figure 3.

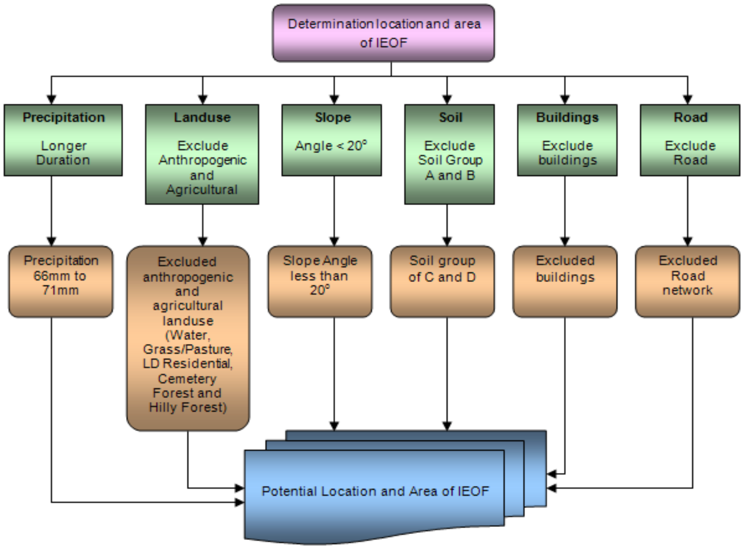


Figure 3: Schematic diagram for determining IEOF area

3.3 Computation of Infiltration and Overland Flow volume within IEOF area

The parameter required for Horton equation; the final constant infiltration capacity (f_c), infiltration rate at time 0 (f_o) and best fit empirical parameter (γ) are obtained through experiment conducted at six different locations. The calculated Horton parameters are than interpolated covering Sungai Pinang basin and assigned to both 20 meter and 5 meter grid cell lying on RSO and Cassini map projection. To determine soil infiltration rate using Green-Ampt equations, the parameter of soil hydraulic conductivity (K_s), soil percent impervious (R_s), percent effective soil area (*Eff*), the initial abstraction (I_a), land percent impervious (R_l), percent vegetation (*Veg*) and the degree of saturation (dry, normal or saturated) are obtained through ground observation and assigned to each grid cell (Smemoe, 1999). Calculations of soil infiltration rate are performed by referring to equation (2) for empirical based Horton method and (4) for physical based Green-Ampt method. Total of overland flow within IEOF areas are computed by subtracting rainfall volume with the infiltrated rainfall volume using the rainfall data recorded on 18th of June, 2006 with duration of 60 minutes for each grid cell.

4.0 POTENTIAL IEOF AREAS

The experiment on determining IEOF areas are illustrated from Figure 4 to 7. Layers of Slope, Precipitation, Soil type and Landuse are intersected together to map the potential areas of IEOF area. The IEOF area (shaded with white); are illustrated in Figure 8 based on 18th of June 2006 precipitation data.

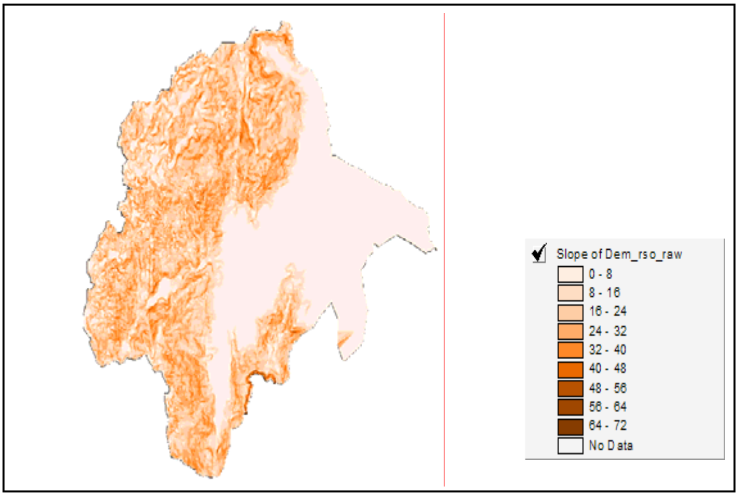


Figure 4: Slope coverage in Sungai Pinang basin

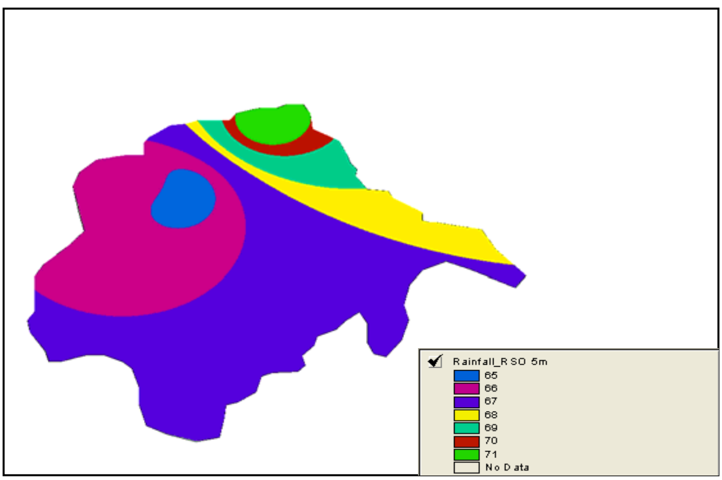


Figure 5: Rainfall Depth coverage in Sungai Pinang basin

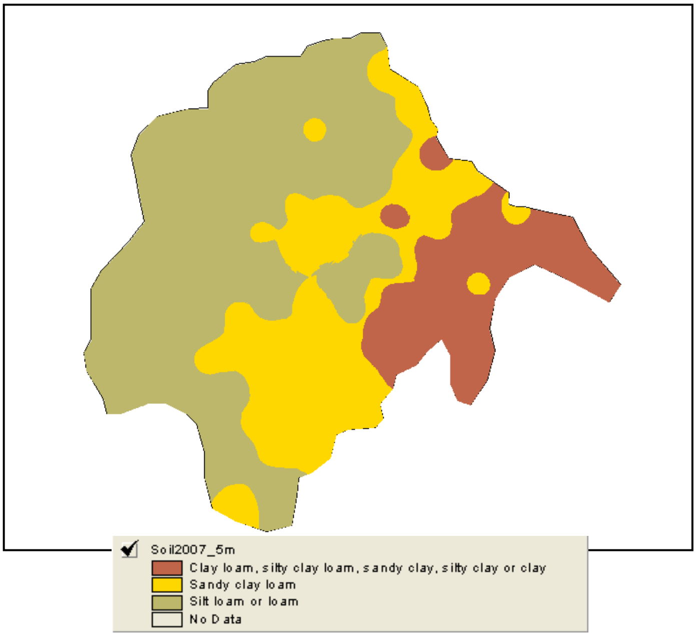


Figure 6: Soil type in Sungai Pinang basin

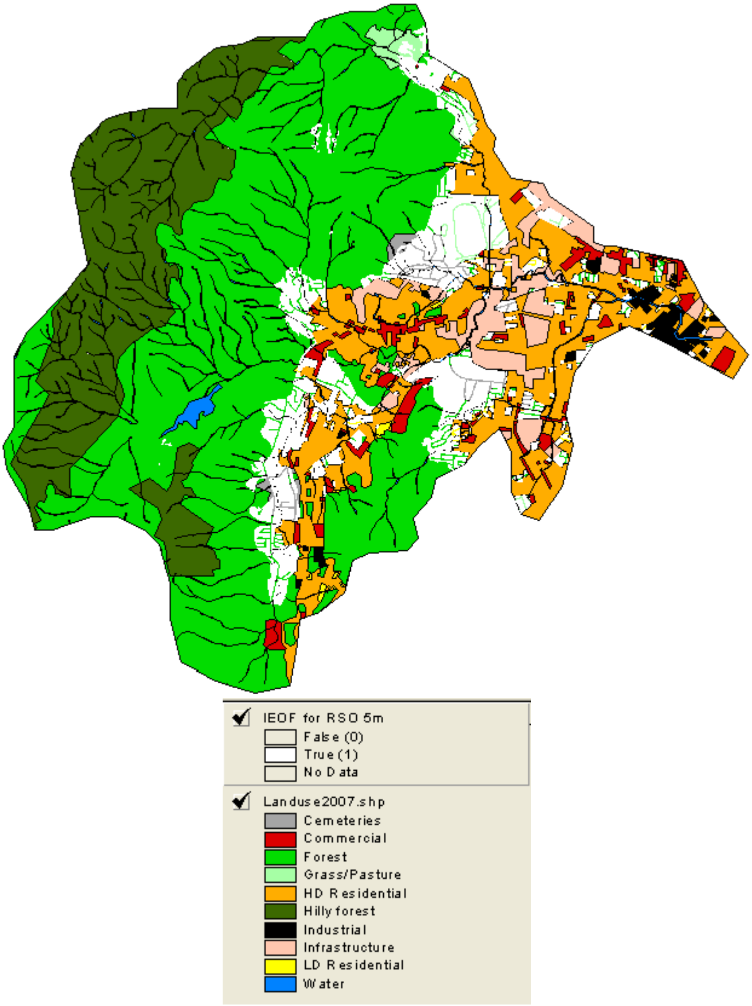


Figure 7: Potential area of IEOF within Sungai Pinang basin based on 18th of June 2006 precipitation data

Approximately total of 5.2 km^2 IEOF area is identified. Most of the IEOF coverage in Figure 6 lies in areas of Paya Terubong, Air Hitam, Sungai Air Terjun, Kebun Bunga, Green Lane and partly in Gelugur and Jelutong. The differential amount of calculated IEOF area using 20 meter and 5 meter grid size under RSO and Cassini map projections are summarised in Table 3. The location of IEOF lies on the sub humid to arid regions, which are the major controls on the various runoff processes based on climate data, landuse, soil topography and rainfall characteristics as stated by (Tarboton, 2003). Constructions of apartments and flats in Paya Terubong and Air Hitam area, Jelutong Coastal Expressway and shop lots increases the land cover with impervious areas; which is the main factor decreasing pervious area and contributes to large direct runoff volumes. Moreover, existing river networks and drainage system of Sungai Pinang basin dealt with degration and stress of water quality and NPS pollutant load (WQI Report, 2006). These have made the existing rivers and drainage systems lack of capability to shift overland flow volumes from highly urbanized areas.

5.0 INFILTRATION AND OVERLAND FLOW VOLUME

Approximately 355,000 m^3 of rainfall volume were recorded within the IEOF boundaries. The estimated volume of rainfall infiltrated into soil using Horton equation is 150,000 m^3, while the Green-Ampt equation estimates 129,700 m^3 of rainfall volume infiltrated into soil. Total of Overland Flow generated from IEOF is 204,200 m^3 based on Horton equation, while Green-Ampt equation estimation is 223,700 m^3. The results obtained are depicted from Figure 8 to 11. Full summary analysed of IEOF area, infiltration volume and overland flow volume based on two different infiltration equations, grid resolution and map projections are illustrated in Table 2.

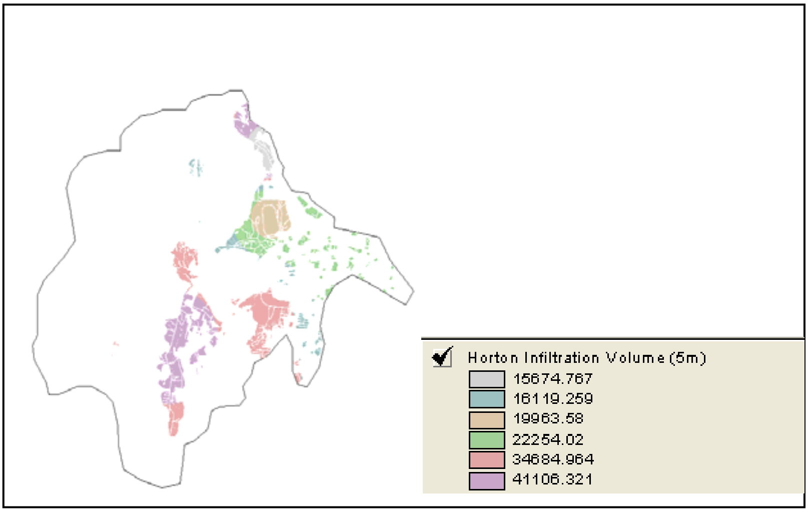


Figure 8: Infiltration Volume based on Horton equation within IEOF area

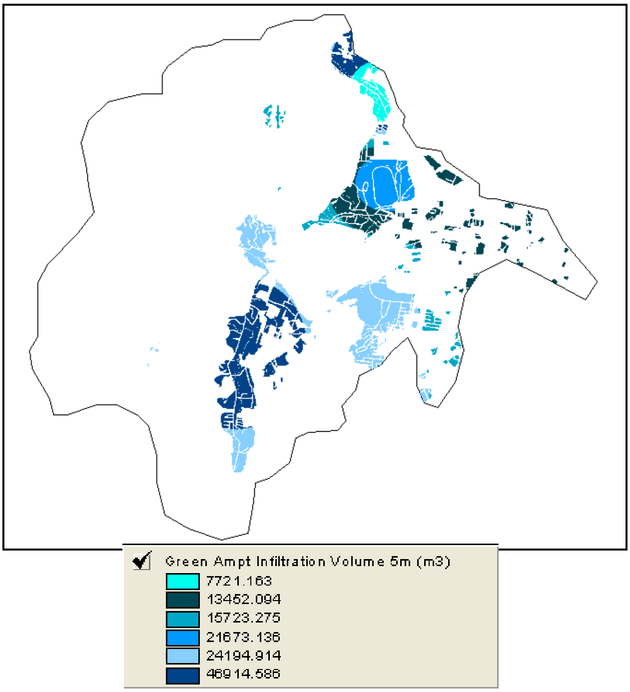


Figure 9: Infiltration Volume based on Green-Ampt equation within IEOF area

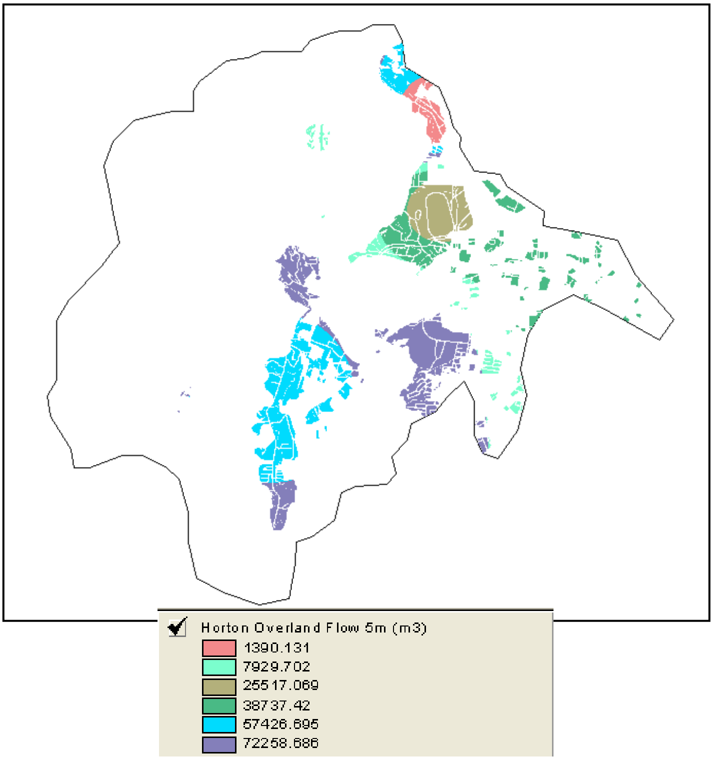


Figure 10: Amount of Overland Flow generated from IEOF area using Horton equation based on 18th of June 2006 precipitation data

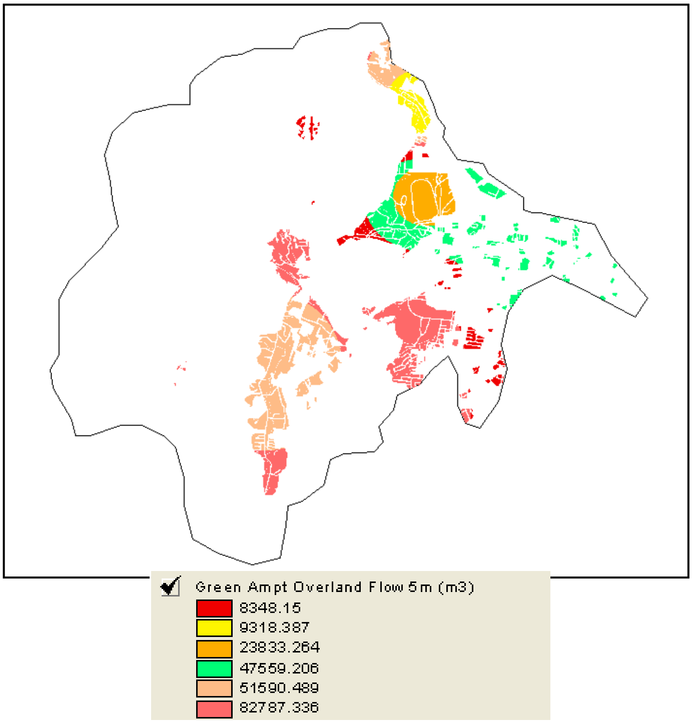


Figure 11: Amount of Overland Flow generated from IEOF area using Green-Ampt equation based on 18th of June 2006 precipitation data

Figure 12 indicates large overland flow is recorded in areas of Georgetown, Jelutong and Air Itam. Constructions of apartments, flats, Jelutong Coastal Expressway and shop lots increase the land cover with impervious areas; which is the main factor contributing to flood risk area. Existing river networks and drainage system of Pinang River basin dealt with degration and stress of water quality and NPS pollutant load. These have made the existing rivers and drainage systems lack of capability to shift runoff volumes from highly urbanized areas. The areas shaded with yellow are prompt to flood risk area.

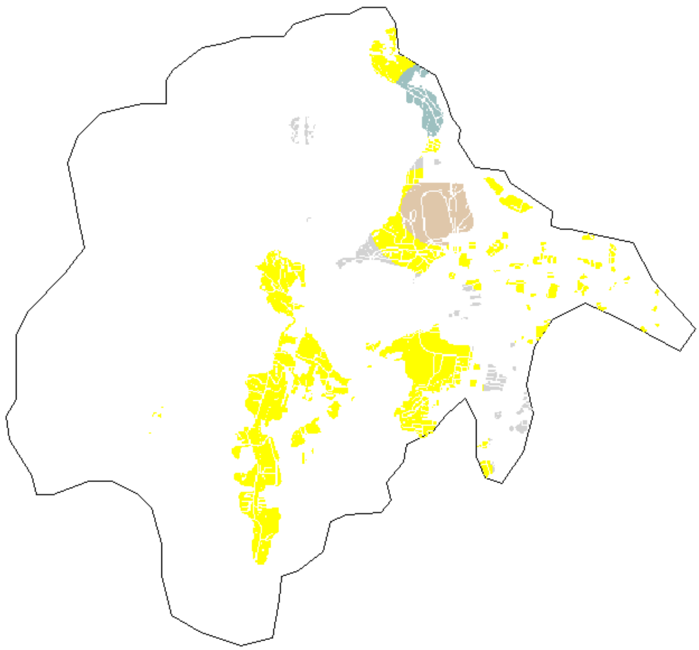


Figure 12: Potential of high overland flow generated and prompt to flood risk area

Table 2: Summary of identified IEOF area, precipitation volume, infiltration volume and overland flow volume using Horton and Green-Ampt equation under RSO and Cassini projection with 20 meter and 5 meter grid cell resolution

Analysis and Results	Raster based	
	20 meter	5 meter
1. Total area of IEOF under RSO Projection (m^2)	**5238000.0000**	**5253950.0000**
Total area of IEOF under Cassini Projection (m^2)	**5265600.0000**	**5255650.0000**
Different (20 meter and 5 meter RSO Projection) (m^2)	± 15950.0000	
Different (20 meter and 5 meter Cassini Projection) (m^2)	± 9950.0000	
Different (20 meter RSO and Cassini Projection) (m^2)	± 27600.0000	
Different (5 meter RSO and Cassini Projection) (m^2)	± 1700.0000	
Different (20 meter RSO and 5 meter Cassini Projection) (m^2)	± 17650.0000	
Different (5 meter RSO and 20 meter Cassini Projection) (m^2)	± 11650.0000	
2. Total Precipitation Volume for RSO projection within IEOF area (m^3)	**352849.60000**	**353944.17500**
Total Precipitation Volume for Cassini projection within IEOF area (m^3)	**355180.80000**	**354057.92500**
Different (20 meter and 5 meter RSO Projection) (m^3)	± 10945.5750	
Different (20 meter and 5 meter Cassini Projection) (m^3)	± 1122.8750	
Different (20 meter RSO and Cassini Projection) (m^3)	± 2331.2000	
Different (5 meter RSO and Cassini Projection) (m^3)	± 113.7500	
Different (20 meter RSO and 5 meter Cassini Projection) (m^3)	± 1208.3250	
Different (5 meter RSO and 20 meter Cassini Projection)	± 1236.6250	
3. Total Infiltration Volume (Horton Equation under RSO Projection), (m^3)	**150054.4765**	**149856.2978**
Total Infiltration Volume (Horton Equation under Cassini Projection),	**150648.3863**	**149802.9101**

(m^3)		
Different (20 meter and 5 meter RSO Projection) (m^3)	± 198.1787	
Different (20 meter and 5 meter Cassini Projection) (m^3)	± 845.4762	
Different (20 meter RSO and Cassini Projection) (m^3)	± 593.9098	
Different (5 meter RSO and Cassini Projection) (m^3)	± 53.3877	
Different (20 meter RSO and 5 meter Cassini Projection) (m^3)	± 251.5664	
Different (5 meter RSO and 20 meter Cassini Projection) (m^3)	± 792.0885	
4. Total Infiltration Volume (Green-Ampt Equation under RSO Projection), (m^3)	**129830.9597**	**129679.1689**
Total Infiltration Volume (Green-Ampt Equation under Cassini Projection), (m^3)	**129923.2375**	**129663.2530**
Different (20 meter and 5 meter RSO Projection) (m^3)	± 151.7908	
Different (20 meter and 5 meter Cassini Projection) (m^3)	± 259.9845	
Different (20 meter RSO and Cassini Projection) (m^3)	± 92.2778	
Different (5 meter RSO and Cassini Projection) (m^3)	± 15.9159	
Different (20 meter RSO and 5 meter Cassini Projection) (m^3)	± 167.7067	
Different (5 meter RSO and 20 meter Cassini Projection) (m^3)	± 244.0686	
5. Total Overland Flow (Horton Equation under RSO Projection), (m^3)	**203757.5235**	**203259.7022**
Total Overland Flow (Horton Equation under Cassini Projection), (m^3)	**204530.8137**	**204498.8899**
Different (20 meter and 5 meter RSO Projection) (m^3)	± 497.8213	
Different (20 meter and 5 meter Cassini Projection) (m^3)	± 31.9238	
Different (20 meter RSO and Cassini Projection) (m^3)	± 773.2902	
Different (5 meter RSO and Cassini Projection) (m^3)	± 1239.1877	
Different (20 meter RSO and 5 meter Cassini Projection) (m^3)	± 741.3664	

Different (5 meter RSO and 20 meter Cassini Projection) (m^3)	± 1271.1115	
6. Total Overland Flow, (Green-Ampt Equation under RSO Projection), (m^3)	**223981.0403**	**223436.8311**
Total Overland Flow (Green-Ampt Equation under Cassini Projection), (m^3)	**224414.3625**	**223391.4970**
Different (20 meter and 5 meter RSO Projection) (m^3)	± 544.2092	
Different (20 meter and 5 meter Cassini Projection) (m^3)	± 1022.8665	
Different (20 meter RSO and Cassini Projection) (m^3)	± 433.3222	
Different (5 meter RSO and Cassini Projection) (m^3)	± 45.3341	
Different (20 meter RSO and 5 meter Cassini Projection) (m^3)	± 589.5433	
Different (5 meter RSO and 20 meter Cassini Projection) (m^3)	± 977.5314	

5.1 Discussion

Results show that there are changes on the calculations of potential IEOF area, precipitation volume, infiltration and overland flow volume. Selection of different cell size and map projection differs the IEOF area, as well as different infiltration equation (Horton and Green-Ampt) results slightly different infiltration volume and overland flow. The alternation of basin shape, size and distance would greatly affect the physical condition and calculations for total infiltrated precipitation onto ground surface, groundwater storage, change of physical soil parameters (soil porosity, conductivity, path of subsurface flow, return flow) with different soil types and amount of direct runoff generated in the study area. Developers, local authority and private sectors need to plan a careful monitoring of datasets accuracy for any construction purposes in site-specific area. The analysis conducted however does not account the water balance equation such as evapotranspiration losses, percolation, return flow, groundwater flow, shallow and subsurface flow. The spatial analysis performed on the grid layer may cause significant effect towards area calculation. Therefore, great care should be taken when selecting a resolution (cell size) for raster structures, in particular when physical properties of linear and areal features, such as stream networks, boundaries or subcatchment areas are being extracted (Garbrecht *et al.,* 2001).

6.0 CONCLUDING REMARKS

This study presents GIS based IEOF data modeling for estimating the potential locations of IEOF area, infiltration volume and overland flow volume based on empirical Horton equation and physically based Green-Ampt equation. A longer duration of precipitation would result significant changes of infiltration and overland flow volume under different map projections. The spatial layers of soils, land use, precipitation and the runoff coefficient are all important sub-basin parameters, but the soil hydraulic properties and runoff coefficient is, by far, the most difficult parameter to determine. It is also an extremely sensitive parameter, where a low runoff coefficient will underestimate the amount of sub-basin runoff while a high runoff coefficient will overestimate the amount of sub-basin runoff. Therefore, it is extremely important to accurately estimate sub-basin runoff coefficients using the best data and most advanced computation methods available.

GIS has proven the capability to model, analyse and integrate geographical and hydrological data of IEOF. The cartographic aspects are also highlighted in terms of selecting appropriate map projections for displaying IEOF data modeling results. A thorough understanding need to be addressed in terms of physical geographic in hydrological process, determining the GIS properties such as map projections, scale and coordinate systems before any runoff modelling and data processing can be performed. A map can be drawn at any scale, but it is unclear to what extent existing hydrologic models can be applied at different map projections and scales in the mean of using GIS. Understanding of IEOF process is crucial to compute runoff volume. The presence of overland flow is due to soil absorption and compaction is maximised and saturated. Land use, soil and precipitation data are the main inputs towards producing IEOF area mapping and overland flow volume computed by performing GIS spatial analysis.

Modellers need to specify the importance of considering map distance, size and shape of basin. To obtain much more accurate computation of IEOF areas, infiltration and overland flow volumes, further investigations needed for possible new criteria by examining daily rainfall data for numerous location and conducting validation using combinations of GIS and hydrologic algorithms. Although the method involves some identifiable sources of uncertainty, the results nevertheless provide an initial indication of the importance of considering map projections, scales and grid resolutions for an actual use of GIS application over a region.

The results obtained would benefits the relevant agencies such as Department of Irrigation and Drainage (DID), Department of Environmental (DOE), Department of Town Planning (DOTP) and Department of Minerals and Geosciences (DMG) to determine flood risk zones, areas of prompt to produce large direct runoff volumes, careful monitoring of NPS runoff pollutant loading, proper development plan and constructions, monitoring water quantity and quality of river networks for analysing long-term hydrological impact towards land use and soils.

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