Characteristics of Stormwater Runoff in Different Land Use Areas

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Abstract—**Research covered in this paper has outlined the basis for a detailed study into the specific effects of land use on storm water runoff and drainage. It can be seen that the runoff is highly variable although still follows some basic trends with one of these being heavily based on land use. This study used different land use areas including residential, commercial, industrial and agricultural areas. Results show the temporal change of rainfall versus overland flow for each land use type. In addition the results concluded the rainfall – runoff relationship for each land use areas. It is obvious from the research carried out here that there are also a lot more factors that affect the runoff quantity and characteristics.**

Keywords-land use, stormwater, runoff, rainfall

I. INTRODUCTION

During rainfall periods there can be a considerable amount of stormwater that does not infiltrate into the ground surface and most of this will become the excess overland flow or direct surface runoff. When analyzing the quantity and temporal variations of this flow there are many contributing factors; these include geology of the land, topography, geography, rainfall intensity and pattern and the land use type [1]. This study aims to examine the variations in surface runoff for different land use types, the two main characteristics that will be looked into are the quantity of runoff and how this quantity varies with time during a rainfall. The study is to be focused on land uses around the Perth area, Western Australia, specifically Victoria Park and surrounding suburbs. This study used runoff coefficients for the different land use categories as the main tool based on runoff quantity data collected and also to assess the temporal variations in this runoff with respect to the rainfall pattern. With this information it should then be possible to form relationships between the direct surface runoff volumes and characteristics and the land use category.

The land use of a catchment area also plays a role in the runoff process although the effects due to land use are not as easy to predict as other factors may be [2]. Land use types can dictate or correlate to many other factors such as ground cover, soil type, topography and even rainfall patterns when looking at a much larger scale. Several researchers have shown that there are strong relationships between the land use of a particular site and the runoff volume and characteristics [3]. Within Perth the land uses typically vary from suburb to suburb although over a long period of time it can be considered that rainfall patterns are fairly common over the entire Perth area although there are differences in the topography and geology of the area although as mentioned these are typically common for a specified land use

II. METHODOLOGY

The overall method for this research was done through field tests alone. This was done by assessing areas for suitability of research and then once a storm front past over the site this storm event was measured with respect to rainfall quantity and time variation. The sump location was then also tested by way of quantity measurements at the outlet of the watershed drainage network and the flow rates were measured at specified increments of time (typically 5~10 minutes apart) such that time variation of the runoff quantity could also be investigated. For the measurements of the rainfall volumes a RG3-M Data Logging Rain Gauge was used, this device was able to record precipitation values at 0.2mm increments and would log each increment along with the time. The values obtained were then to be converted into rainfall intensities with a resolution of 10 minutes and expressed as millimeters of rainfall per hour.

Two measuring devices were to be used to measure the flow at the point where the runoff from the catchment area was discharged into a compensation basin, these devices were the STARFLOW meter and a FP101 Global Flow Probe. The way the tests were carried out meant that the measurements were taken from the pipes and this made it difficult to use the STARFLOW meter and for due to limitations of the device and for these reasons the STARFLOW meter was not used for any of the final results. The FP101 Global Flow Probe was used at most of the sites although this also had limitations on its usefulness. In some cases the flow was low enough that the flow probe could not accurately give a steady flow value as the water would not have enough depth to completely submerge the measuring propeller. For this reason the flow meter was only used where the flow depth was greater than 4 or 5cm depending on the pipe diameter. Where the flow meter was used a flow area had to also be calculated, for this the pipe diameter was measured and by way of geometry the flow area was multiplied with the average flow speed to give a total flow rate at that specific point in time. An accurate flow speed was obtained by ensuring the entire cross section of flow was measured before taking the reading from the flow probe to the negate effects of the velocity profile that exists in open channels and partially filled pipe flow. The flow probe was also set to read average speed values in feet-per-second rather than meters-per-second and these were then converted using the appropriate factor. Due to the resolution of the flow meter it was seen as beneficial to the accuracy that feet-per-second having more increments would be better. These results were taken at roughly 5 minute intervals where possible.

A. *Selected Catchment Areas*

A schematic drainage layout map provided by the Town of Victoria Park was used which had illustrated the locations of each gully drain and associated pipe network layout. Using this map to locate the influencing areas along with an interactive contour map the watershed boundaries could be found for each catchment area; this will give the total area for rainfall volume calculations and can also be used to determine the land use sub areas located over the catchment. The rainfall was measured and recorded at the site of interest and this can then be converted into a total volume of precipitation using the catchment area. The field tests were carried out on several sites within the Town of Victoria Park locality, these ranged from Welshpool in the east of the Town of Victoria Park boundary through to East Victoria Park located towards the west boundary. Agricultural land use tests were also carried out and for this to yield reasonable results a site located in the Swan Valley was selected.

Table 1 shows the catchments selected to represent each land use types. The Planet Street compensation basin is used as an industrial area with many large factories and warehouses, and storage facilities. Raleigh Street compensation basin and the Canterbury Terrace drainage system are selected to represent residential catchment. The Albany Highway drainage area has selected to represent commercial use. This commercial region is mainly made up of the driveway and car park servicing the buildings. The Bishopsgate drainage catchment mainly contains parks and recreational lands. The Herne Hill site was specifically selected to assess the agricultural land use effects. This site was located in the south west corner of Herne Hill. There was no catchment sump in close proximity to the site and as the drainage was not pipe flow but rather open channel flow. Therefore the flow was measured in the channel at the runoff point so that infiltration along the open channel would not affect the measurements taken.

TABLE I. LAND USE CLASSIFICATION SUMMARY

Land Use	Catchment
Industrial	Planet Street Catchment
Residential	Raleigh Street Drainage and Canterbury Terrace Drainage
Commercial	Albany Highway Drainage
Parks and Recreation	Bishopsgate Street Drainage
Agricultural	Herne Hill catchment

III. RESULTS AND DISCUSSIONS

All observed rainfall and runoff values for each catchment were utilized to develop temporal variation of rainfall and runoff and rainfall runoff relationships for the catchments. These relationships were further analyzed to obtain variations and similarities among different land use types.

A. *Runoff Coefficients*

The runoff coefficients could be calculated for the storm event measured by taking into account the total rainfall and total catchment area. These results are site and storm specific and would vary from guidelines given elsewhere as design runoff coefficients are based on specific design intensity and duration storm events.

The runoff coefficients do follow a trend with the exception of a couple. The commercial land use gave, as expected, higher values of runoff with the intensive commercial land use giving 0.8 due to the relatively large areas of sealed ground surfaces and buildings. Residential lands yielded a runoff coefficient of 0.36 and 0.48 with this lower value being due to the increasing areas of soils with higher infiltration capacities such as front gardens and lawns. Park and recreation land use gave a lower value of 0.15 as the catchment area had most of the catchment area made up of grassed parks and sporting fields which having the capacity to infiltrate larger volumes of rainfall but excess overland flow experiences any considerable amount. The agricultural land use gave a relatively high value at 0.56 although this can be attributed to by many factors, for example the initial soil moisture condition may be already saturated due to irrigation networks. Also the site is located on the base of Red Hill leading to the potential of high volumes of base flow which could resurface at the saturated runoff point. The agricultural land was also very flat with a considerable slope meaning rainfall was able to drain off relatively quick and therefore a higher than average runoff coefficient should be expected from sites of this nature.

TABLE II. RUNOFF COEFFICIENT SUMMARY

Land Use	Site	Runoff Coefficient (C)
Industrial	Planet Street Catchment	0.32
Residential	Raleigh Street Drainage	0.36
	Canterbury Terrace Drainage	0.48
Commercial	Albany Highway Drainage	0.80
Parks and Recreation	Bishopsgate Street Drainage	0.15
Agricultural	Herne Hill catchment	0.56

B. Time Variations in Rainfall vs. Runoff

The hydrograph at each particular site can be used to assess how the runoff flow rate varies with time and storm intensity, using this graph lag times can be calculated to determine the length of time between the peak of the rainfall and the peak of the runoff flow rate. Considering the Planet Street compensation basin and its industrial land use catchment area the site had distinct patterns between rainfall and runoff. As shown in Figure 1 the lag time for the first storm front was 10 minutes meaning that the peak runoff flow rate occurred 10 minutes after the peak storm intensity. For the second storm front the lag time was reduced to 5 minutes. This occurs as the initial losses have already been filled meaning the water will immediately enter the drainage system and begin to flow downstream.

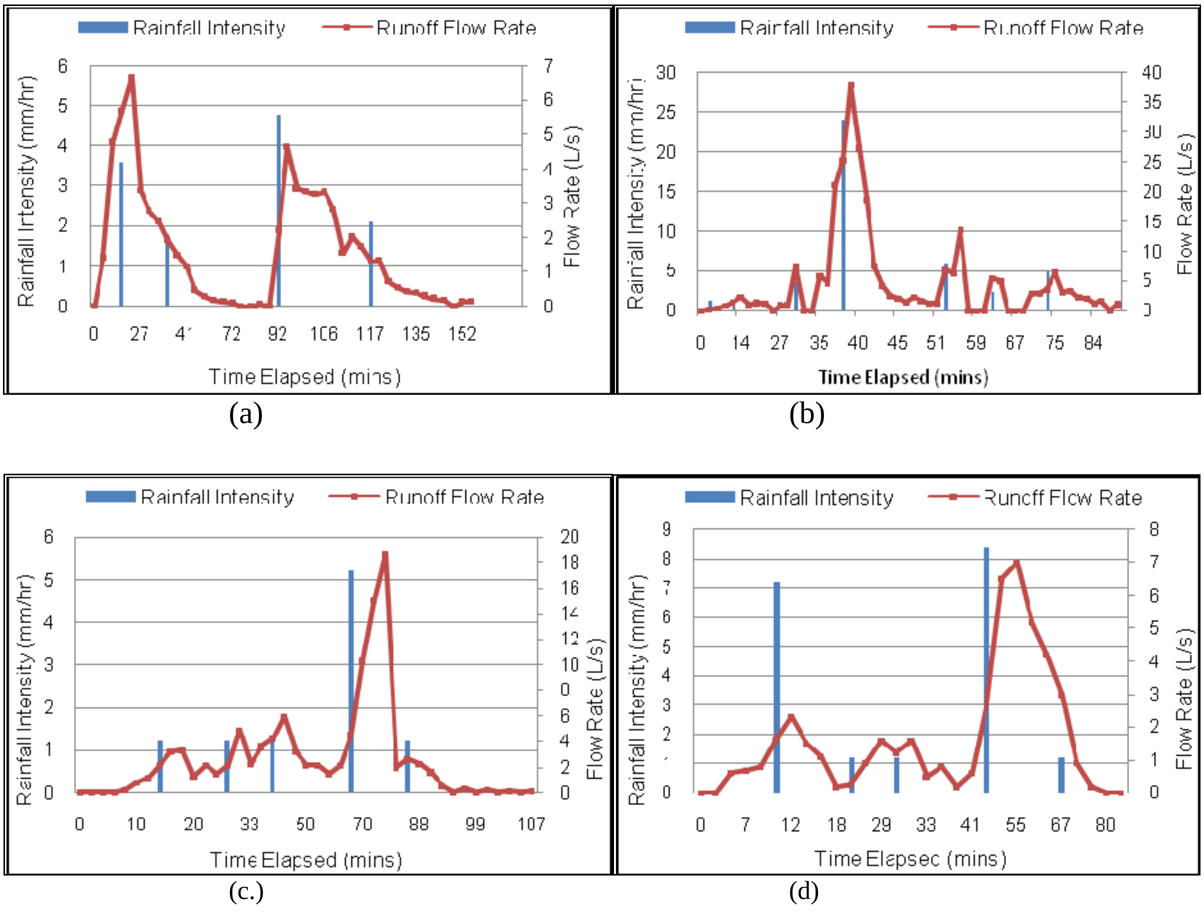

Fig 1: temporal Variation of rainfall versus runoff in (a) residential lands, (b) commercial lands, (c) Agricultural lands and (d) industrial lands

The agricultural land use site did not give a significant and distinct peak in the runoff values, rather the runoff increased steadily until a certain point and then it decreased and with further long showery periods the runoff picked up again. The agricultural land is specifically adapted by land owners to retain storm water in order to grow vegetation and due to the natural surface this land has a high loss coefficient with high depression storage and infiltration values. The time lag for this site being very long in duration and with a relatively smoother formed peak will be a typical feature of agricultural land as most of the time this drainage from the site is not well developed or is specifically designed to retain water on site to promote vegetation growth.

IV. CONCLUSION AND RECOMMENDATIONS

The research covered in this paper has outlined the basis for a detailed study into the specific effects of land use on storm water runoff and drainage. It can be seen that the runoff is highly variable although still follows some basic trends with one of these being heavily based on land use. This study used different land use areas including residential, commercial, industrial and agricultural areas. Results show the temporal change of rainfall versus overland flow for each land use type. In addition the results concluded the rainfall – runoff relationship for each land use areas. The results of this study will assist decision makers to come up with decision of where land use is changed the adequacy of the existing drainage system shall be checked and where not appropriate must be redesigned. One way to make this task easier and simpler would be to form guidelines on how land use change will affect the existing storm water and general drainage system.

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