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RESEARCH ARTICLE

INFLUENCE OF LAND USE CHANGE ON FLOODING IN THE WILD CAT CREEK WATERSHED

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ABSTRACT

City Expansion due to human migration for better civic amenities changing original land use posing flood risk in the cities located near river. Present study was conducted to investigate flood risk of Big Blue River/ Wildcat Creek due to expansion of Manhattan city, Riley County, Kansas State, USA. Hydrographs and peak runoff were determined for three different scenarios current zoning, future zoning, and adding 20% impervious surfaces onto current zoning. Stage discharge relationship was developed for all three land use characters for 5 and 25 years storm events. Assumption was made that, if the water exceeded 6 meter depth, the area it could submerge was considered prone to flooding. Results of the study revealed that, there was no increase in depth of water (stream stage) in Wildcat Creek before and after planned rezoning of Manhattan. However, by increasing the impervious areas by 20%, stream stage in the Wildcat creek exceeds 6m threshold level posing potential of flooding.

INTRODUCTION

The Manhattan city in Riley County, Kansas State, USA created a plan for rezoning and expansion of the area around the city.

This plan changes rural areas into urban and industrial areas. Furthermore, some of the residential areas within Manhattan had been rezoned to allow denser residential areas. The changes to land use change hydrologic properties of Manhattan area and increased peak flow rates and total runoff in Manhattan and areas in the vicinity of the city.

The hydrologic changes could result in the flooding and erosion problems, and must be prevented with properly designed storm water structures. This study provide city planners and developers, information needed to evaluate impacts of rezoning and continued development of the city.

The objective of this study was to;

- Develop peak flow rates and hydrographs for various design storms on different development scenarios.
- Perform statistical analysis of peak flow rates for different development scenarios.
- Analyze potential flood risk, for the 5 and 25 year design storm for the different development scenarios.

MATERIALS AND METHODS

Study Area

Manhattan city is located at Riley county in the northeast part of Kansas state at the junction of Kansas river and Big Blue river. The city is situated in the Flint Hills region, and experiences a continental climate, with an annual precipitation of 800 mm. The soils are mainly silty loam and silty clay. Storm runoff from the city drains either into the Big Blue River or Wildcat creek, (both streams drain into the Kansas river). The study area (Figure .1) was delineated to cover Manhattan city boundaries and Wildcat creek watershed. Total drainage area of the watershed is 193.1 km^2.

Creation of Land Use

To create the land use/zoning layers for current and future development, the land use of riley county and zoning of Manhattan had to merge together. The zoning layer for Manhattan, Kansas was obtained from the Riley County GIS website. The future zoning is an image in Manhattan Urban Area Comprehensive Plan report (Manhattan, 2006). This

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image was georeferenced with the current zoning layer in ArcMap®. Any area not currently zoned was digitalized and added to the layer as a new polygon (Figure 2). Because, the catchments extend beyond the zoned areas of Manhattan, both zoning layers were merged with the land use layer, after the layer was converted to a polygon feature class (USGS, 2000). The merging was accomplished in Arc Catalog® by first subtracting the current or future zoning layer, fixing the geometry of the resulting layer, and merging that layer with zoning layer.

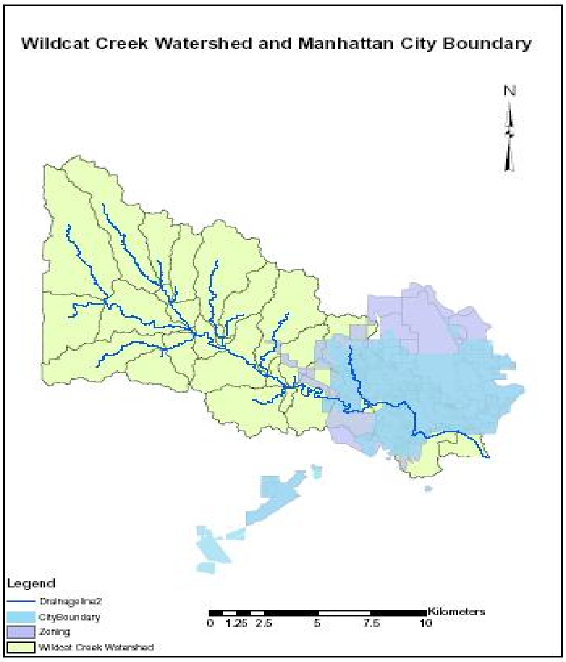

Figure 1 Wildcat creek watershed and Manhattan, KS boundaries**.**

Obtaining Average Curve Numbers

After creating both zoning layers, the average curve numbers for catchments must be calculated. The curve number is a method of determining runoff developed by the NRCS (NRCS, 2004). The curve number CN was used in equation 1 to determine the depth of runoff R (mm) with a rainfall P (mm). For the catchments level, the curve number should be weighed with area to determine the average.

$$R = \frac{(P - 0.2S)^2}{P + 0.8S} \quad \text{Where } S = 25.4\left(\frac{1000}{CN} - 10\right) \qquad (1)$$

The first step in determining the curve number was to overlay the zoning layers with soil type layer (USDA, STATSGO database). Each soil type was classified into hydrologic type A, B, C or D. This soil classification was used to factor soil factors into the curve numbers. In the overlaid layer, a field was added for the curve numbers. It was populated with the curve number matching the soil/land use combinations. The curve numbers were obtained from the National Engineering Handbook (NRCS, 2004). With the curve numbers enter, the layer was overlaid with the catchment layer generated by ArcHydro a watershed analysis tool plugin to the ArcInfo. For each catchment, the curve numbers were weighed with the area to calculate the average curve number for the catchment.

Stage-Discharge Development

Estimated peak discharge rates for 5 and 25 year return periods, for each reach in the study area estimated by the USGS was used to develop stage-discharge relationships (Table 1) using Manning's equation (Appendices,equation1). While calculating the stage-discharge relationship, the stream channel was assumed to conform to a trapezoidal shape. The time of concretion was needed to create hydrographs for a catchment (Appendices, equation 2). The time of concentration was calculated using NRCS method.

Hydrographs and peak runoff for Wildcat Creek were determined by using the TR-20 program developed by NRCS. The three different scenarios were tested on Wildcat Creek current zoning, future zoning, and adding 20% impervious surfaces onto current zoning. For each catchment, TR-20 need the average curve number, area (km^2), time of concentration (hr), and reach that receive water. Only reaches that flow through catchments needed to be modeled. Each reach need the channel length, slope and stage-discharge relationship. The channel length was generated by ArcHydro and slope was the average slope of the catchments. Storm analysis was set to a NRCS type II storm and all storm amounts are show in the Table 2.

Table 4 shows the peak discharge at the outlet of Wildcat Creek. 3 and 4 show 5 and 25 year storm hydrographs at the outlet for the three scenarios.

Peak discharge rates corresponding to 5 and 25 year return intervals for pre-rezoning, post-rezoning and post-rezoning plus 20% impervious area, were computed using the TR-20 model. A stage-discharge relationships for the three zoning scenarios (Table 5,6 and 7) were then developed using the computed peak discharge rates (for the two return intervals), at each stream reach in the study area.

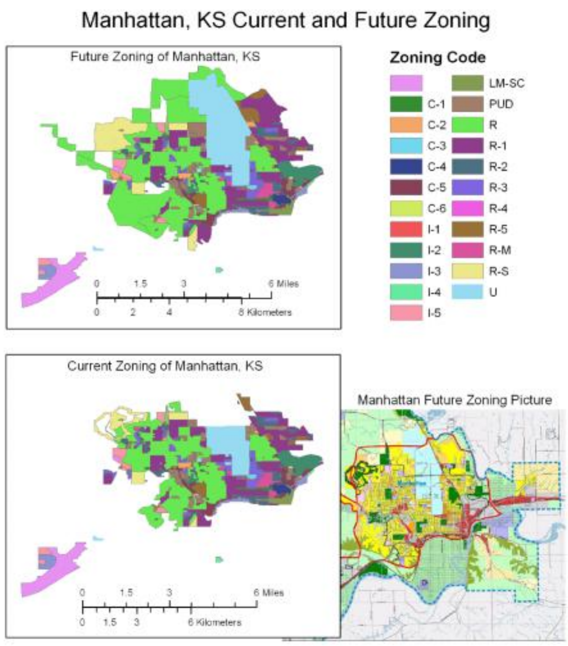

Figure 2 Map of current and future zoning of Manhattan, KS with picture used to create future zoning.

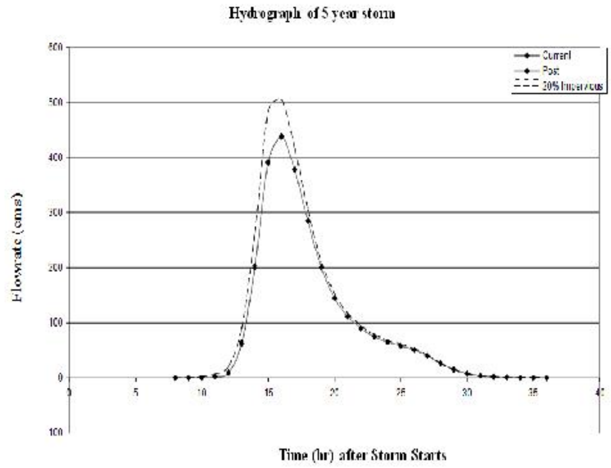

Figure 3 Hydrograph at Outlet of Wildcat Creek for 5 year storm.

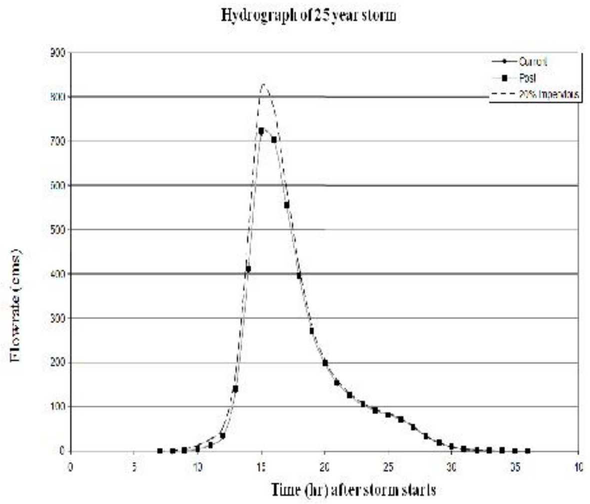

Figure 4 Hydrograph at Outlet of Wildcat Creek for 25 year storm.

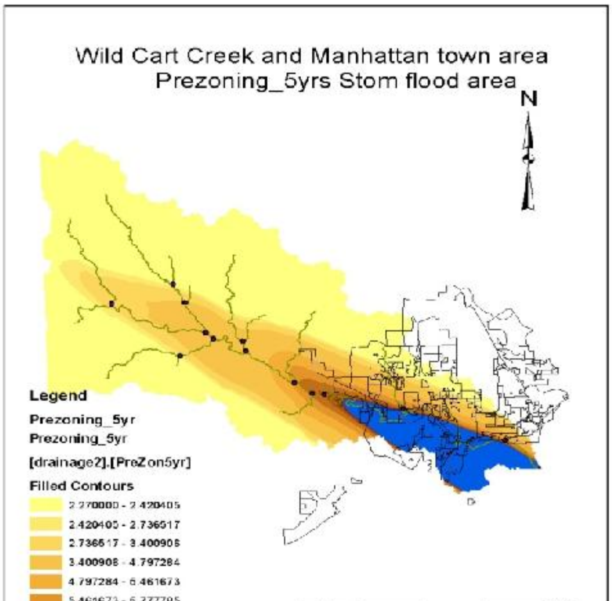

Figure 5 Map of the watershed showing areas prone to flooding, considering a 5 year Storm for pre-rezoning scenario.

RESULTS

Assumption was made that, if the surface depth of water exceeded 6 meter depth, the area was considered prone to flooding. Considering lower Wildcat creek and Manhattan city areas, the area in blue was considered flood prone, as the stage exceeded 6 m depth.

By increasing the impervious surface area (post-rezoning + 20% impervious area scenario), and considering the 5 year storm event, the same area near the outlet of the watershed indicates that a larger area is prone to flooding, Considering a 25 year storm (for pre-rezoning scenario, fig.7) the same conclusions drawn about the 5 year storm above, apply. However, the flood prone area is larger compared to the flood prone area caused by the 5 year storm event. Considering the post-rezoning + 20% impervious area increase scenario (for a 25 year storm event), the stage increases to a height of 8 m. It is obvious that from the threshold value of 6 meter depth, this storm will flood a larger area of the watershed (Fig.8).

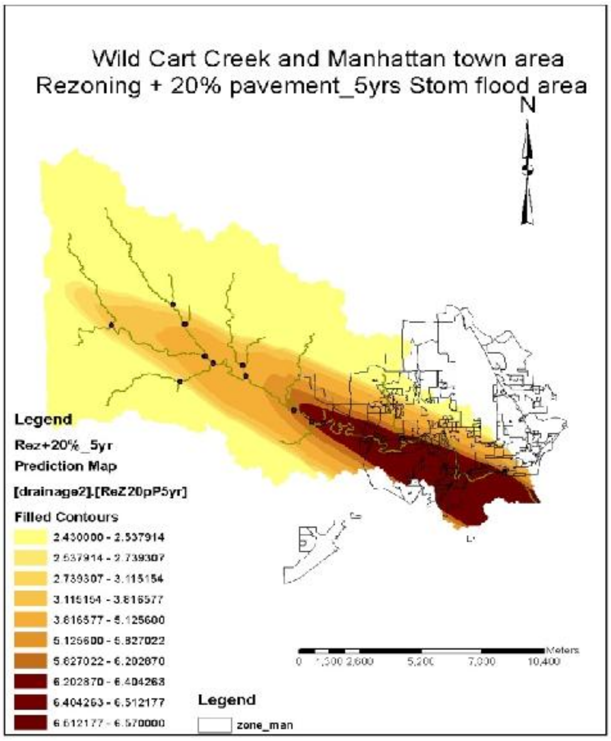

Figure 6 Map showing areas in the watershed prone to flooding, post-rezoning + 20% impervious areas scenario, 5 year storm event.

Peak discharge rates at the watershed outlet for the three zoning scenarios (Pre-rezoning, post-rezoning and post-rezoning with 20% impervious areas) (treatments) were considered for analysis.

Each treatment was replicated with six observations of storm return periods 2, 5, 7.5, 10, 17.5, and 25 years. SAS 9.1 statistical program was used to analyze the data. Pair wise comparison was carried out to test the significance of variability among the treatments (three scenarios) using LSD (Least Significance Difference) method. It was observed that, the peak discharge rates for all the three zoning scenarios were not significantly different from each other (Table 8)

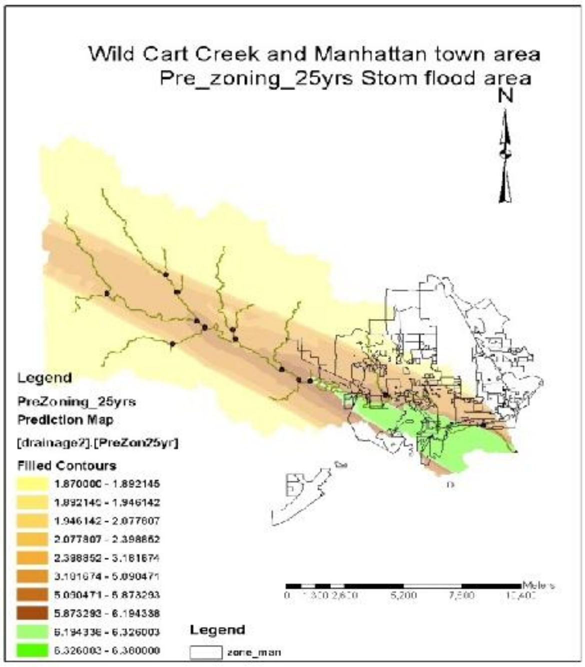

Figure 7 Map showing areas prone to flooding in the pre-rezoning, 25years storm event

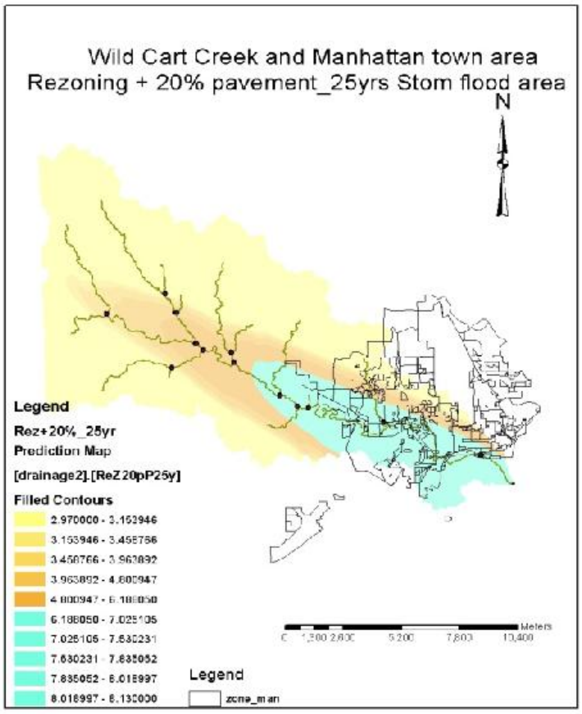

Figure 8 Map showing areas prone to flooding, post-rezoning + 20% increase in impervious area for 25years storm event

Table 8 Summary of Statistical Analysis

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	2	25963.6633	12981.8317	0.42	0.6623
Error	15	459774.0417	30651.6028		
Corrected Total	17	485737.7050			
R-Square		CV	Root MSE	Peak flow Mean	
0.053452		31.33538	175.0760	558.7167	
Alpha			0.05		
Error Degrees of Freedom			15		
Error Mean Square			30651.6		
Critical Value of t			2.13145		

Table 1 Channel variables and stage-discharge relationship for stream reaches.

Hydro ID	s	h (m)	b (m)	z	T (m)	n	A (m^2)	P (m)	R	Q (m^3/s)	Yrs
378	0.0016	3.80	14.00	3	36.8	0.045	96.52	38.03	2.54	161.76	5
365	0.0016	5.00	14.00	3	44.0	0.045	145.00	45.62	3.18	282.36	25
355	0.0016	3.40	12.00	3	32.4	0.045	75.48	33.50	2.25	116.84	5
	0.0016	4.80	12.00	3	40.8	0.045	126.72	42.36	2.99	237.00	25
347	0.0016	3.40	10.00	3	30.4	0.045	68.68	31.50	2.18	104.01	5
	0.0016	4.80	10.00	3	38.8	0.045	117.12	40.36	2.90	214.65	25
337	0.0016	2.80	8.00	3	24.8	0.045	45.92	25.71	1.79	60.88	5
	0.0016	4.20	8.00	3	33.2	0.045	86.52	34.56	2.50	143.68	25

Table 2 Rainfall amount and peak discharge at outlet for all three storms

Storm	Rainfall (mm)	Peak Outlet Discharge (cms)		
		Current	Post	20% Impervious
25-yr	147.32	740.6	743.2	833.6
5-yr	109.22	441.4	443	519.3
10-yr	129.54	598.1	600.1	684.7
2-yr	83.82	262.9	264	324.3
Random 1	115	485.1	486.9	565.9
Random 2	137	657.5	659.6	746.7

Appendix

1. Manning's equation:

$Q = A * V$

$V = R^{2/3} \times S^{1/2}/n$

$R = A/P$

$A = h(b+hz)$

$P = b+2h(1+z^2)^{1/2}$

Where: Q- Peak Discharge (m^3/s)
V- Flow velocity (m/s)
A- Channel cross sectional area (m^2)
R- Hydraulic radius (m)
P- Wetted perimeter (m)
n- Manning's roughness coefficient
S- Channel slope (m/m)
h- Depth of flow in channel

b- Width of channel bottom
z- Slope of channel banks

2. Time of concentration

$$T_c = \frac{L^{0.8}\left[\left(\frac{1000}{CN}\right)-9\right]^{0.7}}{\left(4407S^{0.5}\right)}$$

Where,

T_c = Time of concentration (hr)
L = longest length of the slope (m)
CN = curve number
S = Slope (m/m)

CONCLUSION

There was no increase in depth of water (stream stage) in Wildcat Creek before and after planned rezoning of Manhattan. By increasing the impervious areas by 20% in Manhattan city, the depth of water (stream stage) in Wildcat creek increased which may mean a potential of flooding, considering a 6 m depth threshold value at the watershed outlet. However, mean peak discharge rates calculated at the watershed outlet were not statistically significant, for all the three zoning scenarios.

References

Charlchai Tanavud, *et.al*, (2004). Assessment of flood risk in Hat Yai Municipality, Southern Thailand, using GIS, Journal of Natural Disaster Science, 26 (1): 1-14,

Ravikumar B. Choodegowda, *et al* (2014). Assessing the impact of rezoning and urbanization on surface watershed hydrology. International Journal of Research in Engineering and Technology, 2(7): 19-32,

C. Kubal *et.al*, (2009) Integrated urban flood risk assessment – adapting a multicriteria approach to a city Natural Hazards Earth System Sciences, 9(1): 81–95,

Shirish Gokhale, *et al* (2010).Urban Flood Risk Assessment Using Gis Based Hydraulic Modelling. Journal of Advances in Engineering Science Section, 4 (1): 77-84,

Aggrey Daniel, Maina Thuo, (2013).Urbanization on Land Use Planning, Livelihood and Environment in the Nairobi Rural-Urban. International journal of scientific & technology, 2(7): 70-82,

Yueling Wang, and Xiaoliu Yang,(2013). Land use/cover change effects on floods with different return periods: a case study of Beijing, China. Frontiers of Environmental Science & Engineering, Volume, 7(5): 769-776,

James D. Miller, *et al* (2014).Assessing the impact of urbanization on storm runoff in a peri-urban catchment using historical change in impervious cover, 16(1): 59–70

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