Visualization of the Effects of Urbanization on Water Resources in Johnson County, KS

CE 394.K

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12-06-2013

Background:

Johnson County, Kansas is one of the fastest growing suburban areas of the Kansas City metro area and it is the most populous county in the state of Kansas. The United States Census Bureau estimated the current population to be 559,913 people. Johnson County has been one of the fastest growing suburbs of Kansas City since the 1950's. During the Civil Rights movement, realtors in Kansas City foresaw desegregation. In an attempt to kept segregation intact, the realtors created a superficial segregation by initiating "white flight" or "suburban sprawl". Table 1 depicts the United State Census Bureau population data from 1940 to 2010, which shows significant growth in Johnson County during the civil rights movement (1950-1970).

Table 1 – Johnson County, KS Population Changes from 1940 to 2010

Decade	Population	Percent Change
1940	33327	--
1950	62783	88%
1960	143792	129%
1970	220073	53%
1980	270269	23%
1990	357048	32%
2000	451086	26%
2010	544179	21%

The table also shows Johnson County has sustained a population growth of greater than 20% for seven consecutive decades. This phenomenon sparked a curiosity about the effects that the steady population growth has had on the water resources in the county; according to the Mid America Regional Council (MARC) roughly one third of Johnson County is urbanized. Figure 1 one page 2 is a map of the study area. The purple outline is the area of the Kansas City Metro that is considered urbanized by MARC. The black outline is the shape file for Johnson County.

The first goal of this project was to quantify and visualize the change in annual discharge through four different steams, and compare the change in annual discharge with the change in land cover.

The second goal of this project was to consider the changes in water quality that have occurred as a result of urbanization. Temperature, pH, and specific conductance were chosen as the water quality indicators to consider based on availability of data.

Annual Discharge Analysis:

The streams that were chosen for the study of the change in annual discharge and land cover change were Indian Creek, Tomahawk Creek, Kansas River, and Blue River. These gages were chosen based on location inside the county and availability of annual discharge data. The gage locations of the chosen streams are included in Figure 1, as well as, the drainage areas for each gage.

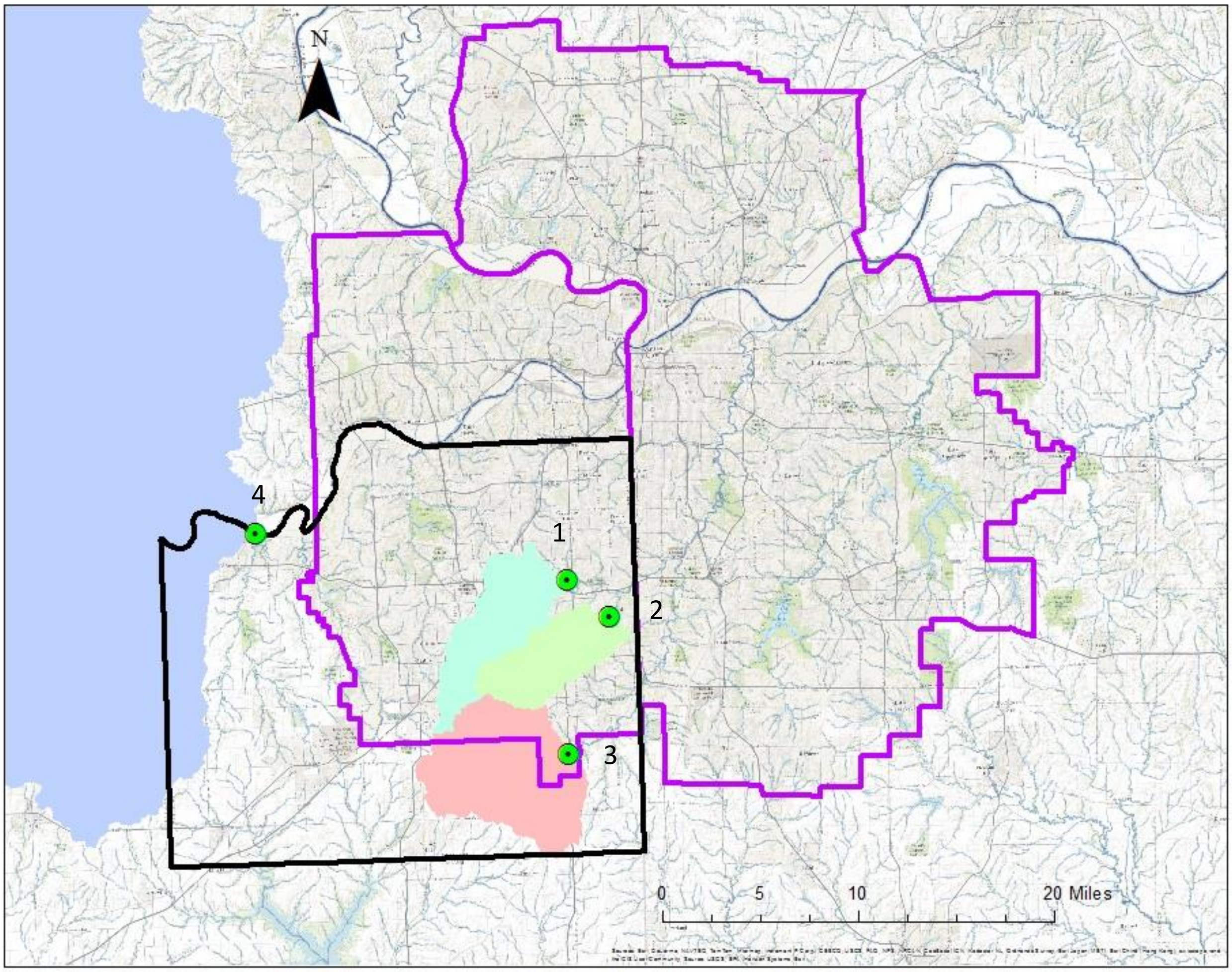

Figure 1 – Map of Study Area with Gages of Discharge Study

The drainage area for the Kansas River gage is not fully shown in Figure 1 because it extends the width of Kansas and into Colorado as well as Nebraska. Figure 2 shows the full extent of the Kansas River Drainage Area. The drainage area of each gage was found using the Hydrology Watershed tool in ArcMap.

Table 2 – Map Gage Definitions of Figure 1

Gage Number	Name	USGS number	Drainage Area (mi^2)
1	Indian Creek	06893300	26.6
2	Tomahawk Creek	06893350	23.9
3	Blue River	06893080	46
4	Kansas River	06892350	59756

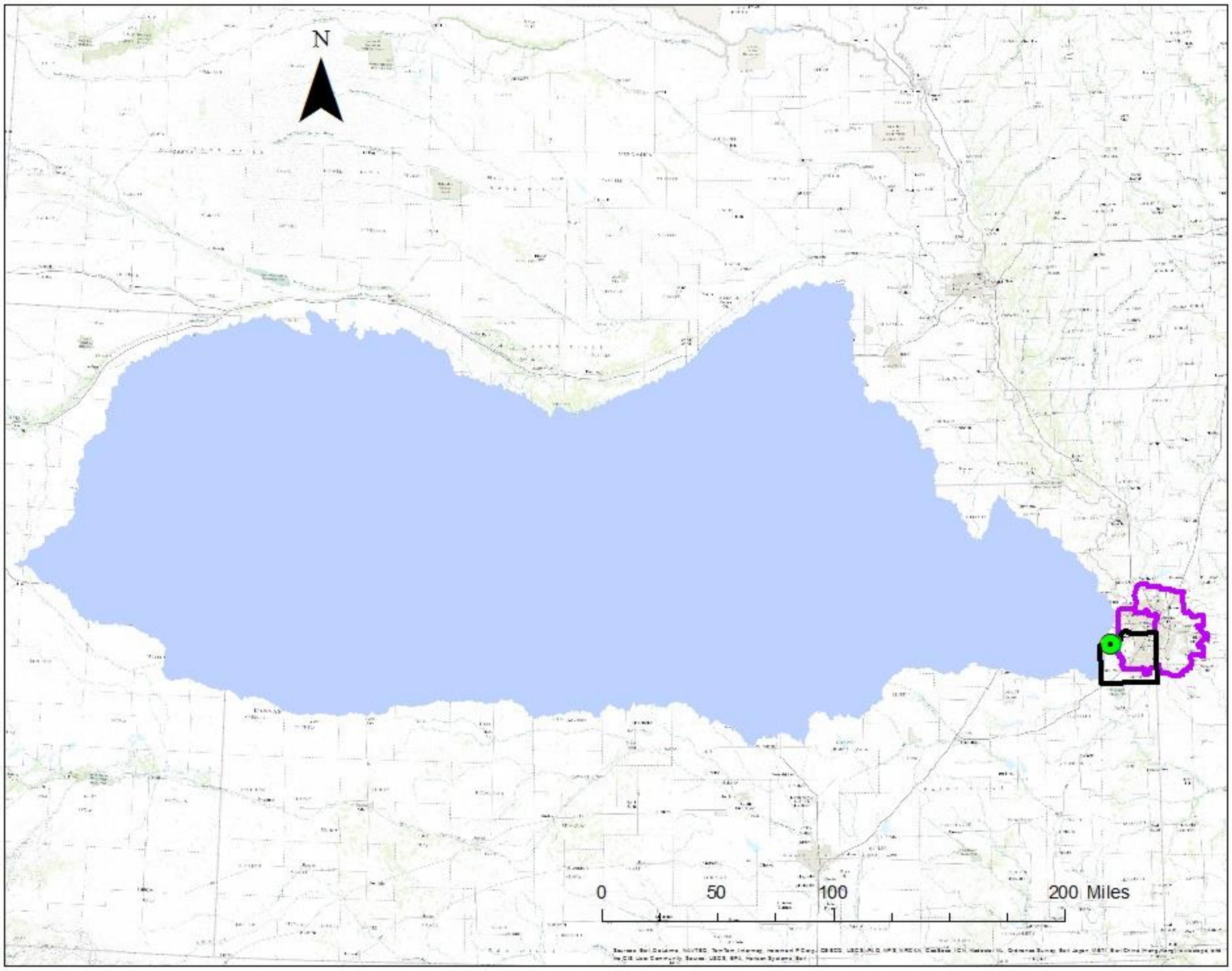

Figure 2 – Kansas River Drainage Area

The annual discharge data was collected for each gage described in Table 2 from the United States Geological Survey (USGS) website. After the data was collected it was normalized for the drainage area to account for large difference in the drainage areas between all four stream gages. The Kansas River stream gage has a drainage area of almost 60,000 mi^2 while the other drainage areas are less than 50 mi^2 as shown in Table 2.

On page 5, Figure 3 shows the annual discharges per unit of drainage area for each gage from 1973 to 2012. Unfortunately, there was not annual discharge data for Tomahawk Creek from 1983 to 2011. The figure shows that Indian Creek had the highest annual flows per the drainage area while the Kansas River had the lowest. That is likely a result of the Indian Creek drainage area being mostly urbanized while the Kansas River watershed is largely un-urbanized. To confirm that the discharges measured at the Indian Creek gage were opposing the trend, a double mass curve of the creek against the Kansas River was created. A double mass curve compares the cumulative discharges of two streams of interest over a specified time period. Figure 4, on page 6, is the resulting double mass curve for Indian Creek and the Kansas River from 1963 to 2012. After 1988 the annual discharge measured in Indian Creek was increasing faster than the annual discharge of the Kansas River so the curve began to deviate from the trend line, which confirmed the prediction annual discharge in Indian Creek was not following the trend of the other stream's discharges.

The Blue River was also investigated using a double mass curve analysis. Figure 5, on page 7, is the resulting double mass curve for the Kansas River and the Blue River from 1975 to 2012. After 2001 the annual discharge in the Blue River began to deviate from the trend. Both the Blue River and Indian Creek gages are located in Overland Park, KS where the population and development has been expanding toward the south-west, therefore, it makes sense that the gage on the Blue River would not show any notable changes until 2001 while the gage on Indian Creek started to show the effects of urbanization in 1988. Since the gage at Tomahawk Creek had a large gap in the annual discharge data from 1983 to 2012 a double mass curve analysis could not be conducted for that gage.

To better understand the discharge analysis a land cover analysis was conducted. The Land Cover Change Product from 1992 – 2001 was used to determine the change in land use for each drainage area considered in the annual discharge analysis. The Land cover change product was a raster file, therefore, to complete the analysis each drainage area had to be converted into raster form using the polygon to raster spatial analysis tool. Then the raster calculator tool was used to multiply the two raster files together to find the overlap. The output was analyzed in excel to get the final results related to urban land cover. The results of the study are outlined in Table 3.

Table 3 – Percent Urban Land Cover for each Gage's Drainage Area

	Percent Urban Land Cover	
Gage	1992	2001
Indian Creek	73%	91%
Tomahawk Creek	39%	69%
Blue River	12%	16%
Kansas River	4%	4%

Tomahawk Creek's drainage area experienced the greatest change in urban land cover from 1992, Indian Creek's drainage area was in the middle, and the Blue river drainage area experienced the lowest change in urban land cover. The significant increase in urban land cover for Tomahawk Creek would have been interesting to compare with the changes in discharge for that gage if there had been enough annual discharge data. The Kansas River urban land cover stayed the same which is good since the Kansas River discharge was the used as the baseline for the double mass curves. Figure 6, on page 8, shows the Land Cover Tomahawk River drainage area. Figure 7 shows the land cover change for all of Johnson County.

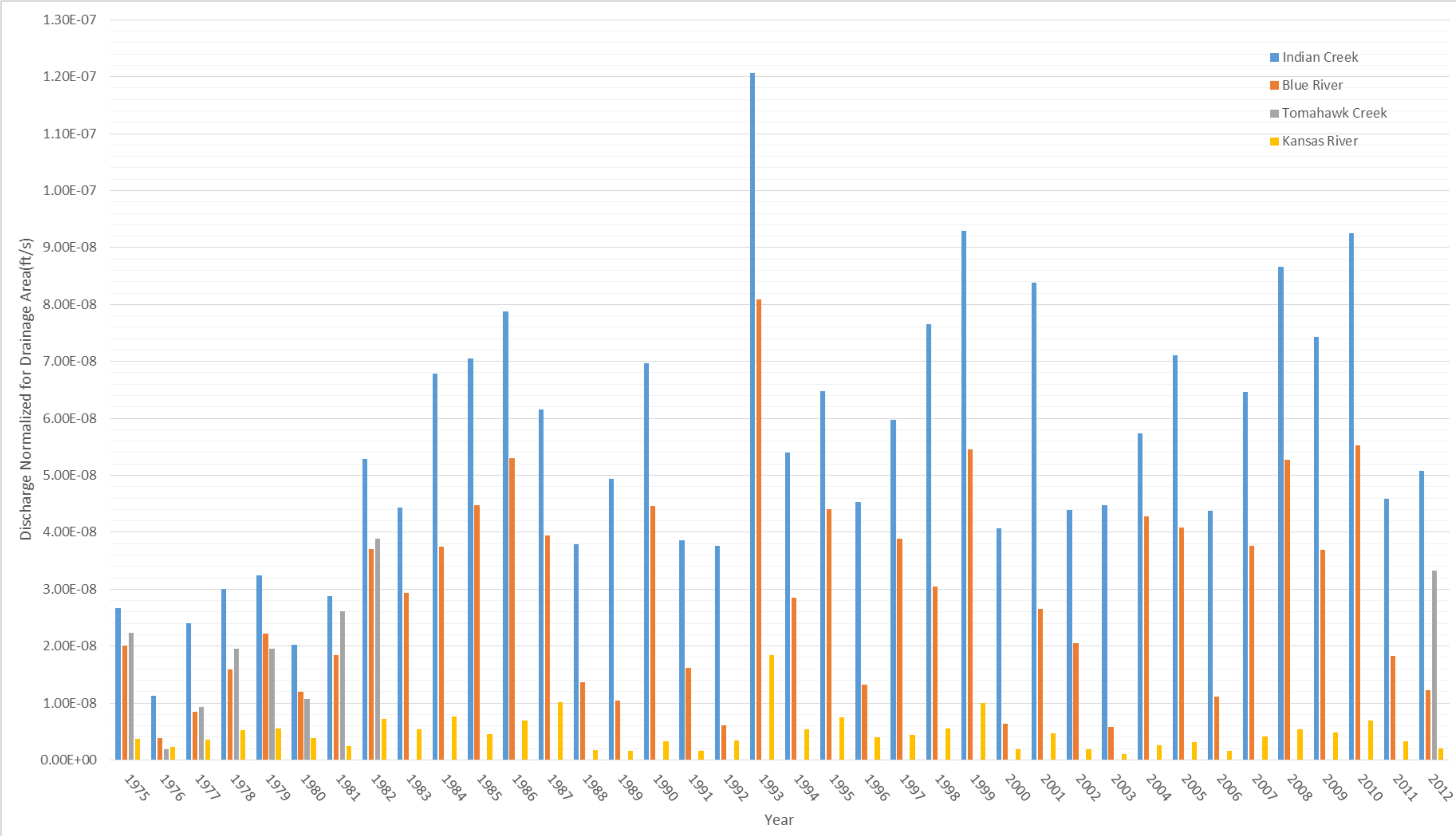

Figure 3 – Annual Discharge Normalized for Drainage Area from 1975 to 2012

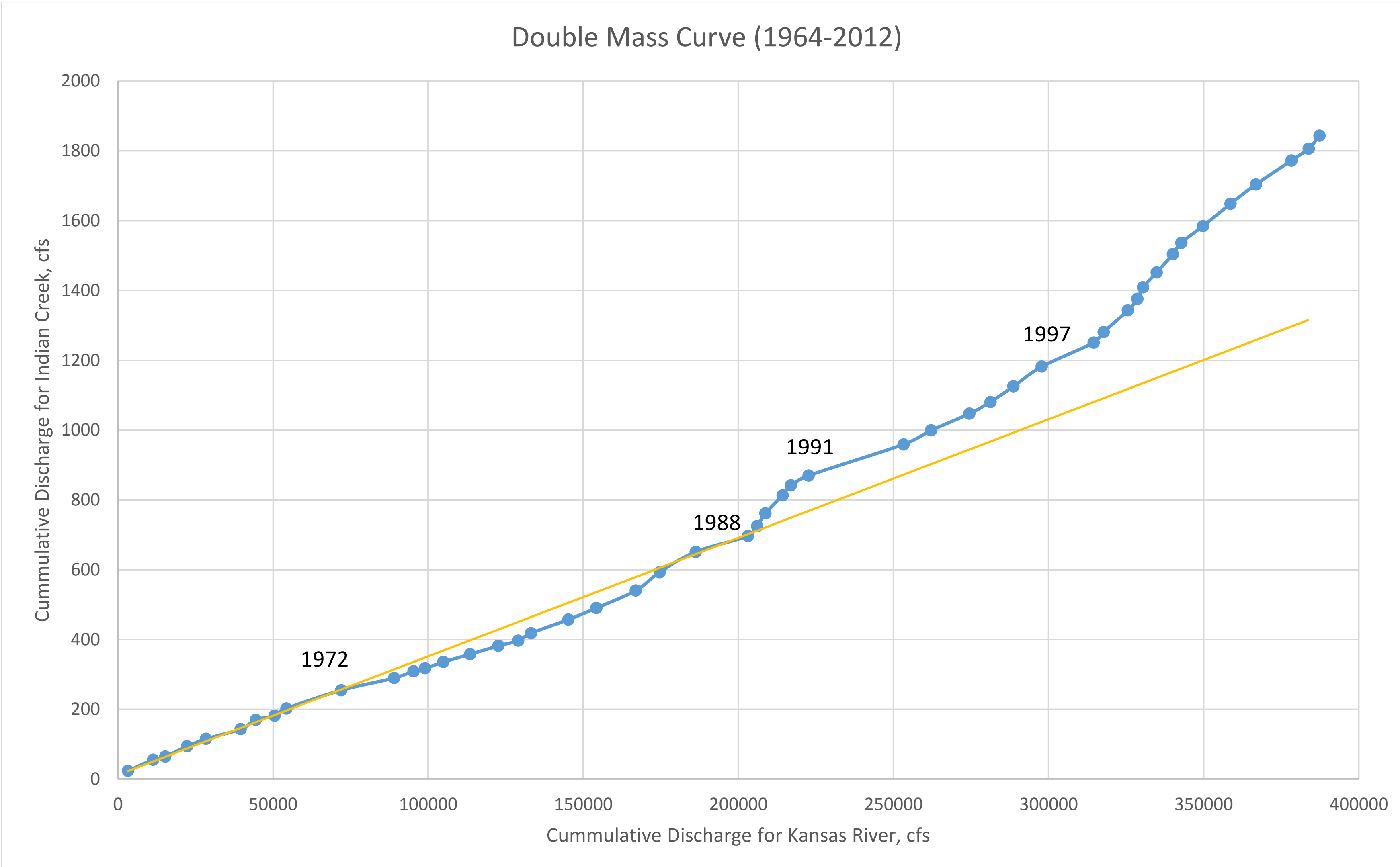

Figure 4 – Double Mass Curve for Kansas River and Indian Creek from 1963 to 2012

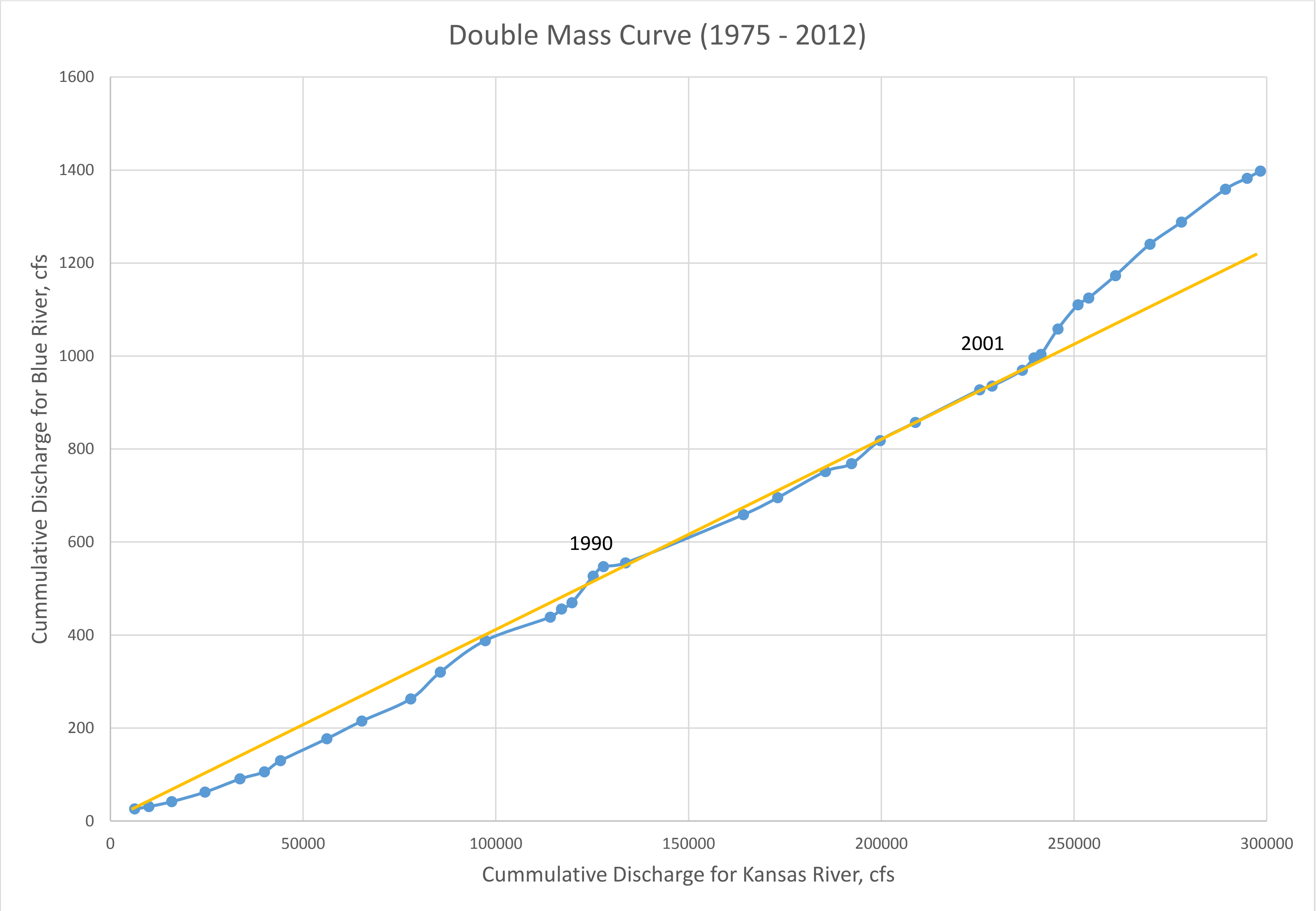

Figure 5 – Double Mass Curve for Kansas River and Blue River from 1975 to 2012

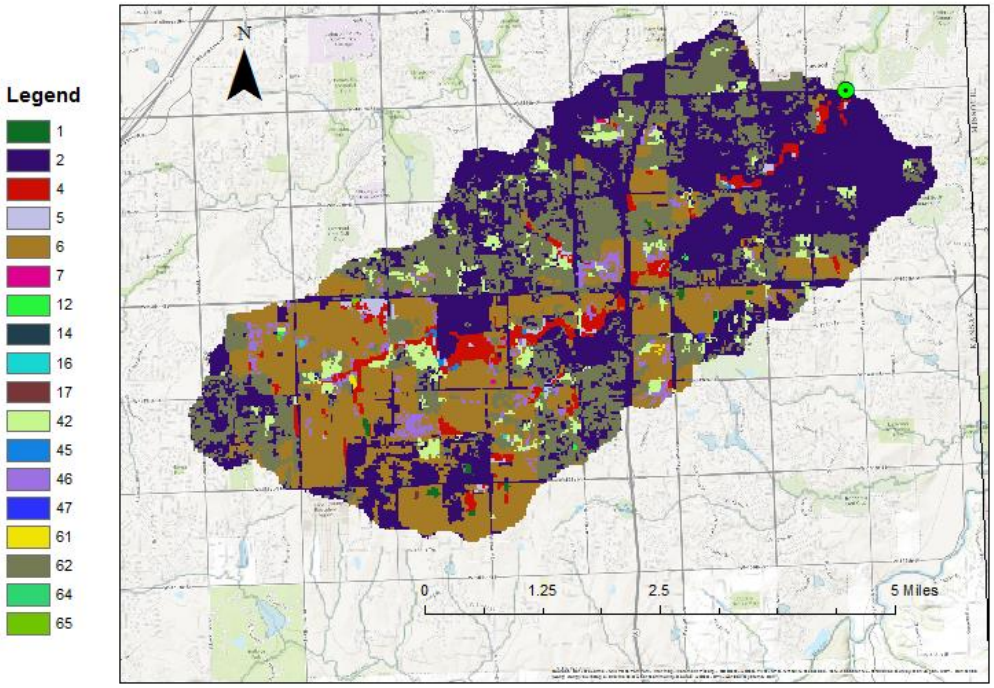

Figure 6 – Land Cover Change for Tomahawk Creek Drainage Area 1992 to 2001

Table 4 describes what the legend means in Figure 6. The values 1 through 7 represent the cells whose land cover did not change from 1992 to 2001. The values 12 or greater describe the cells that experienced a change in land cover. The first number describes what the cell was in 1992 and the second number describes what the cell changed to by 2001.

Table 4 – Description of the Legend in Figure 6

Value	Meaning	Value	Meaning
1	Open Water	12	Open Water to Urban
2	Urban	14	Open Water to Forest
3	Barren	16	Open Water to Agriculture
4	Forest	17	Open Water to Wetlands
5	Grassland/shrub	42	Forest to urban
6	agriculture	43	Forest to Barren
7	wetlands	45	Forest to grassland/shrub
		46	Forest to Agriculture
		47	Forest to Wetlands
		61	Agriculture to Open water
		62	Agriculture to Urban
		63	Agriculture to Barren
		64	Agriculture to Forest
		65	Agriculture to grasslands/shrubs
		67	Agriculture to wetlands

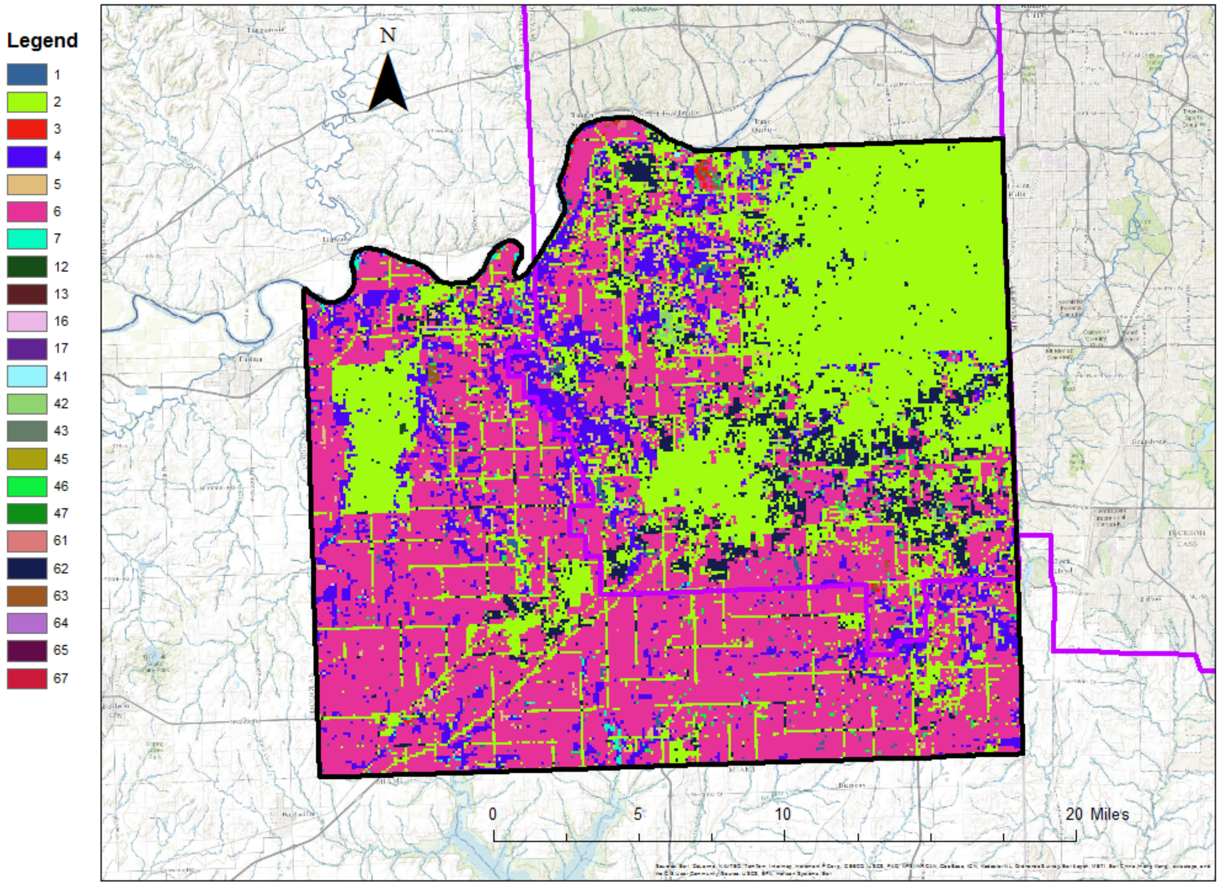

Figure 7 – Land Cover Change over Johnson County from 1992 to 2001

While the colors of each cell type in the legend are different for Figures 6 and 7, the numbers mean the same thing. There are also a few cell types on the Johnson County Map that are not included in Table 4, but the numbers are easy to understand. For example, a cell with a value of 13 was open water in 1992 and changed to barren by 2001.

Water Quality Analysis:

In addition to looking at the annual discharges, water quality indicators were examined to determine the additional effects that urbanization has had on the streams in Johnson County. Figure 7 shows the gages that were used to examine water quality.

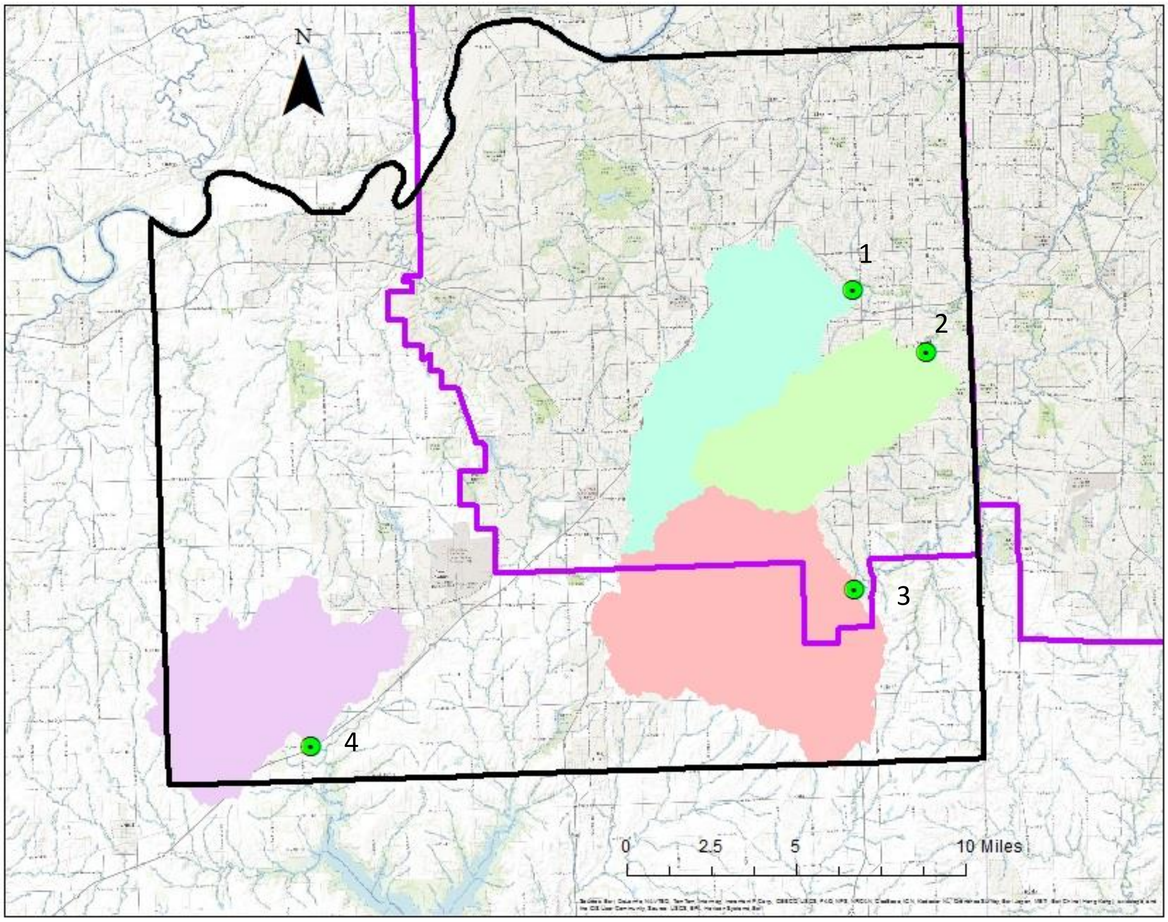

Figure 8 – Map of the Study Area and Gages for the Water Quality Study

The drainage areas for each gage were delineated using the hydrology watershed tool which created a polygon of each drainage area. A land cover change analysis was conducted for the Big Bull Creek drainage area to have a comprehensive understanding of how much of the land cover is urban for each gage. Big Bull Creek had 11% urban land cover in 1992 and 13% in 2001. Table 3 displays the urban land cover of the other drainage areas depicted in Figure 8. Table 5 explains each gage in Figure 8.

Table 5 – Map Gage Definitions of Figure 8

Gage Number	Name	USGS Number	Drainage Area (mi^2)
1	Indian Creek	06893300	26.6
2	Tomahawk Creek	06893080	46
3	Blue River	06893350	23.9
4	Big Bull Creek	06914950	28.7

The water quality indicators that were examined were temperature, pH, and conductance. The data was collected from the USGS. Each type of data was a field measurement taken at different times each year. The temperature and pH of each stream did not yield any interesting trends, as shown in Figures 9 and 10.

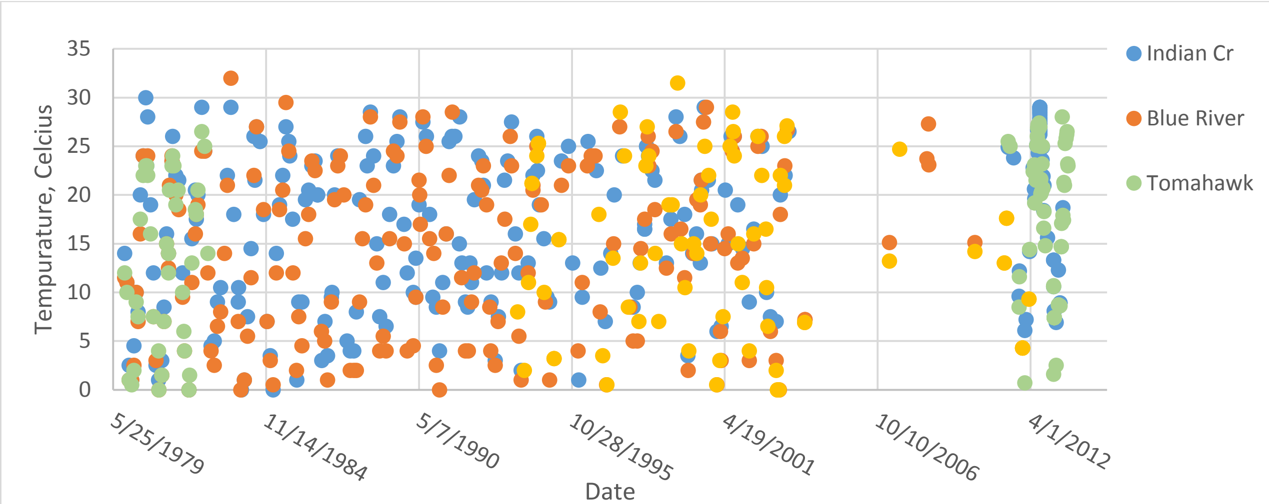

Figure 9 – Temperature Measurements from 1979 through 2013

There is no obvious trend of the water temperature over time for these gages indicating that land cover change does not have a large impact on the temperature of the water in the steams.

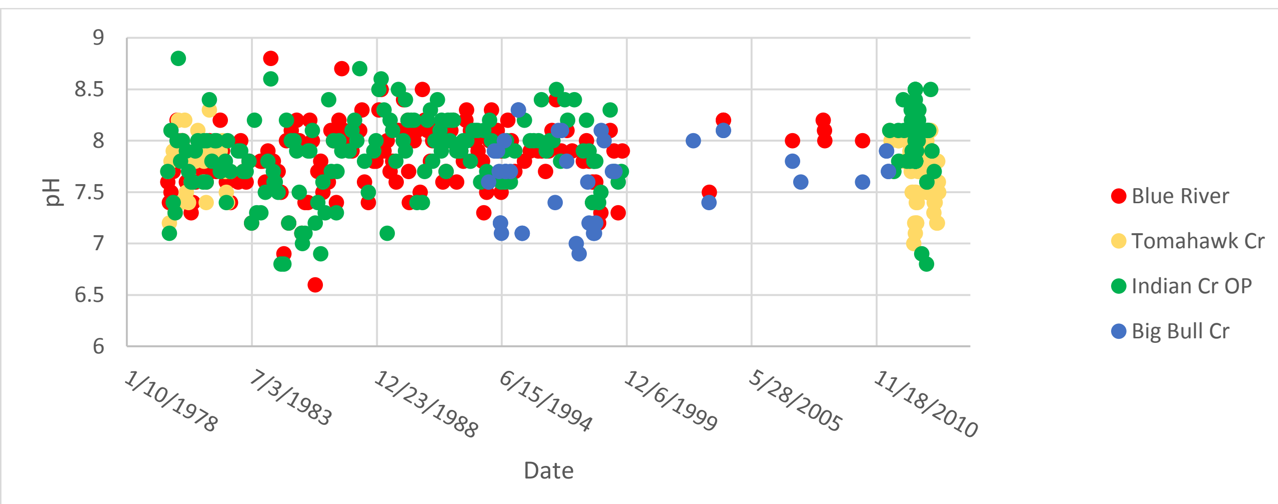

Figure 10 – pH measurements from 1979 – 2013

The pH data also does not yield a significant trend. An average of all the pH data Indian Creek yielded a slightly higher average pH value of 7.9, compared to Tomahawk Creek which had an average pH of 7.7 and Big Bull Creek which had an average pH of 7.6. The average pH value for the Blue River is 7.8. Since there doesn't seem to be a correlation between increased urban land use of increased discharge and pH no further examination of pH was completed.

The third water quality that was examined was conductance, which is used to indicate the amount of dissolved solids in the water. Water with a higher specific conductance will have a higher concentration of dissolved solids than water with a low specific conductance. According to the Environmental Protection Agency's "Water: Monitoring and Assessment" webpage, "dissolved solids in streams consist of calcium, chlorides, nitrate, phosphorus, iron, sulfur, and other ions particles" and high dissolved solids concentrations can have an adverse effect on aquatic organisms. Figure 11 displays all the field measurements taken at the gage sites from 1979 to 2013.

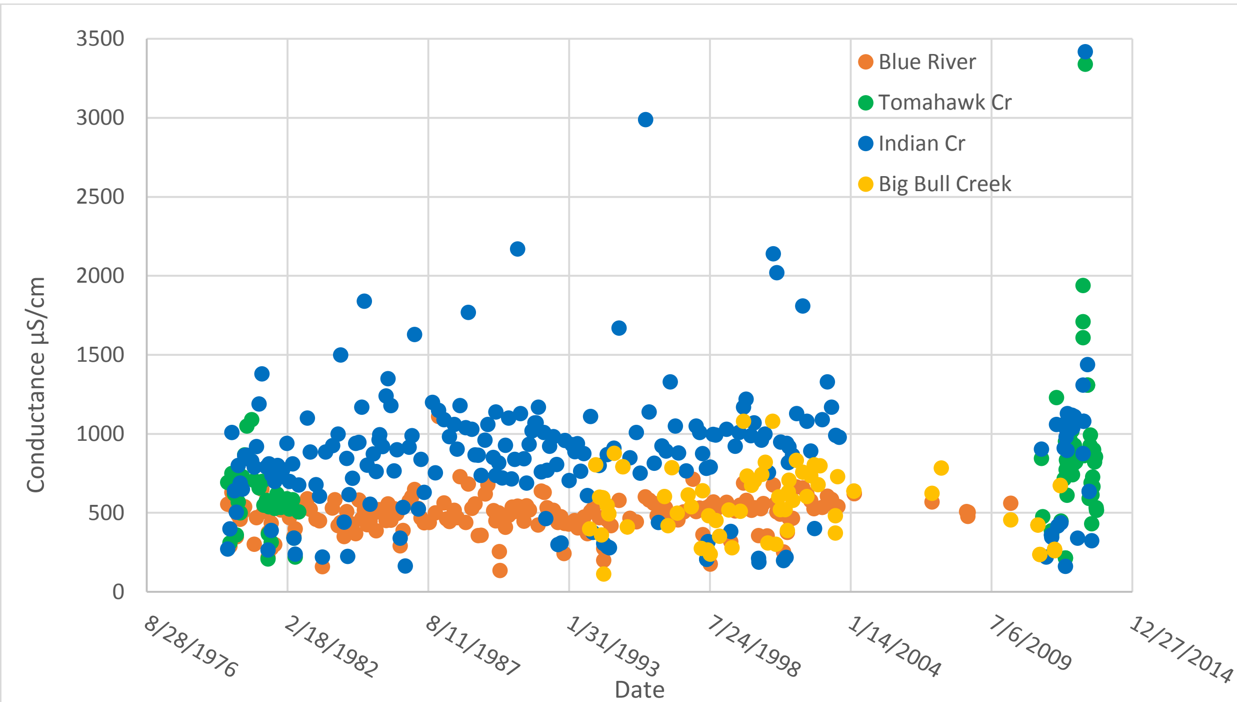

Figure 11 – Conductance (suspended solids)

Indian Creek and Tomahawk Creek have the highest readings of conductance over all, especially after 2010 indicating that urbanization likely has an effect on the amount of dissolved solids in the water.

Conclusions:

The discharge analysis showed a correlation between increased urban land cover and increased annual discharge. Considering the double mass curves and the change in land cover the effect of urbanization is an increase in annual discharge for the steams that drainage areas that have been urbanized. Understanding the point at which the steam discharge begins to be affected could help city planners decided where development should be encouraged and where it should be limited. It also could highlight areas were Best Management Practices (BMPs) should be implemented.

The water quality analysis showed an increase in specific conductance through the streams with urbanized drainage areas which indicates high concentrations of dissolved solids. There did not seem to be any noticeable changes with temperature of the water or of the pH due to land cover changes. The water quality data was not continuous or taken over even intervals so more analysis would need to be done to confirm or deny the findings of this short analysis. Also, for each water quality indicators examined there was a considerable lack of data from 2004 to 2009. The lack of data made it difficult to make a supportable prediction of the effects that urbanization has had on these water quality indicators.

To complete a better analysis of the effects that urbanization has had on Johnson County a more comprehensive set of discharge and water quality data would have to be obtained as well as the land cover change from 2001 to 2006.

Additional Remarks:

For oral presentation purposes a few different times series were created to demonstrate the change in annual discharge through the gages that were used in the discharge portion of this study. These time series were not included in this term project because they did not add any additional information to the study. However, using a time series animation has a lot of power for visualizing the changes in water resources due to urbanization. While the times series that were created do not add much to this paper they could be very useful in the future to communicate an idea during an oral presentation. The idea for creating these visualizations was to help advocate for BMP implementations in Johnson County in the future. The Johnson County Stormwater Board and the City of Olathe, KS (located inside Johnson County) created a cost share program in 2011 that refunds property owns 50% of the material costs of an implemented rain garden, or other type of BMP.

An analysis using the Gravity Recovery and Climate Experience (GRACE) soil storage data was also preformed but it was not particularly useful for visualizing the effects of urbanization on water resources. More analysis could be conducted using the GRACE data in the future for other purposes.

Summary of Data Sources:

Automated Information Mapping System. (2012). Johnson County [Shape file]. Retrieved from http://aims.jocogov.org/AIMSData/FreeData.aspx

Mid-American Regional Council. (2010). Urbanized Areas [Shape file]. Retrieved from http://marc.org/Data-Economy/Maps-and-GIS/GIS-Data/GIS-Datasets

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"Water: Monitoring & Assessment - 5.8 Total Solids." EPA, March 06, 2012. Web. December 03, 2013.