Environmental Assessment of K-State Campus Creek

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This study of Campus Creek is completed, in part, to meet the requirements of the Natural Resources and Environmental Sciences senior capstone project at Kansas State University. The lead instructor for the course and director of the NRES Secondary Major is Dr. J.M. Shawn Hutchinson and the project team advisor is Dr. Aleksey Sheshukov from the department of Biological and Agricultural Engineering.

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Contents

1. Introduction

Campus Creek is a small tributary to the Kansas River that runs through the Manhattan campus of Kansas State University. Because of the urban development of the Campus Creek watershed almost the entire creek has been altered from its predevelopment state. The only remaining part of the creek that flows through near natural-conditions is a half mile stretch upstream of a box culvert at Manhattan Ave. Downstream of this point is almost entirely artificially directed, mostly underground.

In the spring of 2017, as part of K-State's Natural Resources and Environmental Sciences Secondary Major capstone project, an interdisciplinary group of six undergraduate students conducted this study of the ecosystem services, change in land cover, hydrology, water quality, plant life, and aquatic life of the creek. The goal was to conduct a comprehensive analysis to assess the environmental quality of the remaining "natural" stream. The hope is that this study will provide insight into the problems facing the system so that Manhattan residents, K-State students, and policymakers alike can be more informed on how their actions impact their immediate environment.

This study began with a literature review of all the areas of focus mentioned above in order to develop a better understanding of what factors are important to consider when conducting an environmental study of an urbanized stream. The knowledge gained from the literature review was applied to conduct an effective primary data based analysis of Campus Creek. The methods used below are based on those used by other similar studies and are cited accordingly. The results from the study are thereafter, along with discussion of the data. Finally, a conclusion to the report evaluates the implications of the findings and proposes potential actions for future action.

2. Methods

Ecological Services

A study was conducted via online survey to gauge the attitudes of students and faculty members toward Campus Creek and the surrounding area on Kansas State University's campus. The survey was open for a total of 10 days, and consisted of nine questions in multiple choice and fill in the blank format, **Appendix 6.1**. It was shared via social media platforms, such as Facebook and text messaging, word of mouth, and emailed to students and faculty members within the student's respective departments.

Land Use Change

The study of land use was completed visually by walking along the creek on multiple occasions and through satellite imagery. The exits for storm drains are visible along the banks of the creek. The orientation of the pipes indicate the sources of the water, such as parking lots, roads, and buildings. To see how the land use has changed throughout time, two past satellite images were compared to the present Campus Creek area.

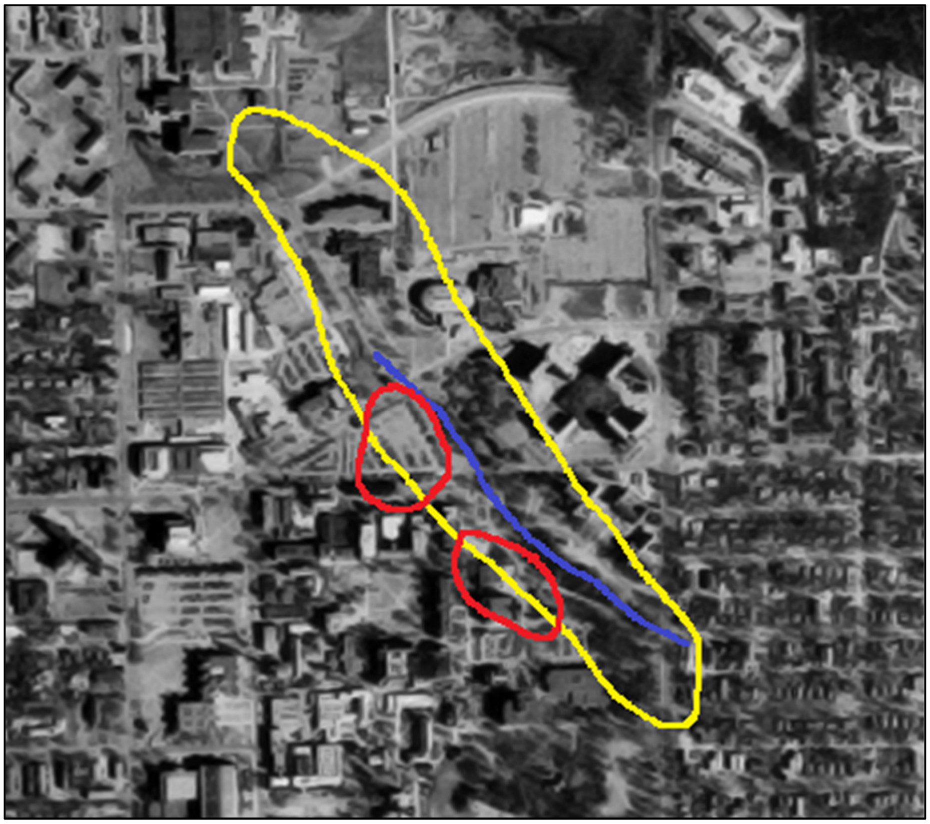

Figure 2.1: Satellite image of Campus Creek areas in 1996. (Campus Creek outlined in yellow, open land in red, and creek channel in blue)

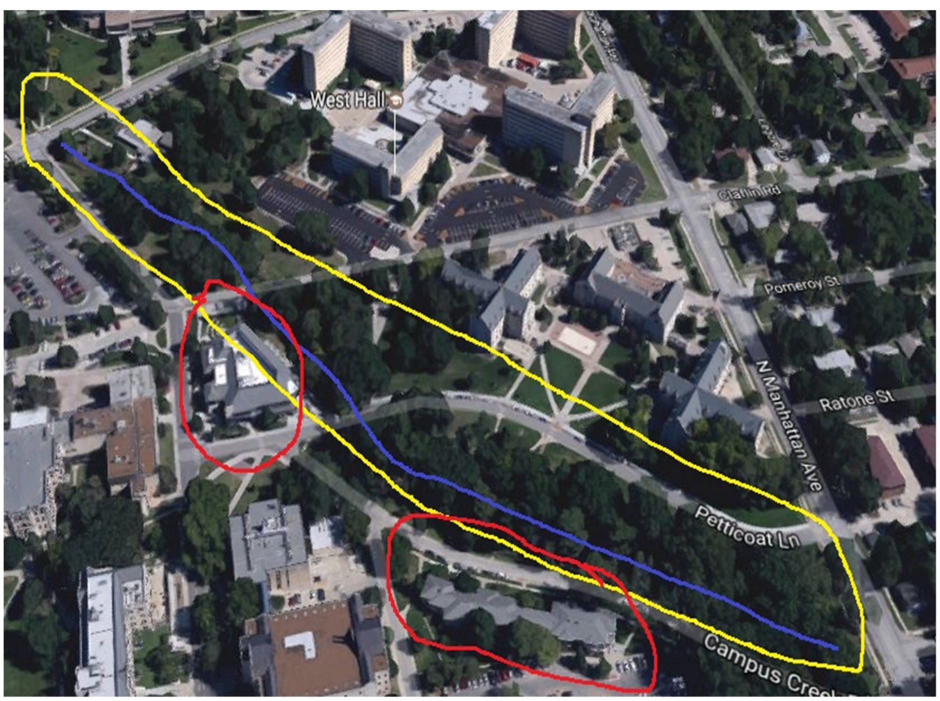

Figure 2.2: Satellite image of Campus Creek area in 2016. (Campus Creek outlined in yellow, new buildings in red, and creek channel in blue)

Figure 2.1 was acquired from the USGS Imagery website and is from the year 1996. **Figure 2.2** was acquired from Google Earth and is from 2016. If you compare the two images based on the number of trees and shrubbery, in 1996 there is less coverage of trees and shrubbery. In twenty years, woody vegetation completely engulfed the creek. The yellow circles outline the creek itself. The blue lines indicate where the creek runs. The red circles show the addition of new buildings constructed within that twenty-year span alongside the creek.

Watershed Hydrology

The US Natural Resource Conservation Service's program, WinTR-55 Urban Hydrology for Small Watersheds, was used to produce a hydrologic model of the Campus Creek Watershed. It was determined that this program best fit the scope of this project because it is the commonly accepted standard for small watershed modeling and provides sufficient enough data for the goals of the project (NRCS, 1986).

Delineation of watersheds and sub-watersheds is the first thing to do when creating a hydrologic model. This was done using a Digital Elevation Model (DEM) from US Department of Agriculture. This was imported into ArcGIS a Geographic Information System (GIS) which has the ability to automatically delineate watersheds and create streamlines from the DEM layer using the Soil and Water Assessment Tool (SWAT) similar to that used by Luzio, Arnold, and Srinivasan in their study of Goodwin Creek in Mississippi (2005). **Figure 2.3** depicts the Campus Creek watershed division into seven sub-areas (outlined in red) and includes the reaches (in blue) with soil hydrologic group overlaid on the map. Once the watershed has been established and it is broken into sub-areas the next step is to create a hydrologic model. Each sub-area has six main inputs that are used by WinTR-55. These inputs are: land use, hydrologic soil group, slope, surface roughness, channel dimensions, and rainfall data.

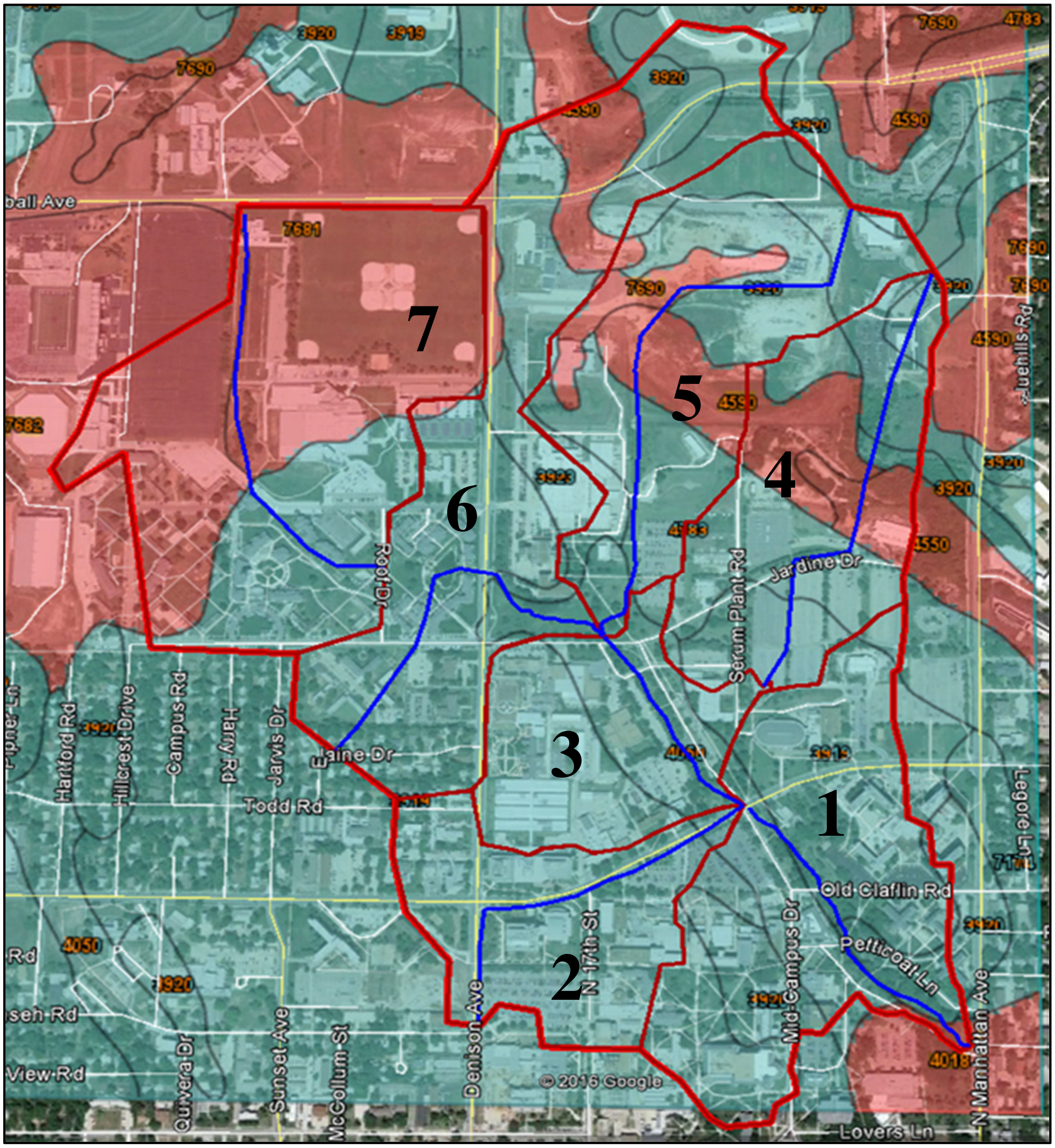

Figure 2.3: Delineation of Campus Creek Watershed

Current land use was estimated using aerial and satellite imagery from Riley County GIS and Google Earth Pro respectively. This data was then combined with soil hydrologic group data from the NRCS Web Soil Survey. **Table 2.1** lists the number of acres in each sub area that contain particular land cover type and hydrologic soil group. For predevelopment conditions, it was assumed that almost all land cover was meadow with riparian forest buffers along the creek flow path. A future (built-out) land cover condition assumed the conversion of 24 acres grass cover to impervious surfaces in sub-areas 4 and 5. This was based on development plans from the K-State 2025 Master Plan (KSU, 2012) and the construction of the National Biological and Agro-Defense Facility (USDHS, 2017) in the Northeastern part of the watershed in Sub-areas 4 and 5.

Table 2.1: Sub-area land cover and hydrologic soil group acreage

Sub-area	Land Cover	Hydro. Soil Group	Acreage
1	Open space; grass cover 50-75% (fair)	C	25
	Impervious	C	30
	Woods - grass combination (fair)	C	4
	Total		**59**
2	Open space; grass cover 50-75% (fair)	C	10
	Impervious	C	21
	Woods - grass combination (fair)	C	3
	Total		**34**
3	Open space; grass cover 50-75% (fair)	C	9
	Impervious	C	22
	Woods - grass combination (fair)	C	2
	Total		**33**
4	Open space; grass cover 50-75% (fair)	C	19
	Impervious	C	22
	Woods - grass combination (fair)	C, D	4, 5
	Total		**50**
5	Open space; grass cover 50-75% (fair)	C, D	45, 5
	Impervious	C	10
	Woods - grass combination (fair)	C, D	4, 2
	Total		**66**
6	Open space; grass cover 50-75% (fair)	C, D	15, 2
	Impervious	C	24
	Woods - grass combination (fair)	C, D	5, 2
	Residential district (⅛ acre)	C	26
	Residential district (¼ acre)	C	12
	Total		**86**
7	Open space; grass cover 50-75% (fair)	D	27
	Impervious	C	23
	Residential district (⅛ acre)	C, D	26, 15
	Total		**91**

Slopes of each sub area were normalized over the entire course of the area, so the difference between the highest elevation and the lowest elevation was divided by the longest flow path length to get a slope in ft/ft. All these values were found using the path tool of Google Earth Pro. For surface roughness coefficients (Manning's n), it was assumed that each sub area had 100 ft of sheet flow with a Manning's n depending on the surface being smooth or short grass. This was then followed by varying lengths of shallow concentrated flow, on either paved or unpaved surface. Finally, sub-areas 1, 3, 5, and 6 included channel flow with a Manning's n of 0.04 (NRCS, 1986). Channel dimensions for 3, 5, and 6 were assumed to be 5 ft wide and 2 ft deep. The channel for sub-area 6 was roughly measured in the field to be 10 ft wide and 5 ft deep. **Table 2.2** shows all of the time of concentration details that were inputted into WinTR-55 as well as the calculated time of flow for each section of flow. For predevelopment, all n values for sheet and concentrated flows were changed to grass dense (0.24) and unpaved respectively. Built out conditions followed the same trends except with added smooth surface and paved surfaces.

Table 2.2: Time of concentration data for WinTR-55

Sub-area	Flow Type	Length (ft)	Slope (ft/ft)	Surface (Manning's n)	Dimensions	Time (hr)
1	Sheet	100	0.012	0.011		0.024
	Shallow Concentrated	200	0.012	Paved		0.025
	Channel	1490	0.012	0.04	10' x 5'	0.055
	Total	**1790**				**0.104**
2	Sheet	100	0.0185	0.011		0.021
	Shallow Concentrated	300	0.0185	Paved		0.030
	Shallow Concentrated	1699	0.0185	Unpaved		0.215
	Total	**2099**				**0.266**
3	Sheet	100	0.0238	0.15		0.15
	Shallow Concentrated	200	0.0238	Unpaved		0.022
	Channel	916	0.0238	0.04	5' x 2'	0.041
	Total	**1216**				**0.213**
4	Sheet	100	0.038	0.011		0.015
	Shallow Concentrated	200	0.038	Paved		0.014
	Shallow Concentrated	2459	0.038	Unpaved		0.217
	Total	**2759**				**0.246**
5	Sheet	100	0.03	0.15		0.137
	Shallow Concentrated	3000	0.03	Unpaved		0.298
	Channel	239	0.03	0.04	5' x 2'	0.015
	Total	**3479**				**0.45**
6	Sheet	100	0.022	0.15		0.155
	Shallow Concentrated	1500	0.022	Unpaved		0.174
	Channel	598	0.022	0.04	5' x 2'	0.028
	Total	**2198**				**0.357**
7	Sheet	100	0.0105	0.011		0.026
	Shallow Concentrated	454	0.0105	Paved		0.061
	Shallow Concentrated	2000	0.0105	Unpaved		0.336
	Total	**2554**				**0.423**

Storm data, the final input to WinTR-55, is automatically calculated by the program given the location of the watershed based on NRCS hydrometeorological data. It found that every year there is a 10% chance of having 5.1 inches of rain over a 24 hour period (10 yr - 24 hr event). And there was a 2% chance every year of having a 6.5 inches of rainfall over a 24 hour period (50 yr - 24 hr event). This is the same for all three land cover scenarios. It is important to note however that due to climate change, it has been found by a team of researchers at Kansas State University that precipitation events are trending upwards in terms of both intensity and depth (Rahmani, Hutchinson, Harrington, & Hutchinson, 2016). So when using this model for future assessment, it may underestimate the size of storm events.

Water Quality

To assess the water quality of Campus Creek, pH, conductivity, turbidity, dissolved oxygen, and total solids were evaluated at three chosen locations (Figure 2.2). These variables were assessed because they have direct effects on organisms within and surrounding the stream (Baralkiewicz et al., 2014, Tate, 1990). Sample sites were selected based on stream characteristics, pipe inputs, and vegetation coverage. Samples were collected at three time points (Table 2.3) as past research has shown water quality varies from day to day (Fronczyk et al., 2016; Polkowska et al., 2009). Precipitation events were recorded as rainfall amount and intensity can account for a majority of the variance in contaminant levels (Tang et al., 2015)

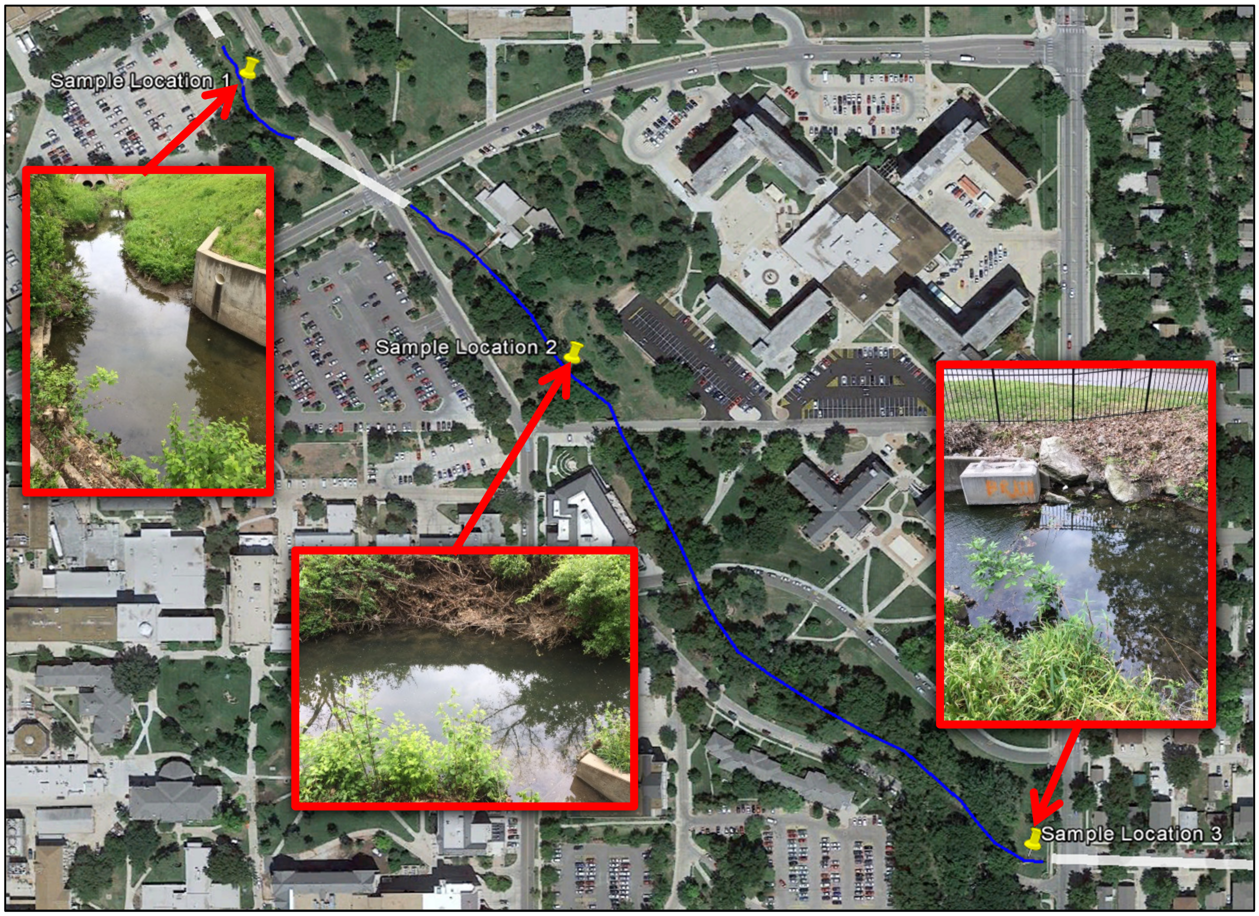

Figure 2.2: Campus Creek through K-State main campus with the location of sample points.

Table 2.3: Days since last precipitation event for each sample day.

Sample Day	Date	Days Since Last Precipitation Event
1	4/11/17	7
2	4/13/17	1
3	5/4/17	4

Samples were collected in airtight glass vials in situ and transported to the Environmental Engineering Lab for testing. For analysis, the Hach pH Digital Probe, Hach Conductivity Digital Probe, Hach Turbidimeter, and Hach Dissolved Oxygen Digital Probe were utilized, in addition to a drying procedure to test total solids. Data was recorded and later analyzed.

Riparian Tree Population

Campus Creek has a wide variety of tree species lining its banks. The tree portion of the Campus Creek study was conducted to provide an overview of the status of the tree population, basic information vital to mapping the trees, as well as to draw conclusions about the health of the stream and its riparian zone.

This study included all trees within approximately 10 meters of the edge of the creek on either side in the area between Location 1 (Latitude 39.1948, Longitude -96.5813) and Location 3 (Latitude 39.1910, Longitude -96.5767).

The data collected includes the common name of each tree species, the tree's taxonomic family, the latitude and longitude of each tree, the circumference of each tree trunk at 4.5 feet off the ground, the Diameter at Breast Height (DBH) of each tree trunk, listed as "Trunk Diameter", and the crown width of each tree's foliage.

Each species was identified with the help of tree identification keys. The latitude and longitude data was acquired using the GPS capabilities of a cell phone. A "waypoint" marker was placed while standing next to the trunk of each tree to record its location. The circumference was acquired by simply measuring each trunk with measuring tape at 4.5 feet off the ground. The DBH was acquired by dividing the circumference measurements by π to calculate the trunk's diameter. The crown width was acquired by measuring the distance from one edge of the tree's foliage to another. This measurement was taken at the widest point of each tree's crown.

The data acquired was compiled into a spreadsheet and then mapped in a visual representation indicating the location and family. Using the data gathered, location 1, 2, and 3 were analyzed and compared with the results of the water quality and the fish sampling to see how the trees may play a role in the stream's health in the form of the water and the aquatic life.

Using the map of the trees, an inventory of trees within 50 meters of locations 1, 2, and 3 was taken. The effect of trees on Campus Creek's fish populations were studied by comparing the data from the riparian tree field count to that of the fish sampling analysis.

Ichthyology

Campus Creek is an ecosystem that provides food, water, and shelter to numerous species. However, due to the extreme fluctuation in water health, elevation, and clarity, it was difficult to gather a plethora of data. During this portion of the project, aquatic life was the main focus. Each pre-determined location was sampled twice for aquatic species. Due to circumstances and strict regulations from the Institutional Animal Care and Use Committee (IACUC) only visual analysis was allowed.

There are many factors that influence the quality and quantity of aquatic life in an urban environment like Campus Creek. One of the major influences is Environmental Estrogens (EEs). These are a broad range of stressors that may affect a fish's quality, quantity, health, physiology, etc. (Shultz, 2013).

As a result of visual analysis being difficult to assess at times, due to water depth and clarity, readings were taken as approximate. The stream showed an abundance of certain species and some diversity with multiple species found. Species name, number, habitat, etc. were noted at each location. Interactions between specimens were also noted as this is important due to the limited space aquatic life has to survive in within the creek.

Figure 2.3: Fishes of Campus Creek sign posted in Quinlan Natural Area

3. Results

Ecological Services

From the survey, which was accessible to participants for a total of 10 days, 113 responses were gathered. Of the 113 responses, 95 (84.07%) were from current students, 12 (10.62%) were from faculty and staff, and 6 (5.31%) were from former students of K-State.

When asked if Campus Creek was a familiar landmark, 84 individuals were familiar with the area and 29 individuals were not. In order to make any improvements to campus there needs to be a form of funding, which prompted the question of if individuals would be willing to have an extra fee added to their tuition bill to fund improvements, and if a fee were to be put in place how much the respondent would be willing to pay. Half (54.45%) of the respondents would be willing to pay an extra fee, and the average amount participants would be willing to add to their bill is $22 per student. When asked if participants would be willing to volunteer in a club that would aid in cleaning and maintaining the creek, of the 113 respondents, 54 individuals noted that they would be willing, however 59 individuals would not like to participate in such an activity. This question arose from a study by McKinley et al. (2015) who brought up the concept of citizen science, which is "the use of the general public on projects that involve topics, in this case maintaining biodiversity, and natural resource management is called citizen science." This practice can help reduce the cost of maintaining the creek, and is used by other universities, such as Auburn University where students helped monitor the Wolf Bay Watershed, which is an area of 60 streams, bays and bayou sites (McKinley et al. 2015).

Figure 3.1 shows how the participants use the creek and the surrounding area. They were given the option to mark if they currently partake in an activity, do not partake in an activity, or would be willing to partake in an activity if improvements were made to the Campus creek area.

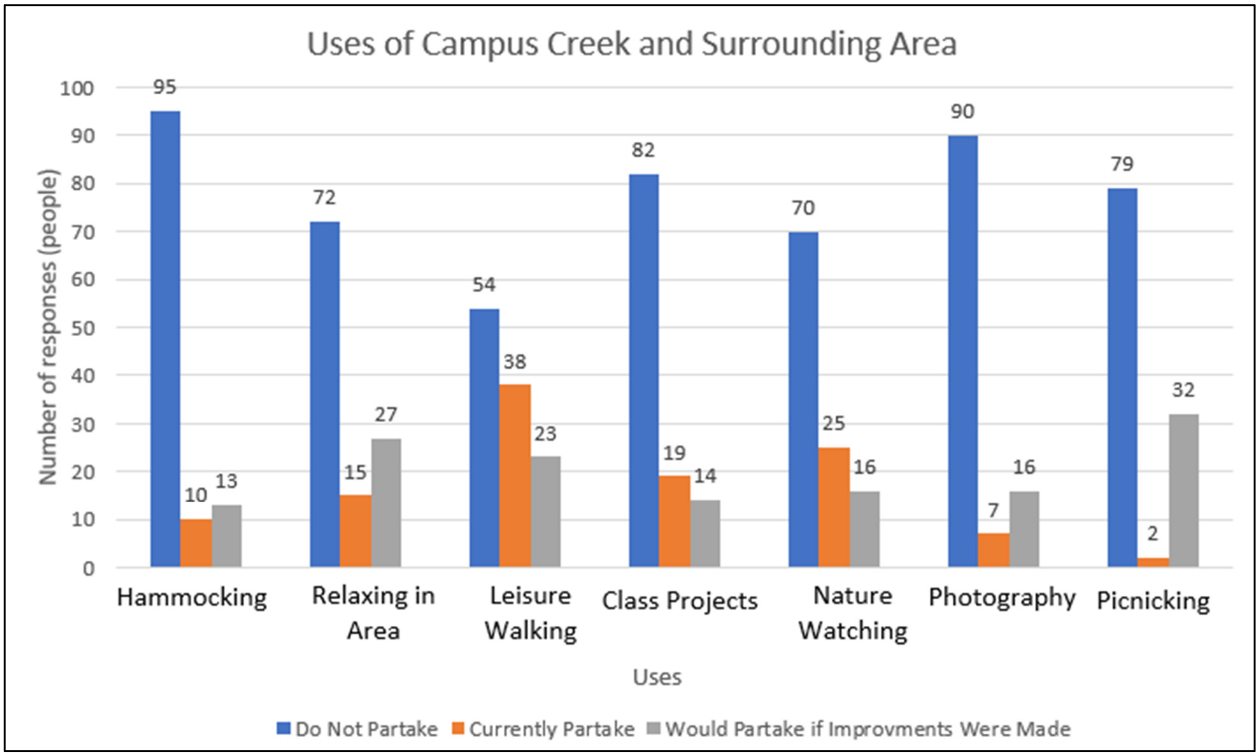

Figure 3.1 Uses of Campus Creek and surrounding area

The majority (89%) of the responses came from current students. For all activities, "do not partake" was the leader, however many participants partake in activities such as, leisure walking, nature watching, and relaxing in the area. There is also room for growth in potential use, as indicated in the third column where many would be willing to change their habits if the state of the area was improved.

Ecosystem services are the benefits humans receive from ecosystem functions and the contributions from ecosystems to well-being (Gómez-Baggethun & Barton, 2003), thus the need for a question to assess the value participants place on the area. Using a point system, personal perception and importance of the area was gauged. Participants were given a scale of "not important", valued at one point, to "very important", valued at five points, to rank how important wildlife, cleanliness, appearance/aesthetic, and recreational use is to Campus Creek. The results of the valuation are below in **Figure 3.2.**

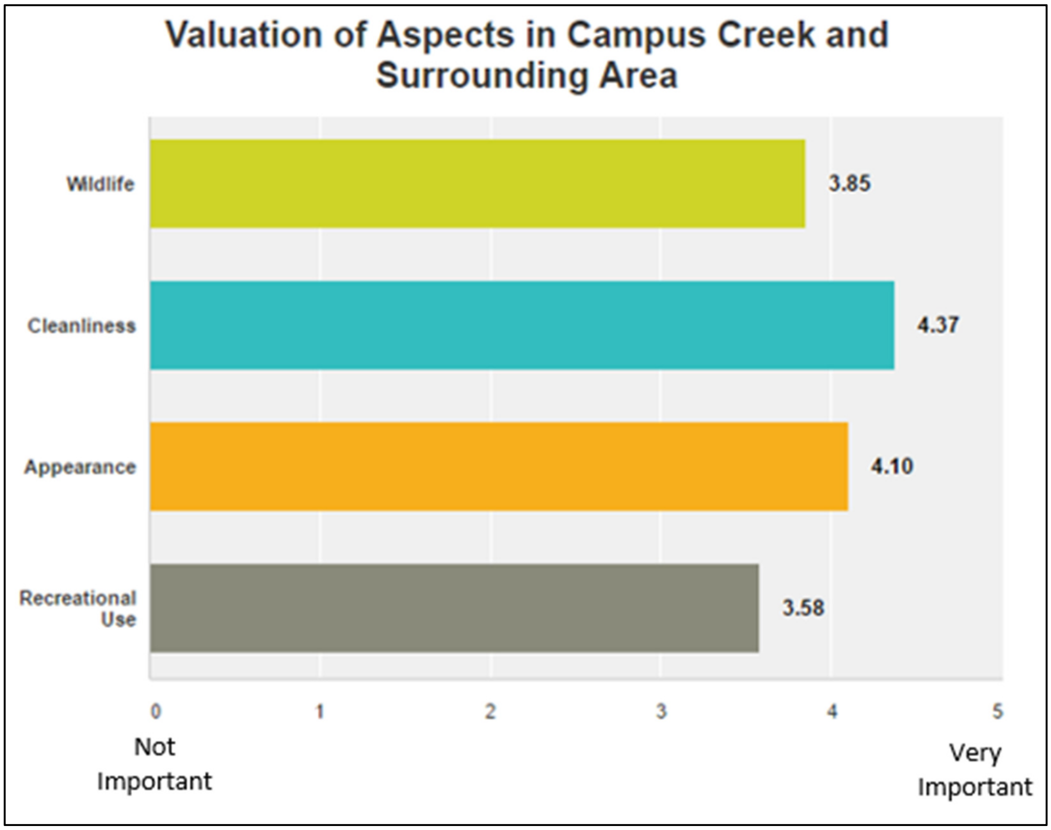

Figure 3.2: Valuation of aspects in Campus Creek and surrounding area

In order for there to be changes made in regards the area, a value must first be assigned to it. Once there is a value to the aspect, it can be seen as a public good which will aid economists or decision makers in identifying which issues are most important to pursue, and which aren't in immediate danger (Helm & Hepburn, 2012). According to respondents, the most valuable aspect is cleanliness, which has an average score of 4.37. The second most valuable aspect is the appearance and aesthetic of the creek, with a score of 4.10. The third most valuable aspect is the presences of wildlife, 3.85, and the least important to respondents was recreational use.

Lastly, participants were asked to describe the creek in three words or less. Of the 113 total survey responses, 86 responded to this specific question, however due to inappropriate content only 61 responses were usable. Common phrases and words included "unappealing," "disappointing," "dirty," "needs improvement," "has potential," "not aesthetically pleasing," "overgrown/unmaintained," "polluted/trash-filled," "inaccessible," and "not easily identified." These negative comments could be due to the degraded state of Campus Creek, which is subject to "urban creek syndrome" as a result of the run-off from buildings, parking lots and other water sources (Booth et al, 2016).

Land Use Change

Since the creek was first constructed, not many changes have occurred in where it was originally dug. Some buildings were constructed within only 50 feet of the creek's original banks; therefore erosion off the banks is of concern. Erosion is mainly controlled by trees and shrubs along the banks; the roots of trees and shrubs reinforce the sides so they can withstand the various amounts of water flowing through the creek. In the 1920s, these trees were planted by

Dr. Leon Quinlan and the area between the dorms and the creek was named the Quinlan Natural Area. Other than the planting of trees and construction of buildings near the creek, the actual creek has remained virtually the same.

Watershed Hydrology

The WinTR-55 output data from the three different land cover conditions yielded peak flow and peak time for two-three 24 hour storm return periods. A 100 year, 24 hour storm event could not be modeled using WinTR-55 as it exceeded the fundamental requirements for the structures. A 100 year return period storm was still ran for predevelopment land cover conditions to provide an interesting comparison to existing and built-out conditions. All results for peak flow and peak time are listed in **Table 3.1**. Hydrographs for each scenario are compared to each other in **Figures 3.3 & 3.4.**

Table 3.1: Peak flow and peak time for specified land cover conditions and storm events.

Condition	24 hr Storm Event	Peak Flow (cfs)	Peak Time (hr)
Predevelopment	**10 yr**	773	12.33
	50 yr	1180	12.33
Existing	**10 yr**	1455	12.14
	50 yr	1880	12.14
Built-Out	**10 yr**	1494	12.14
	50 yr	1911	12.14

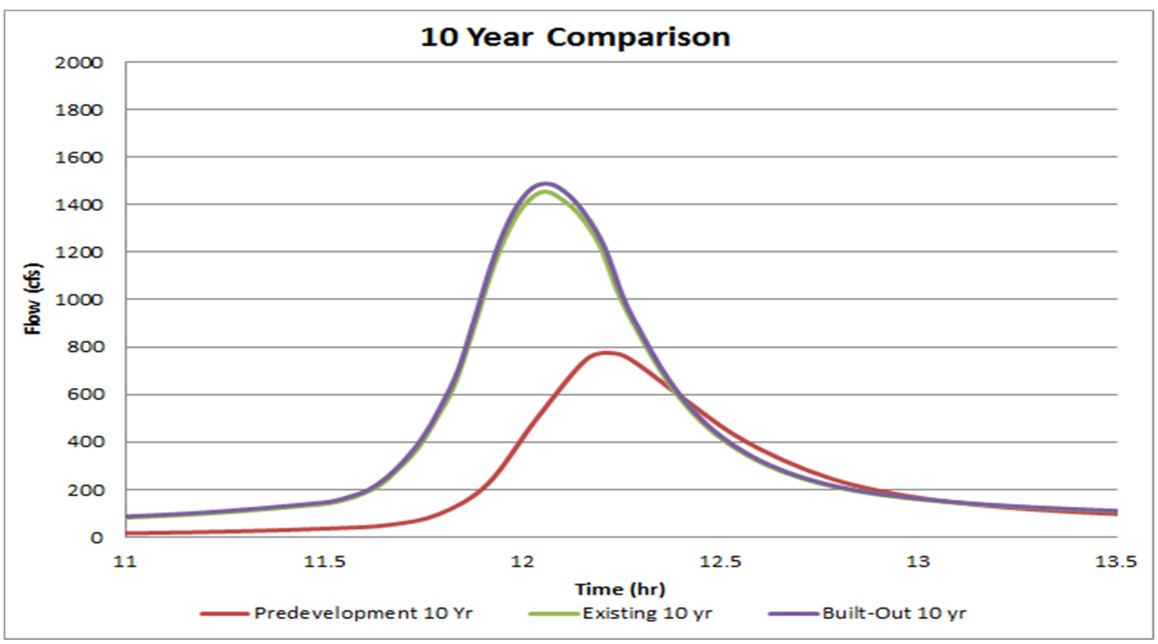

Figure 3.3: Hydrographs for the three land cover scenarios with 10 year storm events

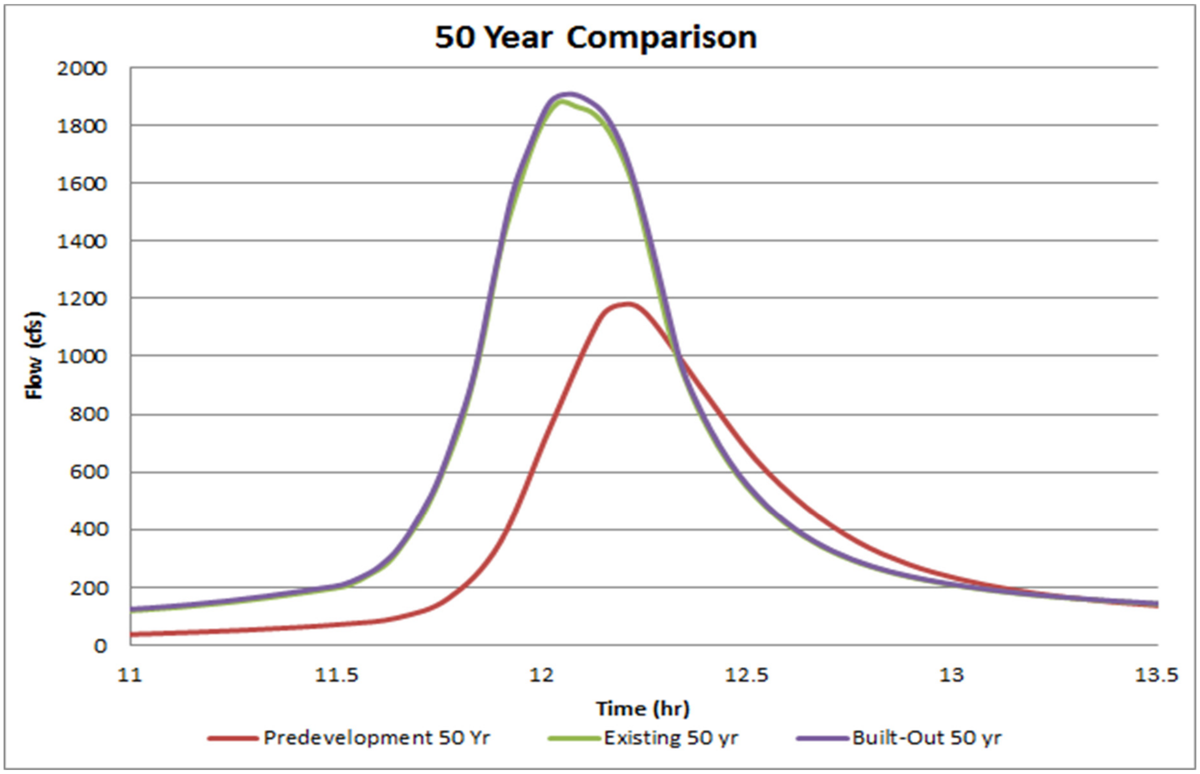

Figure 3.4: Hydrographs for the three land cover scenarios with 50 year storm events

As is shown in the table and hydrographs above, the development of Kansas State University's Manhattan campus has significantly increased the peak runoff for the Campus Creek Watershed. The peak runoff for a 10 yr - 24 hr rainfall event has increased by almost 100% from pre development to current conditions and by 50% for a 50 yr - 24 hr event. The continued development of the watershed will further increase the peak runoff by 2-3%, indicating that the area is nearing the maximum peak runoff potential for the watershed. This can be seen in the aerial images of the region from the Land Use section above that show a landscape with very high percentages of impervious surface area in the form of parking lots and building roof tops. These surfaces do not allow water to infiltrate into the soil and have a much lower friction coefficient which is the reason why they contribute greatly to an increase in peak discharge for small watersheds such as Campus Creek.

High runoff rates typically correlate with higher velocities and therefore a higher erosion potential, as well as contamination from nonpoint pollution sources such as lawn fertilizers and road salts. This additional flow into Campus Creek could lead to flood damage and may have detrimental effects on the water chemistry of the creek, leading to loss of ecosystem quality and services.

Some potential solutions to the increase in peak runoff of the watershed have been proposed. One such proposal was made by a group of K-State students in conjunction with faculty from the department of Biological and Agricultural Engineering and Landscape Architecture. Their study focuses on the Strong Dormitory Complex and Quinlan Natural Area in Sub-Area 3 and proposed the construction of a number of runoff mitigating technologies outlined in **Figure 3.5.** Their study found that these instalments would yield a "46% Reduction in runoff volume during the 1.1" water quantity storm event" (McDonough *et al.* 2016). However, this number is just for the relatively small sub watershed of that complex. When equivalent runoff reducing numbers were inputted into the WinTR-55 model of the upper Campus Creek watershed, it was found only a 0.2% reduction in peak discharge of the system. This shows the importance of a comprehensive plan across the entire campus is needed to make a significant reduction in flooding.

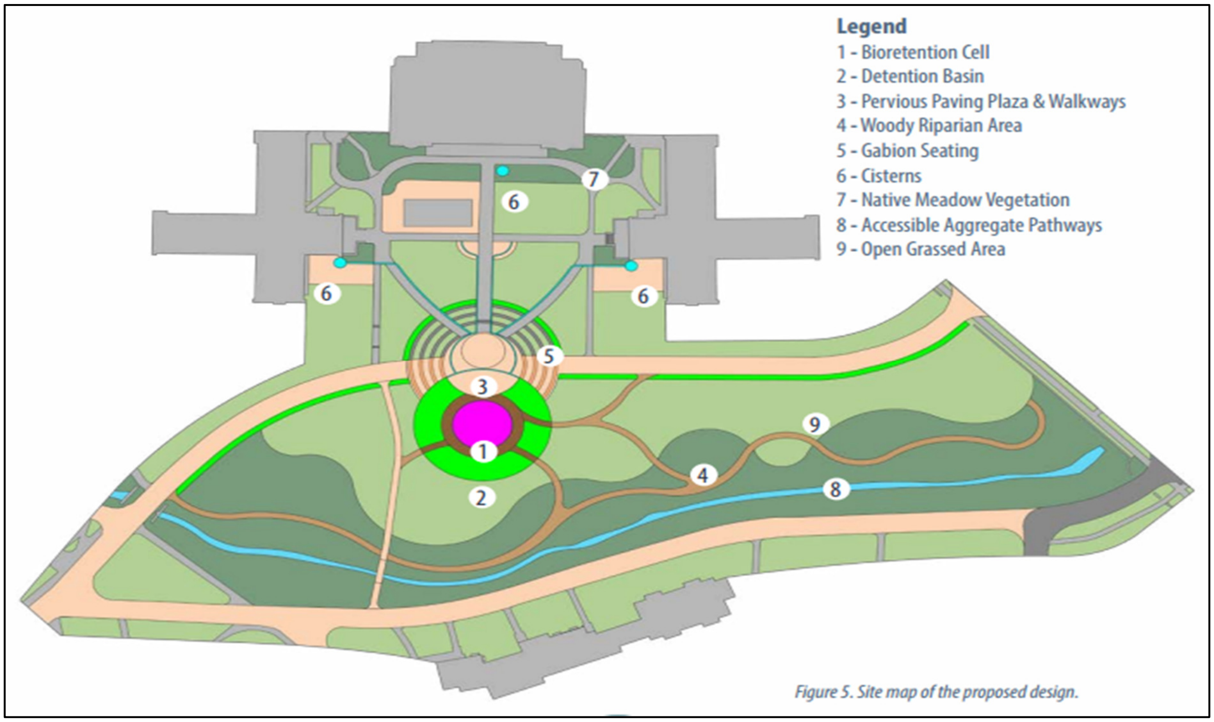

Figure 5. Site map of the proposed design.

Figure 3.5: Proposed design to reduce runoff from Strong Complex (McDonough *et al.* 2016).

Water Quality

Analysis of water quality showed several trends as the stream progressed. From location 1 to location 3, pH decreased and conductivity increased on all sample dates (**Figure 3.6 & 3.7**). This indicates the water is becoming more acidic and that more ions are present as the stream travels from Claflin Road to the edge of K-State's campus. This effect could be due to increased organic matter, however it is most likely due to contaminants entering from roadways and rooftops. Although the water is becoming more acidic, the average pH was 8.08 indicating the creek meets the EPA's pH freshwater guidelines of between 6.5-9 (National recommended water quality criteria - aquatic life criteria table).

The turbidity of water was trending towards an increase from location 1 to location 3 (**Figure 3.8**). However, precipitation was the main factor influencing turbidity as large precipitation events led to increased turbidity. Overall, the stream is not turbid. Total solids were also trending towards an increase from location 1 to location 3 (**Figure 3.9**). These results could indicate an increase of organic matter, pollutants, or other substances as you move downstream.

In addition to pH, conductivity, turbidity, and total solids, dissolved oxygen was also assessed. Results showed oxygen levels met freshwater biological standards and could support fish, macro and macroinvertebrates (National recommended water quality criteria - aquatic life criteria). Dissolved oxygen data from sample day 1 was excluded because the sampling containers may have influenced results (**Figure 3.10**).

Generally, water quality of Campus Creek is meeting the minimum standards required for life as defined by the EPA (National recommended water quality criteria - aquatic life criteria table). However, the results indicate runoff from the parking lots, rooftops, or roadways could be influencing water quality. To correct this issue, vegetation surrounding the creek should be restored. Increased vegetation around a water system decreases the rate of contaminants entering (Huber et al., 2016). In addition to blocking pollutants, vegetation also provides benefits to the biological life within and around the creek, as well as ecosystem services to humans.

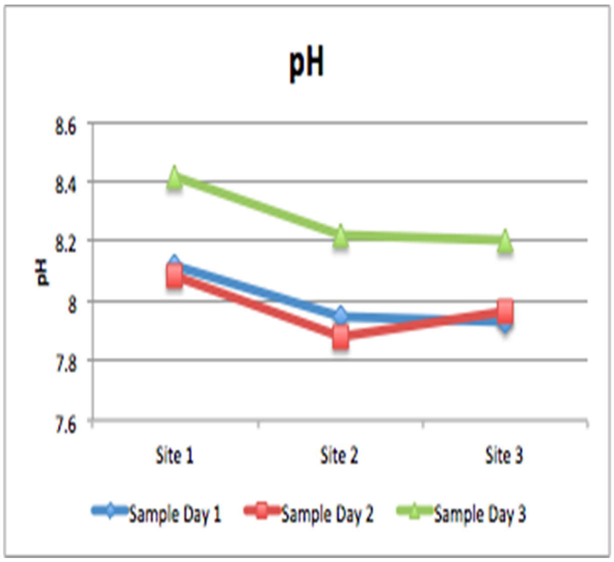

Figure 3.6: pH levels

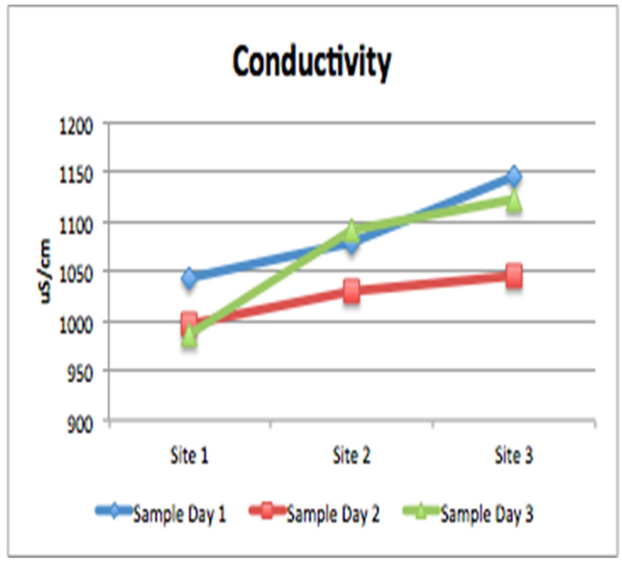

Figure 3.7: Conductivity levels

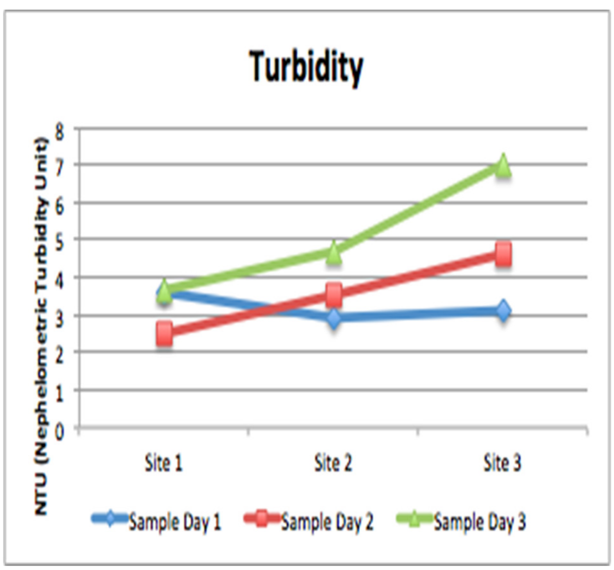

Figure 3.8: Turbidity

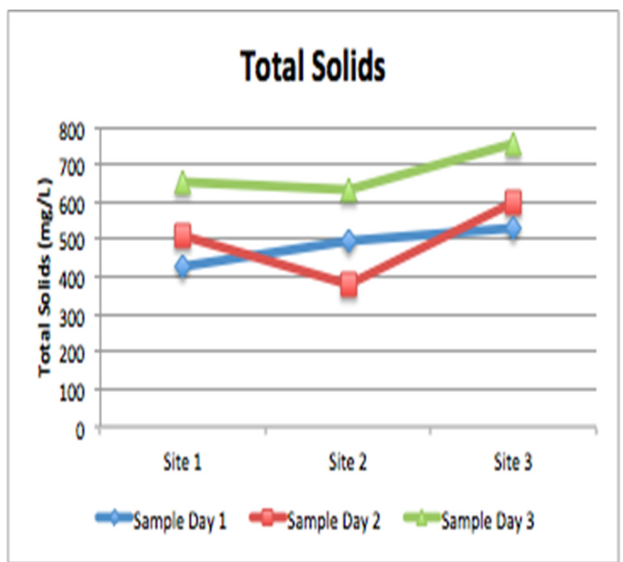

Figure: 3.9: Total Solids (TS)

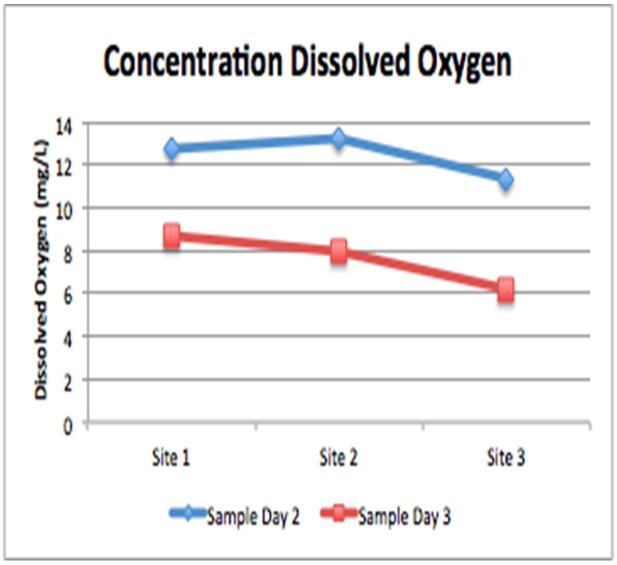

Figure 3.10: Concentration of Dissolved Oxygen (DO)

Riparian Tree Population

The data acquired in the study on the trees of Campus Creek (see **appendix 6.2**) was quite interesting; out of the 126 species recorded there is an impressive species diversity. There are at least 36 different species which fell under 16 different recorded families. The most dominant family is Fagaceae, the oak family, with 22 trees. Other prominent tree families near campus creek are Aceraceae with 10 trees, Cornaceae with 10 trees, Cupressaceae with 13 trees, Fabaceae with 11 trees, and Platanaceae with 10 trees. While there is a large amount of species diversity, the average DBH of Campus Creek trees is 20.6 inches. This number is higher than expected due mostly to a lack of small, young trees. The average crown width is 472.9 inches. This continues to show that there is a greater amount of larger trees compared to the number of young ones. This is of great concern as many of these large, old trees show signs of wood rot and other damages meaning that their years may be limited. Another concern is the approaching threat to Ash trees, the Emerald Ash Borer. This invasive species is rapidly spreading across North America, killing most of the ash trees in its path. When they get here, if the trees are not treated, it will kill most if not all of the Ash trees (Nisbet et al., 2015). Once some of these old trees fall, it is important that there are more trees growing to take their place.

The ground cover created by the foliage of trees is tremendous. If the crown width is used to create circles to represent the foliage cover of the trees as seen in **Figure 3.11**, the area covered is approximately 2,372,617 square feet. This amount of coverage makes a huge difference in the creek's ecosystems, as well as its aesthetics. The foliage provides a habitat for countless organisms, it keeps the area shaded, causing cooler temperatures in the water and soil, it provides shelter from rainfall, and when the leaves drop in the fall it adds large amounts of organic matter to the ground.

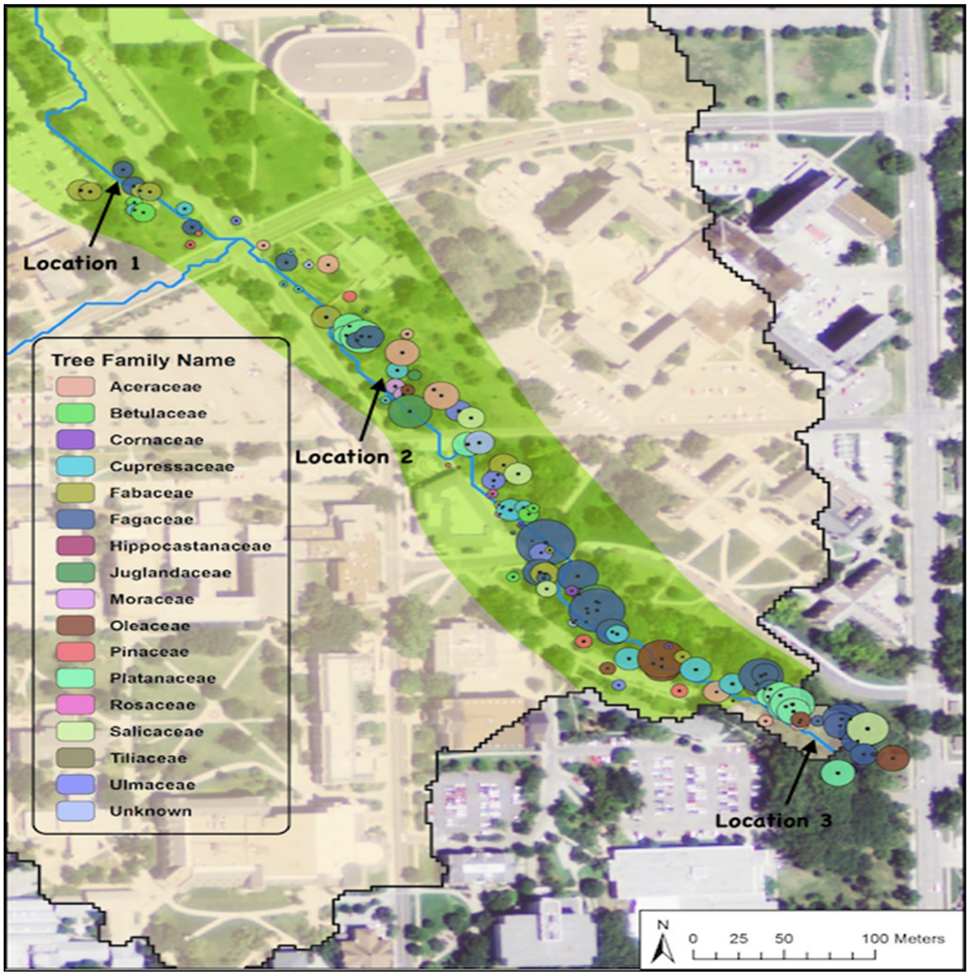

Figure 3.11: Map of trees along campus creek coded by family name

To look into the effect of trees on Campus Creek's water quality, data in **table 3.3** showing all the trees within a 50 meter radius of each water sampling location was compared with the data from **figures 3.6, 3.7, 3.8, 3.9,** and **3.10** showing the changes in pH, conductivity, turbidity, concentration dissolved oxygen, and total solids. In a 1968 study on leaf fall's effect on water quality, an increase in leaf fall led to a decrease of pH and dissolved oxygen and an increase in conductivity (Slack and Feltz, 1968). This trend may be the same with Campus Creek's water quality. **Table 3.3** shows that there is an increasing number of trees at each location. **Figure 3.10** shows the concentration dissolved oxygen decreases, **Figure 3.6** shows that the pH decreases, and **Figure 3.7** shows that conductivity increases. These changes give evidence that the tree population might impact the water quality.

In order to look into the effect of trees on Campus Creek's fish populations, data in **Table 3.3** showing all the trees within a 50 meter radius of each fish sampling location was compared with the data from **Table 3.4** showing the results of the fish sampling conducted at each location. Before the study, it was expected that the locations with more trees would foster a habitat that supported more fish. The results were not expected to show drastic changes based on trees, but minor differences were anticipated.

Location 1 ended up having the most fish, but not the most diversity in species of fish even though it had the least trees. Location 2 had no fish, but the second most trees. Location 3 had less fish than location 1 did, but it had more species diversity and it had the most trees. One possible explanation as to why location 2 did not have any fish could be the allelopathic traits common in trees in the Juglandaceae family as well as the Ulmaceae family. There were trees in both these families at location 2, while there were none at either of the other locations. It is possible that the fish have trouble living around these allelopathic trees and stay away from this section of the creek. The greater diversity in species as well as lower total population in location 3 compared to location 1 could possibly be explained by the trees. If fish are able to hide within roots and such, there is a higher likelihood of having a more diverse ecosystem with predators present. Predators would keep the populations of the prey under control. In a setting with fewer trees, the fish may have nowhere to hide causing the predators to not be able to sustain themselves and therefore limiting diversity as well as letting species lower on the food chain's populations grow.

Table 3.3: Tree populations within 50 meter radius of the three sample locations

Location	Family	Number of Trees
1	Betulaceae	2
	Cupressaceae	2
	Fabaceae	4
	Fagaceae	2
	Total	**10**
2	Aceraceae	4
	Cupressaceae	2
	Fagaceae	2
	Juglandaceae	2
	Moraceae	2
	Oleaceae	1
	Platanaceae	3
	Ulmaceae	1
	Total	**17**
3	Aceraceae	2
	Fagaceae	8
	Oleaceae	2
	Platanaceae	6
	Salicaceae	1
	Total	**19**

Ichthyology

Location 1

This location is closest to the headwaters of the stream. At this location, two different species of fish were found. The first and most abundant species was the Fathead Minnow. There seemed to be one school of this species thriving in the deepest part of the first location. Approximately 75-100 specimens mainly inhabiting a 50 square foot area. The school stayed in the deep part of the cut formed by the water coming out of the drainage pipes during heavy rainfall.

The second species found at this location was Creek Chub; four Creek Chub were seen in the deepest part of the pool. They were staying close to the school of Fathead Minnows and in a way herding them around. The Chub were approximately three inches long with the Fathead Minnows being half that size. They stayed in about a 5x10' area at location one.

Location 2

The second determined location was more difficult to analyze. At this specific location no aquatic life was visually identified. The size of the pool was approximately 10' x 20' and around 3' deep. This would be great habitat for larger school of Minnows and Chub as it is a much larger area than the first they were visually seen. One contributing factor that could be a reason for the lack of specimens is allelopathic traits. These traits are common in the Juglandaceae and Ulmaceae families of trees. It is possible this could be an influencing factor in the water quality, therefore, the lack of aquatic life in that area.

Location 3

The final location was much more analysis friendly due to the water clarity and depth. It was similar to the first location, however wider and not as deep. The abundance in numbers were not as impressive as location one, however, the diversity in species was. Three different species of fish were visually documented at location three. The first two species were those documented at location one: Fathead Minnow and Creek Chub. There were approximately 15-20 Fathead Minnows and 5-10 Creek Chub recorded. The new species visualized at this location was Bluegill. Three Bluegill were viewed in a specific area at location three. They were also coming into close contact with the other schools of fish. With the Bluegill being larger, approximately 3-4", it appeared as if they were herding the other schools of fish.

For the health and size of campus creek, it was impressive to have viewed diversified species and numbers of aquatic life. If physical samples were taken, presumably two or three more species would likely have been found living in Campus Creek. With the fluctuation of water elevation and flow, multiple specimens may be washing in and out of the creek section at any time.

Table 3.4: Fish sampling results

Location	Fish Species	Population
1	Fathead Minnow	75-100
	Creek Chub	4
2	None	None
3	Fathead Minnow	15-20
	Creek Chub	5-10
	Bluegill	3

Campus Creek restoration has been a viable discussion point for years now. The lack of attention it has been given is having detrimental effects on not only the aesthetic aspect of the creek, but also the habitat and living conditions for the species that call it home. There are many things that could be done that would make the creek flowing through K-State's campus a great ecosystem for numerous species. However, it will require a lot of money and man hours. In the future, further analysis and comprehensive sampling of campus creek should be completed. Physical samples would reveal the true number of species thriving in the creek and how the fluctuation in water elevation and flow affects their quality of life.

4. Conclusion

Data from this project indicates there is much room for improvement in the areas surrounding Campus Creek. There is currently a negative stigma surrounding Campus Creek, evident from the lackluster words used to describe it; with the improvement of the creek, the stigma will change and the area will become a well-regarded icon to campus. With the results of the survey conducted, it is evident there needs to be more attention brought to Campus Creek and the surrounding area. Kansas State University currently has a plan to improve Campus Creek called "Stronger Quinlan" (McDonough *et al*, 2016). The current state of the creek is approaching poor. The plan states many problems such as poor water quality, unmaintained banks, and invasive species. The watershed creates frequent flash flooding which increases channel erosion. Many of these issues were also identified by our research group.

According to McDonough *et al.* (2016), the project seeks to repair the ecosystem's health and provide flood mitigation services along the creek. They plan to disconnect the upper watershed from the creek and store the water for a brief amount of time on-site. This upper watershed is where Boyd, Van Zile, and Putnam residence halls are located. Three 10,000 gallon tanks will be placed near the residence halls to collect roof runoff from those three buildings to relieve the creek of water that is otherwise piped directly to the creek. The water collected by the Van Zile tank will be kept and used for the use of irrigation which will reduce the amount of water demand from the City of Manhattan. The Boyd and Putnam tanks will slowly release the water they contain to an interactive water plaza located in front of the residence halls. Once the water passed through the plaza it will then be released into the storm drains.

By containing water from that watershed, it is believed that the health of the creek will be improved and also make the area more visually appealing by adding a fountain for the water to pass through before being released to the storm drain.

If the plan is successful in improving Campus Creek and surrounding area, the types of activities outlined in the ecosystem service survey will increase in usage for both students and faculty. The "Stronger Quinlan" plan, as stated above, aims to improve the quality of stream banks, which in turn will lead to an elevated level of user perception as the area will be more aesthetically pleasing and easier to access.

To improve the quality of Campus Creek, we recommend the vegetation surrounding the creek be restored in addition to land use changes enacted to prevent flash flooding and pollution to the water system. Restoring vegetation is vital as trees are extremely beneficial to the creek's health as well as a recreational asset. Vegetation could be utilized to reduce erosion and stabilize the soil. This would increase water quality and provide necessary habitats for aquatic life. Improved land-use would decrease max flow, prevent pollutants from entering the system, and improve quality of the ecosystem. All of these changes combined would lead to increased ecosystem services, making them beneficial to students and fish alike.

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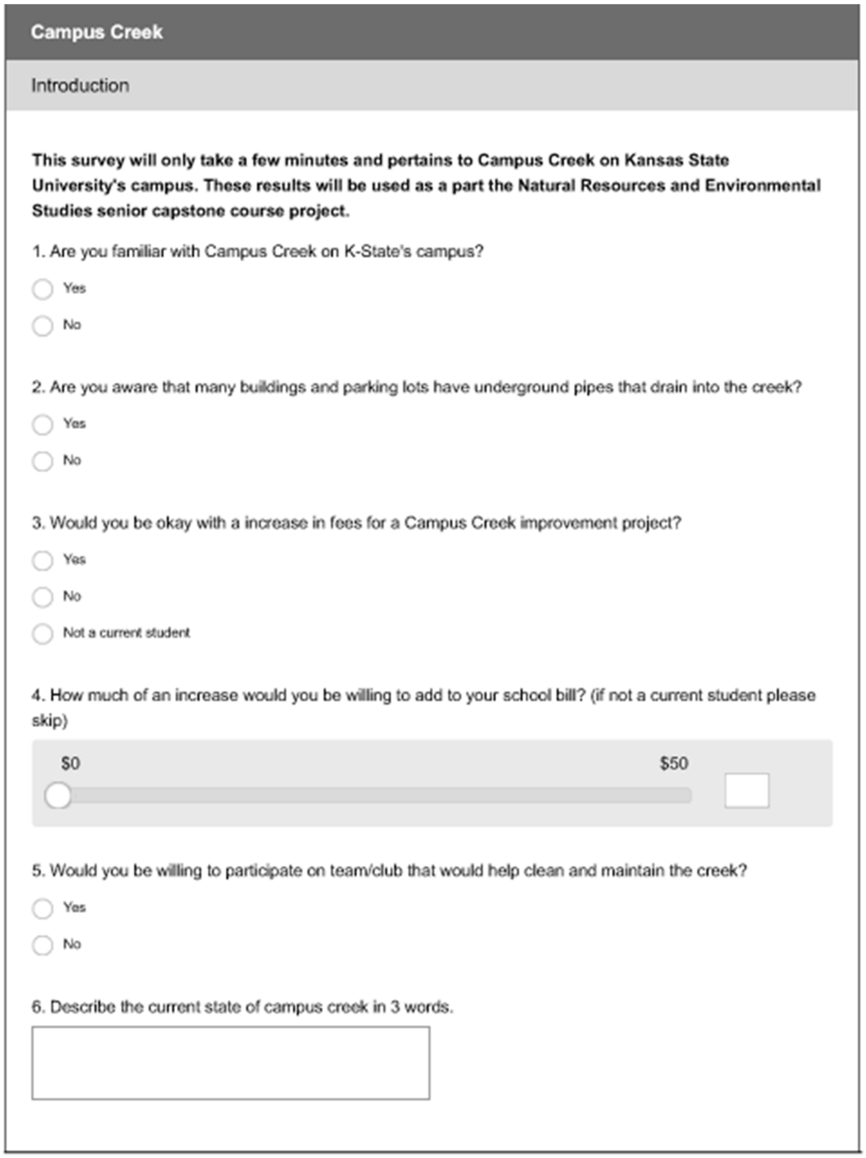
6. Appendix

Appendix 6.1: Campus Creek Survey



Campus Creek

Introduction

This survey will only take a few minutes and pertains to Campus Creek on Kansas State University's campus. These results will be used as a part the Natural Resources and Environmental Studies senior capstone course project.

1. Are you familiar with Campus Creek on K-State's campus?

- Yes
- No

2. Are you aware that many buildings and parking lots have underground pipes that drain into the creek?

- Yes
- No

3. Would you be okay with a increase in fees for a Campus Creek improvement project?

- Yes
- No
- Not a current student

4. How much of an increase would you be willing to add to your school bill? (if not a current student please skip)

$0 $50

5. Would you be willing to participate on team/club that would help clean and maintain the creek?

- Yes
- No

6. Describe the current state of campus creek in 3 words.

Appendix 6.1 Cont: Campus Creek Survey

7. Uses of Campus Creek

	I currently partake	I do not partake	I would partake/partake more if improved
Hammocking			
Relaxing in area			
Walking in area for leisure			
Class projects			
Nature watching			
Photography			
Picniking			

8. How important are the following to you in the Campus Creek area?

	Not Important		Indifferent		Very Important
Wildlife					
Cleanliness					
Appearance/Aesthetic					
Recreational Use (benches, walking paths, etc)					

9. Affiliation to Kansas State University

- Former student
- Current student
- Faculty/staff
- Other

Appendix 6.1 Cont: Campus Creek Survey

Appendix 6.2: Tree Population Data

Species	Family	Trunk Circumference in inches	Trunk Diameter (DBH) in inches	Crown Width (inches)	Latitude	Longitude
Silver Maple	Aceraceae	29	9.2	288	39.194466	-96.580489
Red Maple	Aceraceae	63	20.1	480	39.194341	-96.58008
Norway Maple	Aceraceae	44	14	288	39.193884	-96.579592
Silver Maple	Aceraceae	96	30.6	744	39.193766	-96.579627
White Maple	Aceraceae	99	31.5	776	39.193485	-96.579388
Boxelder	Aceraceae	16	5.1	204	39.192027	-96.57858
Sugar Maple	Aceraceae	48	15.3	588	39.191547	-96.577698
Silver Maple	Aceraceae	5	1.6	60	39.191486	-96.577597
Silver Maple	Aceraceae	50	15.9	324	39.191354	-96.577394
Silver Maple	Aceraceae	39	12.4	432	39.191339	-96.577179
River Birch	Betulaceae	40	12.7	360	39.194758	-96.581301
River Birch	Betulaceae	60	19.1	535	39.194692	-96.581246
Black Alder	Betulaceae	23	7.3	152	39.194043	-96.579851
River Birch	Betulaceae	38	12.1	456	39.192714	-96.578857
River Birch	Betulaceae	20	6.4	264	39.19275	-96.578825
Black Alder	Betulaceae	38	12.1	276	39.192313	-96.57897
Dogwood	Cornaceae	21	6.7	168	39.192643	-96.578909
Dogwood	Cornaceae	15	4.8	172	39.192543	-96.578841
Dogwood	Cornaceae	28	8.9	276	39.192016	-96.578514
Dogwood	Cornaceae	15	4.8	348	39.192192	-96.57855
Dogwood	Cornaceae	12	3.8	120	39.192192	-96.57855
Dogwood	Cornaceae	17	5.4	276	39.192195	-96.578549
Dogwood	Cornaceae	20	6.4	288	39.192217	-96.5786
Dogwood	Cornaceae	15	4.8	192	39.192136	-96.578427
Dogwood	Cornaceae	18	5.7	324	39.191771	-96.578249
Dogwood	Cornaceae	8	2.5	180	39.191849	-96.577994
Bald Cypress	Cupressaceae	56	17.8	357	39.194709	-96.581302
Bald Cypress	Cupressaceae	60	19.1	364	39.194712	-96.580982
Bald Cypress	Cupressaceae	19	6.1	173	39.194421	-96.580315
Bald Cypress	Cupressaceae	20	6.4	175	39.194224	-96.580369
Bald Cypress	Cupressaceae	21	6.7	200	39.19419	-96.580274
Bald Cypress	Cupressaceae	64	20.4	480	39.193653	-96.579663
Bald Cypress	Cupressaceae	25	8	216	39.193463	-96.579744
Bald Cypress	Cupressaceae	122	38.9	612	39.192743	-96.578972
Bald Cypress	Cupressaceae	61	19.4	396	39.192757	-96.578887
Bald Cypress	Cupressaceae	88	28	492	39.191934	-96.57832

Bald Cypress	Cupressaceae	92	29.3	636	39.191771	-96.578249
Bald Cypress	Cupressaceae	106	33.8	684	39.191692	-96.577826
Bald Cypress	Cupressaceae	108	34.4	576	39.191596	-96.577597
Honey Locust	Fabaceae	131	41.7	576	39.194843	-96.581642
Honey Locust	Fabaceae	101	32.2	508	39.194833	-96.58158
Kentucky Coffeetree	Fabaceae	56	17.8	388	39.194833	-96.581263
Kentucky Coffeetree	Fabaceae	58	18.5	512	39.194824	-96.5812
Honey Locust	Fabaceae	115	36.6	637	39.194006	-96.580104
Redbud	Fabaceae	15	4.8	200	39.192896	-96.579076
Redbud	Fabaceae	11	3.5	200	39.192777	-96.579044
Kentucky Coffeetree	Fabaceae	78	24.8	636	39.193031	-96.579005
Honey Locust	Fabaceae	93	29.6	624	39.19233	-96.578767
Redbud	Fabaceae	44	14	192	39.192481	-96.578731
Black Locust	Fabaceae	45	14.3	360	39.191776	-96.577909
Red Oak	Fagaceae	73	23.2	456	39.19497	-96.581366
Red Oak	Fagaceae	77	24.5	516	39.194863	-96.581302
Red Oak	Fagaceae	85	27.1	425	39.194592	-96.580939
Willow Oak	Fagaceae	81	25.8	480	39.194361	-96.580345
White Oak	Fagaceae	101	32.2	464	39.19385	-96.579913
White Oak	Fagaceae	96	30.6	630	39.193872	-96.579832
White Oak	Fagaceae	132	42	1296	39.192529	-96.578755
White Oak	Fagaceae	108	34.4	749	39.192339	-96.578799
Chinkapin Oak	Fagaceae	75	23.9	312	39.192302	-96.578775
Chinkapin Oak	Fagaceae	99	31.5	900	39.19231	-96.578559
Burr Oak	Fagaceae	99	31.5	1218	39.192088	-96.578443
White Oak	Fagaceae	86	27.4	720	39.191948	-96.57835
Black Oak	Fagaceae	125	39.8	972	39.191643	-96.577412
Black Oak	Fagaceae	78	24.8	588	39.191654	-96.577385
Black Oak	Fagaceae	78	24.8	528	39.191557	-96.577356
Burr Oak	Fagaceae	20	6.4	303	39.191347	-96.577061
Black Oak	Fagaceae	99	31.5	876	39.191356	-96.576854
Chinkapin Oak	Fagaceae	104	33.1	840	39.191357	-96.576909
Red Oak	Fagaceae	86	27.4	720	39.191314	-96.576918
Red Oak	Fagaceae	80	25.5	696	39.191213	-96.576812
American Beech	Fagaceae	73	23.2	600	39.191128	-96.576775
Burr Oak	Fagaceae	15	4.8	120	39.191126	-96.576713
Buckeye	Hippocastanacea	39	12.4	360	39.192101	-96.578508
Buckeye	Hippocastanacea	53	16.9	336	39.192101	-96.578508
Buckeye	Hippocastanacea	42	13.4	372	39.192072	-96.578502

Pecan	Juglandaceae	81	25.8	944	39.193388	-96.579592
Hickory	Juglandaceae	Unknown	Unknown	300	39.193619	-96.579554
Pecan	Juglandaceae	108	34.4	936	39.192144	-96.578444
Mulberry	Moraceae	89	28.3	430	39.19355	-96.579679
Mulberry	Moraceae	109	34.7	430	39.193497	-96.57963
Mulberry	Moraceae	110	35	320	39.193524	-96.579434
Ash	Oleaceae	34	10.8	300	39.193524	-96.5796
Ash	Oleaceae	15	4.8	204	39.192766	-96.579017
Ash	Oleaceae	34	10.8	360	39.191711	-96.578388
Ash	Oleaceae	68	21.7	576	39.191736	-96.578097
Ash	Oleaceae	97	30.9	828	39.191716	-96.578042
Ash	Oleaceae	102	32.5	1068	39.191766	-96.578041
Ash	Oleaceae	60	19.1	432	39.191357	-96.57717
Ash	Oleaceae	84	26.8	720	39.191098	-96.57659
Spruce	Pinaceae	Unknown	Unknown	156	39.19455	-96.580899
Pine	Pinaceae	51	16.2	224	39.19448	-96.580953
Spruce	Pinaceae	Unknown	Unknown	300	39.194136	-96.579949
Spruce	Pinaceae	Unknown	Unknown	120	39.193038	-96.579359
Spruce	Pinaceae	Unknown	Unknown	84	39.193021	-96.579293
Pine	Pinaceae	72	22.9	372	39.191891	-96.578535
Cedar	Pinaceae	60	19.1	372	39.191558	-96.577936
Sycamore	Platanaceae	95	30.3	706	39.193944	-96.579958
Sycamore	Platanaceae	94	29.9	576	39.193883	-96.579979
Sycamore	Platanaceae	114	36.3	934	39.193876	-96.579885
Sycamore	Platanaceae	120	38.2	672	39.193169	-96.57923
Sycamore	Platanaceae	104	33.1	744	39.191011	-96.576944
Sycamore	Platanaceae	61	19.4	528	39.191509	-96.577372
Sycamore	Platanaceae	102	32.5	744	39.191516	-96.577293
Sycamore	Platanaceae	98	31.2	804	39.191444	-96.577261
Sycamore	Platanaceae	135	43	984	39.191457	-96.577219
Sycamore	Platanaceae	113	36	732	39.191411	-96.577214
Plum	Rosaceae	20	6.4	220	39.19285	-96.579081
Plum	Rosaceae	8	2.5	152	39.192834	-96.5791
Plum	Rosaceae	16	5.1	216	39.192719	-96.57904
Cottonwood	Salicaceae	104	33.1	600	39.193338	-96.579203
Willow	Salicaceae	92	29.3	612	39.192973	-96.578915
Willow	Salicaceae	60	19.1	456	39.192232	-96.578758
Cottonwood	Salicaceae	149	47.5	920	39.191291	-96.576745
American Linden	Tiliaceae	60	19.1	600	39.191588	-96.577444

American Linden	Tiliaceae	64	20.4	564	39.19156	-96.577389
Elm	Ulmaceae	31	9.9	233	39.194627	-96.580657
Elm	Ulmaceae	132	42	576	39.193384	-96.579279
Elm	Ulmaceae	21	6.7	250	39.192757	-96.579027
American Elm	Ulmaceae	76	24.2	480	39.192971	-96.579044
American Elm	Ulmaceae	89	28.3	516	39.192934	-96.579073
Elm	Ulmaceae	63	20.1	516	39.192465	-96.578786
Elm	Ulmaceae	18	5.7	307	39.191603	-96.578321
Unknown	Unknown	19	6.1	222	39.194343	-96.580203
Unknown	Unknown	11	3.5	120	39.192596	-96.578962
Unknown	Unknown	100	31.8	650	39.193178	-96.579156
Unknown	Unknown	19	6.1	228	39.192011	-96.578597