Exploration of Land Cover Correlations to Water Quality Within the Antietam Creek Watershed: A Case Study

Brandon Duxbury
Kevin Eaton
Kristen Kitchen
Katie Springman

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ABSTRACT

Land cover and land use from 2006 in twenty-one sub basins throughout the Antietam Creek Watershed (753.75 km^2) was assessed for possible correlations to 2011 water quality parameters of temperature, dissolved oxygen, nitrate concentration, phosphate concentration, and turbidity. Individual delineations of drainage basins were created with the USGS StreamStats online tool then imported into GIS software for land cover analysis for the entire basin, and 90 meter riparian buffer zones within the drainage basin. Statistical analysis was performed on the compiled land cover statistics in combination with water quality data obtained for each collection site. Utilizing IBM's statistics software SSPS, a Shapiro-Wilk test for normality was performed prior to executing Pearson and Spearman correlation tests for three major land cover contributors: urban, forest, and agriculture. Statistical analysis found inverse correlations between forested land cover and nitrates and turbidity. Positive correlations were observed between agricultural land cover in relation to nitrates and turbidity. Urban land cover displayed positive associations with temperature and nitrates while an inverse correlation was observed with dissolved oxygen.

INTRODUCTION

The Chesapeake Bay watershed, with the largest land area drained to volume water ratio in the world (2,742.86:1), is extremely sensitive to human impacts and pollution (Horton 2003). One of the most influential factors contributing to the impact on the Bay is land use / land cover throughout the watershed. Several studies have been conducted verifying the importance of regional land cover / land use in relation to water quality and stream health throughout the drainage basin, especially within riparian buffer regions (Roberts and Prince 2009, Teels *et al.* 2006, Claggett *et al.* 2010, Sprague *et al.* 2006, etc.). Three key land covers have been identified to have the largest impact on water quality: beneficial - forests, and detrimental – agricultural and urban.

Forested land cover is a primary classification given to any delineation of land (*i.e.* pixel, tract, parcels) that contains either evergreen forests, deciduous forests, or mixed forests as per the USGS Land Cover Institute's National Land Cover Database 1992 definitions (Land 2010), a derivative of the higher level Anderson land cover classification scheme (Anderson 1976). Forested land cover is beneficial to stream health and water quality for a variety of reasons. By far, the key benefit of forested land cover is the ability act as a natural filter for nutrient pollution (such as nitrogen and phosphorus) influxes into the waterways (Claggett *et al.* 2010, Orzetti *et al.* 2010, Sprague *et al.* 2006, Horton 2003). Forested riparian buffer zones, or areas of transition between the land and the stream, play an exaggerated role in removing sediment and particularly nutrient pollution; it has been found that hardwood riparian forests can remove up to 80 percent of phosphorus and nitrate from runoff (Boesch, Brinsfield, and Magnien 2001). Additionally, the physical vegetation and roots of a forested region provide a structure of support for soil, reducing the likelihood of erosion, therefore reducing suspended solid concentrations (turbidity), and sedimentation in the waterways (Claggett *et al.* 2010). Riparian forests provide summertime shade needed to keep small tributaries at a cool temperature, a necessity for the growth of certain microbes, and benthic macroinvertebrates - indicators of stream health, and necessary to the aquatic food chain (Invertebrates 2011, Orzetti *et al.* 2010, Vidon *et al.* 2010).

Agricultural land cover is a primary classification given to any delineation of land (*i.e.* pixel, tract, parcels) that contains pastures, row crops, small grains, fallow, or hay fields as per the USGS Land Cover Institute's National Land Cover Database 1992 definitions (Land 2010). Agricultural land cover has led to a variety of detrimental consequences. Removal of natural forested land cover greatly reduces the ability to filter nutrients and pollutants. Land tillage weakens the soil structure and greatly disturbs the smoothed natural micro topography, allowing runoff to carry increased amounts of sediment into streams. Farming techniques and practice have evolved into more self-contained, high-intensive, and mass production methods. These practices have increased the overall tonnage of nutrients – fertilizers, pesticides, herbicides – spread on agricultural lands; estimations of two to three times the quantity of 50 years ago (Horton, 2003). Additionally, the need to obtain as much production out of the land as possible has led to farming right up to stream bank edges, allowing no buffer zone for pollutant mitigation. With the removal of streamside forests for agricultural use, waters are subjected to increased insolation, warming their temperatures significantly, which also decreases the ability to hold dissolved oxygen. These modern farming practices have combined to significantly impair water quality within adjacent and downstream water bodies.

Urban land cover is a primary classification given to any delineation of land (*i.e.* pixel, tract, parcels) that contains low intensity residential (low density), high intensity residential (high density), and commercial/industrial/transportation regions as per the USGS Land Cover

Institute's National Land Cover Database 1992 definitions (Land 2010). An overarching definition of urban land cover, and one of the key factors in their ability to degrade water quality, stems from the abundance of impervious surfaces. Impervious surfaces are often linked to declines in the natural biotic operations in practically all types of environments (Kauffman and Brant 2000). Impervious surfaces greatly deteriorate the quality of water through a variety of manners. These environments increase the quantity of runoff (Stormwater 2011), leaving the waterways more susceptible to flooding, scouring, and therefore turbidity increases (Booth et al. 2002). Urban regions are sources of nutrient pollutions such as nitrogen and phosphorous (Russell *et al.* 2008), as well as various other types of pollution e.g. hormone, chemical, solid wastes, etc. The urbanization along streams disrupts the biodiversity in the waterway (Schueler 1994, Horton 2003), and like agriculture, subjects the water to increases in insolation as well as anthropogenic heating (urban heat island, power plant hot water, etc.). Previous studies have found coverage of as little as 10% impervious surface in a watershed can cause moderate to severe detrimental effects to the watershed (Schueler 1994), with much more damaging effects if urban land cover is experienced within (or bypassing through drainage pipes) riparian buffer zones (Roberts and Prince 2009, Teels *et al.* 2006).

Recent legislation, policies, and incentives regarding assessment and conservation of natural lands within the Chesapeake Bay Watershed fueled by the Bay and incoming water source's poor water quality and pollution concerns has led to the need for tributary monitoring and assessment for preventative measures. Easily discernible water quality parameters of temperature, nitrate concentrations, phosphate concentration, turbidity, and dissolved oxygen are made through governmental, institutional, and volunteer *in situ* measurements through a plethora of organizations (Alliance for the Chesapeake Bay, Chesapeake Bay Program, Renfrew Institute, state and national level EPA, etc.) throughout the entirety of the Chesapeake Bay Watershed.

The Antietam Creek Watershed represents a sub-watershed portion of the Chesapeake Bay Watershed under influence from these policies and incentives, and therefore is a reasonable candidate for assessment where results would be applicable. This study makes use of the data gathered by the Renfrew Institute to assess for relationships and statistical correlations between the three main land cover / land use types and the aforementioned water quality parameters within the Antietam Creek Watershed. Due to the information supplied in the reviewed literature, both total drainage basin land cover and riparian buffer zone land cover will be analyzed.

STUDY AREA

The case study analyzes the Antietam Creek Watershed, a sub-watershed located within the Chesapeake Bay Watershed, an area of 166,000 km^2 (Baker et. al. 2006) located throughout six states (Watersheds 2011) in the Mid-Atlantic region (Figure 1). The Antietam Creek travels approximately 27.4 kilometers (17 miles) through southern Pennsylvania and 59.5 kilometers (37 miles) through Maryland before discharging into the Potomac River. The area of the watershed basin is approximately 753.75 square kilometers (291 square miles), with 274 km^2 (106 mi^2) located in Pennsylvania, and 479 km^2 (185 mi^2) of the basin being located in Maryland ("Total" 2008). This study focuses on the northern portion of the watershed located in South-Central Pennsylvania.

Figure 1: This figure show the study area (highlighted in red) located within the Chesapeake Bay Watershed.

Basin wide land use within the entire Antietam Creek Watershed varies spatially, though large portions of forested and agricultural land use are prevalent. Within the watershed, forested land cover accounts for 31% of the total land area in the Maryland portion of the watershed, and 45% in the Pennsylvania portion of the watershed. Agricultural land cover accounts for 28% of the total land in the Maryland part of the watershed and 35% of the land in the Pennsylvania part. In Maryland, 27% of the Antietam Creek Watershed’s total area is urban, while only 11% of the land within the watershed is urban in Pennsylvania (“Total" 2008).

METHODS

The metrics assessed in this project were gathered from a variety of sources. The HUC 11 Database produced by the U.S. Geological Survey provided the boundary data for the Antietam Creek Watershed (HUC 2011). Waterway delineations within the watershed were obtained from the National Hydrography Dataset (U.S. 2011). The metrics utilized to evaluate the land cover patterns in this study were obtained from the Chesapeake Bay Land Cover Data [CBLCD], a subset of the U.S. Geological Survey Data Series produced in 2006 (Irani and Claggett, 2010). Antietam Creek stream quality data were obtained for 2011 through the Renfrew Institute for Cultural and Environmental Studies. These data were collected through volunteer services at twenty-two locations throughout the upper portion of the watershed (Figure 2). The Alliance for Aquatic Resources Monitoring (ALLARM) at Dickinson College provides volunteers with the training necessary to ensure adequate and reliable measurements are taken in the field. ALLARM also oversees volunteers to confirm collected data are consistent with expected and other observed measurements.

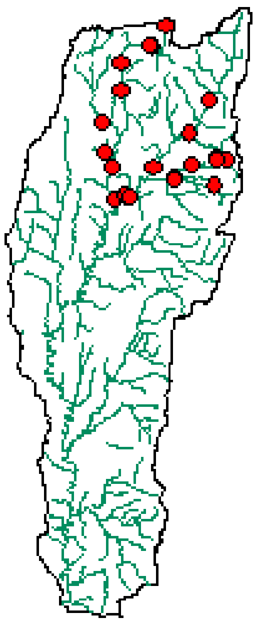

Figure 2: This figure displays the study area with the locations of Renfrew volunteer stream quality data collections.

In order to assess the influences of land cover on the stream at each of the twenty-two data collections points, the upstream drainage basins at that point needed to be defined. Although this process can be completed in GIS programs, the drainage basin delineations were obtained through the U.S. Geological Survey StreamStats® tool (USGS 2011). Ease of use, and researcher familiarity with the tool led to the decision to create the basins with StreamStats®. The resulting basins from the tool are easily exported in a usable format for many GIS platforms for advanced analysis.

Preliminary analysis in this study were analyzed through ESRI geographic information system (GIS) software ArcGIS 10©, but the methods of analysis can be applied to virtually any GIS software. Upon importing and organizing the aforementioned datasets into the GIS program, the CBLCD dataset was reclassified to generalize the types of land cover reported according to the level one Anderson land cover classification scheme. All advanced classification levels were reclassified into the following level one categories for simplification of numerical analysis and visual representations: 1 – water, 2 – urban, 3 – barren, 4 – forest, 5 – low level shrubs, 7 – grasslands, 8 – agriculture, and 9 – wetlands. For further information on the original classification scheme, and understanding on this study's subsequent reclassification see: Anderson (1976).

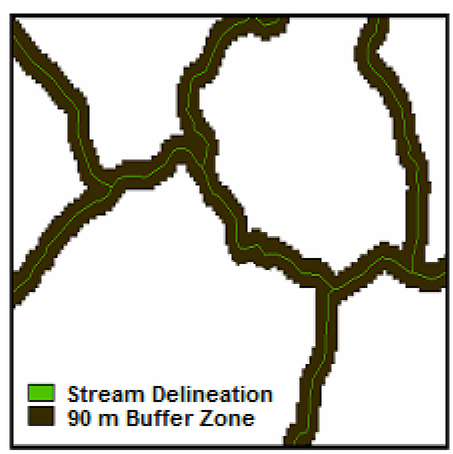

Figure 3: This figure displays an example of the 90 meter buffer used to analyze land cover in the riparian buffer zone.

Using the National Hydrography Dataset, riparian buffer zones were computed with a linear distance of 90 meters from the center of all streams within the Antietam Creek Watershed (Figure 3). The 90 meter distance selected as per previous studies estimations that at least a 100m buffer zone is needed to significantly reduce pollutants entering the waterway (Teels *et al.* 2006). Note: a pixel length of 30 meters did not allow for the 100 meter recommended distance, therefore the closest multiple was selected. These created buffer zones provide an analysis platform for land cover influences in the riparian buffer zone, a parameter closely related to water quality (Roberts and Prince 2009, Teels *et al.* 2006).

Each StreamStats® calculated drainage basin delineation was then combined with both the total watershed land cover map, and the riparian buffer zone map to provide statistics pertaining to each individual area for relation to stream quality parameters. Percentage of land cover for each of the twenty two drainage basins was then calculated in terms of total drainage basin (Table Appendix-I), and riparian buffer zones (Table Appendix-II) for use in statistical analysis for correlations between land cover type / abundance and water quality parameters of temperature, nitrates, phosphates, turbidity, and dissolved oxygen.

Statistical analyses were applied to determine whether a correlation existed between the previously calculated percentages of each of the three main types of land cover and the five aforementioned measurements of water quality. Monthly water quality data ascertained from the Renfrew Institute for 2011 was then averaged for each water monitoring site. Land cover and water quality data for each site were then compiled into a master database for analysis. The Antietam site was removed from the final database as no water quality data were collected for it leaving a total of twenty one sites analyzed.

The database was then imported into SPSS, a statistical analysis program available from IBM. A Shapiro-Wilk test was run on the data to determine normality. Both a Pearson's and

Spearman's correlation test was run to determine an association of urban percent land cover type within the drainage basins and the five water quality variables. Based on the results of the normality test, the test statistic would be taken from either the Pearson's (normal data) test results or the Spearman's (non-normal data) test results. After recording results, we repeated the correlation tests for urban land cover percent within the 90 meter buffer. We also determined an association between agricultural and forested land cover percentages within the entirety of drainage basins and the 90 meter stream buffers and the five water quality variables.

LIMITATIONS

This study is limited by a number of factors that are important to keep in mind when discussing results and for future research projects. First, the water quality data are collected by volunteers who are generally assigned one or two testing sites. The quality tests themselves are conducted in the field, not in a laboratory. Because the tests are conducted by multiple individuals of varying backgrounds, the tests become subjective; results may vary from volunteer to volunteer. It is important to keep in mind that while the volunteers are trained to accurately record results, some level of subjectivity is involved.

Second, our basin delineations overlap each other which brings into question the role of additive processes from basin to basin. For example, the Mont Alto site is predominantly forested with few nitrates and phosphates recorded. The Blueberry Farms site drainage basin includes all of Mont Alto and any other drainage basins upstream from that point. The assumption cannot be made that nutrients from those upstream basins are flowing downstream to the next data collection site unimpeded. Two sites, Mackey Run and Red Run 1, have a high percentage of wetland cover within 90 meters of the stream. Water entering these wetlands would be filtered before continuing downstream. These processes would need to be studied in order to better correlate land cover types and water quality.

RESULTS

The Shapiro-Wilk test resulted in both normal and non-normal data (Appendix III). Data for temperature, dissolved oxygen, and phosphates tested normal. As a result, Pearson's correlation was used to determine the association between land cover percentages and those three water quality variables. Turbidity and nitrates tested non-normal, requiring the Spearman's correlation test to be used for those variables. Both correlation techniques were run on all the data. The temperature, dissolved oxygen, and phosphate coefficients were then disregarded in the Spearman's test output while turbidity and nitrate coefficients were ignored in the Pearson's test output.

Percentage of forested land in the drainage basins was not correlated to dissolved oxygen, temperature, or phosphate levels. Nitrates and turbidity had a significant inverse association with forested land; as forested land decreased, nitrate levels and turbidity increased. The same results were seen when the water quality data were compared to percentage of forested land within the 90 meter stream buffers. No correlation was seen with dissolved oxygen, temperature, or phosphates while an inverse relationship was seen with forest cover and nitrate levels and turbidity.

Like forested land, no correlation was seen between agricultural land cover within the basins and 90 meter stream buffers and dissolved oxygen, temperature, and phosphate levels. Unlike forested land, both nitrates and turbidity had a positive relationship with total agricultural land percentages and agricultural land within the 90 meter buffers. As agricultural land increases, nitrates and turbidity increases.

Urban land within the drainage basin had no significant correlations among any of the water quality variables; urban land across the basin does not significantly affect water quality. Urban land within the 90 meter stream buffers, however, had a significant positive correlation with temperature and nitrates. As urban land increases within the buffer, temperature and nitrate levels increase. There is also a significant inverse relationship between urban land in the buffer and dissolved oxygen; as urban land decreases, dissolved oxygen increases. There was no correlation between urban land within the buffers and phosphates or turbidity.

DISCUSSION

Forests play a number of important roles in water quality management within a watershed. Forests act as sponges by soaking up rainfall and filtering nutrients before they are released into a stream, decreasing the amount of harmful pollutants entering watershed streams. Excess nutrients such as nitrogen and phosphorus can be filtered by up to 90% in forested areas (Sprague, 2006). They also reduce the amount of runoff, lessening the sediment load washed into streams which ultimately decreases turbidity.

The inverse correlation of forested land cover and nitrates and turbidity in both the entire area of the watershed drainage basins and the 90 meter stream buffers was expected. As forested land decreases, more nitrates are allowed to enter the stream unfiltered. Likewise, forest loss leads to increased sedimentation creating higher turbidity rates in streams. Water quality in the Chesapeake Bay watershed has long been linked to the removal of forests to make way for agricultural and urban areas (Sprague, 2006). While poor water quality is associated with loss of forest, intensive agricultural practices are also an issue.

Agricultural practices have been a major source of water pollutants since European settlement of the Chesapeake Bay region. Technology has allowed for more intensive agricultural practices, resulting in higher yields without expanding farm sizes. While farmland acreage has actually seen a decrease in total area within the watershed, the tonnage of nutrients – fertilizers, pesticides, herbicides – spread on agricultural land has doubled and in some areas tripled (Horton, 2003). Likewise, plowing of land has been linked to increased levels of turbidity within streams, leading to anoxic and hypoxic conditions (Boesch et al., 2001).

Unlike forested areas in the Antietam Creek Watershed, there was a positive linear relationship between agricultural land cover and nitrates and turbidity in both the drainage basins and the 90 meter stream buffers. As agricultural land within the watershed increases, nitrates and turbidity increased, which was to be expected. Agricultural land within the drainage basins was second in total percent area to forests. As a result, farming practices such as plowing and nutrient spreading largely impact stream quality within the watershed.

Increased turbidity is associated with conventional tillage techniques where the soil structure is disturbed. Loose soil is easily carried away by runoff and deposited in streams. Implementing no-till farming and planting cover crops can provide a reduction of sedimentation in the watershed. These techniques strengthen soil structure, reduce erosion, increase nutrient absorption into the soil, and reduce water runoff (Dinnes, 2004).

Higher levels of nitrates in waterways near agricultural land are explained by the use of commercial nitrogen fertilizer and the application of manure for use as a fertilizer. Nitrogen is lost to the environment in a variety of ways, such as leaching and agricultural runoff, making it more hazardous than other nutrients applied to the land. A popular BMP to reduce nitrates entering streams is waste management. Storing manure in concrete holding tanks and applying it to land according to nutrient management plans has helped to decrease the level of nitrates entering waterways (Boesch et al., 2009).

The fact that phosphorous was not associated with agricultural land cover is significant. Phosphates can be found in many commercial fertilizers today. Although phosphorous is vital to plant growth, it becomes a pollutant when it moves from agricultural land to streams (US Department of Agriculture, 1998). Because turbidity was significantly associated agricultural land cover and phosphates were not, future research should be conducted to understand the relationship between phosphates and turbidity in the Antietam Creek watershed.

Urban areas also have a negative impact on water quality. Impervious surfaces increase water runoff while transporting nutrients and pollutants directly into streams. The Antietam Creek watershed saw a significant positive correlation between urban land and temperature and nitrate levels. Water temperatures tend to increase as anthropogenic heating, such as an urban heat island, increases. Because impervious surfaces warm faster than land cover, runoff is warmer when it enters streams. Also, a lack of forested buffers can expose water to direct sunlight, warming it as a result. Nitrate levels can be explained by the increased amounts of runoff created by impervious surfaces and the volume of nutrients it carries away from fertilized lawns and parking lots.

There was also an inverse association between land cover and dissolved oxygen in the Antietam Creek watershed. Water temperatures generally have an inverse correlation with dissolved oxygen; as temperatures increase, dissolved oxygen decreases. Since urban land in the watershed has a positive association with temperature, it was expected that dissolved oxygen would decrease as a result.

CONCLUSION

Forests in the Antietam Creek Watershed play a major role in protecting water quality in streams. Statistical analysis exhibited that an inverse correlation existed between urban land cover and two stream quality variables, nitrates and turbidity. Agricultural and urban areas, on the other hand, displayed a positive association; when percentage of land cover increased, nitrates also increased. These associations indicate that forests adequately perform their role of filtering nutrients and pollutants within the delineated drainage basins of the study area. As the percentage of forested area decreases, however, higher nitrate levels are seen. Protecting forested areas and improving riparian stream buffers, especially in highly agricultural and urban areas, would significantly improve water quality within the watershed.

The research presented in this report provides an analysis of land cover and its relation to water quality. While the results offer an adequate indication of that relationship, further research should be conducted to better understand how additive processes occur within the watershed. Recognizing how nutrients and pollutants are transferred between drainage basins is important in understanding downstream water quality. Equally important are the role wetlands play in filtering those nutrients. This preliminary study provides the next logical steps to take in understanding the relationship between water quality and land cover types within the Antietam Creek Watershed.

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APPENDIX I

Table Appendix I – This table displays the percentages of given land cover within the entire drainage basin delineation from the site of data collection (Site) derived from GIS analysis used in statistical assessment.

Site	Water	Urban	Barren	Forest	Shrub	Grassland	Ag	Wetland
Baumgardner	0.27	7.93	0.01	65.96	0.23	0.10	24.68	0.82
Blueberry Farms	0.02	7.70	0.00	61.79	0.16	0.09	30.22	0.01
Bob Lawn West	0.04	7.48	0.01	23.94	0.13	0.05	68.20	0.15
Bob Lawn East	0.44	0.34	0.00	98.11	0.27	0.06	0.71	0.07
Buena Vista/Falls Creek	0.91	15.95	0.01	73.09	0.12	0.14	9.38	0.39
Foster Prop	0.26	9.60	0.01	63.99	0.22	0.10	25.02	0.80
George Prop	0.54	14.57	0.01	68.17	0.21	0.08	16.06	0.36
Henicle	0.32	14.35	0.02	72.51	0.19	0.15	9.72	2.74
Hess Benedict/Site #2	0.02	7.55	0.00	54.90	0.14	0.10	37.26	0.03
Iron Bridges	0.03	7.07	0.01	22.53	0.13	0.05	70.03	0.14
Mackey Run	0.00	15.96	0.03	72.09	0.19	0.20	5.08	6.45
McGuilliard/Brookdale	0.00	7.34	0.00	82.62	0.06	0.02	9.79	0.17
Mont Alto/Site #3	0.00	0.21	0.00	99.48	0.06	0.00	0.23	0.02
Nicodemus Dam	0.00	2.47	0.00	2.66	0.00	0.00	94.87	0.00
Nicodemus Dam2	0.03	3.46	0.01	4.27	0.05	0.02	92.11	0.04
Red Run 1	0.00	23.49	0.05	57.99	0.30	0.32	7.71	10.14
Red Run 2	0.00	0.00	0.00	99.64	0.00	0.00	0.00	0.36
Red Run Park	0.39	10.34	0.02	82.14	0.21	0.13	3.58	3.20
Renfrew	0.26	4.46	0.00	78.07	0.24	0.09	16.23	0.66
Tick Ridge Springs	0.00	6.61	0.03	7.35	0.03	0.00	85.97	0.00
West Branch Source	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00

APPENDIX II

Table Appendix II – This table displays the percentages of given land cover within 90 meter riparian buffer zones within the given drainage basin from the site of data collection (Site) derived from GIS analysis used in statistical assessment.

Site	Water	Urban	Barren	Forest	Shrub	Grassland	Ag	Wetland
Baumgardner	1.49	7.34	0.01	60.43	0.39	0.17	26.47	3.71
Blueberry Farms	0.13	8.88	0.00	63.63	0.17	0.00	27.19	0.00
Bob Lawn West	0.05	8.69	0.01	24.12	0.11	0.06	65.93	1.03
Bob Lawn East	2.57	0.25	0.00	95.63	0.64	0.00	0.53	0.39
Buena Vista/Falls Creek	10.31	28.49	0.00	44.64	0.00	0.00	16.01	0.54
Foster Prop	1.44	7.67	0.01	59.16	0.37	0.16	27.55	3.63
George Prop	3.63	21.24	0.00	46.63	0.28	0.00	27.56	0.66
Henicle	1.29	13.96	0.04	66.98	0.42	0.15	8.79	8.37
Hess Benedict/Site #2	0.08	10.46	0.00	49.31	0.12	0.10	39.74	0.18
Iron Bridges	0.05	8.25	0.01	22.50	0.12	0.06	68.05	0.96
Mackey Run	0.00	17.49	0.00	52.60	0.00	0.00	3.34	26.57
McGuilliard/Brookdale	0.00	7.00	0.00	74.20	0.00	0.00	17.64	1.17
Mont Alto/Site #3	0.00	0.48	0.00	99.04	0.00	0.00	0.48	0.00
Nicodemus Dam	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00
Nicodemus Dam2	0.08	7.38	0.02	2.95	0.13	0.11	89.10	0.23
Red Run 1	0.00	2.47	0.00	45.14	0.00	0.00	5.85	46.54
Red Run 2	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00
Red Run Park	1.59	7.84	0.00	79.08	0.51	0.19	1.49	9.29
Renfrew	1.49	4.21	0.00	74.19	0.45	0.19	15.72	3.74
Tick Ridge Springs	0.00	8.59	0.00	2.77	0.00	0.00	88.64	0.00
West Branch Source	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00

APPENDIX III

Output Appendix III – The output of the statistics calculations in IBM's SPSS

Normality Test

H_O: The data are not significantly different than normal.
H_A: The data are significantly different than normal.

	Urban	Kolmogorov-Smirnov[a] Statistic	df	Sig.	Shapiro-Wilk Statistic	df	Sig.
temp_11	.0000	.345	3	.	.838	3	.210
DO_11	.0000	.276	3	.	.942	3	.537
nitr_11	.0000	.383	3	.	.754	3	.008
turb_11	.0000	.385	3	.	.750	3	.000
phos_11	.0000	.245	3	.	.971	3	.672

a. Lilliefors Significance Correction

Because .210, .537, and .672 > .05, accept the null.

Temperature, dissolved oxygen, and phosphates are not significantly different than normal ($SW_{.838,.942,.971,}$ p=.210, .537, and .672).

Because .008 and .000 < .05, reject the null.

Nitrates and turbidity are significantly different than normal ($SW_{.754,.750,}$ p=.008 and .000).

Because nitrates and turbidity are non-normal, a Spearman's correlation test will be used. Temperature, dissolved oxygen, and phosphates are normal and a Pearson's correlation test will be applied to those data.

Forest Basin Land Cover Correlation to Water Quality

H_O: There is no significant correlation between forested land cover and water quality.
H_A: There is a significant correlation between forested land cover and water quality.

Pearson's test for normal data

Correlations

		Forest	nitr_11	ln_turb	ln_phos	ln_temp	ln_DO
Forest	Pearson Correlation	1	-.899**	-.691**	.123	-.190	.082
	Sig. (2-tailed)		.000	.004	.703	.410	.723
	N	21	21	15	12	21	21
nitr_11	Pearson Correlation	-.899**	1	.695**	.119	.335	-.307
	Sig. (2-tailed)	.000		.004	.712	.137	.176
	N	21	21	15	12	21	21
ln_turb	Pearson Correlation	-.691**	.695**	1	-.443	.583*	-.317
	Sig. (2-tailed)	.004	.004		.199	.023	.250
	N	15	15	15	10	15	15
ln_phos	Pearson Correlation	.123	.119	-.443	1	.206	.037
	Sig. (2-tailed)	.703	.712	.199		.520	.908
	N	12	12	10	12	12	12
ln_temp	Pearson Correlation	-.190	.335	.583*	.206	1	-.489*
	Sig. (2-tailed)	.410	.137	.023	.520		.024
	N	21	21	15	12	21	21
ln_DO	Pearson Correlation	.082	-.307	-.317	.037	-.489*	1
	Sig. (2-tailed)	.723	.176	.250	.908	.024	
	N	21	21	15	12	21	21

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Because .723, .410, and .703 > .05, accept the null.

There is no significant correlations between forested land cover and phosphates, temperature, and dissolved oxygen (p=.723, .410, and .703, r_s=.082, -.190, and .123).

Spearman's test for non-normal data

Correlations

			Forest	nitr_11	ln_turb	ln_phos	ln_temp	ln_DO
Spearman's rho	Forest	Correlation Coefficient	1.000	-.820**	-.700**	-.018	-.263	.150
		Sig. (2-tailed)	.	.000	.004	.957	.249	.517
		N	21	21	15	12	21	21
	nitr_11	Correlation Coefficient	-.820**	1.000	.654**	.246	.434*	-.364
		Sig. (2-tailed)	.000	.	.008	.442	.049	.105
		N	21	21	15	12	21	21
	ln_turb	Correlation Coefficient	-.700**	.654**	1.000	-.425	.517*	-.362
		Sig. (2-tailed)	.004	.008	.	.221	.048	.185
		N	15	15	15	10	15	15
	ln_phos	Correlation Coefficient	-.018	.246	-.425	1.000	.275	.011
		Sig. (2-tailed)	.957	.442	.221	.	.387	.974
		N	12	12	10	12	12	12
	ln_temp	Correlation Coefficient	-.263	.434*	.517*	.275	1.000	-.480*
		Sig. (2-tailed)	.249	.049	.048	.387	.	.028
		N	21	21	15	12	21	21
	ln_DO	Correlation Coefficient	.150	-.364	-.362	.011	-.480*	1.000
		Sig. (2-tailed)	.517	.105	.185	.974	.028	.
		N	21	21	15	12	21	21

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Because .000 and .004 < .05, reject the null.

There is a significant inverse correlation between forested land cover and nitrates levels and turbidity (p=.000 and .004, r_s=-.700 and -.820).

Forest Buffer Land Cover Correlation to Water Quality

H_O: There is no significant correlation between forested stream buffer land cover and water quality.
H_A: There is a significant correlation between forested stream buffer land cover and water quality.

Pearson's test for normal data

Correlations

		Forest	nitr_11	ln_temp	ln_DO	ln_tubidity	ln_phosphate
Forest	Pearson Correlation	1	-.869**	-.261	.181	-.696**	.011
	Sig. (2-tailed)		.000	.254	.431	.004	.973
	N	21	21	21	21	15	13
nitr_11	Pearson Correlation	-.869**	1	.335	-.307	.695**	.218
	Sig. (2-tailed)	.000		.137	.176	.004	.475
	N	21	21	21	21	15	13
ln_temp	Pearson Correlation	-.261	.335	1	-.489*	.583*	.232
	Sig. (2-tailed)	.254	.137		.024	.023	.445
	N	21	21	21	21	15	13
ln_DO	Pearson Correlation	.181	-.307	-.489*	1	-.317	-.038
	Sig. (2-tailed)	.431	.176	.024		.250	.902
	N	21	21	21	21	15	13
ln_tubidity	Pearson Correlation	-.696**	.695**	.583*	-.317	1	-.443
	Sig. (2-tailed)	.004	.004	.023	.250		.199
	N	15	15	15	15	15	10
ln_phosphate	Pearson Correlation	.011	.218	.232	-.038	-.443	1
	Sig. (2-tailed)	.973	.475	.445	.902	.199	
	N	13	13	13	13	10	13

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Because .973, .254, and .431 > .05, accept the null.

There is no significant correlations between forested buffer land cover and phosphates, temperature, and dissolved oxygen (p=.973, .254, and .431, r_s=.011, -.261, and .181).

Spearman's test for non-normal data

Correlations

			Forest	nitr_11	ln_temp	ln_DO	ln_tubidity	ln_phosphate
Spearman's rho	Forest	Correlation Coefficient	1.000	-.791**	-.257	.222	-.545*	-.215
		Sig. (2-tailed)	.	.000	.261	.333	.036	.480
		N	21	21	21	21	15	13
	nitr_11	Correlation Coefficient	-.791**	1.000	.434*	-.364	.654**	.329
		Sig. (2-tailed)	.000	.	.049	.105	.008	.272
		N	21	21	21	21	15	13
	ln_temp	Correlation Coefficient	-.257	.434*	1.000	-.480*	.517*	.328
		Sig. (2-tailed)	.261	.049	.	.028	.048	.274
		N	21	21	21	21	15	13
	ln_DO	Correlation Coefficient	.222	-.364	-.480*	1.000	-.362	-.056
		Sig. (2-tailed)	.333	.105	.028	.	.185	.857
		N	21	21	21	21	15	13
	ln_tubidity	Correlation Coefficient	-.545*	.654**	.517*	-.362	1.000	-.425
		Sig. (2-tailed)	.036	.008	.048	.185	.	.221
		N	15	15	15	15	15	10
	ln_phosphate	Correlation Coefficient	-.215	.329	.328	-.056	-.425	1.000
		Sig. (2-tailed)	.480	.272	.274	.857	.221	.
		N	13	13	13	13	10	13

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Because .000 and .036 < .05, reject the null.

There is a significant inverse correlation between forested land cover and nitrates levels and turbidity (p=.000 and .036, r_s=-.791 and -.545).

Agriculture Basin Land Cover Correlation to Water Quality

H_O: There is no significant correlation between agricultural land cover and water quality.
H_A: There is a significant correlation between agricultural land cover and water quality.

Pearson's test for normal data

Because .766, .546, and .851 > .05, accept the null.

There is no significant correlations between agricultural land cover and phosphates, temperature, and dissolved oxygen (p=.766, .546, and .851, r_s=-.96, .140, and -.044).

Correlations

		Agriculture	nitr_11	ln_turb	ln_phos	ln_temp	ln_DO
Agriculture	Pearson Correlation	1	.928**	.626*	-.096	.140	-.044
	Sig. (2-tailed)		.000	.013	.766	.546	.851
	N	21	21	15	12	21	21
nitr_11	Pearson Correlation	.928**	1	.695**	.119	.335	-.307
	Sig. (2-tailed)	.000		.004	.712	.137	.176
	N	21	21	15	12	21	21
ln_turb	Pearson Correlation	.626*	.695**	1	-.443	.583*	-.317
	Sig. (2-tailed)	.013	.004		.199	.023	.250
	N	15	15	15	10	15	15
ln_phos	Pearson Correlation	-.096	.119	-.443	1	.206	.037
	Sig. (2-tailed)	.766	.712	.199		.520	.908
	N	12	12	10	12	12	12
ln_temp	Pearson Correlation	.140	.335	.583*	.206	1	-.489*
	Sig. (2-tailed)	.546	.137	.023	.520		.024
	N	21	21	15	12	21	21
ln_DO	Pearson Correlation	-.044	-.307	-.317	.037	-.489*	1
	Sig. (2-tailed)	.851	.176	.250	.908	.024	
	N	21	21	15	12	21	21

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Spearman's test for non-normal data

Because .000 and .005 < .05, reject the null.

There is a significant positive correlation between agricultural land cover and nitrate levels and turbidity (p=.000 and .005, r=.913 and .680).

Correlations

			Agriculture	nitr_11	ln_turb	ln_phos	ln_temp	ln_DO
Spearman's rho	Agriculture	Correlation Coefficient	1.000	.913**	.680**	.074	.320	-.176
		Sig. (2-tailed)	.	.000	.005	.820	.157	.445
		N	21	21	15	12	21	21
	nitr_11	Correlation Coefficient	.913**	1.000	.654**	.246	.434*	-.364
		Sig. (2-tailed)	.000	.	.008	.442	.049	.105
		N	21	21	15	12	21	21
	ln_turb	Correlation Coefficient	.680**	.654**	1.000	-.425	.517*	-.362
		Sig. (2-tailed)	.005	.008	.	.221	.048	.185
		N	15	15	15	10	15	15
	ln_phos	Correlation Coefficient	.074	.246	-.425	1.000	.275	.011
		Sig. (2-tailed)	.820	.442	.221	.	.387	.974
		N	12	12	10	12	12	12
	ln_temp	Correlation Coefficient	.320	.434*	.517*	.275	1.000	-.480*
		Sig. (2-tailed)	.157	.049	.048	.387	.	.028
		N	21	21	15	12	21	21
	ln_DO	Correlation Coefficient	-.176	-.364	-.362	.011	-.480*	1.000
		Sig. (2-tailed)	.445	.105	.185	.974	.028	.
		N	21	21	15	12	21	21

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

<u>Stream Buffer Agricultural Land Cover Correlation to Water Quality</u>

H_O: There is no significant correlation between stream buffer agricultural land cover and water quality.
H_A: There is a significant correlation between stream buffer agricultural land cover and water quality.

<u>Pearson's test for normal data</u>

Because .979, .492, and .688 > .05, accept the null.

There is no significant correlations between agricultural stream buffer land cover and phosphates, temperature, and dissolved oxygen (p=.979, .492, and .688, r_s=-.008, .159, and -.093).

Correlations

		Agriculture	nitr_11	ln_tubidity	ln_phosphate	ln_temp	ln_DO
Agriculture	Pearson Correlation	1	.941**	.663**	-.008	.159	-.093
	Sig. (2-tailed)		.000	.007	.979	.492	.688
	N	21	21	15	13	21	21
nitr_11	Pearson Correlation	.941**	1	.695**	.218	.335	-.307
	Sig. (2-tailed)	.000		.004	.475	.137	.176
	N	21	21	15	13	21	21
ln_tubidity	Pearson Correlation	.663**	.695**	1	-.443	.583*	-.317
	Sig. (2-tailed)	.007	.004		.199	.023	.250
	N	15	15	15	10	15	15
ln_phosphate	Pearson Correlation	-.008	.218	-.443	1	.232	-.038
	Sig. (2-tailed)	.979	.475	.199		.445	.902
	N	13	13	10	13	13	13
ln_temp	Pearson Correlation	.159	.335	.583*	.232	1	-.489*
	Sig. (2-tailed)	.492	.137	.023	.445		.024
	N	21	21	15	13	21	21
ln_DO	Pearson Correlation	-.093	-.307	-.317	-.038	-.489*	1
	Sig. (2-tailed)	.688	.176	.250	.902	.024	
	N	21	21	15	13	21	21

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

<u>Spearman's test for non-normal data</u>

Because .000 and .002 < 0.05, reject the null.

There is a significant positive correlation between agricultural stream buffer land cover and nitrate levels and turbidity (p=.000 and .002, r=.926 and .739).

Correlations

			Agriculture	nitr_11	ln_tubidity	ln_phosphate	ln_temp	ln_DO
Spearman's rho	Agriculture	Correlation Coefficient	1.000	.926**	.739**	.110	.350	-.237
		Sig. (2-tailed)	.	.000	.002	.719	.120	.300
		N	21	21	15	13	21	21
	nitr_11	Correlation Coefficient	.926**	1.000	.654**	.329	.434*	-.364
		Sig. (2-tailed)	.000	.	.008	.272	.049	.105
		N	21	21	15	13	21	21
	ln_tubidity	Correlation Coefficient	.739**	.654**	1.000	-.425	.517*	-.362
		Sig. (2-tailed)	.002	.008	.	.221	.048	.185
		N	15	15	15	10	15	15
	ln_phosphate	Correlation Coefficient	.110	.329	-.425	1.000	.328	-.056
		Sig. (2-tailed)	.719	.272	.221	.	.274	.857
		N	13	13	10	13	13	13
	ln_temp	Correlation Coefficient	.350	.434*	.517*	.328	1.000	-.480*
		Sig. (2-tailed)	.120	.049	.048	.274	.	.028
		N	21	21	15	13	21	21
	ln_DO	Correlation Coefficient	-.237	-.364	-.362	-.056	-.480*	1.000
		Sig. (2-tailed)	.300	.105	.185	.857	.028	.
		N	21	21	15	13	21	21

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Urban Basin Land Cover Correlations to Water Quality

H_O: There is no significant correlation between urban land cover and water quality.
H_A: There is a significant correlation between urban land cover and water quality.

Pearson's test for normal data

Because .191, .353, and .740 > .05, accept the null.

There is no significant correlation between urban land cover and water temperature, dissolved oxygen, and phosphates (p=.191, .353, and .740, r_s=.297, -.214, and -.107).

Correlations

		Urban	temp_11	DO_11	ln_nitr	ln_turb	ln_phos
Urban	Pearson Correlation	1	.297	-.214	.205	.221	-.107
	Sig. (2-tailed)		.191	.353	.386	.429	.740
	N	21	21	21	20	15	12
temp_11	Pearson Correlation	.297	1	-.471*	.516*	.555*	.221
	Sig. (2-tailed)	.191		.031	.020	.032	.489
	N	21	21	21	20	15	12
DO_11	Pearson Correlation	-.214	-.471*	1	-.365	-.328	.050
	Sig. (2-tailed)	.353	.031		.114	.233	.876
	N	21	21	21	20	15	12
ln_nitr	Pearson Correlation	.205	.516*	-.365	1	.659**	.203
	Sig. (2-tailed)	.386	.020	.114		.008	.527
	N	20	20	20	20	15	12
ln_turb	Pearson Correlation	.221	.555*	-.328	.659**	1	-.443
	Sig. (2-tailed)	.429	.032	.233	.008		.199
	N	15	15	15	15	15	10
ln_phos	Pearson Correlation	-.107	.221	.050	.203	-.443	1
	Sig. (2-tailed)	.740	.489	.876	.527	.199	
	N	12	12	12	12	10	12

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Spearman's test for non-normal data

Because .453 and .548 > .05, accept the null.

There is no significant correlation between urban land cover and nitrates and turbidity (p=.453 and .548, r_s=.178 and .169).

Correlations

			Urban	temp_11	DO_11	ln_nitr	ln_turb	ln_phos
Spearman's rho	Urban	Correlation Coefficient	1.000	.359	-.240	.178	.169	.021
		Sig. (2-tailed)	.	.110	.295	.453	.548	.948
		N	21	21	21	20	15	12
	temp_11	Correlation Coefficient	.359	1.000	-.480*	.386	.517*	.275
		Sig. (2-tailed)	.110	.	.028	.093	.048	.387
		N	21	21	21	20	15	12
	DO_11	Correlation Coefficient	-.240	-.480*	1.000	-.341	-.362	.011
		Sig. (2-tailed)	.295	.028	.	.141	.185	.974
		N	21	21	21	20	15	12
	ln_nitr	Correlation Coefficient	.178	.386	-.341	1.000	.654**	.246
		Sig. (2-tailed)	.453	.093	.141	.	.008	.442
		N	20	20	20	20	15	12
	ln_turb	Correlation Coefficient	.169	.517*	-.362	.654**	1.000	-.425
		Sig. (2-tailed)	.548	.048	.185	.008	.	.221
		N	15	15	15	15	15	10
	ln_phos	Correlation Coefficient	.021	.275	.011	.246	-.425	1.000
		Sig. (2-tailed)	.948	.387	.974	.442	.221	.
		N	12	12	12	12	10	12

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Urban Buffer Land Cover Correlations to Water Quality

H_O: There is no significant correlation between urban land cover within stream buffers and water quality.
H_A: There is a significant correlation between urban land cover within stream buffers and water quality.

Pearson's test for normal data

Because .003 and .028 < .05, reject the null.

There is a significant positive correlation between urban land cover within the 90 meter buffers of streams and water temperature and an inverse association with dissolved oxygen (p=.003 and .028, r_s=.609 and -.479).

Because .832 > .05, accept the null.

There is no significant correlation between urban land cover within the 90 meter buffers of streams and phosphate levels (p=.832, r_s=.065)

Correlations

		Urban	temp_11	DO_11	ln_nitrate	ln_tubidity	ln_phosphate
Urban	Pearson Correlation	1	.609**	-.479*	.487*	.274	.065
	Sig. (2-tailed)		.003	.028	.029	.323	.832
	N	21	21	21	20	15	13
temp_11	Pearson Correlation	.609**	1	-.471*	.516*	.555*	.255
	Sig. (2-tailed)	.003		.031	.020	.032	.401
	N	21	21	21	20	15	13
DO_11	Pearson Correlation	-.479*	-.471*	1	-.365	-.328	-.021
	Sig. (2-tailed)	.028	.031		.114	.233	.946
	N	21	21	21	20	15	13
ln_nitrate	Pearson Correlation	.487*	.516*	-.365	1	.659**	.326
	Sig. (2-tailed)	.029	.020	.114		.008	.277
	N	20	20	20	20	15	13
ln_tubidity	Pearson Correlation	.274	.555*	-.328	.659**	1	-.443
	Sig. (2-tailed)	.323	.032	.233	.008		.199
	N	15	15	15	15	15	10
ln_phosphate	Pearson Correlation	.065	.255	-.021	.326	-.443	1
	Sig. (2-tailed)	.832	.401	.946	.277	.199	
	N	13	13	13	13	10	13

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Spearman's test for non-normal data

Because .049 < .05, reject the null.

There is a significant positive correlation between urban land cover within 90 meter buffers of the streams and nitrate levels (p=.049, r_s=.445).

Because .130 > .05, accept the null.

There is no significant correlation between urban land cover within 90 meter buffers of the streams and turbidity (p=.130, r_s=.409).

Correlations

			Urban	temp_11	DO_11	ln_nitrate	ln_tubidity	ln_phosphate
Spearman's rho	Urban	Correlation Coefficient	1.000	.542*	-.308	.445*	.409	-.017
		Sig. (2-tailed)	.	.011	.175	.049	.130	.957
		N	21	21	21	20	15	13
	temp_11	Correlation Coefficient	.542*	1.000	-.480*	.386	.517*	.328
		Sig. (2-tailed)	.011	.	.028	.093	.048	.274
		N	21	21	21	20	15	13
	DO_11	Correlation Coefficient	-.308	-.480*	1.000	-.341	-.362	-.056
		Sig. (2-tailed)	.175	.028	.	.141	.185	.857
		N	21	21	21	20	15	13
	ln_nitrate	Correlation Coefficient	.445*	.386	-.341	1.000	.654**	.329
		Sig. (2-tailed)	.049	.093	.141	.	.008	.272
		N	20	20	20	20	15	13
	ln_tubidity	Correlation Coefficient	.409	.517*	-.362	.654**	1.000	-.425
		Sig. (2-tailed)	.130	.048	.185	.008	.	.221
		N	15	15	15	15	15	10
	ln_phosphate	Correlation Coefficient	-.017	.328	-.056	.329	-.425	1.000
		Sig. (2-tailed)	.957	.274	.857	.272	.221	.
		N	13	13	13	13	10	13

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).