Impact of land use on water quality of Mill Creek Watershed in the Mahoning Valley, Ohio

By

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Abstract

This is a study of the influence of the various land use practices on water quality parameters of Mill Creek Watershed that flows north from Columbiana County, then through Boardman Township and Mill Creek Park, before finally merging with the Mahoning River in Youngstown, Ohio. Land uses in the Mill Creek sub-watershed vary from residential to urban industrial as well as from agricultural to forested and recreational areas.

Water samples were collected from eleven different points of Mill Creek. Various physical, chemical and biological water quality parameters like temperature, DO, pH, ammonia, soluble reactive phosphorous, nitrate-nitrogen, TSS, VSS, TDS, VDS, Total Coliform, *E.coli* and BOD were measured using standard methods. Graphical representations showed the difference in the averages of different water quality parameters before and after rain events. Inverse distance weighted (IDW) interpolation techniques were used to represent the spatial dispersion of nutrients, solids and bacteria at the scale of whole watershed. Different types of land cover i.e., herbaceous land, forest, developed areas, cultivated crops, open water and wetlands of Mill Creek Watershed are used in this study.

Principal Component Analysis (PCA) of water quality parameters shows a positive correlation of the potential runoff from impervious surfaces and cultivated land with the concentrations of ammonia, TSS, *E.coli*, VSS and Coliform. On the other hand, percentage of forest does not depict any trend with the concentrations of ammonia, TSS, *E.coli*, VSS and Coliform. Principal Component Analysis with whole data covering

2016-2018 indicate that the high precipitation events in summer 2016 diverged from high precipitation events in the fall. Excluding the high precipitation events from summer of 2016 results implications that are similar to that of 2017-18. Thus, high precipitation events of summer 2016 apparently produced water parameters similar to that of low flow conditions. This study shows that the runoff from cultivated land and impervious surfaces has negative impact on the water quality of the watershed. Beside runoff from impervious surfaces and cultivated land, input of nutrients, bacteria and solids from the tributaries of the Mill Creek River might be contributing to reduced water quality in Mill Creek River. It is recommended to expand the sampling into the tributaries of the Mill Creek River.

Keywords: Land use, Water quality variables, precipitations, averages, spatial dispersion, Principal component analysis, tributaries.

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Chapter 1: Introduction

Watersheds are land areas that drain into a river, stream, lake or other surface water. The land in the watershed is connected to the surface water through runoff and drainage. The presence of higher concentration of sediments, pathogens, nutrients, metals, salts, oils and petroleum products in the watershed, flows through the watershed to the water resulting in pollution. This type of diffused runoff pollution is termed non-point. When pollutants are directly discharged into the waterway from factories and sewage treatment plants, they are called point sources.

Sand, soil, and gravel eroded by runoff usually ends up in streambeds or at the shores of lakes and reservoirs. This sediment can alter stream flow, shortens reservoir life, and decrease the availability of healthy aquatic habitat. Some major sources of sediment include cropland erosion, poorly protected construction sites, erosion from unprotected and exposed areas from golf course and parks, erosion from lawns and gardens, wash off from streets and other impervious areas, overly steep slopes and stream bank erosion (Donaldson 2004). The sources of most of the pathogens such as bacteria and viruses, are from fecal material from wildlife, livestock manure, malfunctioning septic systems, sewage treatment plant discharges, leaky sewer lines, and boat sanitary disposal systems. Higher concentration of pathogens introduces disease-bearing organisms to aquatic life, increases public health risks, results in loss of wetland, and introduces harmful organisms to aquatic life and food chain (Donaldson 2004).

Nitrogen and phosphorous are the major types of nutrients that cause water pollution through cultural eutrophication. High concentration of these nutrients increased productivity of photosynthetic algae and plants promoting algae blooms. The algal blooms die increasing the amount of decaying organic matter and, reducing dissolved oxygen levels which causes stress in aquatic organisms. In addition, algal blooms can result in odors and poor taste, alter wetland vegetation and habitat, and decreases aesthetic value of the watershed (Donaldson 2004). Fertilizers, animal manure, and pet waste runoff are the primary sources of these nutrients (EPA 2017). Beside these primary sources, septic systems, discharge from sewage treatment plants or industries, home lawn care products, atmospheric deposition (car exhaust), car washing runoff, etc., are also sources of nutrients like nitrogen and phosphorous (Donaldson 2004).

Toxic contaminants are the chemicals that can harm the health of human beings and the health of the entire ecosystem. Many of these chemicals are very resistant to breakdown and can easily passed through the food chain and get concentrated in large predators. Toxic chemicals include hydrocarbons, metals (lead, mercury, and cadmium), pesticides (DDT), and organic compounds such as polychlorinated biphenyls (PCBs) (Donaldson 2004).The major sources of these contaminants are oil, grease and gasoline (hydrocarbons) from roadways solvents from industrial practices; chemicals used in homes, gardens and yards, and on farm crops. These contaminants can accumulate in sediments, affecting bottom feeders, bio accumulates in fish tissues, hinders photosynthesis in aquatic plants, affects reproductive rates and life span of wetland organisms (Donaldson 2004).

Land use practices are the most crucial factors in determining water quality of the watershed. Deforestation, agricultural activities, and urbanization generally modifies land surface characteristics, alter runoff volume, change water temperature, generate pollution, and increase algal production and decrease concentration of dissolved oxygen in water bodies (Ding et al. 2015, Chu et al. 2013).

This research is an attempt to study the influence of the various land use practices on water quality parameters of Mill Creek watershed. Mill Creek sub-watershed is located in the eastern border of Ohio flowing north from Columbiana until it merges with the Mahoning River in Youngstown, Ohio. One of the major attractions is Mill Creek Metro Park which encompasses more than 18.21 Km2 (4,500 acre) of the 190.20 Km2 (47,000 acre) sub-watershed and 17.7 Km (11miles) of the 38.62 Km (24 miles) of Mill Creek. Land use in the Mill Creek sub-watershed vary from residential to urban and industrial as well as from agricultural to forested and recreational areas. Mill Creek has had a problem with local water quality issues including lack of clarity, bacteria contamination, algae blooms, and fish kills. In 2013, a substantial number of fish in the Lily Pond died due to an algae blooms and sultry weather conditions with temperature hovering around 90 degrees for several days followed by depletion of oxygen (Dick 2013). Two years later, in 2015 after another fish kill in Lake Newport due to low oxygen conditions, water test were conducted by the Mahoning Country Health District. The laboratory test indicated besides low oxygen the waters in the park, there was also elevated levels of E. coli bacteria. This led to a summer closure of water activities in the park (Killiken & Klein 2015). The sources of water quality issues in the Mill Creek watershed include animal waste, combined sewer overflows, failing septic systems, agricultural erosion, as well as erosion and contaminants from urban activities, such as constructions and land enhancements (fertilizers, pesticides).

The main objective of this study is to understand the water quality status of Mill Creek Watershed and also to identify the land use that is most prone to cause pollution in the watershed.

Research Hypotheses

- Forest land use will decrease nutrients (nitrogen and phosphorous), bacteria and sediments. Forest absorb a great amount of precipitation reducing runoff and them gradually releases it to natural channels thus contributing less pollution impact on the water quality.
- Agricultural land increase input of nutrients (nitrogen and phosphorus), bacteria, and sediment. Agricultural land use typically apply chemical fertilizer, manure, and bio solids directly to the agricultural land. Pollutants like sediments, fertilizers, pesticides, and heavy metals are often attached to the soil particles and wash into the water bodies during heavy rainfall.
- Developed area will have higher concentration of solids, nutrients, bacteria, and heavy toxic metals which impact the water quality of the watershed. Pollution from roads and industries, higher rate of anthropogenic activities, and the number of combined sewer overflows causes higher percentage of pollutants loading to streams during high flow periods. In addition, these areas will have higher percentage of impervious surfaces which prevent rainfall from infiltrating into soil and ground water which increases runoff to streams.
- Impervious surfaces include roads, parking lots, sidewalks, roof tops, and other impermeable areas. These land use practices prevent rainfall from infiltrating into

soil and ground water and also, increases the runoff containing sediments, nutrients, toxic heavy metals and solids inputs to the stream, deteriorating the water quality of the watershed.

Objectives

- To sample from Mill Creek from the headwaters to the outflow during low flow (baseline) and high flow events.
- To determine water parameters such as solids, pH, dissolved oxygen, nutrients, bacteria, and soluble metals, as a measure of water quality of Milk Creek.
- To determine the percentage of land use from each sampling location and to make connection between different types of land use practices and the water quality of the watershed with respect to rain fall events.

Chapter 2: Literature Review

Water Temperature

Most of the physical, chemical and biological characteristics of streams are directly affected by water temperature which can vary according to season, weather conditions, as well as the time of the day. Runoff from impervious urban surfaces (i.e. roadways, footpaths, parking lots, concrete yards and rooftops), overflow or filter discharges from heated swimming pools, heated waste water discharge and industrial water from cooling processes can affect the temperature of the receiving water. Similarly, sediment and other suspended materials absorb heat from the sun which increases the water temperature (Wai 2003). Increase in water temperature increases the energy consumption by stream life through increased activity which results in greater oxygen use by aquatic organisms like fishes, insects, and bacteria. Additionally, water temperatures enable plants to grow more vigorously and may lead to algal blooms (Wai 2003). Aquatic organisms; fish, insects, zooplankton, phytoplankton, all have a temperature tolerance range. As temperatures get too far above or below this tolerance range, the number of individuals of the species decreases, and could lead to the totally disappearance (USGS 2016).

pH

The pH of a stream is a measure of how acidic or alkaline the water is on a scale of 0 to 14. A change of 1 unit on a pH scale represents a 10 fold change in the pH, for example, water with pH of 6 is times more acidic than water with a pH of 7, and water with a pH of 5 is 100 times more acidic than water with a pH of 7 (Mesner & Geiger 2010). Measuring pH can indicate information about the natural condition of a water bodies and monitoring pH over time can reveal whether it is being polluted. Eutrophication and excessive growth of algae and in-stream aquatic plants can lead to elevated pH levels. Industrial wastewater or contaminated storm water can cause significant changes to pH (either up or down) in the water bodies (Wai 2003). Furthermore, pH alters the behavior of other chemicals in the water which can affect aquatic plants and animals. For example, ammonia is relatively harmless to fish in water that is neutral or acidic (pH<7). However, as the water becomes more basic (pH>7), the toxicity of ammonia increases. Similarly, many of the heavy metals such as cadmium, lead, and chromium dissolve more easily in acidic water and become much more toxic (Mesner & Geiger 2010). The normal pH range for freshwater aquatic systems is 6 to 9 and most of the aquatic plants and animals have adapted their life in that pH range and they may suffer, even with slight change in pH. Moderately acidic water may reduce the hatching success of fish eggs, irritate fish and aquatic insect gills, and damage membranes. The pH level below 4 or above 10 will kill most of the fish and only few animals can tolerate waters with a pH below 3 or above 11 (Mesner & Geiger 2010).

Dissolved Oxygen and Biochemical Oxygen Demand

Dissolved oxygen (DO) is the amount of oxygen molecules dissolved in water. Under normal circumstances oxygen is not very soluble in water, about 12 parts of oxygen can dissolve in a million parts of water (12 mg/liter) at 7°C (Mesner & Geiger 2010). Oxygen can only enter the water bodies from a limited number of sources: it dissolves into water from contact with the atmosphere (surface-air interface or turbulence expanding surface area) or is produced by plants during photosynthesis. The maximum amount of oxygen that can dissolve into water is affected by water temperature, elevation, and the salinity of the water. An increase in any of these factors result in lower the ability of oxygen to be dissolved in the water. Other variable environmental factors can also affect dissolved oxygen. Higher concentration of total suspended solids in the surface water can block light from reaching submerged vegetation. As the amount of light passing through the water is reduced, photosynthesis is also reduced and the level of dissolved oxygen (DO) that is released into the water by plants diminishes. All aquatic organisms, from bacteria to fish, use oxygen from the water as they respire. If light is completely blocked from bottom dwelling plants, the plants will stop photosynthesizing and die. As the dead plants are decomposed, bacteria will use up even more oxygen from the water decreasing DO further as decomposition increases (Murphy 2007).

Biochemical oxygen demand (BOD) is a measure of the amount of oxygen in a sample of water used to degrade organic material primarily by biological processes over a 5-day period (Delzer & McKenzie 2003, Wai 2003). If substantial amounts of biodegradable material enters the waterway, much of the oxygen can be consumed by the bacteria during the decomposition leaving less oxygen for larger aquatic organisms (Mesner & Geiger 2010). BOD is one of the basic parameters for assessing the effectiveness of wastewater treatment as well as the biodegradability of organic substances released from industry. The value of BOD_5 in surface water depends on the conditions of aeration, type and degree of contamination, the amount of total suspended solids, and the quantity of the flow-discharged into the stream from wastewater or other point or non-point source discharges into the water (Noskovic et al. 2017, Murphy 2007).

Dissolved oxygen and BOD are inversely related, when BOD is high, dissolved oxygen is consumed and the amount of DO available to organisms decrease.

Solids

Solids can be found in many forms depending on their size and their rate of settling. Total suspended solids are the solids that do not pass through the standard glass fiber filter with a pore size of 0.45 micrometers and consists of different materials like silt, industrial waste and sewage, decaying plants, and animal waste (Murphy 2007). The concentration of total suspended solids (TSS) for discharging sanitary waste water should be below 12mg/L for thirty-day limit and 18mg/L for daily or seven-day limit (EPA 2014). Factors that determine the amount of total suspended solids are high water flow rates, soil erosion, urban runoff, wastewater and septic system effluent, decaying plants and animals, and bottom- feeding fish (Murphy 2007). Furthermore, suspended solids can serve as a heat sink by absorbing solar radiation, which ultimately may increase water temperatures, stress aquatic organisms, and potentially may create conditions favorable for disease in fish populations (Milligan & Pope 2001). Total dissolved solids (TDS) are solids in water that can pass through a filter (usually with a pore size of 0.45 micrometers) or the amount of material dissolved in water (Murphy 2007). It includes the inorganic salts and small, highly decomposed organic matter present in solution in water. The major sources of TDS in water are from natural sources, sewage, urban and agricultural run-off, and industrial wastewater. Salts used for road de-icing in winter can also contribute to the TDS loading in water (WHO 1996).

Fecal Coliform

Fecal coliform is an indicator of bacterial contamination from humans and other warm-blooded animals (livestock, pets, and wildlife). Elevated levels of fecal coliform in the water can affect the public health, economy, and overall quality of the environment (Washington State Department of Ecology 2005). Total coliform, fecal coliform, and fecal streptococci typically increases two- to three fold during storm events compared to base flow levels (Bolstad & Swank 1997). The amount of fecal coliform in a stream or lake increases with the amount of sewage waste and manure (Butler 2002, Washington State Department of Ecology 2005). Temperature, sunlight, seasonality, flow rate, and other abiotic factors are also associated with fecal coliform (McCulloch 2015). The concentration of fecal coliform bacteria increases with the increase mean velocity of the stream. The faster velocity of water causes an increase in the amount of sediment and associated *E. coli* being resuspended in the water column (McCulloch 2015). Beside being an indicator for potential pathogens, high fecal coliform can deplete oxygen in the water that is needed by fish and other aquatic animals, affect the natural acidic/alkaline (pH) balance of water, create odor problems and cause unpleasant views, and these can affect the local property values (Butler 2002).

Nutrients

Phosphorus is a crucial nutrient for plants, animals and humans. Under natural conditions phosphorus (P) is typically uncommon in water. However, human activities have resulted in excessive inputs of phosphorus into many freshwater systems (MPCA 2008). Phosphorus is a common constituent of agricultural fertilizers, manure, and organic wastes in sewage and industrial effluent. Soil erosion occurring during floods can transport phosphorous from adjacent land and the river banks into streams (USGS 2018). Most of the phosphorus discharged by wastewater treatment facilities is in the dissolved form of ortho-phosphorus (PO_4^{-3}). This form is readily available to algae and aquatic plants. Cycling of particulate phosphorus to the dissolved forms occurs in response to a variety of environmental conditions. The source of particulate phosphorus is from organic matter such as algae, plant and animal tissue, and waste solids. Microbial decomposition converts organic particulate P to dissolved P by decomposition. Additional P from soil minerals can be converted to dissolve P in the water and with changes in bottom sediment due to chemical and physical activity (MPCA, 2008). For example as temperature increases, the activity of bacteria, benthic alga, and phytoplankton get enhanced, and encourages bioturbation to release the phosphorus from the sediments (Hou et al. 2013). In addition, there is a positive relationship between phosphorous and total suspended solids (TSS). When TSS load is high, phosphorous load tended to be high, and when TSS is low, phosphorous load tended to be low. Phosphorous binds to suspended sediment particles that are included in TSS (Bunch 2016).

Chemical fertilizers and animal manures are commonly applied to crops to add nutrients (phosphorus, nitrogen, potassium, etc.). Heavy rainfall can generate runoff containing these materials into nearby streams and lakes. Some nitrate (NO_3^-) from automobile and industrial exhaust enters surface water from atmospheric deposition. Nitrate can be formed through oxidation of nitrite (NO_2^{-2}), ammonia (NH_3), and organic nitrogen compounds such as amino acids (USGS 2017). Sewage effluent and runoff from land where manure has been applied, can load additional ammonia and organic nitrogen into surface water. For warm water habitat the acceptable range of concentration of ammonia is 1.1 mg/L to 13 mg/L, depending upon pH and temperature (EPA 2014). Excess nitrogen and phosphorous can cause overstimulation of growth of aquatic plants and algae. Eutrophication of the lakes causes excessive growth of these organisms which decreases the DO and increases BOD. This can cause fish kills in lakes by depriving them of oxygen (USGS 2017).

Heavy Metals

Heavy metals are naturally occurring metallic elements which have a relatively high density and high atomic weights as compared to water. Heavy and toxic metals include metalloids, such as arsenic that are able to induce toxicity at low levels of exposure (Tchounwou et al. 2014). Various anthropogenic activities like mining and smelting operations, industrial production and use, and domestic and agricultural use of metals and metal-containing compounds are some of the major contributor to heavy metals. In addition, natural phenomena such as weathering and volcanic eruptions can be a significant contributor to heavy metal pollution. The presence of heavy and toxic metals in solutions in urban runoff is of concern as they are more toxic due to enhanced bioavailability and are non-degradable in the environment (Herngren & Ayoko 2005) Most of the heavy metals in the urban storm water runoff are attached to the suspended solids and the concentration of the metal generally increase with decreasing particle size. This is due to relatively large surface area of the fine sediments and their higher cation exchange capacity (Herngren & Ayoko 2005) Heavy metals like mercury, chromium, cadmium, lead, and arsenic are carcinogenic in nature. Higher concentration of these metals is toxic to biotic organisms and has been found to affect cellular activity in components like cell membrane, mitochondria, lysosome, endoplasmic reticulum, nuclei, and some enzymes (Tchounwou et al. 2014).

Land use and Sources

The land use within the watershed has many impacts on its water quality. Changes in the land cover and land management practices have been considered as key factors behind the alteration of hydrological systems. These land use changes lead to the alteration of runoff water as well as surface water quality (Huang et al. 2013). Understanding the relationship between land use and water quality can be used to identify target land use areas and to institute applicable best management practices or measures to minimize pollutant loadings (Ding et al. 2015).

Forest plays an incredible role in reducing storm water runoff to the waterways and by removing or filtering pollutants. The leafy canopy of the forests helps to filter and regulate the flow of water by intercepting rainfall, slowing the water decent to the ground and the forest floor. Forest can absorbs up to 18 inches of precipitation (depending on soil composition) which helps to recharge groundwater or is slowly released into the natural channels (Cotrone 2017). The vegetation and soil in forest and grassland can effectively reduce the nutrients, solids, salts, and other potential pollutants brought into the river by the surface runoff. Additionally, they play an important role in conserving water and soil (Huang et al. 2013). Total phosphorous, total nitrogen and ammonia nitrogen were strongly negatively correlated with the forest and positively correlated with urban areas in both dry and rainy season in Dongjiang River Basin of southeastern China (Ding et al.

2015). Similarly, a significant negative relationship between the forest and grassland area with total nitrogen, total phosphorus, chemical oxygen demand, and ammonia-nitrogen was found in Chaohu Lake basin of China (Huang et al. 2013). In central Japan forest area was found inversely related to almost all tested ions (i.e., K^+, Mg^{2+}, Ca^{2+}, NO_3^+, HCO_3^-, electrical conductivity and total major ions) (Bahar et al. 2008).

Expansion and intensification of agriculture in many countries has led to an increase use of commercial fertilizers and pesticides. When these fertilizers are not well managed, the applied chemicals runoff resulting in degraded water quality of rivers, lakes, and marine water bodies (Sagasta & Burke 2011). Agricultural fertilizer, herbicides, pesticides and insecticides have different chemicals within them, many containing nitrogen and phosphorous. These chemicals can potentially infiltrate into groundwater and contaminate water and food sources for humans as well as fish and wildlife or alter aquatic habitats (Permatasari 2017, EPA 2005). Increase in the proportion of agricultural land in the watershed area of Danish's lakes led to higher total nitrogen, total phosphorous and chlorophyll a (Nielsen et al. 2012). Similarly, positive relationship between the cultivated land area (%) and the concentration of NH_3-N and DO was found in Chaohu Lake basin of China (Huang et. al. 2013). The concentration of the sediment, nutrient like phosphorous, nitrate nitrogen and total nitrogen increases with the increase in planting area of corn and soybean and decreases with spring wheat, forest and pasture land (Lin et. al. 2015).

Impervious surfaces such as roads, parking lots, sidewalks, roof tops has increased as urbanization has increased resulting in the decrease of surfaces that can absorb and filter storm water (Kim et al 2016). Typically storm water runoff flows directly to the surface water with material that have been accumulated like lawn fertilizers, bacteria from animal waste, pesticides from lawn and gardens, metals from rooftops and roadway, and petroleum products from leaking vehicles polluting the surface water system and subsequently causing specific changes in the hydrology, habitat structure, water quality, and biodiversity of aquatic systems (USGS 2016, Kim et al. 2016). In Eastern Fork Little Miami River Basin agricultural and impervious urban land produced much higher level of nitrogen and phosphorous than other land surfaces (Tong & Chen, 2002). Similarly, at the Likangala River of southern Malawi, Total coliform increased by 176.1% and *Ecoli* counts increased by 157% downstream in urban levels similarly they also found, increased concentration of tested anion and cation (HCO_3^-, Cl^-, CO_3^{2-}, SO_4^{2-}, $NO_3^{-,}$ PO_4^{3-}, F^-, Ca^{2+}, Mg^{2+}, Na^+, K^+ and total iron) at the downstream of urban areas (Pullanikkatil et al. 2015). In the study done by (Permatasari 2017) at Ciliwung River in Jakarta found that the proportion of urban land was strongly positively associated with total nitrogen and ammonia nitrogen concentration.

Understanding the relationship between land use and water quality can provide insights to policymakers, researchers, and other interested stakeholders and thus play a key role in improving land management and water quality.

Mill Creek Watershed

The Mill Creek Watershed (MCW) is a sub watershed of the Lower Mahoning River Watershed located in northwest Ohio (Figure 1). Land uses around Mill Creek Watershed vary from residential to urban industrial as well as from agricultural to forested and recreational uses. In the southern part of the MCW the land uses consist primarily of forest, cropland and pastures. The land in the northern part is primarily devoted to urban and industrial development, residential areas, and contains numerous combined sewer overflows (McCracken 2007). Predominant metals within the watershed include calcium, potassium, magnesium, sodium, phosphorus, and sulfur, however, these metals are most likely due to the geology of the area, which is high in limestone (Hanna 2017). In the study done by Hanna (2017) on the Mill Creek watershed found that areas of agricultural land use had greater quantities of coliforms than that of urban and industrial land use.

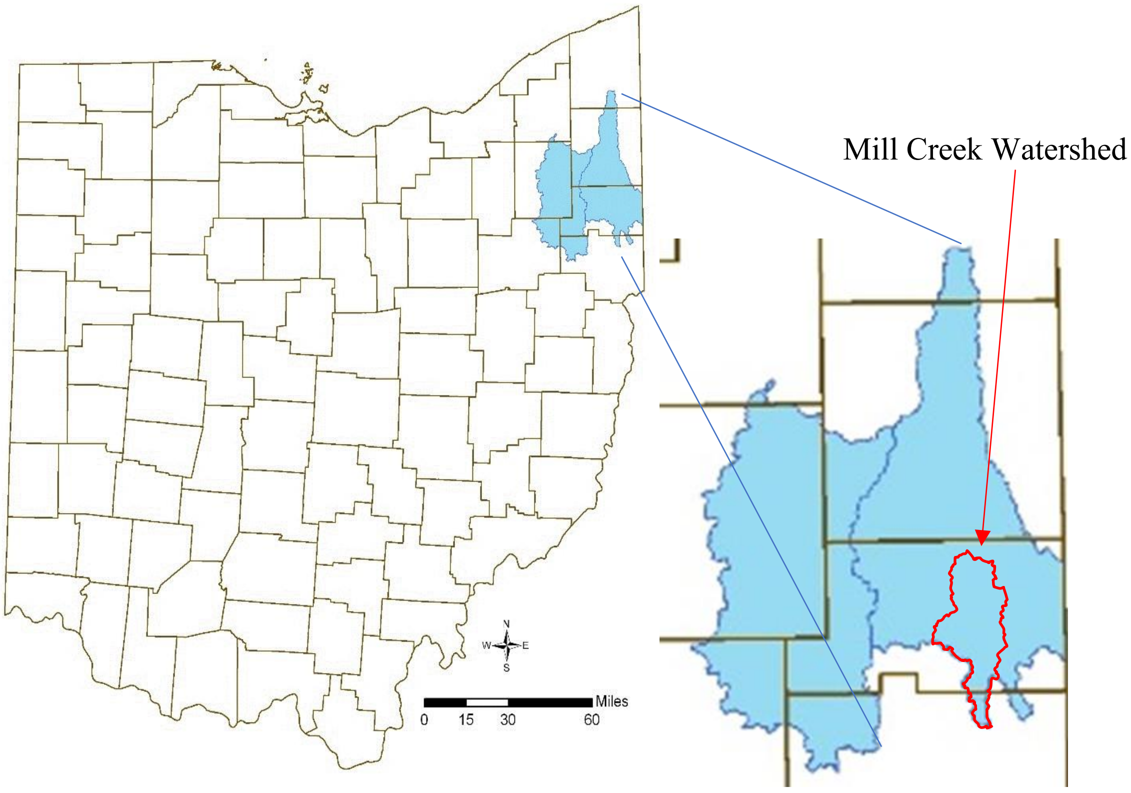


Figure 1: Map of the location of the Mill Creek Watershed in northeast Ohio

Chapter 3: Methodology

Study Area

The Mill Creek watershed (MCW), is a sub-watershed of the Mahoning River Watershed, has an area of 51,070 acres (78.4 squares miles) (McCracken 2007). According to the 2000 US Census Bureau of population and housing, approximately 96,500 citizens living within the Mill Creek watershed Mill Creek emerges from Columbiana County and runs north through Boardman Township and Mill Creek Park before finally merging with the Mahoning River at Youngstown, Ohio. The watershed has one major river, Mill Creek, and seven tributaries: Bears Den Run (6.6Km), Ax Factory Run (6.44 Km), Andersons Run (7.24Km), Cranberry Run (2.57Km), Indian Run (7.72 Km), Saw Mill Run (3.86Km) and Turkey Run (5.95Km) (McCracken 2007). There are no rare, threatened or endangered species of fishes; invertebrates, mammals, reptiles or amphibians in MCW. There are three dam segments within Mill Creek Park on the northern section of Mill Creek. The dams form Newport Lake, Lake Cohasset, and Lake Glacier (from upstream to downstream) (McCracken 2007). These reservoirs have considerable water holding capacity and can affect the hydrology and water quality of Mill Creek (McCracken 2007). Approximately 36 inches of precipitation falls on Mahoning County annually. Based on the 30 years records (1961- 1990) the average precipitation is 7.62 cm (3 inches) per months, with February (4.32 cm, 1.7 inches) typically being the driest month and July (10.41 cm, 4.1 inches) the wettest month.

In the southern part of the MCW, the land use consists primarily of forest, cropland and pastures. The land in the northern part is primarily devoted to urban development, residential areas, and combined sewer overflows. The forest is diverse and includes mixed mesophytic, mixed oak, beech, oak sugar maple, and elm-ash swamp (McCracken 2007). There are 15 different land use types as shown in Figure 2. These classifications were merged to seven types to enable better management as depicted in Figure 3.

Sampling Sites

Water samples were taken from eleven different locations in Mill Creek from inlet in Columbiana to outlet of at Mahoning River during low flow (baseline) and 24 - 36 hours after significant rainfall (>2 cm) events. Sampling points were chosen in such a way to make it representative of the whole watershed in terms of land use and practices. The sub-watershed was determined for each sampling point starting at the southern point where Mill Creek starts (Watershed 1) to the last point where the creek joins the Mahoning River (Watershed 15) (Figure 5). The delineate watersheds are based on the coordinate points that are collected from the field thus there might be some small portion of land between Mill Creek watershed and Mahoning river that is not included in this study.

Detailed information about each of these sampling sites is provided in the following subsections.

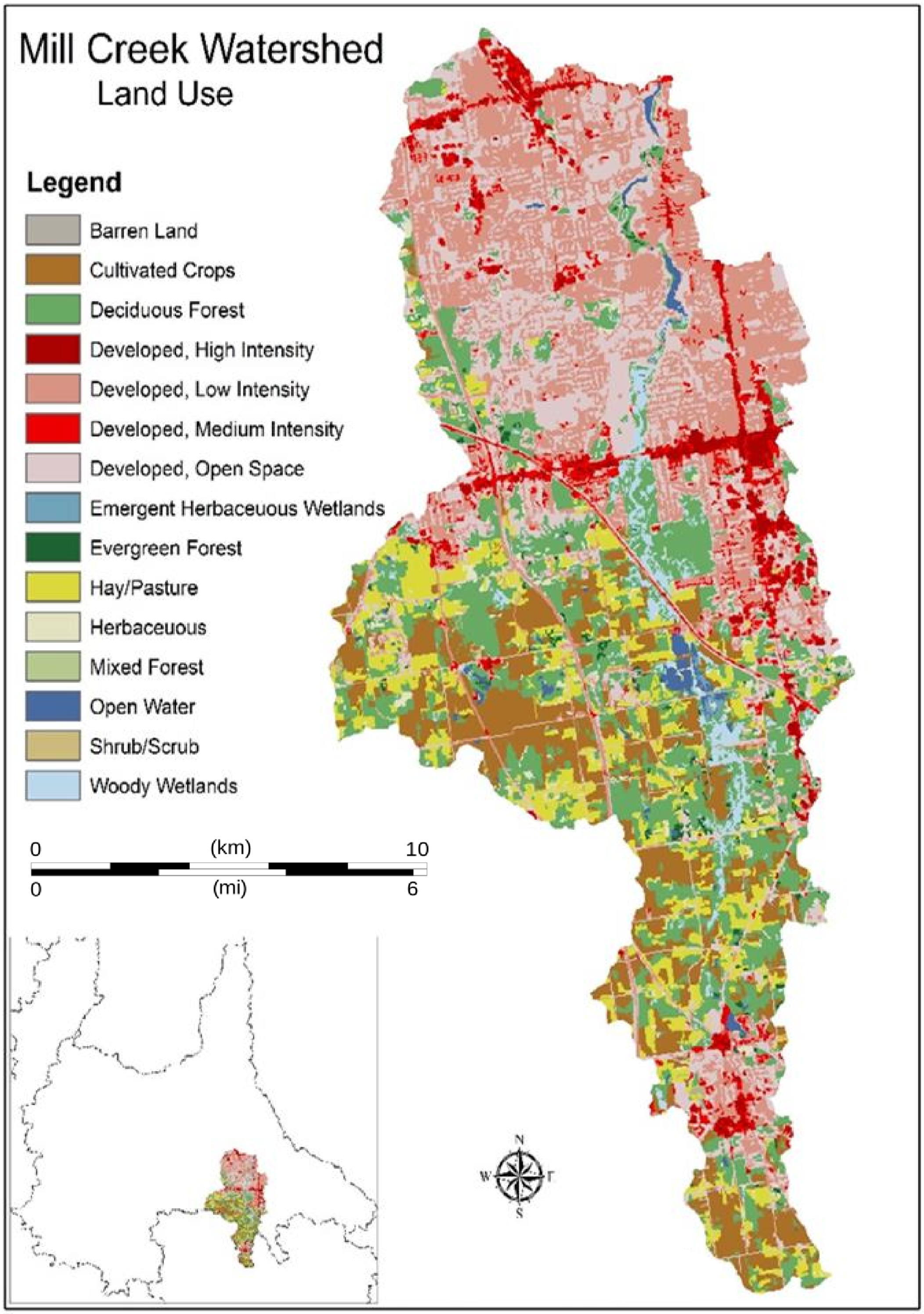


Figure 2: Land use pattern in Mill Creek Watershed (Source: Kimosop 2017)

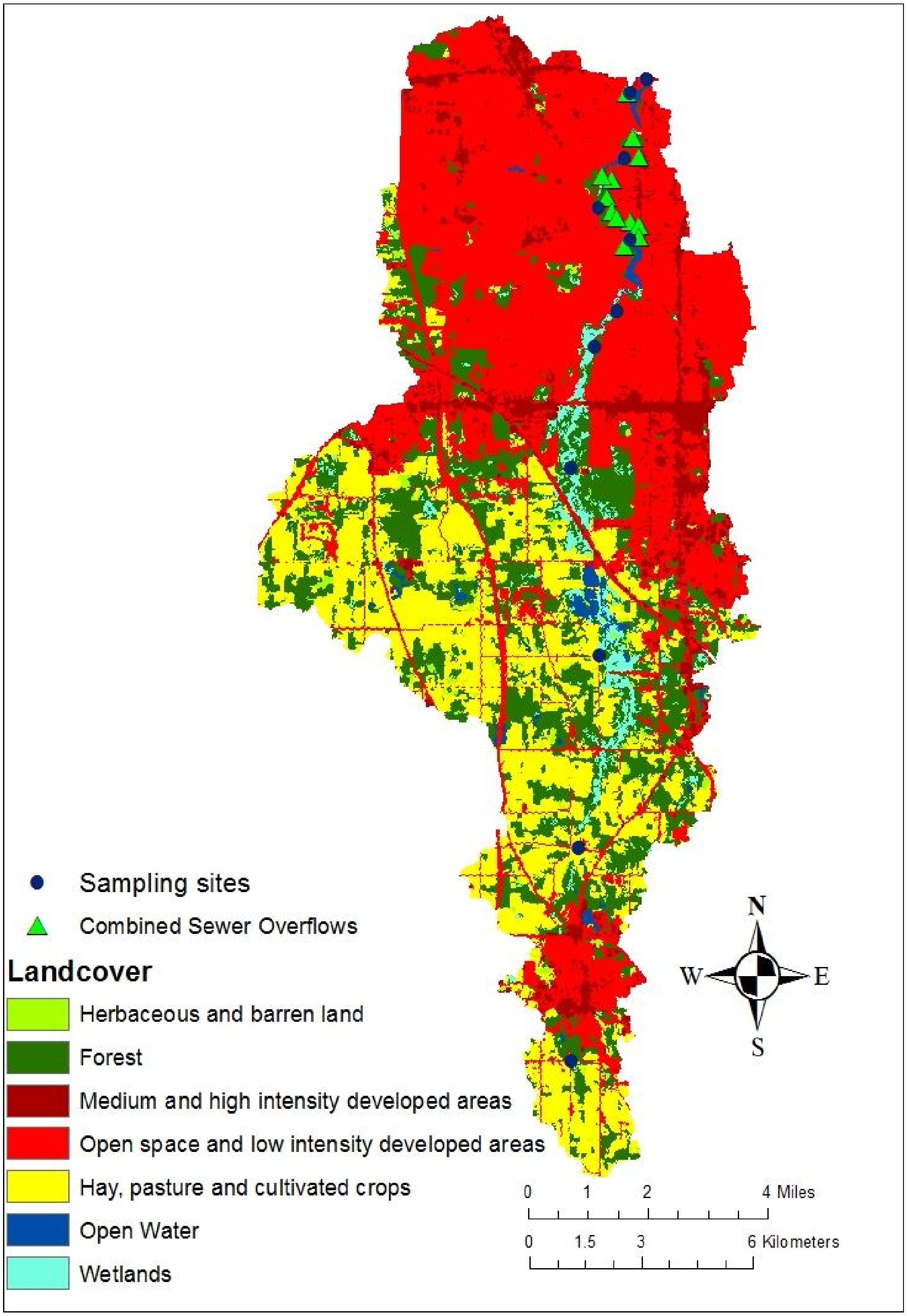


Figure 3: Reclassification of land use to sampling sites and combined sewer overflows of Mill Creek Watershed.

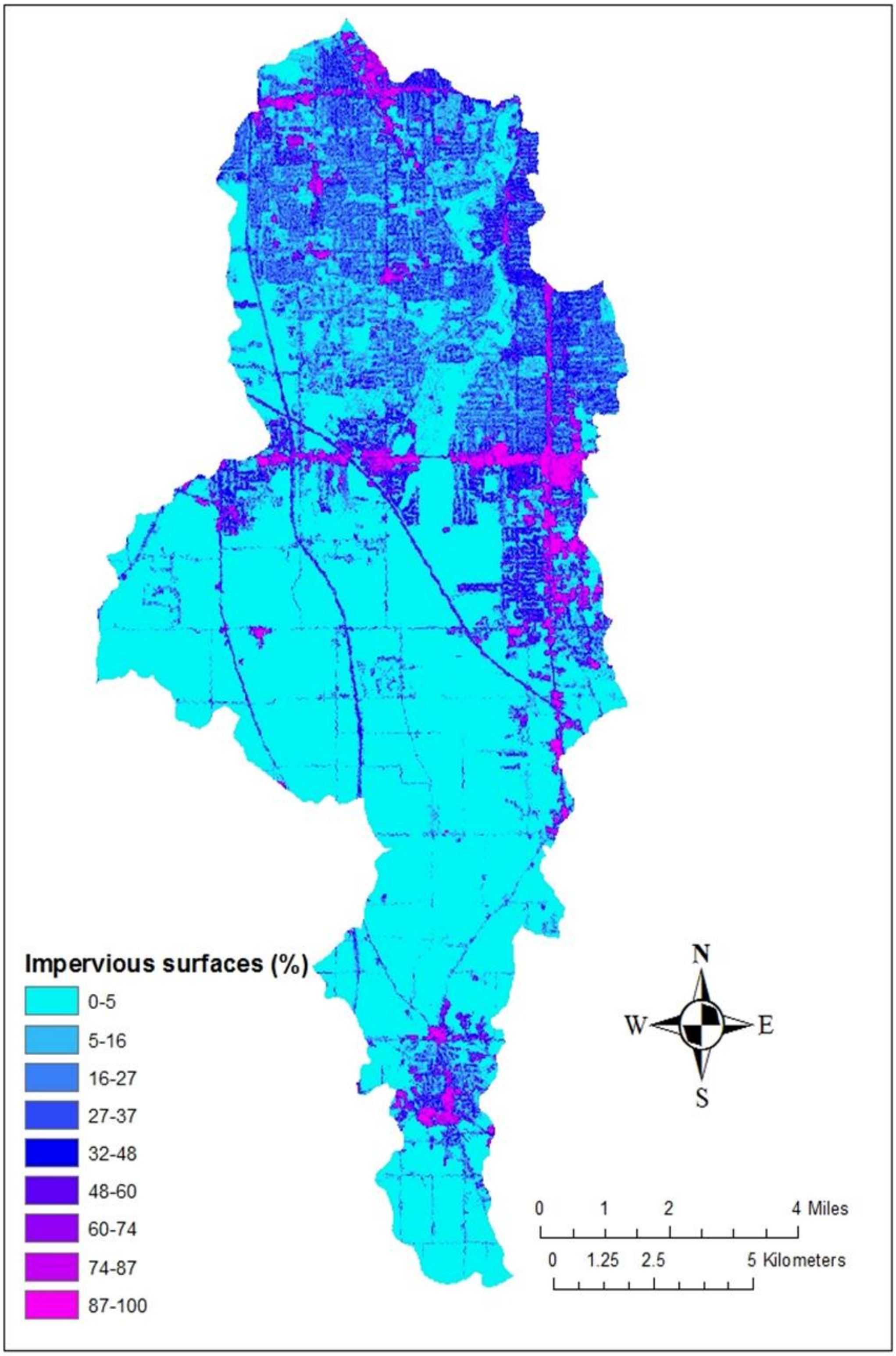


Figure 4: Imperviousness of Mill Creek Watershed

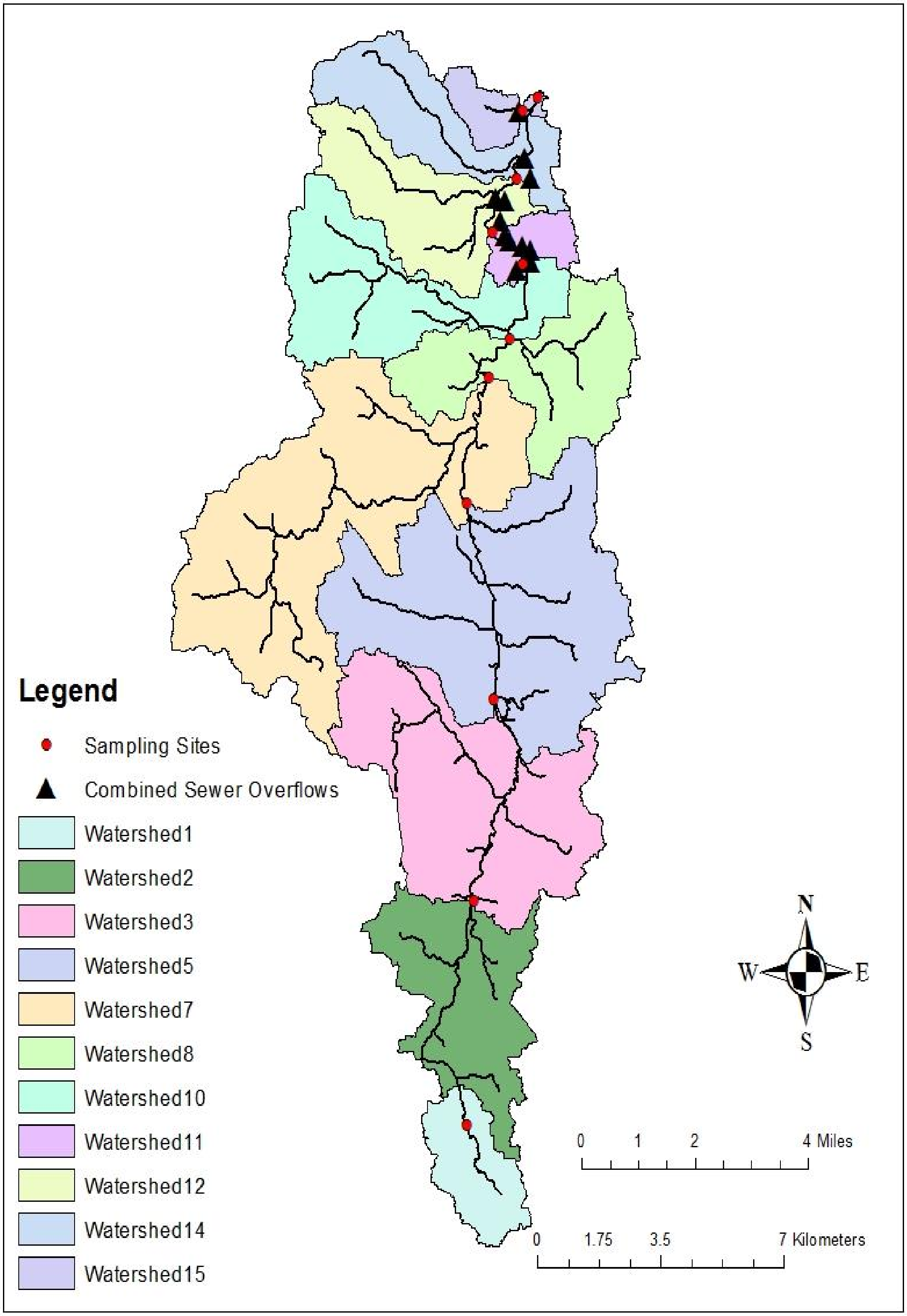


Figure 5: Delineation of Mill Creek Watershed into Sub-Watersheds and its tributaries based on the sampling points

Site 1 is located at the intersection of the Matz Rd and Camelot Dr (40°52'15.2" N 80°41’54.9’’ W) in Columbiana County with the total drainage area of 1736.90 acres. The nearby land use practices are agricultural with buffer strip and impervious surfaces. Impervious surfaces make about 4.038% of the surrounding land by area. The surface water flow rate and sampling depth range from 0.03 to 0.24 m/sec and 0.15m to 0.3m respectively. Figure 6 and Table 1 both present the land use practices in the sub-sub-watershed.

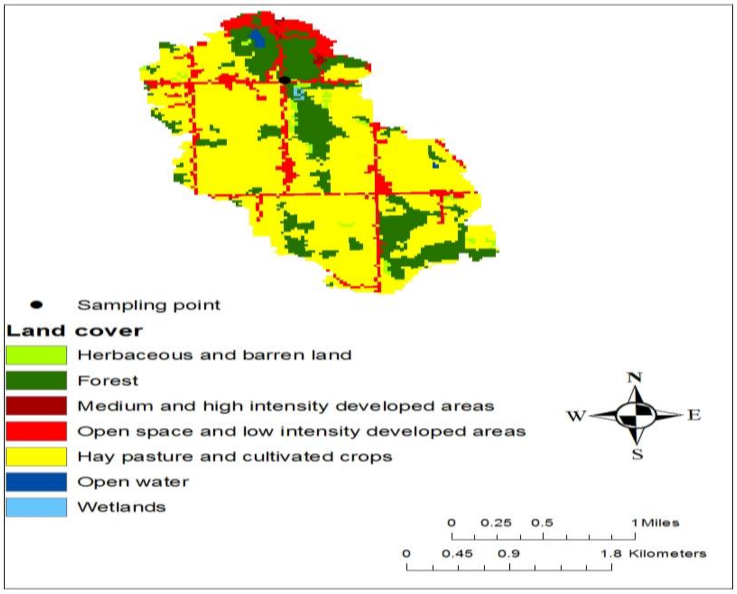


Figure 6: Spatial pattern of land cover for sub-watershed 1

Table 1: Distribution of land use for Watershed 1 (Site1)*

Land use	Area in acres	Percentages (%)
Herbaceous	25.13	1.45
Open space and low intensity developed areas	199.7	11.50
Medium intensity developed areas	5.120	0.29
Hay, pasture, Cultivated crops	1120	64.48
Forests	377.4	21.73
Open water	6.890	0.40
Wetlands	2.670	0.15

- Site 1 is located at Intersection Matz Rd and Camelot Dr. The area near by the sampling point is dominated with cultivated land

Site 2 is located at Mill Creek at Rt 40 (40°55'15.5"N 80°41'43.5" W) near a farm on Renkenberger Rd, at the Columbiana County. The total drainage area for this site is 5901.91 acres and the area from Site 2 to Site 1 is 4165.004 acres. This site is surrounded by agricultural land with buffer strip while the Youngstown Elser metro airport is also located within this site. The surface water flow rate and sampling depth depend upon rain events range from 0.05 to 0.65 m/sec and 0.25m to 0.8m respectively. Impervious surfaces make only about 4.038% of the land by area. The detailed information about different land use for this sub-sub-watershed is presented in Table 2 and Figure 7.

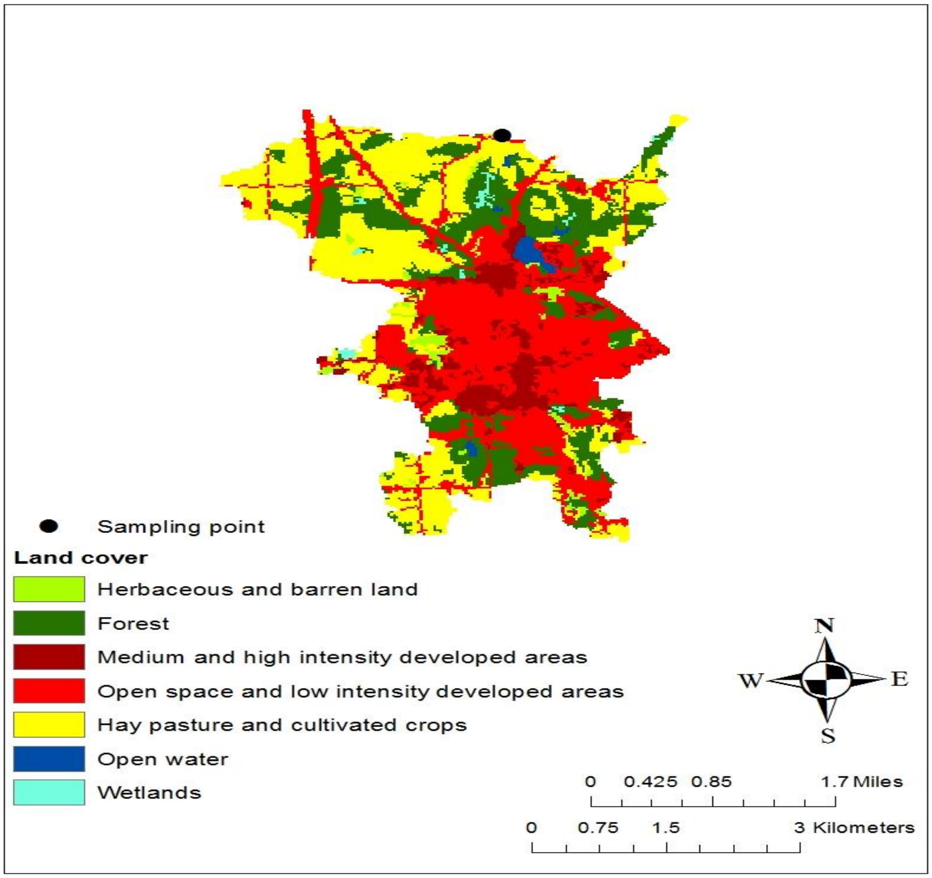


Figure 7: Spatial pattern of land cover for Sub-sub-watershed 2

Table 2: Distribution of land use for Watershed 2 (Site 2)*

Land use	Sub-sub basin area (from site 2 to site 1) in acres	Percentages (%)
Herbaceous and barren land	88.07	2.11
Forest	820.9	19.17
Medium and high intensity developed areas	408.8	9.81
Open space and low intensity developed areas	1504	36.10
Hay, pasture and cultivated crops	1271	30.52
Open water	1504	36.10
Wetlands	32.47	0.78

* Site 2 is located at near Renkenberger Rd. The area near by the sampling point is dominated with cultivated land

Site 3 is located at the intersection of Lynn and Bassinger (40°57’57.8’’N 80°41’19.0’’ W) at the Columbiana County with the total drainage area of 13281.18 acres. The area from Site 3 to Site 2 is 7379.27 acres. Surrounding land has been used for cow farming, pastures. The Lake Front golf course is located nearby and there is a cemetery as well. The surface water flow rate and sampling depth ranges from < 0.01 to 0.35 m/sec and 0.3 to 1.4 m respectively. The surrounding land has 4.419% of impervious surfaces. Figure 8 and Table 3 depict detailed land use information for this sub-sub-watershed.

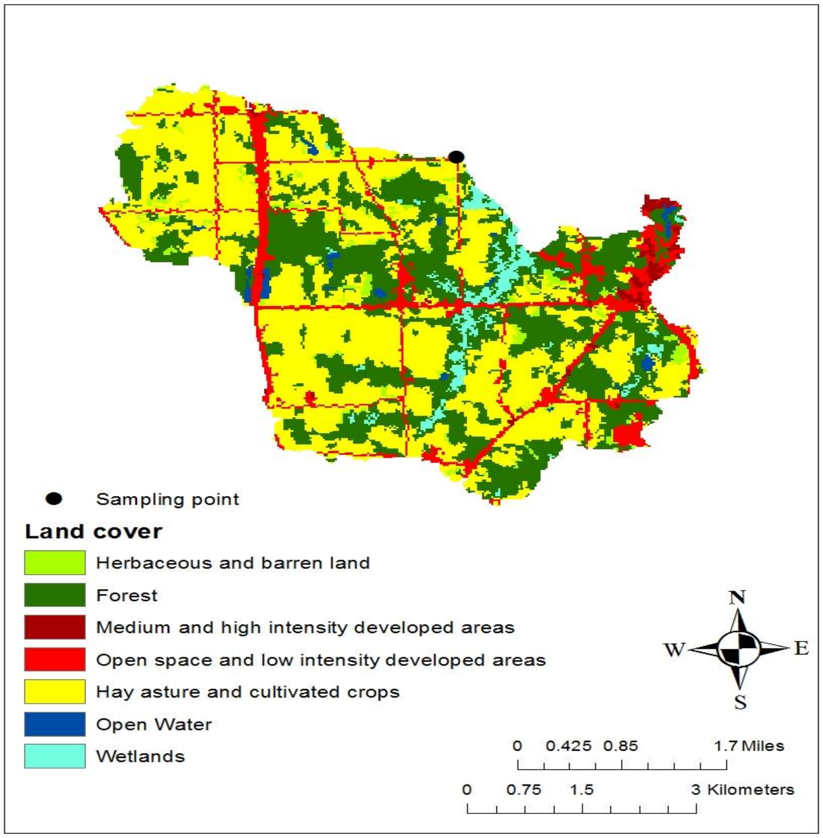


Figure 8: Spatial pattern of land cover for Sub-sub-watershed 3

Table 3: Distribution of land use for Watershed 3 (Site 3)*

Land use	Sub-sub basin area (from site 3 to site 2) in acres	Percentages (%)
Herbaceous and barren land	200.4	2.72
Forest	2479	33.59
Medium and high intensity developed areas	89.62	1.21
Open space and low intensity developed areas	73.39	0.99
Hay, pasture and cultivated crops	3483	47.20
Open water	73.39	0.99
Wetlands	233.7	3.17

* Site 3 is located at the intersection of Lynn and Bassinger. Cow farm and pasture land are the nearby land use practices of this sampling point

Site 5 is located near the Boardman wastewater treatment (41°00'35.3"N 80°41’49.8’’W) plant at the Mahoning County with the total drainage area of 23084.99 acres. The area from Site 5 to Site 3 is 9803.82 acres. Besides the Boardman WWTP nearby land is also used for housing development while the impervious surfaces account for about 14.61% of total land area. The detailed land use information of this sub-sub-watershed is presented in Figure 9 and Table 4. The surface water flow rate ranges from 0.04 to 0.11 m/sec and sampling depth ranges from 0.37 to > 1.5 m respectively.

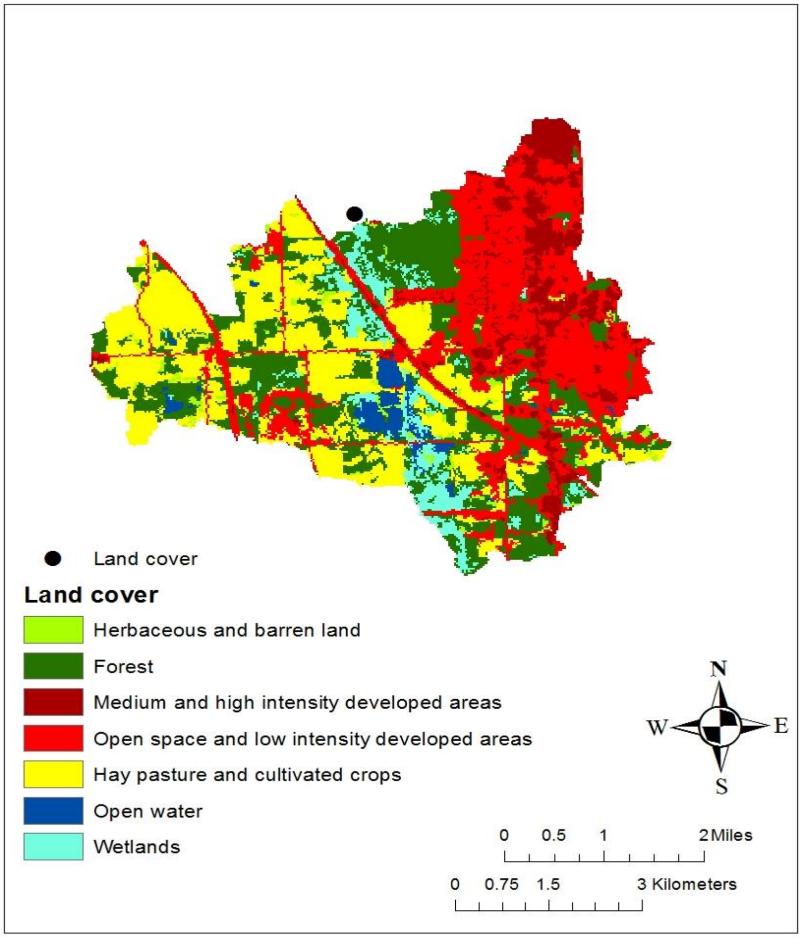


Figure 9: Spatial pattern of land cover for Sub-sub-watershed 5

Table 4: Distribution of land use for Watershed 5 (Site 5)*

Land use	Sub-sub basin area (from site 3 to site 5) in acres	Percentages (%)
Herbaceous and barren land	238.2	2.43
Forest	2473	25.23
Medium and high intensity developed areas	998.6	10.19
Open space and low intensity developed areas	2714	27.68
Hay, pasture and cultivated crops	2557	26.08
Open water	248.6	2.54
Wetlands	573.6	5.85

* Site 5 is located near Boardman Waste Water Treatment Plant. Surrounding Land use practices at this site are housing development and Boardman WWTP.

Site 7 is located at the end of Lundy lane near the Mill Creek Golf course (41°02’16.8’’N 80°41’23.1’’W) at the Mahoning County with the total drainage area of 23688.35 acres. The area from Site 7 to Site 5 is 603.36 acres. Land nearby is basically used for housing development while it also includes the Mill Creek Golf Course. Impervious surfaces around this site make about 11.56% of total land area. Detailed land use information for this sub-sub-watershed is presented in Figure 10 and also in Table 5. The surface water flow rate and sampling depth ranges from 0.05 to 1 m/sec and 0.17 to 1m respectively. The flow rate and sampling depth changes with the intensity of rainfall.

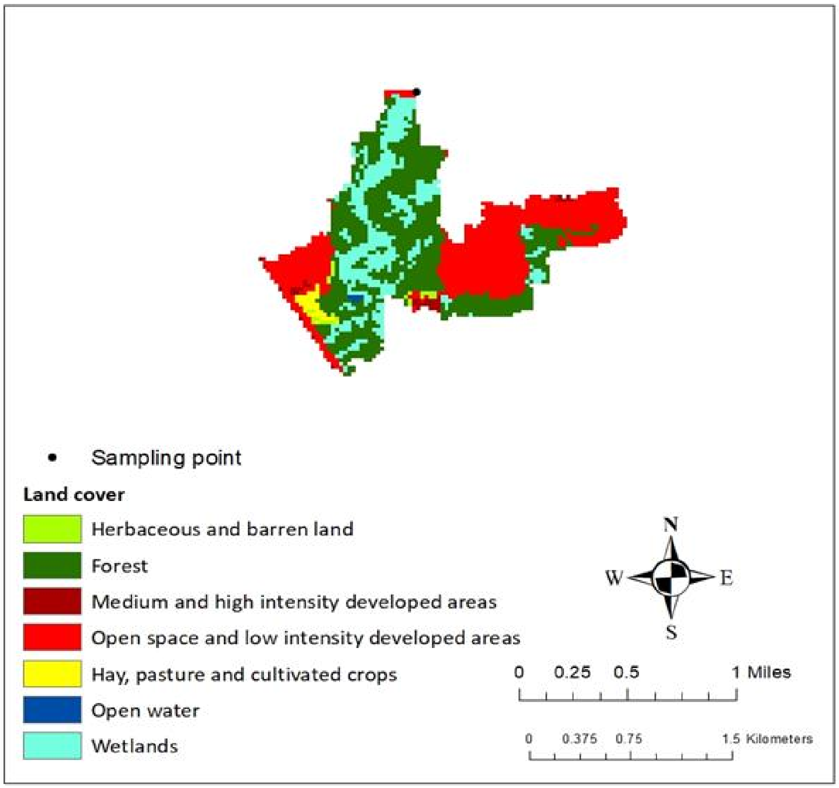


Figure 10: Spatial pattern of land cover for Sub-sub-watershed 7

Table 5: Distribution of land use for Watershed 7 (Site 7)*

Land use	Sub-sub basin area (from site 5 to site 7) in acres	Percentages (%)
Herbaceous and barren land	6.230	1.03
Hay, pasture and cultivated crops	245.5	40.70
Medium and high intensity developed areas	10.45	1.73
Open space and low intensity developed areas	214.4	35.53
Wetlands	8.670	1.44
Open water	1.330	0.22
Forest	116.8	19.35

* Site7 is located at the ends of Lundy lane near the Mill Creek Golf Course. The nearby land use of this site is housing development

Site 8 is located at the south of Newport wetland near Cranberry run joins at the Mahoning (41°02'47.3"N 80°40’57.4’’W) County with the total drainage area of 33665.41 acres. The area from Site 8 to Site 7 is 9977.06 acres. The surface water flow rate at this site is 0.03 to 0.46m/sec and sampling depth ranges from 0.18 to 1.15 meter respectively depending on the rainfall events. The surrounding area of this site consists of 13.21% of impervious surfaces. This site is located nearby the Shield’s road and the Mill Creek Golf Course. Figure 11 and Table 6 show detailed information about the land use pattern for this sub-sub-watershed.

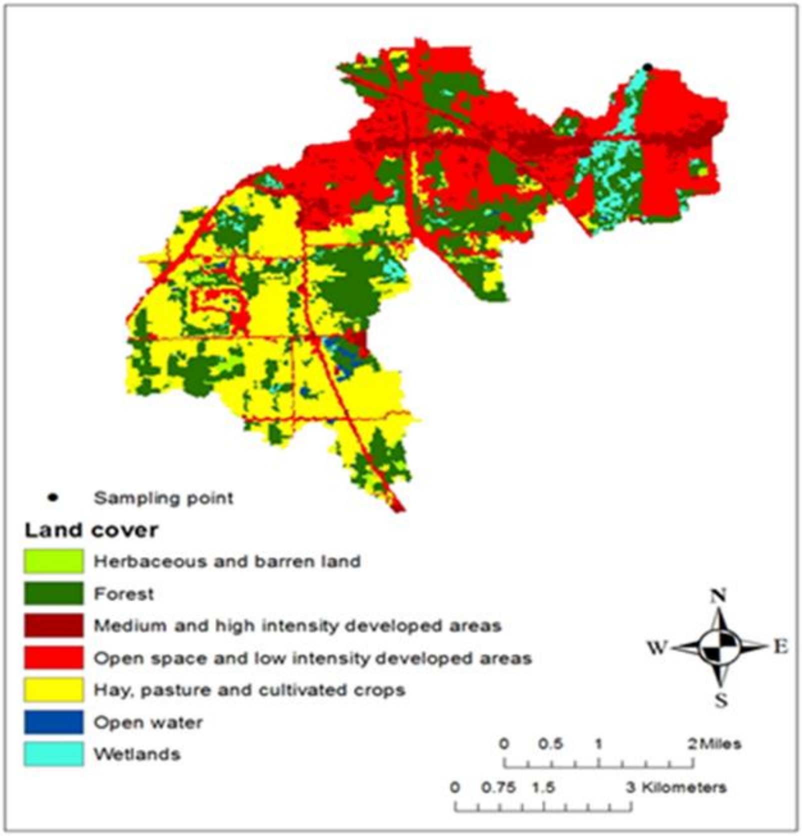


Figure 11: Spatial pattern of land cover for Sub-sub-watershed 8

Table 6: Distribution of land use for Watershed 8 (Site 8)*

Land use	Sub-sub basin area (from site 10 to site 8) in acres	Percentages (%)
Herbaceous and barren land	237.1	2.38
Forest	2666	26.72
Medium and high intensity developed areas	778.8	7.81
Open space and low intensity developed areas	3088	30.95
Hay, pasture and cultivated crops	2933	29.39
Open water	56.04	0.56
Wetlands	219.3	2.20

* Site 8 is located near the Cranberry run near the shield road at the overpass. Nearby land use practices include impervious surfaces and Shield's road

Site 10 is the Newport Lake at the Mahoning County (41°03'47.0'' N 80°40'41.5'' W) with the total drainage area of 37837.53 acres. The area from Site 10 to Site 8 is 4172.12 acres. While a portion of the site is wetland, part of the nearby land is also dedicated to housing development and consists of 27.10% of impervious surfaces. Detailed land use information for this sub-sub-watershed is presented in Figure 12 and Table 7. The surface water flow rate and sampling depth ranges from<0.01 to 0.24 m/sec and 0.43 to 0.75m respectively, which depends upon rainfall events.

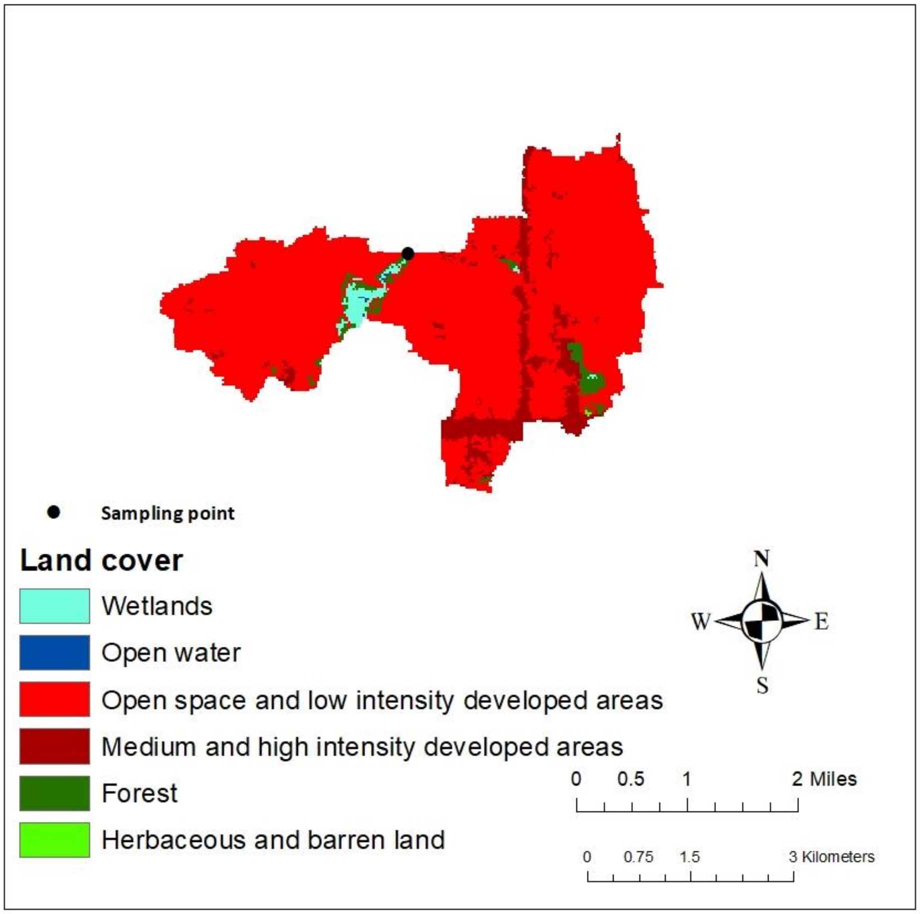


Figure 12: Spatial pattern of land cover for Sub-sub-watershed 10

Table 7: Distribution of land use for Watershed 10 (Site 10)*

Land use	Sub-sub basin area (from site 11 to site 10) in acres	Percentages (%)
Herbaceous and barren land	1.110	0.03
Forest	102.5	2.46
Medium and high intensity developed areas	416.9	10.0
Open space and low intensity developed areas	3584	85.90
Hay, pasture and cultivated crops	0	0
Open water	3.560	0.09
Wetlands	64.05	1.54

* Site 10 is located near the Lake Newport. Nearby land use practices are housing development and wetland.

Site 11 is located at the Lantermann's Mill (41°04'13.6"N 80°41'18.4''W) at the Mahoning County with the total drainage area of 42437.54 acres. The area from Site 11 to Site 10 is 4172.12 acres. This site is dominated by housing and development and 16.37% of that is impervious. The surface water flow rate at this site ranges from<0.01 to 0.23m/sec and the sampling depth ranges from 0.1 to 0.4 m which depend upon the intensity of rainfall. There is one combined sewer overflow near this sampling site. Detailed distribution of land use for this sub-sub-watershed is presented in Figure 13 and Table 8 below.

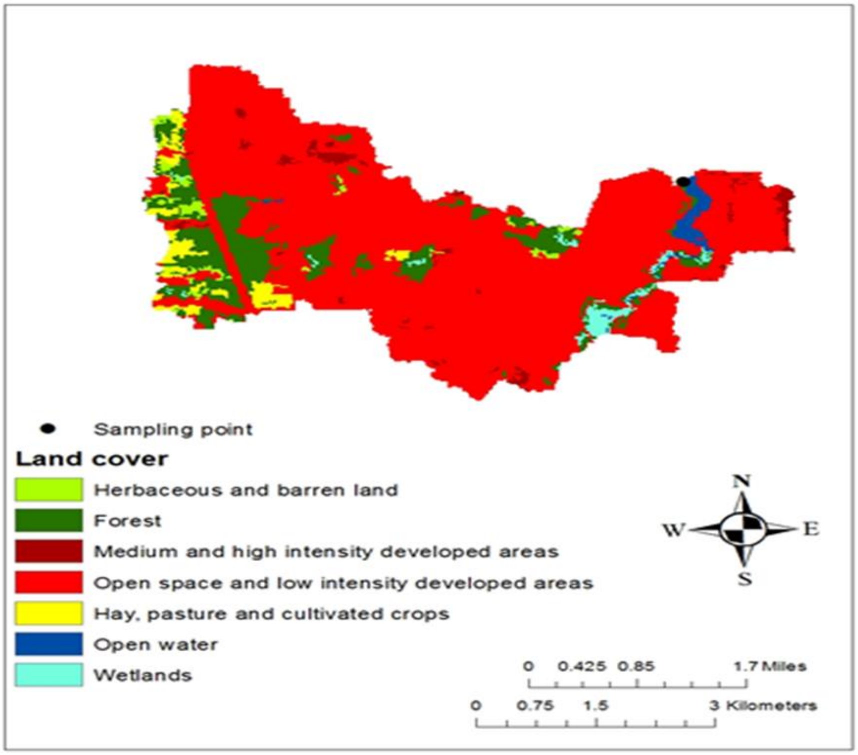


Figure 13: Spatial pattern of land cover for Sub-sub-watershed 11

Table 8: Distribution of land use for Watershed 11 (Site 11)*

Land use	Sub-sub basin area (from site 12 to site 11) in acres	Percentages (%)
Herbaceous and barren land	91.18	1.98
Forest	686.1	14.91
Medium and high intensity developed areas	115.9	2.52
Open space and low intensity developed areas	3426	74.47
Hay, pasture and cultivated crops	177.9	3.87
Open water	68.50	1.49
Wetlands	34.92	0.76

* Site 11 is located near the Lanterman's Mill. The site is dominated with housing development

Site 12 is located at the west Cohasset trail 5, near the Lake Cohasset (41°04'55.9"N 80°40'47.4''W) at the Mahoning County. The total drainage area of this site is 43227.26 acres and has 5 CSOs. The area from Site 12 to Site 11 is 789.72 acres and has 4 CSOs. Nearby land is basically used for housing development and about of 29.88% land by area is impervious. The recorded surface water flow rate and sampling depth ranges from 0.1 to 0.31m/sec and 0.2 to >1.5m respectively depending on rain events.

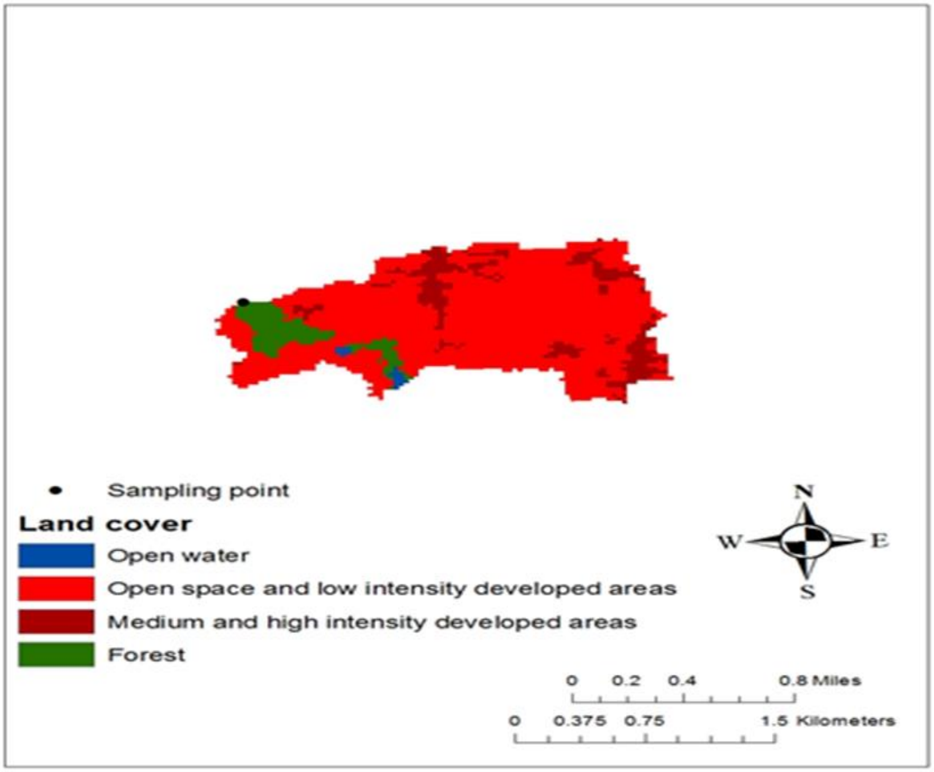


Figure 14: Spatial pattern of land cover for Sub-sub-watershed 12

Table 9: Distribution of land use for Watershed 12 (Site 12)*

Land use	Sub-sub basin area from site 14 to site 12 in acres	Percentages (%)
Herbaceous and barren land	0	0
Forest	52.04	6.59
Medium and high intensity developed areas	80.95	10.25
Open space and low intensity developed areas	643.6	81.50
Hay, pasture and cultivated crops	0	0
Open water	13.12	1.66
Wetlands	0	0

* Site 12 is located near the lake Cohasset just after the dam. The nearby land use practices are housing development.

Site 14 (watershed 14) is the Lake Glacier near the Boat Center Dock (41°05'50.7"N 80°40'40.5"W) at Mahoning County with the total drainage area of 46659.26 acres with

11 CSOs. The area from Site 14 to Site 12 is 3432.0 acres with 3 CSOs. The nearby land use practice is predominantly housing development and impervious surfaces make about 24.25% of the land by area. Figure 15 and Table 10 below show the spatial pattern and distribution of land use for this sub-sub-watershed. The surface water flow rate ranges from <0.01 to 0.50m/sec and sampling depth ranges from 0.5 to 1.5m respectively.

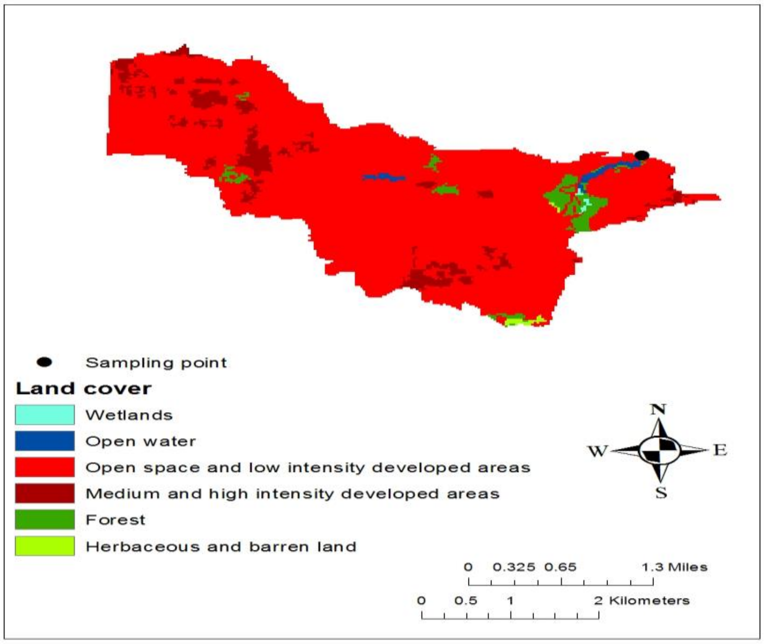


Figure 15: Spatial pattern of land cover for Sub-sub-watershed 14

Table 10: Distribution of land use for Watershed 14 (Site 14)*

Land use	Sub-sub basin area from site 14 to site 12 in acres	Percentages (%)
Herbaceous and barren land	11.56	0.34
Forest	107.6	3.14
Medium and high intensity developed areas	257.8	7.51
Open space and low intensity developed areas	3021	88.03
Hay, pasture and cultivated crops	0	0
Open water	29.36	0.86
Wetlands	4.450	0.13

* Site 14 is located at the Lake Glacier. The nearby land use practices are housing developments

Site 15 is Mill Creek to Mahoning River (41°06'02.1"N 80°40'21.9"W) with the total drainage area of 50786.90 acres. There are 12 CSOs at the total drainage area of this site. The area from Site 15 to Site 14 is 4127.64 acres with 4 CSOs. Land use around this site is basically housing development and impervious surfaces account for 29.04% of the land. Detailed information of land use pattern for this sub-sub-watershed is presented in Figure 16 and Table 11. Depending on rainfall, the surface water flow rate and sampling depth ranges from <0.01 to 0.1m/sec and 0.5 to 1m respectively.

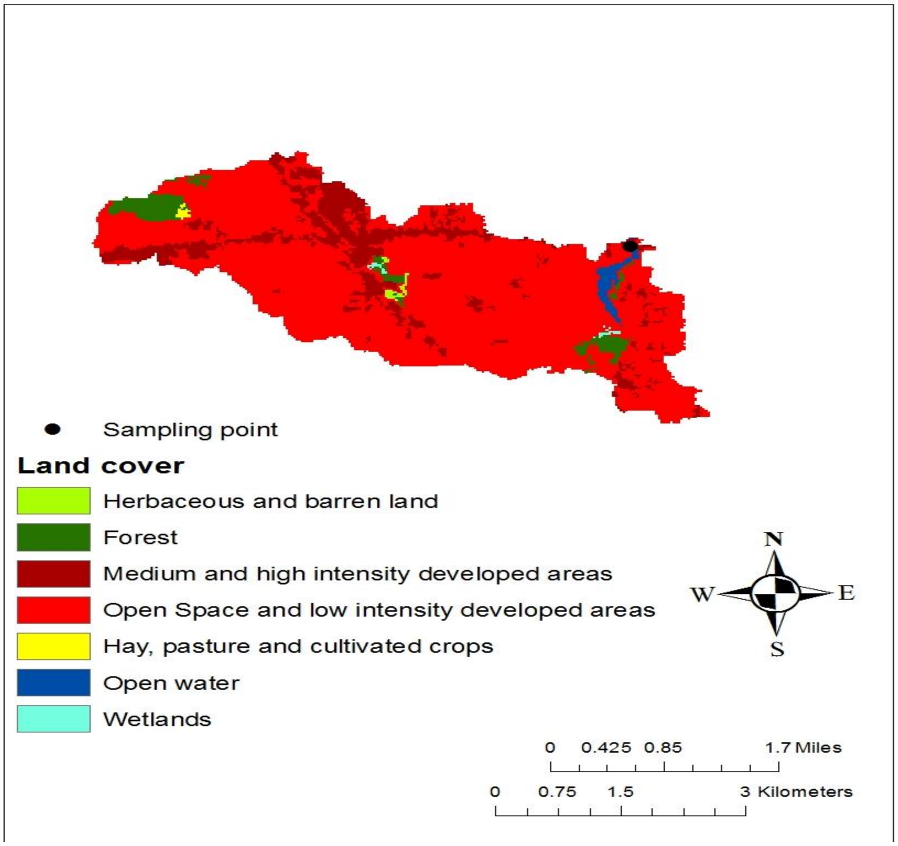


Figure 16: Spatial pattern of land cover for Sub-sub-watershed 15

Table 11: Distribution of land use for Watershed 12 (Site 15)*

Land use	Sub-sub basin area (from site 14 to site 15) in acres	Percentages (%)
Herbaceous and barren land	19.46	0.45
Forest	190.6	4.62
Medium and high intensity developed areas	599.4	14.52
Open space and low intensity developed areas	3191	77.30
Hay, pasture and cultivated crops	76.50	1.85
Open water	42.48	1.03
Wetlands	9.630	0.23

* Site 15 is located at the Lake Glacier. The nearby land use practices are housing developments

Water Quality Parameters

Physical parameters like temperature, pH, conductivity and dissolve oxygen were taken on site using YSI probe (GENESYS 10S VIS). Float method was used to determine the surface water flow rate and the sampling depth was measured with a measuring-stick. Nalgene bottles (1000mL) were used to collect the duplicate samples and each clean bottle was rinsed with sample water before taking samples. Different water quality parameters like total coliform, *E. coli*, BOD, soluble reactive phosphorous, solids, ammonia, nitrate, and soluble metals were determined by using standard methods in the YSU ‘s laboratory, that are described in detail in the following paragraphs.

Total Solids (TS)

Porcelain dishes were cleaned and dried at 105^{o}C for 1 hour and for the volatile solids dishes were kept in a muffle furnace (Thermolyne, 1400 Furnace) at 550^{o}C for 1 hr, then were cooled, and their mass were measured using an analytical balance. Approximately, 25 to 50 ml of well-mixed samples were added to porcelain dishes with the help of a volumetric pipette and the samples were evaporated to dryness in an oven at 105°C. The dishes were cooled to room temperature and the final mass was measured. Total solids were measured by subtracting from final mass of residue plus dish to the initial mass of dish and the obtained result was divided by the volume of the aliquot (Clesceri et al. 1999) (Eq. 1).

Equation 1 $$TS = \frac{(M2-M1)}{V}.$$

TS= Total Solids (mg/L)
M2= Final mass of residue plus dish (mg)
M1= Initial mass of dish (mg)
V= Volume of sample (L)

Total suspended solids (TSS)

Pre-weighted glass filter papers were placed into filtration funnel with the help of forceps. Water samples, 100-200 ml, were measured with graduated cylinder and a vacuum was applied to draw the samples through the filter. The filter was removed with the forceps and returned it to the same aluminum pan and dried in an oven at 105°C for 1 hour or until dry. The final mass of filters and residues were determined (Clesceri et al. 1999) (Eq. 2).

Equation 2 $$TSS = \frac{(M2-M1)}{V}$$

TSS = Total Suspended Solids (mg/L)
M1 = Initial mass of Pan plus filter (mg)
M2 = Final mass of Pan, Filter and Residue (mg)
V = Volume of Aliquot (L)

Total Volatile Solids and Volatile Suspended solids (TVS and VSS)

The porcelain dish and filters from determining TS or TSS were placed in a muffle furnace (Thermolyne, 1400 Furnace) and heated at 550°C for at least 1 hour. The dishes or filters were cooled, and the mass were determined using an analytical balance for TVS and for VSS (Clesceri et al. 1999) (Eq. 3).

Equation 3 $$TVS\ or\ VSS = \frac{(M2-M3)}{V}$$

TVS = Total Volatile Solids (mg/L)
VSS = Volatile Suspended Solids (mg/L)
M2 = Mass of dish or pan filter & residue (at 105°C) (mg)
M3 = Final mass at 550°C (mg)

Total dissolved solids

Total Dissolved solids were calculated by subtracting total solids with the total suspended solids of water samples (Eq. 4).

Equation 4 $$TS - TSS = TDS$$

Ammonia: Berthelot method

Five different concentrations of NH_3N standard solutions (manufactured by RICCA Chemical Company) ranging from 0.1ppm to 1ppm and a blank were prepared in volumetric flask. Then, 25 ml of each water samples and standards were taken in the Erlenmeyer flask. One ml of Na_2 EDTA reagent and few drops of DI water were added to water samples and standards and are allowed to sit for 1 min. Then, 4ml of the Salicylate – Nitroprusside reagent and 2ml of buffered hypochlorite were added to flasks and were placed in the water bath maintained at 37ºC and allowed to remain there for 30 minutes until the color changed into green. The flasks were removed and cooled to room temperature for approximately 10 minutes and the absorbance of the colored complex at the wavelength of 667nm was determined against a blank solution using (GENE SYS 10S VIS) spectrophotometer.

Calibration curve of concentration vs. absorbance of standard was plotted. Ammonium concentration was plotted in abscissa and absorbance was plotted in ordinate. Equation of the straight line obtained from the calibration curve was used to find out the concentration of ammonia in water samples (Sparks 1996).

Nitrate – nitrogen: Colorimetric Method

Five different concentrations of standard solutions (manufactured by RICCA Chemical Company) of NO3-N between 10ppm to 60ppm and a blank were prepared. To test the water sample, 0.25ml of water sample and the standards were taken in the Erlenmeyer flasks. Water samples and standards were mixed thoroughly with 0.8ml of 5% salicylic acid and then allowed to cool for 20 minutes at room temperature. After that 19ml of 2N NaOH was added to raise the pH above 12 and was allowed to cool at the room temperature. Then, the absorbance of the colored complex at the wavelength of 410nm was determined using the spectrophotometer (GENE SYS 10S VIS) against a blank solution.

Calibration curve of concentration Vs absorbance of standard was plotted. No3-N concentration is plotted in abscissa and absorbance was plotted in ordinate. Equation of the straight line obtained from the calibration curve was used to find out the concentration of No3-N in water samples (Cataldo et al. 1975).

Nitrate- nitrogen: Ion - selective electrodes method

Four different concentration's standard solutions of NO_3N (manufactured by RICCA Chemical Company) ranging from 10ppm to 50ppm and a blank were prepared. To test the standards and the water sample, 25ml of sample was transfer in the 50ml of Erlenmeyer flask. Then 1ml of suppressor solution (Orion ion plus by Thermo scientific) was added and mixed thoroughly. A nitrate electrode (manufactured by Thermo Scientific) attached to meter was inserted into the sample. The millivolt reading was taken with the help of the nitrate electrode.

Calibration curve of logarithmic concentration vs potential measurement of standard was plotted. NO_3-N concentration was plotted in abscissa and absorbance was plotted in ordinate. The straight line obtained from the calibration curve was used to find out the concentration of NO3-N in water samples (Clesceri et al. 1999).

Soluble reactive phosphorus: Ascorbic Acid Method

First, combined reagent was prepared by dissolving 100mL of 5N H_2SO_4, 10mL of potassium antimony tartrate solution and 60 mL of ascorbic acid at 200mL volumetric flask. Then, five different standards were prepared at the concentration between 0.1 ppm to 1 ppm, using the phosphate standard solution and 25ml volumetric flask. In addition to standards one blank solution was also prepared. In order to determine the amount of soluble reactive phosphorous, 25ml of samples and the standard were transferred into Erlenmeyer flasks. Then 4mL of combined reagent was added to the samples, blank solution and the standards and were mixed well and set for 10 minutes until it developed a blue color and their absorbance were taken at 880nm with the help of spectrophotometer (GENE SYS 10S VIS).

The standard calibration curve was plotted with the concentration on the abscissa and the absorbance on the ordinate. The resulting regression equation was used to predict the concentration of soluble reactive phosphorous (Clesceri et. al. 1999).

BOD_5- 5 day BOD test

To estimate the BOD of the sample dilution water is a key ingredient. The dilution water was made according to recommended method by the standard method of water and wastewater analysis. The dilution water was aerated for at least 10 minutes to ensure that it was saturated with dissolved oxygen. Then each composite sample were prepared in 4 different volume (50ml,100ml,150ml and 200ml) with the help of graduated cylinder and were transferred to 300 ml of 4 different BOD bottles. Then 3ml of seed were added, and then BOD bottles were filled with dilution water. After the preparation, DO was measured by using the DO meter and the neck of the bottles were filled with DI water and they were covered with Parafilm to prevent evaporation. Similarly standard check were prepared with two BOD bottles of dilution water, two samples with dilution water and 3mL of seed, two samples with 6% of GGA and 3mL of seed, and with 100mL and 150mL of standard check solution. After that the bottles were kept in the incubator at 20^{0}C for 5 days. After the 5 days' incubation period, the final DO concentrations were measured (Clesceri et al. 1999).

5- Days BOD was calculated by using the following formula

Equation 5
$$BOD5 = \frac{[(D1-D2)-(B1-B2)f]}{P}$$

D1 = DO of sample immediately after preparation, mg/L
D2 = DO of sample after 5day incubation at 20^{0}C, mg/L
B1 = DO of seeded control immediately after preparation, mg/L
B2 = DO of seeded control immediately after preparation, mg/L
f = fraction of seed volume in seeded test water to seeded control
P = decimal volumetric fraction of sample used

Total Coliform and E. coli

To measure the total Coliform and *E.coli* in water samples IDEXX- Quanti tray method was used. First quanti- tray was held upright with the well side facing the palm. Then the upper part of the quanti- tray was squeeze so that the Quanti- tray bends towards the palm. After that the quanti- tray was opened by pulling the foil tap away from the well side without touching the inside of the tray. Then the water sample with colilert reagent was mixed thoroughly in 100ml bottle and the mixture was directly poured into the quanti-tray by avoiding contact with the foil tab. Then sample- filled quanti-tray was placed on to the rubber tray carrier of the quanti-tray sealer facing down to fit the carrier and quanti- tray was sealed with quanti- tray sealer. Sealed quanti- tray was incubated at 35 +/- 0.5degree centigrade for 24 hours. After incubation, positive wells were yellow in color and negative well did not change the color. Then positive wells were counted by referring the MPN tables from the instructions sheet.

For the *E. coli* test same, sealed quanti- trays were placed under ultra-violet light to check for E.coli bacteria. *E. coli* would fluoresce under ultra violet light. If the sample fluoresces or glows, then it indicates positive results for E.coli, if they do not fluoresce it indicates negative results for *E.coli*.

Secondary Data Source

To make the connection between different types of land use practices and the water quality of the watershed, land cover data and impervious surfaces data were used from various sources. National land cover database (NLCD) of 30m resolution were taken from USDA, Geospatial Data Gateway. Impervious surface data were extracted from Multi-Resolution Land Characteristics Consortium (MRLC). National elevation datasets were taken from the 2006 datasets of 3m resolution from the national map (V1.0) (USGS). Mill Creek shape file (NRCS HUC 12) was taken from transportation mapping information system website (TIMS). Digital Elevation Model (DEM) data and land cover data were extracted by using shape file of Mill Creek Watershed and Arc GIS (10.4.1) software. National land cover database showed 16 different types of land cover. Those 16 different types of land cover were reclassified into seven different classes by using Arc GIS (10.4.1) software. Additional water quality data of 2016 were taken from the graduate student’s thesis (Hanna 2016). Combine Sewer Overflows (CSO_s) data were taken from the Ohio EPA (Division of Surface Water, Combined Sewer Overflow Locations).

Data Extraction

Coordinates of sampling points were taken from field readings and plotted on Mill Creek Watershed’s digital elevation model (DEM) map. Drainage area for each sample sites were delineated by keeping the pour point at the water channel from where the samples were taken. The pour point in GIS is defined as the point on the surface at which water flows out of an area. These sub-watersheds were delineated using various hydrology tools (fill, flow direction, flow accumulation, snap pour point and watershed). After delineating the 11 different sub-watersheds, land cover data for each were extracted from national land cover database by using extract by mask tool. The area and percentage of different land use for each site was calculated. Similarly, impervious surfaces data were extracted. The extracted data for impervious surfaces were in the ranges of percentage, thus weighted averages were taken to make them one single variable.

Data’s Weakness

In DEM data sets, water channel for Site 1 was not found exactly on the coordinate point from where the samples were taken. So, while delineating the sub-watershed for site 1 little portion of land might have been included from drainage area of Site 2. Site 15 is Mill Creek to Mahoning River. The watershed for site 15 was delineated based on the coordinate point from where the samples were taken, thus a very little portion of land might not be included between Millcreek and Mahoning River. The construction of water quality data requires field activities and laboratory experiments; therefore the data might be prone to human and instrumental errors.

Spatial Interpolation by using Inverse Distance Weighted (IDW) Method

Spatial interpolation is the process of estimating the unknown value of a location based on known values. IDW interpolation process assigns a higher weight to a values of known point that is closer to the location being interpolated and lower weights to those that are farther away (Shellito, 2015).

The interpolated value at the unknown point (F[x, y] is calculated by taking the sum of all the values of the known points (f_i) which is multiplied by the weight (w_i) for each of the value of known point (Shellito 2015) . E.q 6

Equation 6 $$F(x,y) = \sum_{i=1}^{N} w_i f_i$$

The weights of each points are calculated by measuring the distance (d) from the known point to the unknown point and dividing it with the sum total of all distance values. A separate value for power (p) is used in the weighting formula (Shellito 2015). Eq. 7

Equation 7 $$Wi = \frac{d_{i0}^{-p}}{\sum_{i=1}^{N} d_{i0}^{-p}}$$

If a high value is used for power, the points at closer distances will be weighted more heavily. The default value for power used in ArcMap is 2 (Shellito 2015).

Statistical Analysis: Principal Component Analysis

Since there are a substantial number of water quality variables and these variables are most likely correlated with each other, it is difficult to interpret these variables. Furthermore, gaphical displays are not helpful since they require a substantial number of three-dimensional scatterplots. To interpret the data in a more convenient way, the Principal Component Analysis (PCA) was employed which reduces the dimension of the data.

The PCA constructs new variables, which are known as the principal components, as the linear combination of the original variables. These principal components are independent to each other. The number of principal components equals the number of explanatory variables and these components are constructed as follows.

The coefficients of the first principal component are chosen so that its variance is maximized subject to the constraint that these coefficients squared sum to unity. The coefficients of the second principal component are then chosen so that its variance is maximum and satisfy the constraint that the sum of their squares sum to 1. It however requires one more constraint that the covariance of the second principal component and the first is zero. Similar procedure is repeated for all the subsequent principal components.

The PCA procedure is a bit involved and requires sophisticated optimization tools. Fortunately, statistical packages such as SPSS have made these calculations convenient. The solution involves the calculation of eigenvalues and eigenvectors of the variance-covariance matrix. These eigen values represent the amount of variance each principal component contain. The largest eigen value is associated with the first principal component and its ratio to the sum of eigen values is the variation explained by the first principal component. Similarly the second largest eigen value is associated with the second principal component and so on.

After the principal components are constructed, it is important to decide how many of these principal components are chosen for analysis. The number must be decided so that the chosen principal components cumulatively explain an adequate amount of variation in the data. The correlations between the original data and each principal component are used in order to interpret the obtained principal component. Interpretation of the principal components is based on finding which variables are most strongly correlated with each component.

Once the principal components are constructed, they can be used to produce ordination plots. The ordination plots are graphical tools that can be helpful in investigating association of land use patterns and runoff from impervious surfaces with water quality.

Chapter 4: Results and Discussion

In order to investigate the impact of land use practices on water quality, water samples were taken from 11 different sites on Mill Creek during the period from May 2017 to May 2018. Site 1 is near the headwaters and Site 15 is just before water merges with Mahoning River. The averages are based on five low flow data and three high flow data. Several water quality parameters were measured using standard laboratory methods. Over the period of this project, eight samples were taken from 11 sites, five of which were baseline data and three of them were rain events data. For rain events samples were taken 24-48 hours of significant rainfall (>2cm). The highest rain fall recorded was 4.95cm and the lowest was 1.63cm for the high flow period. Rain events sampled for May 22, 2018 was 1.63 cm but considered as high flow periods in this study. Baseline data were taken during dry periods with very little or no rainfall. The descriptive statistics of these variables are presented in Table 12, Table 13 and Table 14 below.

Table 12: Descriptive statistics of different water quality parameters for Mill Creek Watershed in northeast Ohio. These observations include baseline of the year 2017-2018

Variables	Observations	Mean	Minimum	Maximum	Standard deviation
Temperature(^{0}C)	55	21.09	16.80	28.00	2.42
Rainfall (cm)	55	0.06	0	0.15	0.07
Ammonia (ug/L)	55	141.70	27.20	269.23	75.65
Soluble Phosphorous (ug/L)	55	209.2	17.13	543.22	168.4
Nitrate-nitrogen (mg/L)	55	4.43	0.17	15.91	4.60
DO (mg/L)	55	7.29	3.49	11.60	1.81
pH (mg/L)	55	7.73	6.57	9.00	0.59
TSS (mg/L)	55	9.83	1.33	56.00	7.88
VSS (mg/L)	55	5.69	0.67	15.50	3.40
TDS (mg/L)	55	418.08	90.50	707.00	176.5
VDS (mg/L)	55	85.69	14.00	331.25	48.70
Total coliform (MPN/100mL)	55	1758.8	100.3	2419.6	846.4
E.coli (MPN/100mL)	55	184.16	5.20	994.15	250.75
BOD (mg/L)	55	3.30	0	9.39	2.10

Table 13: Descriptive statistics of different water quality parameters for Mill Creek in northeast Ohio. These observations include high flow precipitation events of the year 2017-2018

Variables	Observations	Mean	Minimum	Maximum	Standard deviation
Temperature(^{0}C)	33	17.04	8.30	23.90	5.33
Rainfall (cm)	33	3.45	1.63	4.95	1.40
Ammonia (ug/L)	33	283.98	106.2	800	150.2
Soluble Phosphorous (ug/L)	33	223.5	30.73	778.41	138.3
Nitrate-nitrogen (mg/L)	33	2.96	0.44	21.17	4.18
DO (mg/L)	33	7.69	3.43	10.58	1.50
pH (mg/L)	33	7.41	6.55	8.30	0.40
TSS (mg/L)	33	37.87	5	137	28.51
VSS (mg/L)	33	11.10	2	21.50	4.18
TDS (mg/L)	33	287.31	111	693	105.3
VDS (mg/L)	33	56.23	14	113	26.89
Total coliform (MPN/100mL)	33	2419.6	2419.6	2419.6	0
E.coli (MPN/100mL)	33	2240.2	550.8	2419.6	434.89
BOD (mg/L)	33	3.40	1.36	6.79	1.18

Table 14: Descriptive statistics of different water quality parameters for Mill Creek in northeast Ohio. These observations include both baseline as well as high flow precipitation events of the year 2017-1018.

Variables	Observations	Mean	Minimum	Maximum	Standard deviation
Temperature(^{0}C)	89	19.60	8.30	28	4.22
Rainfall (cm)	89	1.33	0	4.95	1.85
Ammonia (ug/L)	89	194.7	27.20	800	128.7
Soluble Phosphorous (ug/L)	89	214.5	17.13	778.4	157.2
Nitrate-nitrogen (mg/L)	89	3.88	0.17	21.2	4.48
DO (mg/L)	89	7.41	3.43	11.6	1.70
pH (mg/L)	89	7.61	6.55	9	0.55
TSS (mg/L)	89	20.35	1.33	137	22.77
VSS (mg/L)	89	7.72	0.67	21.5	4.52
TDS (mg/L)	89	369	90.5	707	166
VDS (mg/L)	89	74.65	14	331.3	44.14
Total coliform (MPN/100mL)	89	2006	100.3	2419.6	741.7
E.coli (MPN/100mL)	89	954.6	5.2	2419.6	1047
BOD (mg/L)	89	3.16	0	9.39	1.79

Surface water temperature over the period of 8 month ranged from a maximum of 28^{0}C and the minimum of 8.30^{0}C (Table 14) .Surface water temperature were higher during summer months than that of fall (Appendix, table 31). The surface water temperature ranges from 8.3^{0}C to 23.9^{0}C (Table13) during high flow precipitation, whereas it ranges from 16.8^{0}C to 28^{0}C during low flow period (Table 12).

The average temperature as well as the pH of the watershed decreases after rainfall (Figures 18 and 19). Normal rainfall pH tends to be slightly acidic (5.3-5.4). Ohio historically has had acid rain (pH range: 4.4 to4.7) due to industrial effluent and power plant generation concentrating along the south east and north east (Figure 17). This acid rain could be the cause of the lower pH found in Mill Creek after precipitation. According to State of Ohio Water Quality Standards for warm water habitat pH lies between 6.55 and 9 (Ohio EPA, 2008). The minimum pH recorded for the year 2017-2018 was 6.5 and maximum recorded was 9.Thus, the obtained results for pH shows that the Mill Creek Watershed have meet the pH criteria for warm water habitat.

Dissolved oxygen concentration was found to be low (3.43mg/L to 3.66mg/L) at Site 15 as compared to other Site for the year 2017-2018 (Appendix table 31). The minimum concentration of DO should be 4mg/L and during spawning season it must maintain at least 5.0mg/L for warm water habitat (Ohio EPA 2008). Site 15 do not meet the criteria for warm water habitat. Similarly for site 14 it ranges from 4.15 to 4.17mg/L (Appendix Table 31), which do not meet the criteria for spawning season.

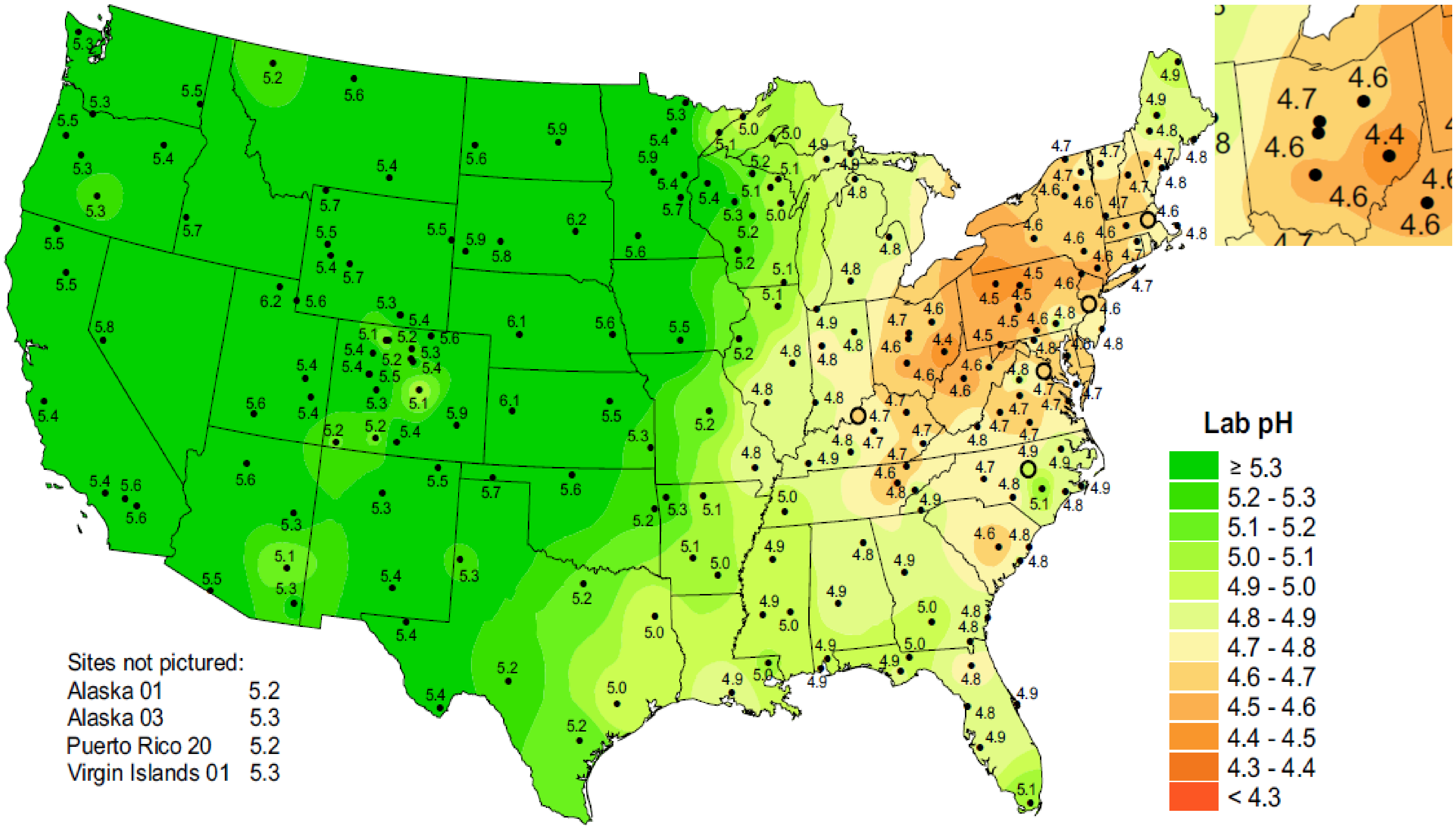


Figure 17: Precipitation pH for the US and close up of Ohio precipitation (National Atmospheric Deposition Program 2009)

At four of the eleven Sites (Sites 8, 12, 14, and 15) (Figure 21), the average concentration of biochemical oxygen demand (BOD) after rainfall is lower than the pre-rainfall value. In contrast the remaining Sites (Sites 1, 2, 3, 5, 7, 10, 11 and 12) (Figure 21) BOD increases with rain events. Site 1, 2, 3 are dominated with agricultural land, Site 5 is Boardman Waste Water Treatment Plant and Site 7 is near Golf course and Sites 10, 11 and 12 are dominated with residential areas and impervious surfaces. The runoff from agricultural land, impervious surfaces and residential areas carry pet wastes, fertilizers, animal manure and other organic material which increases the algal production as well as the microbial activities in the stream which increases the BOD in the stream.

Matysik et al. (2015) found that the higher concentration of nutrients, like phosphorous, are found in an area dominated with agricultural and urbanized land use. Similarly, the average concentration of soluble reactive phosphorous were higher at upstream sites than that of downstream in the Mill Creek watershed. The upstream sites were located in Columbiana County which is dominated by agricultural land use (Figure 3). Phosphorous is usually found in the fertilizers and manures, so runoff from the agricultural land can increase the concentration of phosphorous in the stream. During high flow period, the average concentration of phosphorous was higher at seven of the eleven sites. However in the remaining four sites (Sites 2, 5, 10 and 14) (Figure 22), the concentration were lower after rainfall. All of these sites have comparatively lower flow rate and higher rate of algal and organic matter deposition after rain events except for site 5 that is located near Boardman WWTP. The phosphorous discharge by Waste Water Treatment facilities is mostly in dissolved form, which is readily available to be used by algae and aquatic plants or rapidly bound up by sediments.

The average concentration of ammonia at high flow episodes were highest at site 5 which is near the Waste Water Treatment Plant followed by site 3 which is near the agricultural land (Figure 23). Ammonia is found in fertilizer, animal waste, and decomposing organic material. This indicates that fertilizer and manure runoff from agricultural land as well as discharges from WWTP might be the source of ammonia at site 3 and 5. The maximum limit for ammonia for warm water habitat at pH<7.8 is 13mg/L, pH>7.8 is 8 mg/L, pH>8.2 is 5.0mg/L (Ohio EPA 2008). The range of concentration of ammonia was recorded 27.2ug/L minimum and and 800ug/L maximum from May 2017-May 2018 (Table 14). This indicates that the concentration of ammonia did not exceed these levels and is within the range that is suitable for warm water habitat for Mill Creek Watershed.

On average, the concentration of nitrate increased with rain events for all sampling sites except for site 5, which is located at the Waste Water Treatment Plant (WWTP). The concentration of nitrate - nitrogen ranges from 0.17mg/L to 21.2mg/L (Table 14) during the period of May 2017-May 2018. Nitrate-nitrogen levels below 90mg/L and nitrite level below 0.5 mg/L seem to have no effect on warm-water fish (Ohio EPA 2008) and the obtained results of Mill Creek Watershed are within this range.

The concentration of *E.coli* bacteria increased during high flow episodes for all sites (Figure 25). Similar results were found in Upper Santa Cruz Watershed in south Arizona (Sanders et al. 2013) and also in Huron River of Michigan (Gannon & Busse 1989). The maximum concentrations of *E.coli* were greater than 2419.6 MPN/100mL the watershed. According to statewide numerical criteria for the protection of recreation uses for *E.coli* bacteria, 1030 MPN/100mL is the maximum allowable concentration for secondary contact recreation and primary contact is 126 cfu/100 mL for a 90-day geometric mean and 410 cfu/100 ML for a statistical threshold (EPA 2008). Colony forming units (cfu) and most probable number (MPN) are considered equivalent measuring units, both measure the estimated amount of bacteria in a water sample. Secondary contact recreation refers to surface water that have minimal use for water based recreation such as wading. Primary contact refers to surface water that is used during the recreation season for one or more full body contact recreation such as swimming or boating. The average concentration of *E.coli* bacteria during post rain events exceed 1030MPN/100mL for all sites which indicate that water quality of Mill Creek after rain events is not suitable for recreational secondary contact. Higher concentration of fecal coliform like *E.coli* bacteria can cause gastrointestinal (GI) illness (Soller et al. 2010). *E.coli* bacteria are found in soil, surface waters, and fecal material. During rainfall, bacteria from the soil and fecal material that are resting near the stream can be easily washed into water bodies by storm runoff, which increases the concentration of the *E.coli* bacteria in the stream. However, the gastrointestinal illness risks associated with exposure to recreational waters impacted by fresh cattle feces appear to be substantially lower than those impacted by human sources (Sollar et. al., 2010).

The average concentration of total dissolved solids (TDS) and volatile dissolved solids (VDS) are found to decrease during high flow periods whereas total suspended solids increased (Figures 27, 29 and 28 respectively) for all Sites. Runoff carries much higher amounts of larger solids or suspended solids mostly in the form of inorganic material (e.g. sediment) but it can also include algae, bacteria and organic material. This organic fraction is correlated to the volatile suspended (VSS) fraction of solids. Therefore during higher rainfall events, runoff water carries larger particles into the stream while diluting the amount of dissolved solids. (Kent & Belitz, 2004).

Site 1 is near the headwaters and Site 15 is just before water merges with Mahoning River. Low flow is the baseline while high flow are post-rainfall (1.63 to 4.95 cm) data. The averages are based on five low flow data and three high flow data.

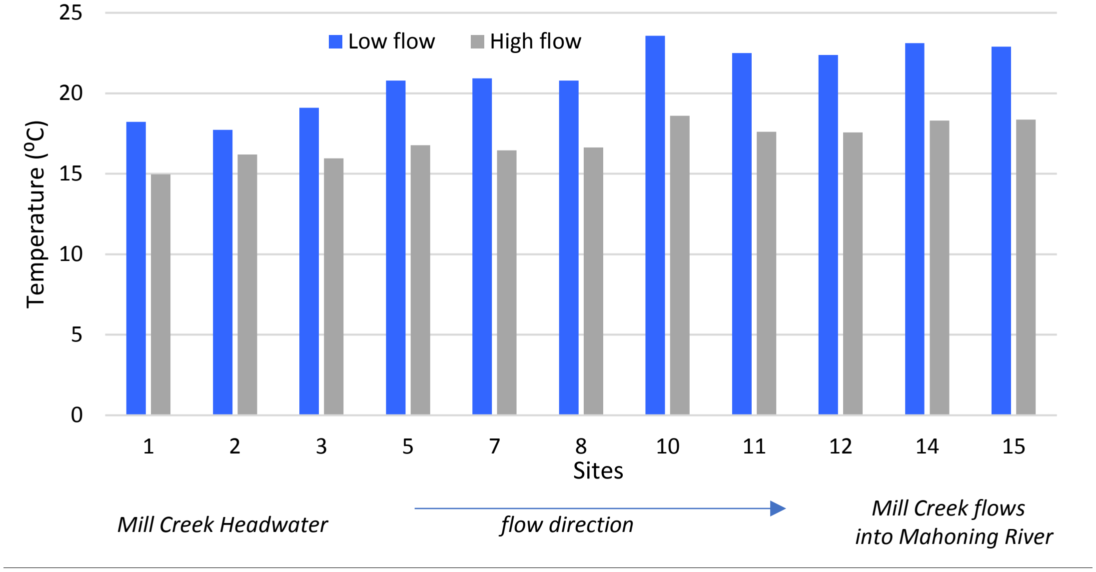


Figure 18: Average pre and post- rainfall temperature for different sites in Mill Creek.

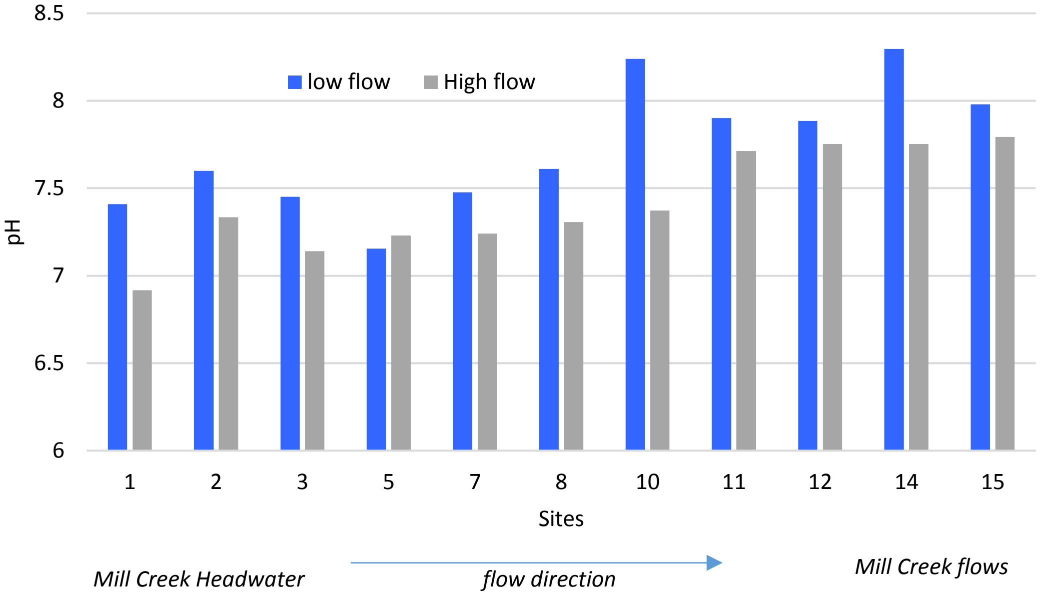


Figure 19: Average pH for different sites before and after rainfall.

Site 1 is near the headwaters and Site 15 is just before water merges with Mahoning River. Low flow is the baseline while high flow are post-rainfall (1.63 to 4.95 cm) data. The averages are based on five low flow data and three high flow data.

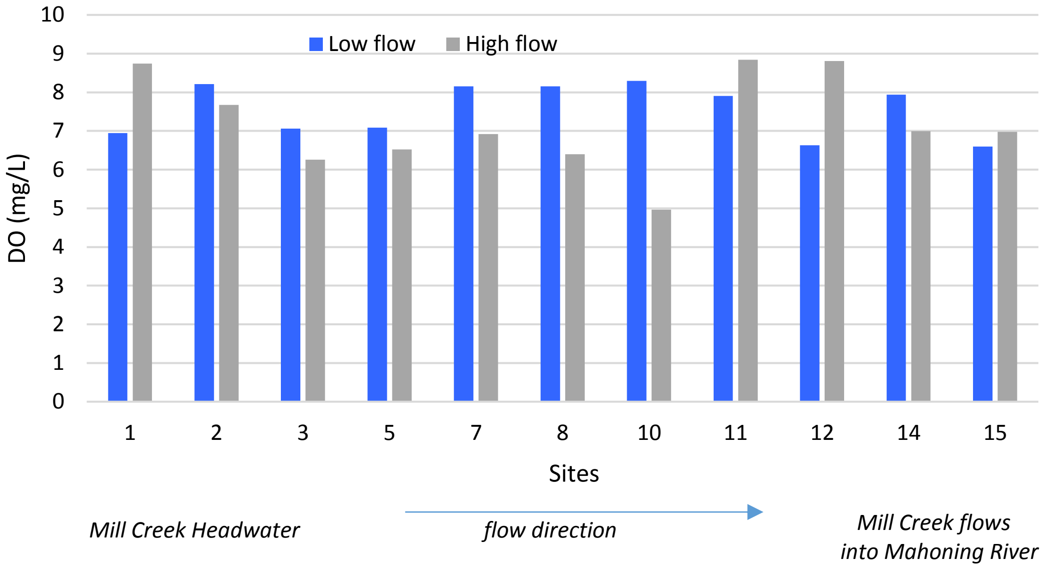


Figure 20: Average Dissolved Oxygen before and after rainfall for different sites.

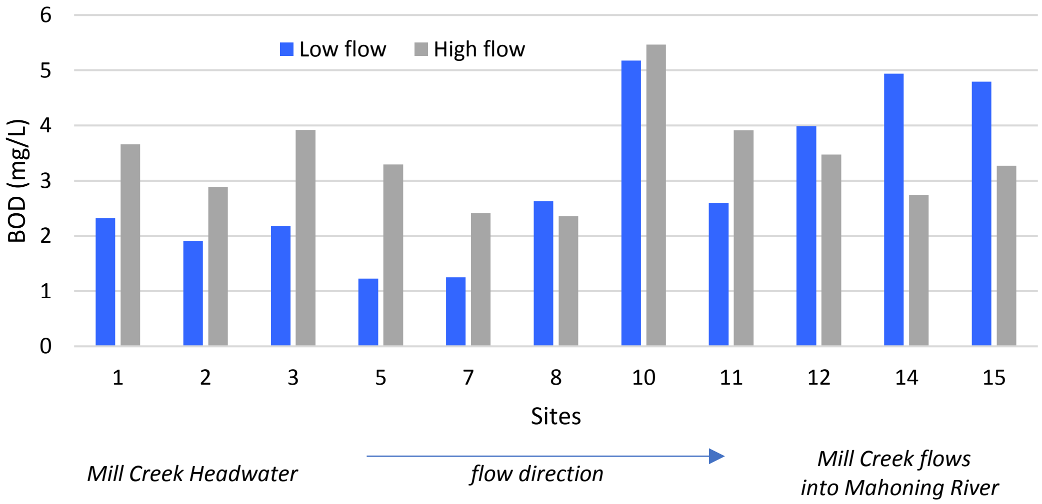


Figure 21: Average BOD before and after rainfall for different site.

Site 1 is near the headwaters and Site 15 is just before water merges with Mahoning River. Low flow is the baseline while high flow are post-rainfall (1.63 to 4.95 cm) data. The averages are based on five low flow data and three high flow data.

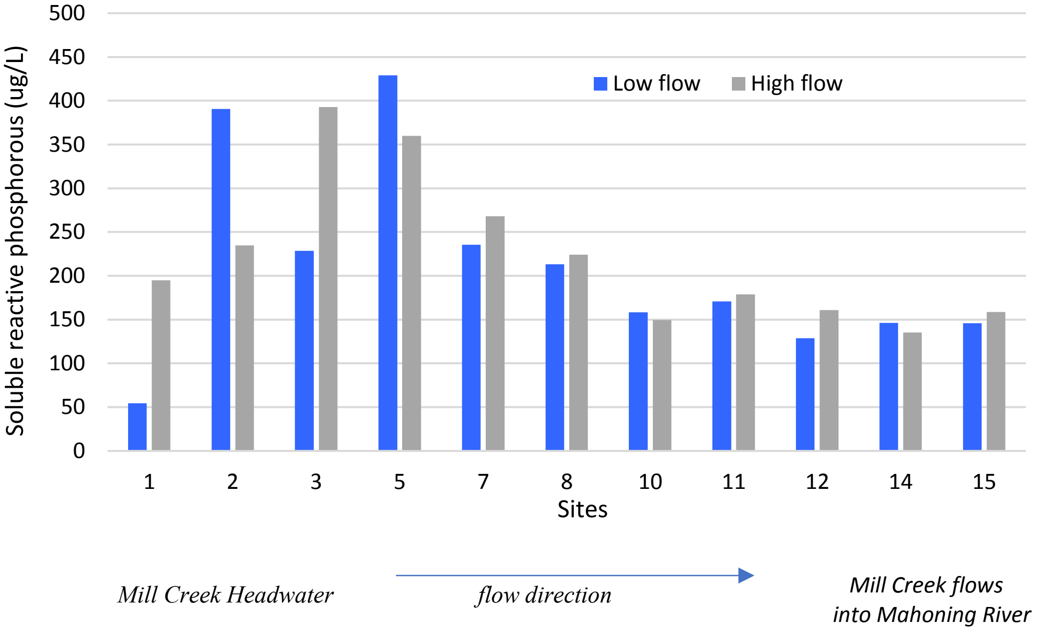


Figure 22: Average Soluble Phosphorous before and after rainfall for different sites.

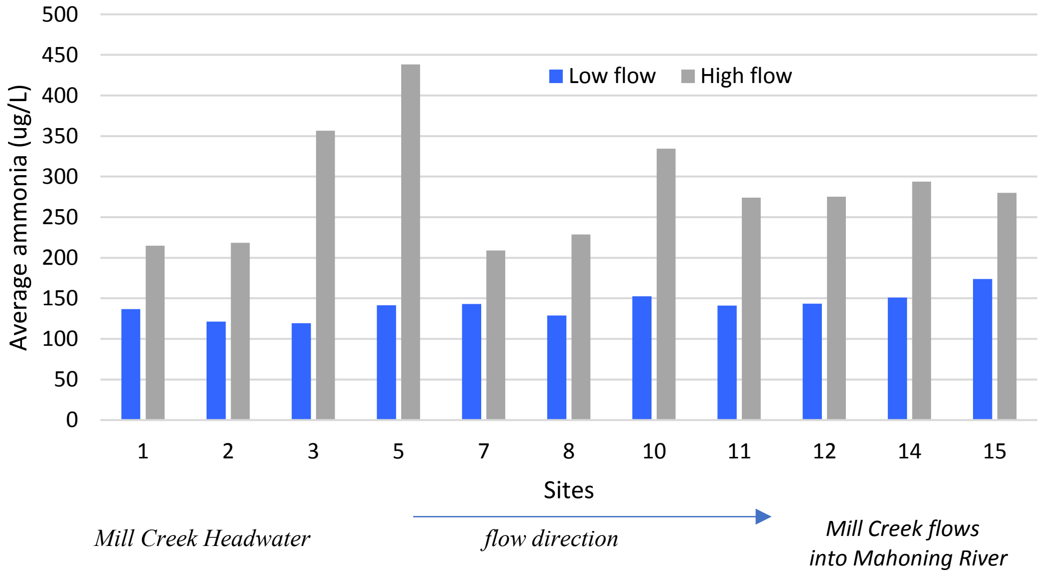


Figure 23: Average Ammonia before and after rainfall for different sites.

Site 1 is near the headwaters and Site 15 is just before water merges with Mahoning River. Low flow is the baseline while high flow are post-rainfall (1.63 to 4.95 cm) data. The averages are based on five low flow data and three high flow data.

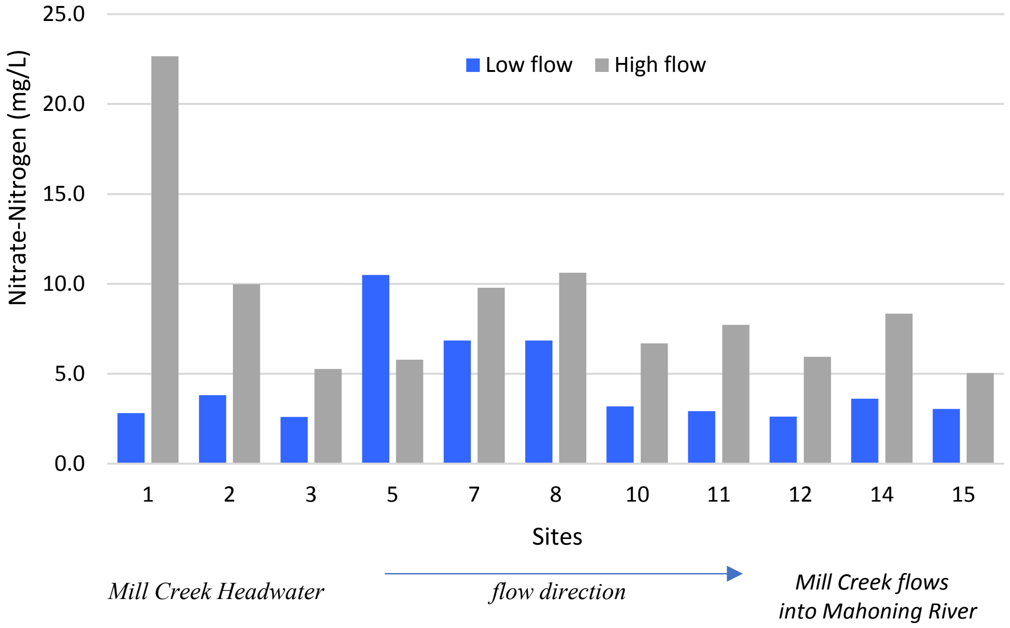


Figure 24: Average Nitrate-Nitrogen before and after rainfall for different sites.

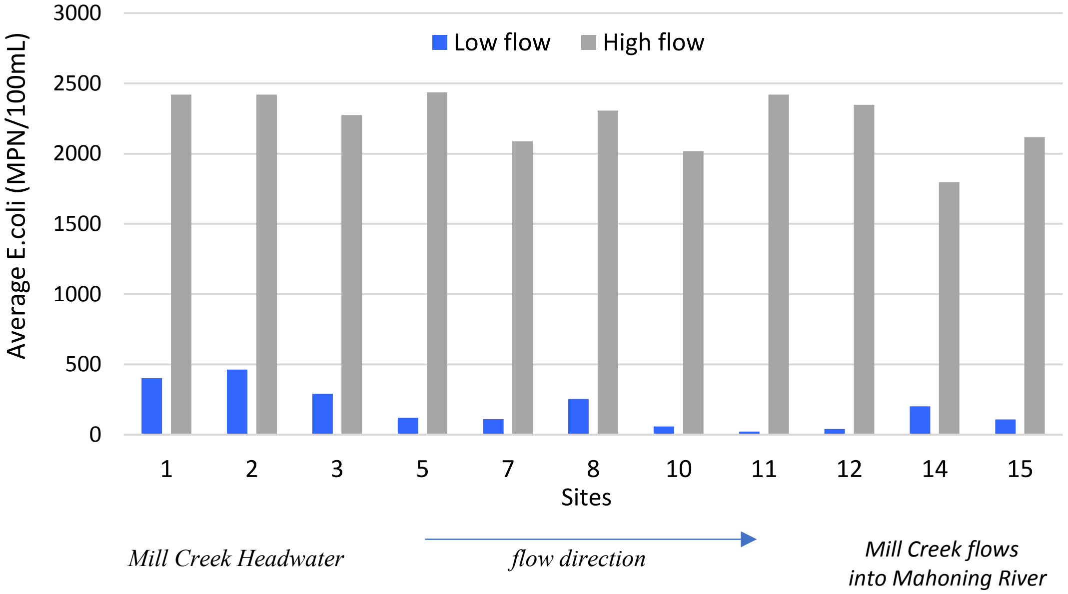


Figure 25: Average *E.coli* before and after rainfall for different sites ***Error! Bookmark not defined.***. The high flow/rainfall values may be underestimates *E. coli* due to measurement limitations in the methodology.

Site 1 is near the headwaters and Site 15 is just before water merges with Mahoning River. Low flow is the baseline while high flow are post-rainfall (1.63 to 4.95 cm) data. The averages are based on five low flow data and three high flow data.

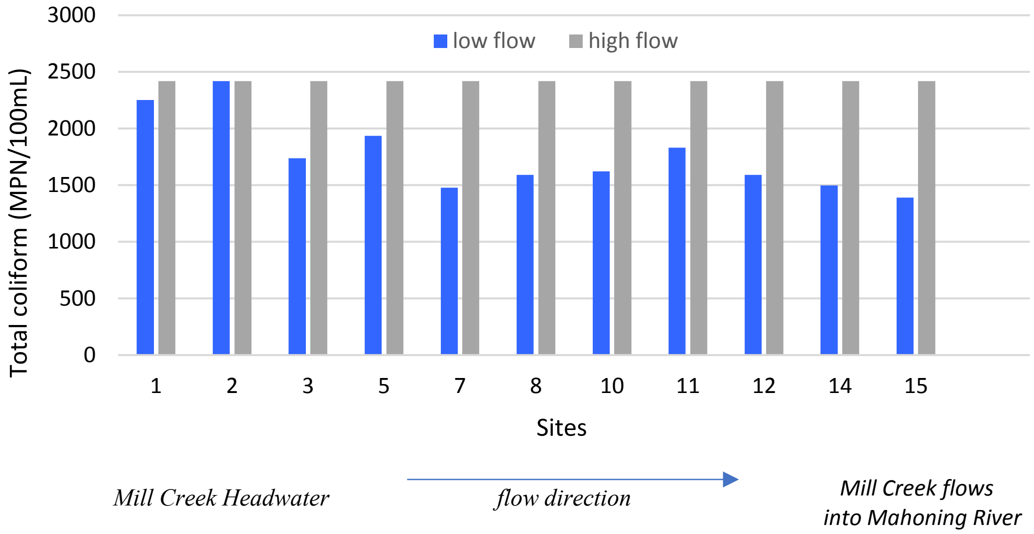


Figure 26: Average Total Coliform before and after rainfall for different sites. The high flow/rainfall values may underestimate total Coliform due to measurement limitations in the methodology.

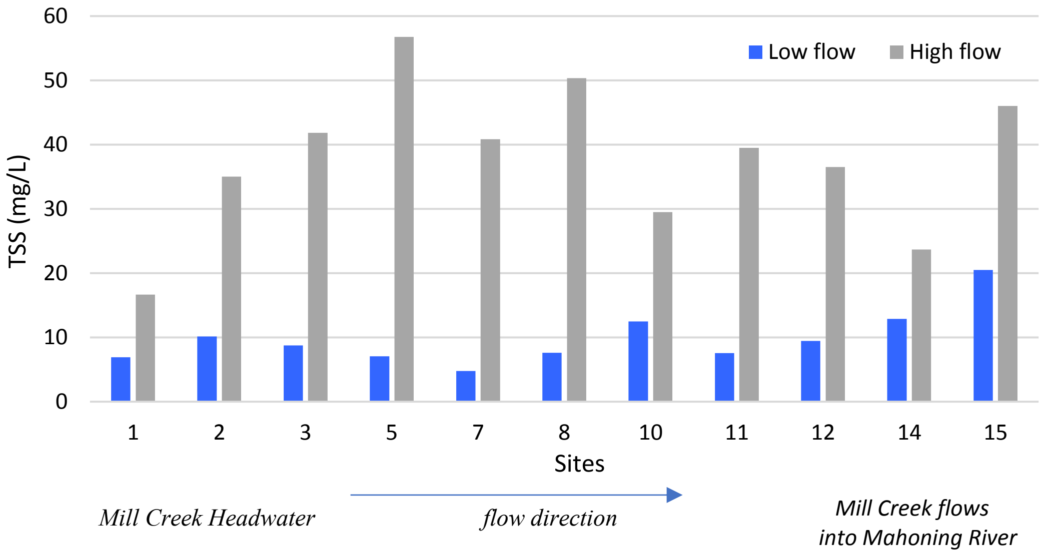


Figure 27: Average Total Suspended Solids before and after rainfall for different sites.

Site 1 is near the headwaters and Site 15 is just before water merges with Mahoning River. Low flow is the baseline while high flow are post-rainfall (1.63 to 4.95 cm) data. The averages are based on five low flow data and three high flow data

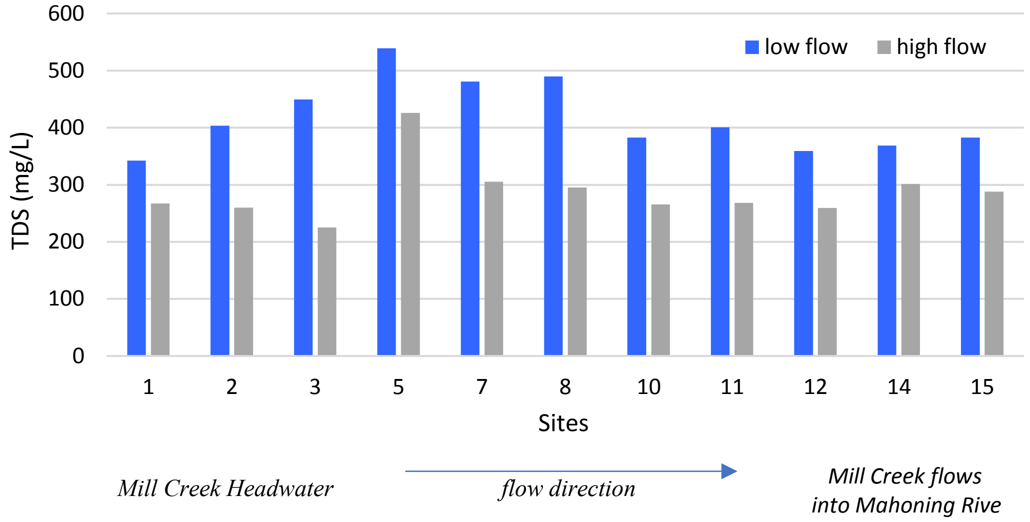


Figure 28: Average Total Dissolved Solids before and after rainfall for different sites.

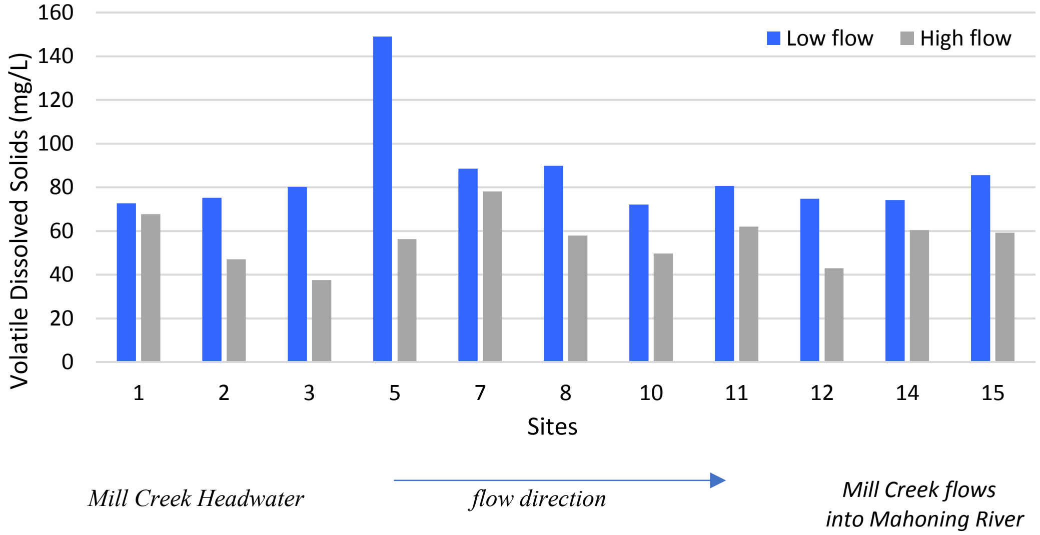


Figure 29: Average Volatile Suspended Solids before and after rainfall for different sites.

Site 1 is near the headwaters and Site 15 is just before water merges with Mahoning River. Low flow is the baseline while high flow are post-rainfall (1.63 to 4.95 cm) data. The averages are based on five low flow data and three high flow data

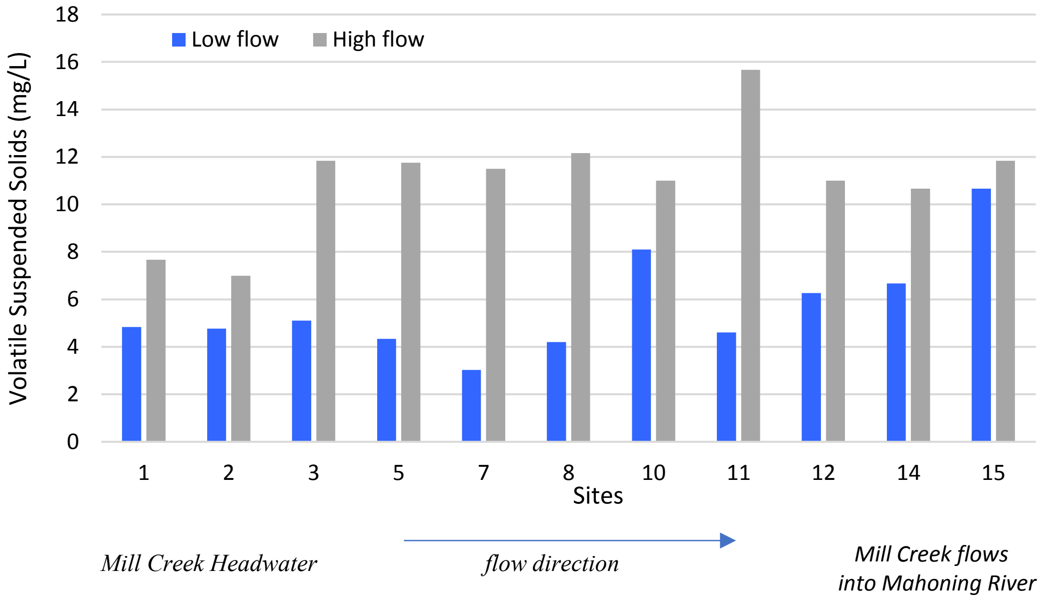


Figure 30: Average Volatile Dissolved Solids before and after rainfall for different sites.

The spatial distribution of nutrients, solids and bacteria at the scale of the whole watershed would give a view of overall trends throughout the watershed. However since water samples were taken only from 11 points, some interpolation technique was necessary. For this purpose standard Inverse Distance Weighted (IDW) interpolation was employed for some of the important water quality parameters using the data for the year 2017-2018.

Soluble phosphorus presented an interesting pattern, at low flow samples sites 2 and 7 had the highest levels (figure 31). Site 2 is adjacent to row crops that could influence the phosphorus level especially during fertilizer application or turning of the soil. Site 7 is in Mill Creek Park and near the Mill Creek golf course. Again, fertilizer application on the golf course could have an impact on the phosphorus.

At high flow (Figure 34), ammonia concentrations increased greatly across the watershed with the highest concentrations at site 3 and 5 and at sites 10 and 11. Site3 is surrounded by pasture land, livestock and row crops. Animal waste and septic systems could provide a significant portion of the ammonia found in the water. Site 10 is Lake Newport and Site 11 is just downstream near Lanterman's Mill both surrounded by an urban park. Mill Creek flows through Lake Newport wetland where water flow slows and collects in Lake Newport. The wetland provides habitat for a variety of animals from turtles, waterfowl, deer, and many others. As precipitation runs off the adjacent land, animal waste, road wash, septic systems as well as combined sewer overflows collect in this area and flows downstream.

The average concentration of *E.coli* bacteria increases after rainfall throughout Mill Creek (Figures 35 and 36). These bacteria are mostly found in the soil, intestines and fecal material from animals and can be released into the water through runoff from impervious surfaces, cultivated land, cow farm etc. In addition during rain events bacteria from the soil and fecal material that are found near the river can easily be washed into to the Mill Creek River.

The spatial distribution of TDS (Figure 37) shows that the concentrations are highest during low flow in Sites 2, 3, and 7 which are located near cultivated land, Cow farm and Golf course respectively. On the other hand, the concentration of TDS at site 5 is highest at high flow. In all but in one (Site5) (Figure 38) the concentration of TDS during low flow was high.

The overall concentration of TSS increased throughout the watershed during high flow period. The concentration of the total suspended solids depends upon the flow rate of the watercourse. Fast running water is more erosive and can carry sand silt clay organic matter and larger-sized sediment. Heavy rains can pick up sand, silt, clay, and organic particles from the land and carry it to surface water (NEOSWTC 2015). The concentration were highest around Site 5 in both the low and high flow conditions. Site 5 is located near Boardman Waste Water Treatment Plant (Figures 39 and 40). The effluent from Wastewater Treatment Plants (WWTPs) can increase the concentration of suspended solids to a stream. The wastewater from the residential areas, human and animal waste, and other solid like sediments, silt clay organic particles are treated in WWTPs. Most of these solids are removed before being discharged to the stream, but treatment can't eliminate everything (NEOSWTC 2015).

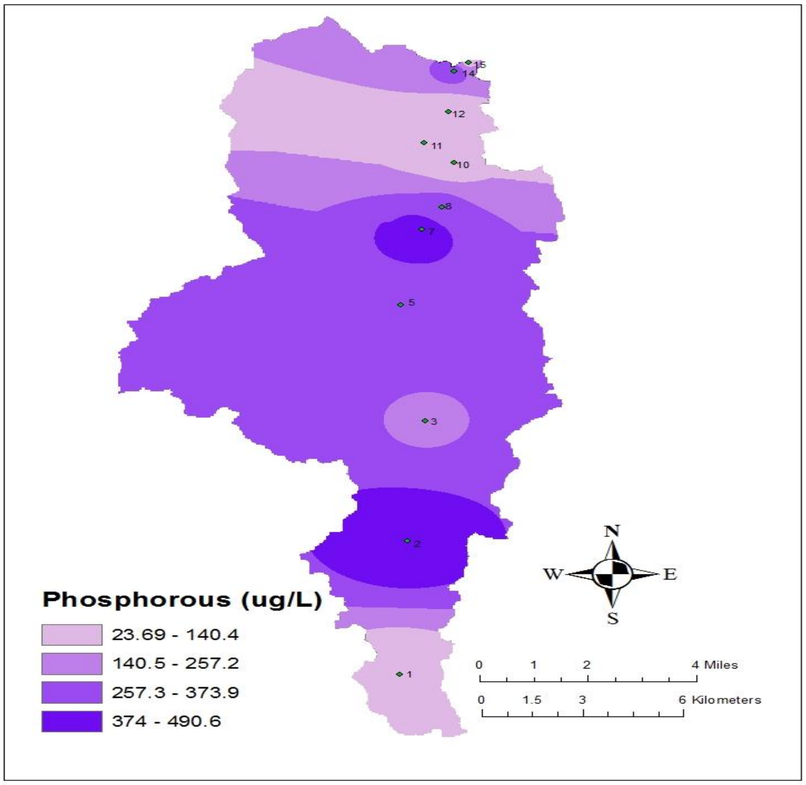


Figure 31: Spatial dispersion of soluble phosphorous at baseline/low flow for 2017-2018.

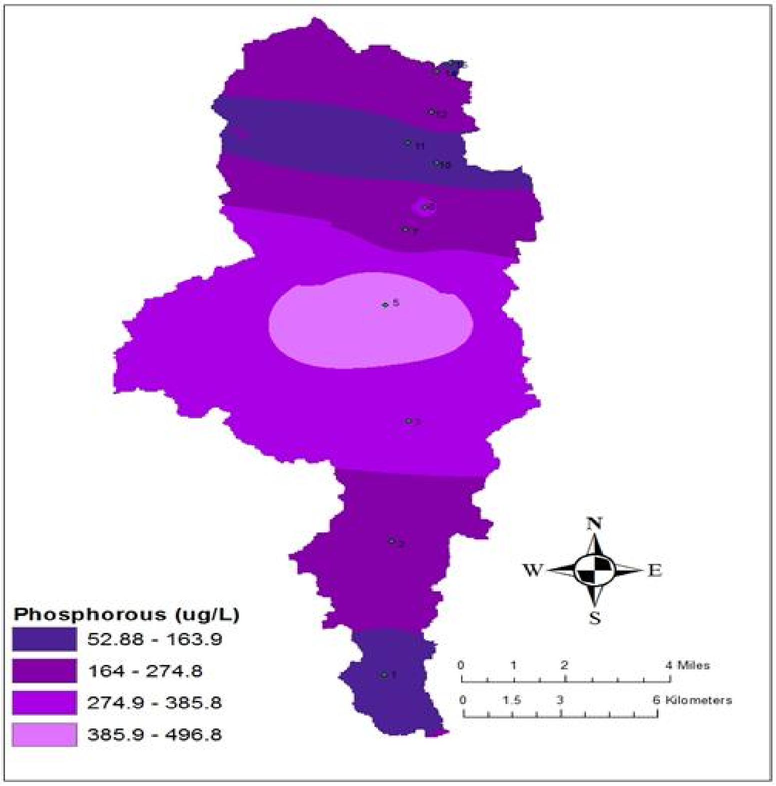


Figure 32: Spatial dispersion of soluble phosphorous at high flow for 2017-2018

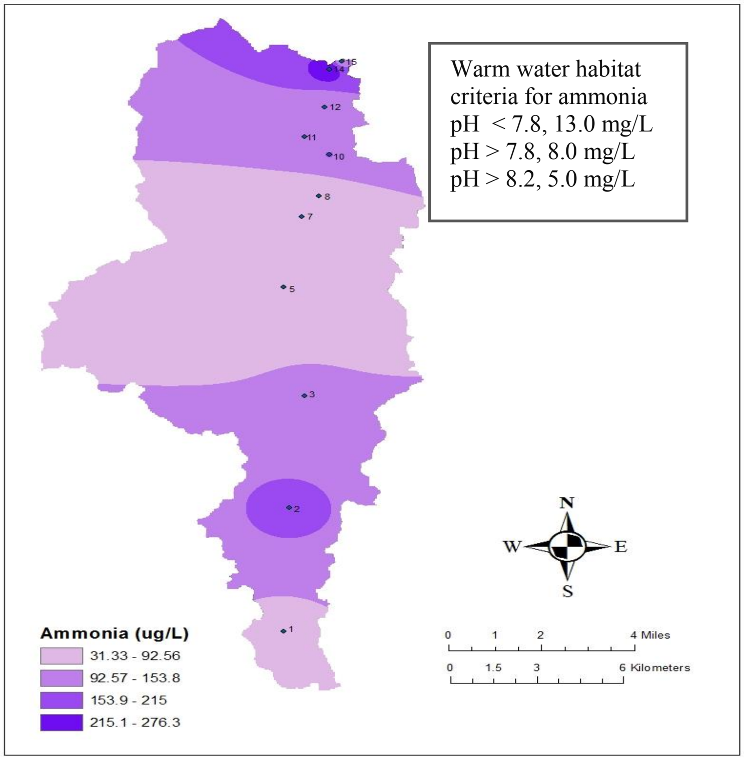

Warm water habitat criteria for ammonia
pH < 7.8, 13.0 mg/L
pH > 7.8, 8.0 mg/L
pH > 8.2, 5.0 mg/L

Figure 33: Spatial dispersion of Ammonia at baseline/low flow for 2017-2018

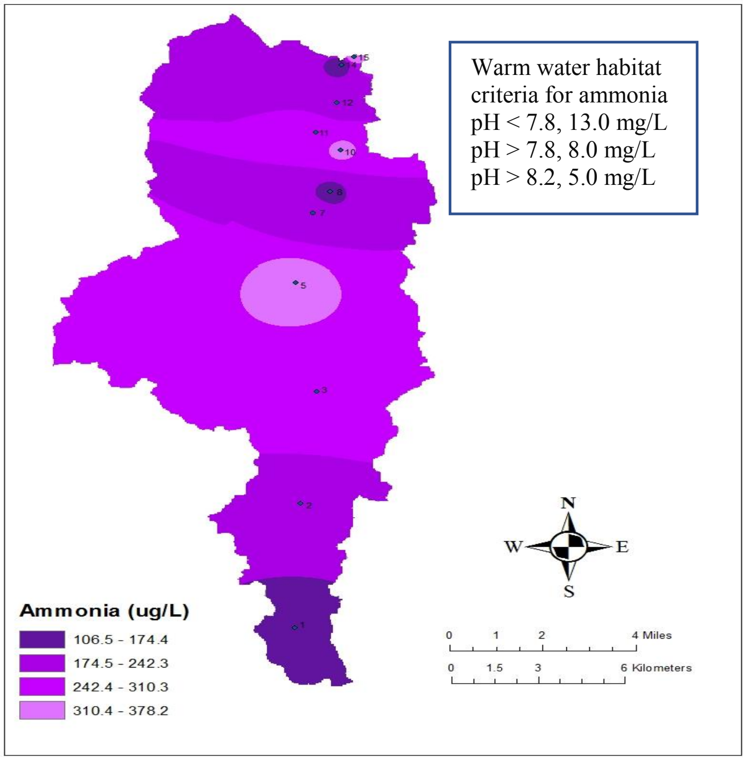


Figure 34: Spatial dispersion of Ammonia at high flow for the year 2017-2018

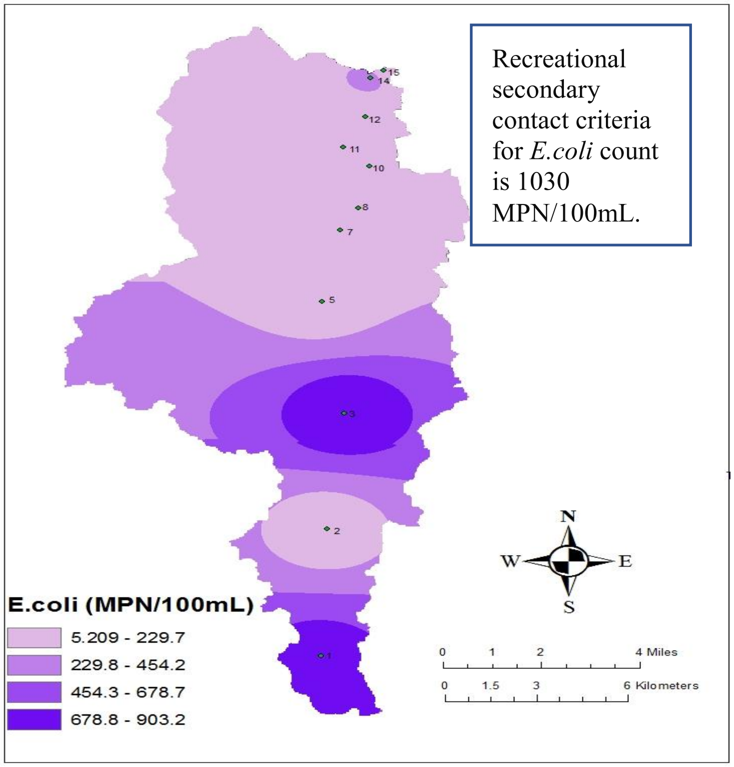
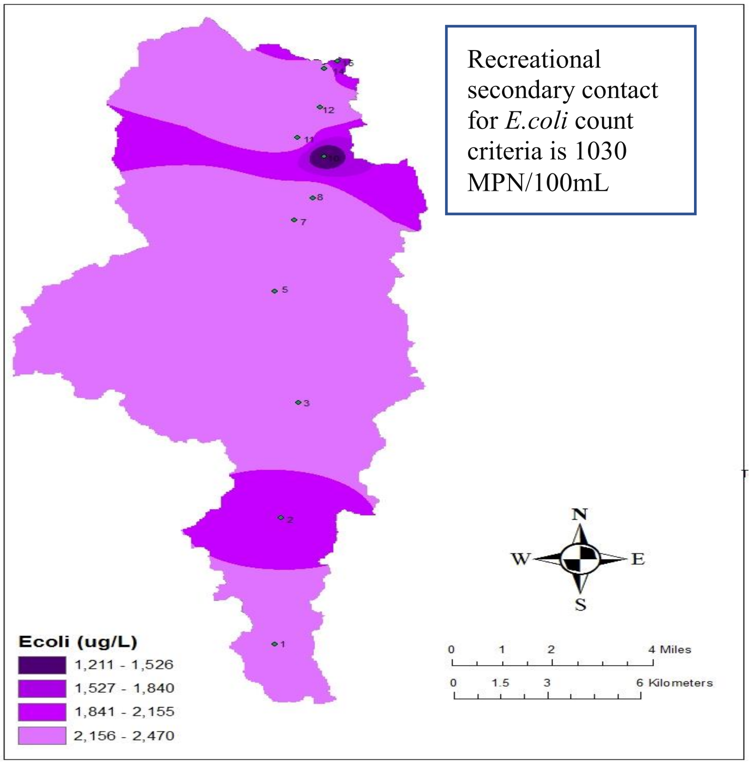


Figure 35: Spatial dispersion of *E.coli* at low flow for the year 2017-2018



Recreational secondary contact for *E.coli* count criteria is 1030 MPN/100mL

Figure 36: Spatial dispersion of *E.coli* at high flow for the year 2017-2018

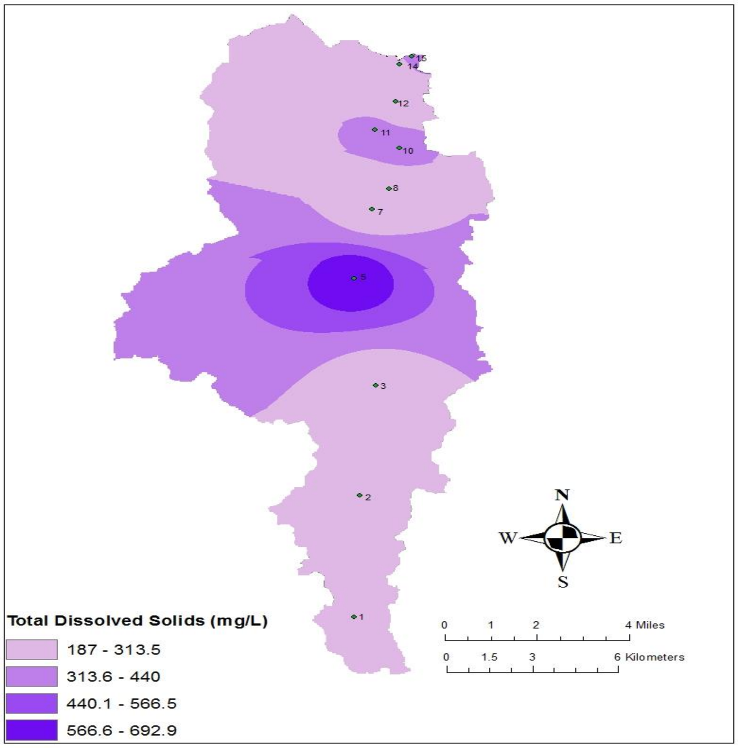


Figure 37: Spatial dispersion of TDS at low flow for the year 2017-2018

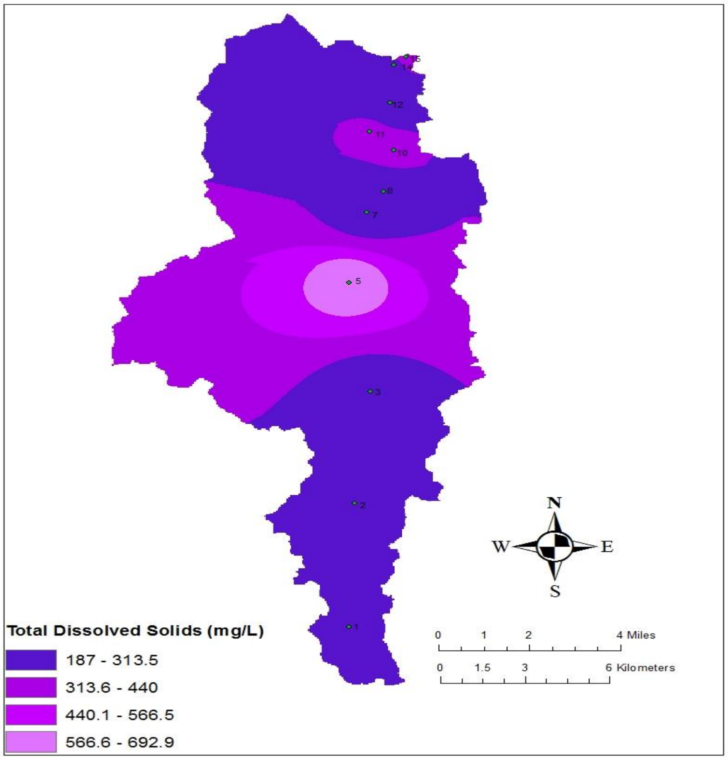


Figure 38: Spatial dispersion of TDS at high flow for the Year 2017-2018

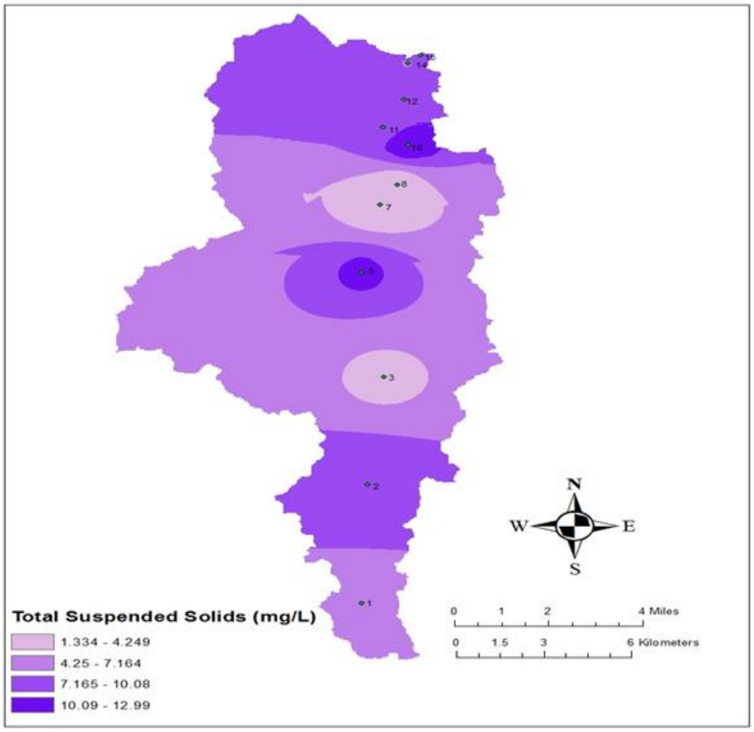


Figure 39: Spatial dispersion of TSS at Low flow for the year 2017-2018.

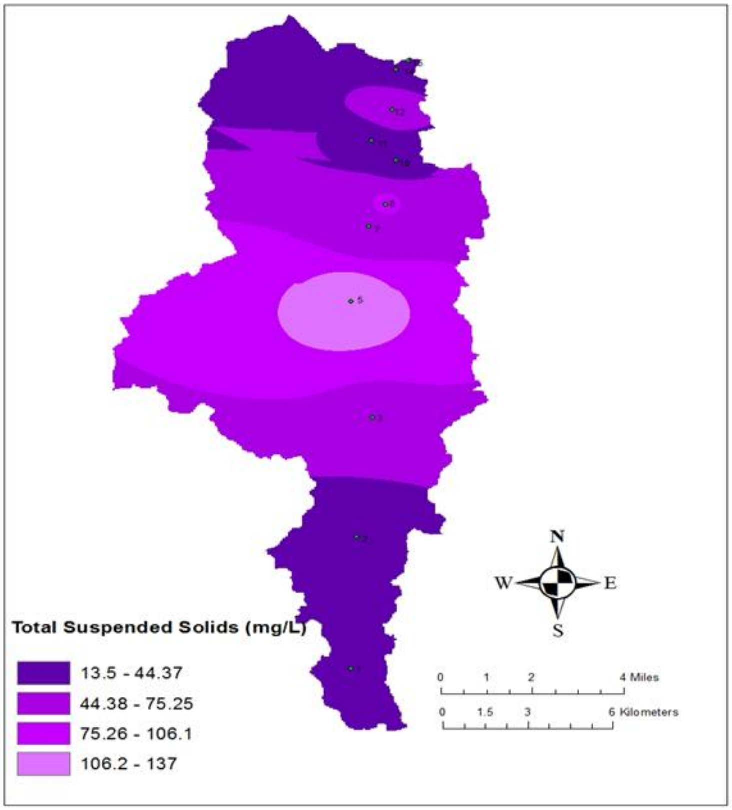


Figure 40: Spatial dispersion of TSS at high flow for the year 2017-2018.

Principal Component Analysis of Water Quality Parameters

Since there are a substantial number of variables and these variables are most likely correlated with each other, it is difficult to interpret individually. To interpret the data in a more meaningful way, it is necessary to reduce the number of variables to those that have the highest influence by employing Principal Component Analysis (PCA). PCA constructs new variables, which are known as the principal components, as the linear combination of the original variables. These principal components are independent to each other as well as the dimension of the data is reduced

Since we have 13 different variables, PCA constructs 13 different principal components. Table 15 below shows the eigenvalues corresponding to each of these principal components. The ratio of each eigenvalue to the sum represents the share of variance of the respective principal component. For example, the first principal component explains 28.27% of the variation in the data. Similarly, the second and the third principal components respectively explain 16.73% and 16.09% of the variance. Moreover, the first 3 principal components collectively contain more than 61% of the total variance in the data.

The first three principal components are chosen for analysis as they contain a substantial amount (61.13%) of variation in the data. The component matrix that shows the relationship of each of these three principal components with the original variables is shown in Table 16. The magnitude of the elements of this matrix thus measures the importance of each of the original variables for each of the principal components.

As shown in Table 16, the first principal component is strongly positively correlated with 5 of the original variables (ammonia, TSS, VSS, Total coliform, E.coli). Thus this component is basically a measure of these five variables. Similarly, the second component is negatively correlated with soluble reactive phosphorous, nitrate, and positively correlated with pH. Finally, the third principal component is strongly positively correlated with temperature, TDS and VDS and negatively correlated with DO.

Table 15: Eigen values of the principal components and the variance they contain

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.675	28.27	28.27	3.675	28.271	28.271
2	2.179	16.76	45.03	2.179	16.764	45.034
3	2.092	16.09	61.13	2.092	16.091	61.125
4	1.507	11.59	72.72			
5	0.898	6.909	79.63			
6	0.572	4.404	84.03			
7	0.445	3.421	87.45			
8	0.404	3.106	90.56			
9	0.373	2.870	93.43			
10	0.311	2.391	95.82			
11	0.214	1.645	97.46			
12	0.203	1.560	99.03			
13	0.127	0.975	100.0			

Table 16: Component Matrix

Variable	Component		
	1	2	3
Ammonia	0.722	0.121	0.307
SP	0.299	-0.581	0.315
NO3N	-0.040	-0.687	0.114
Temp	-0.257	-0.051	0.675
DO	-0.336	-0.032	-0.565
pH	-0.463	0.639	-0.104
TSS	0.809	0.135	0.338
VSS	0.722	0.397	0.355
TDS	-0.479	-0.065	0.525
VDS	-0.430	-0.151	0.626
Coliform	0.587	-0.439	-0.335
Ecoli	0.856	0.066	-0.230
BOD	0.056	0.737	0.159

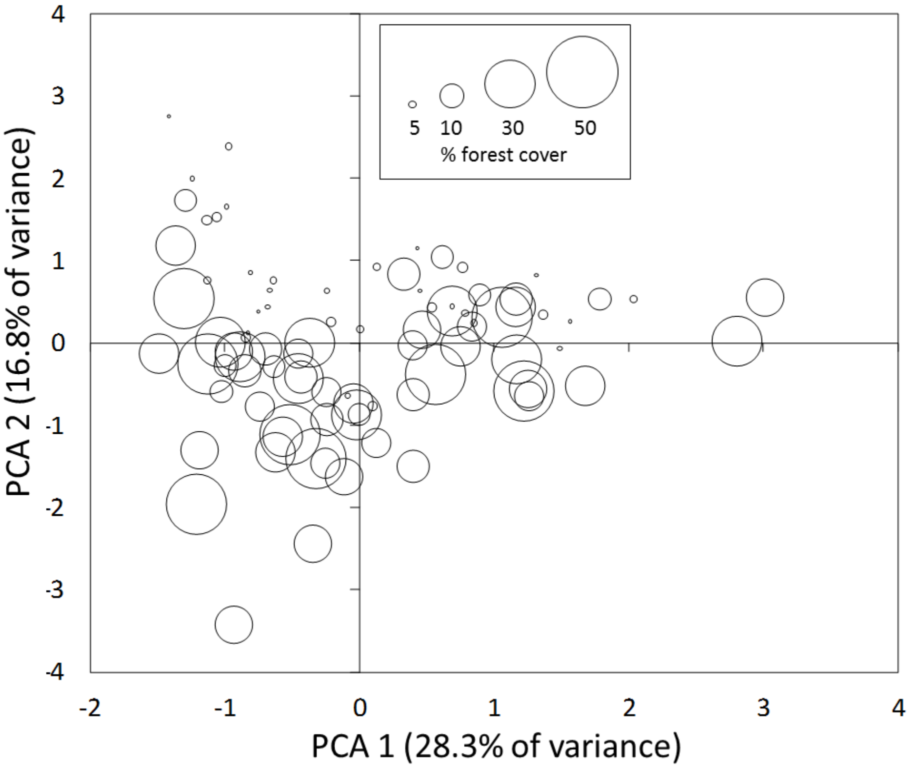


Figure 41: Association of percentage of forest cover with PCA1 and PCA2.

Figure 41 above shows the variation of percentage of forest cover with principal components 1 and 2 (which respectively explain 28.3% and 16.8% of the data variation). The size of the bubbles in the graph represents the % of forest cover. The graph shows weak negative association between % of forest cover and PCA2. It implies that soluble reactive phosphorous and nitrate-nitrogen is negatively associated with percentage of forest cover. On the other hand, pH and the concentration of BOD are positively associated with percentage of forest cover. However PCA 2 contains only 16.8% of the variance in the data. Association with PCA 1 (or together) would have been better but unfortunately the graph does not depict any trend with regards to PCA 1 and% of forest cover.

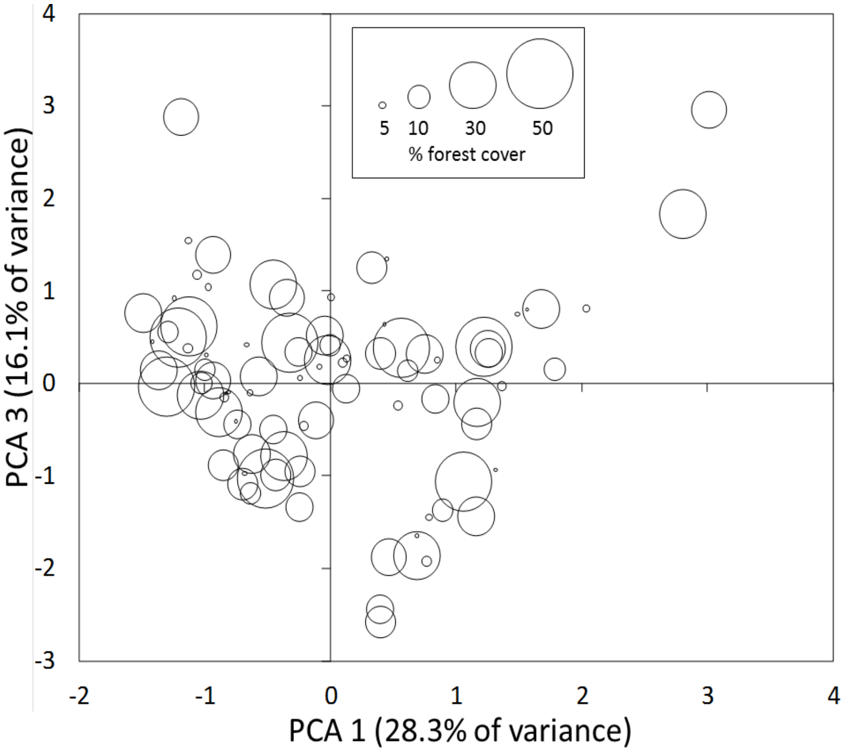


Figure 42: Association of percentage of forest cover with PCA1 and PCA2.

Similar plot of PCA 1 and PCA 3 with percentage of forest cover as shown in Figure 42, does not depict any trend with regards to PCA 3 and% of forest cover. The land use around Mill Creek watershed is surrounded with different types of forest and herbaceous land. Forest reduces storm water runoff to the waterways by removing, absorbing or filtering the pollutants like nutrients, solids and salts before gradually releasing it to natural channel (Cotrone 2017). This might be the reason behind weak negative or no correlation between water quality and the land cover.

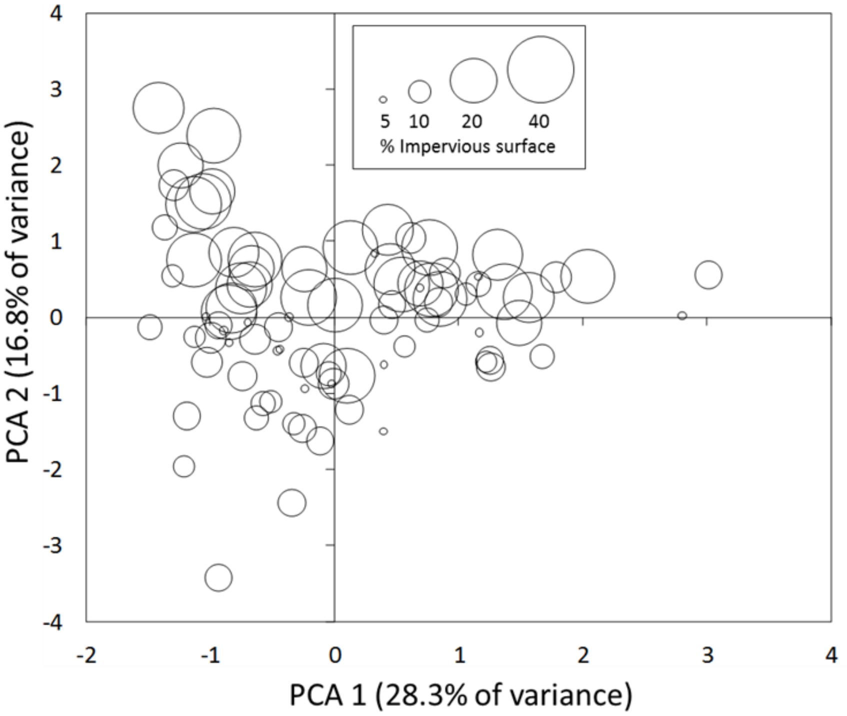


Figure 43: Association of imperviousness with PCA1 and PCA2

Figure 43 above shows the variation of percentage of imperviousness with principal components 1 and 2 (which respectively explain 28.3% and 16.8% of the data). The size of the bubbles in the graph represents the % of impervious surface. The graph shows a positive association between % of impervious surfaces and PCA2. Since PCA2 is negatively correlated with SP and NO3N, it implies that SP and NO3N are negatively correlated with the % imperviousness of land. On the other hand, since pH and BOD are positively correlated with PCA2, the graph implies that these two variables are positively correlated also with percentage of impervious surface. However PCA 2 contains only 16.8% of the variance in the data. Association with PCA 1 (or together) would have been better but unfortunately the graph does not depict any trend with regards to PCA 1 and% of imperviousness. Similar plot of PCA 1 and PCA 3 with imperviousness as shown in Figure 44, does not provide additional information in this regard.

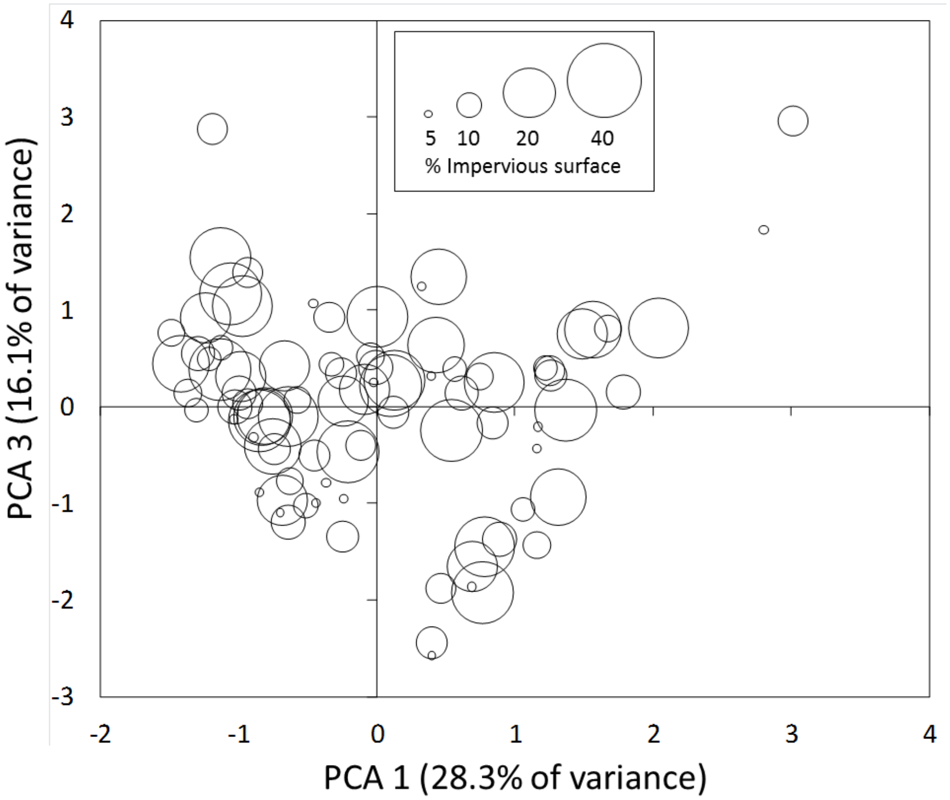


Figure 44: Association of imperviousness with PCA1 and PCA3

Figure 45 shows the variation of potential runoff with the first principal component (PCA1) and the second (PCA2). The size of the bubbles in the graph represents the potential runoff factor, which is the product of rainfall and the average imperviousness of the surrounding land. The dots/small circles indicate zero runoff. As depicted in the graph, there is a positive correlation between potential runoff and PCA1. As there is a strong positive correlation between PCA1 and the different water quality parameters (Ammonia, TSS, *E.coli*, VSS and Coliform), it implies a positive correlation of runoff with each of these variables. Thus, the concentrations of each of these five variables are strongly positively correlated with the rate of runoff. The graph (Figure 45) shows the positive association between PCA2 and the runoff factor. However it explains only 16.8% of variation in the data. Similar plot of PCA 1 and PCA 3 with potential runoff from impervious surfaces as shown in Figure 46, Shows strong association with PCA1 and the runoff factor but does not provide any additional information with PCA3, even though the graph is slight different.

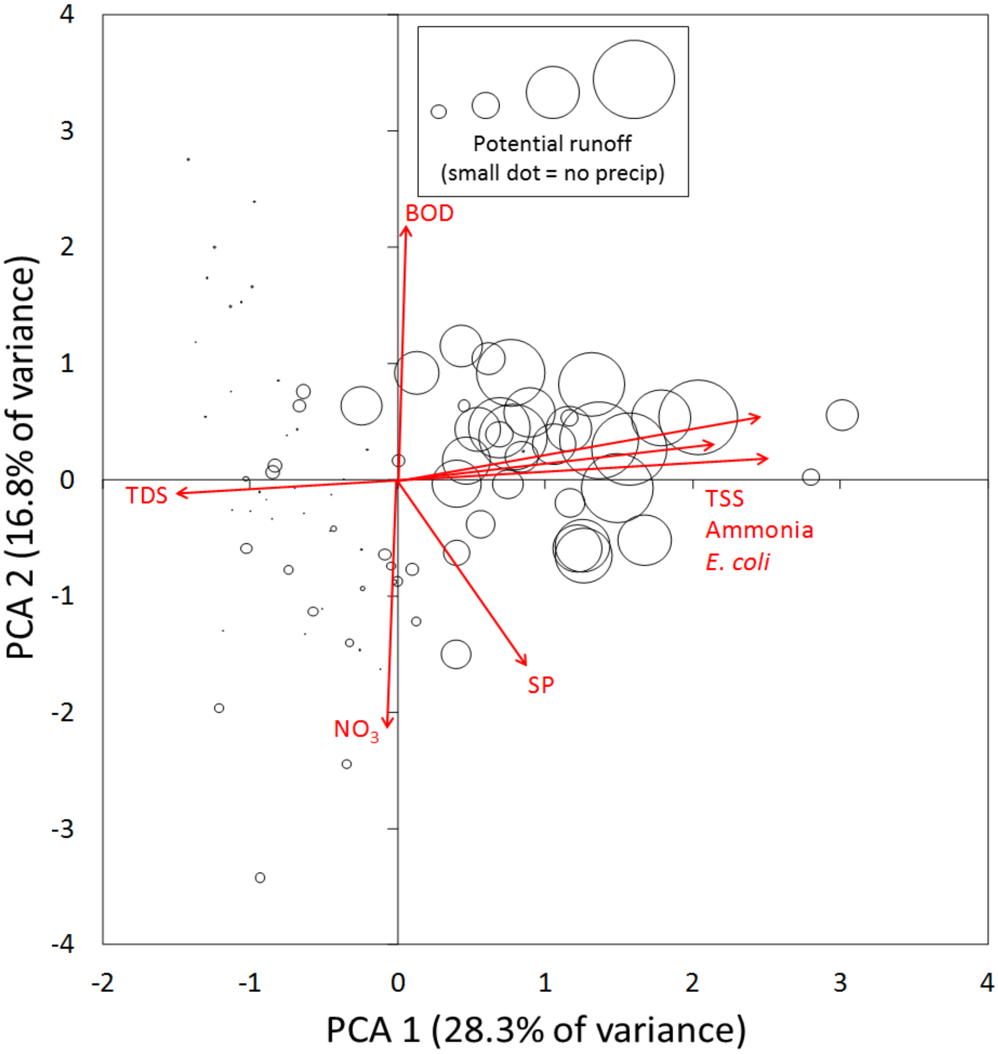


Figure 45: Association of potential runoff from impervious surfaces with PCA1 and PCA2

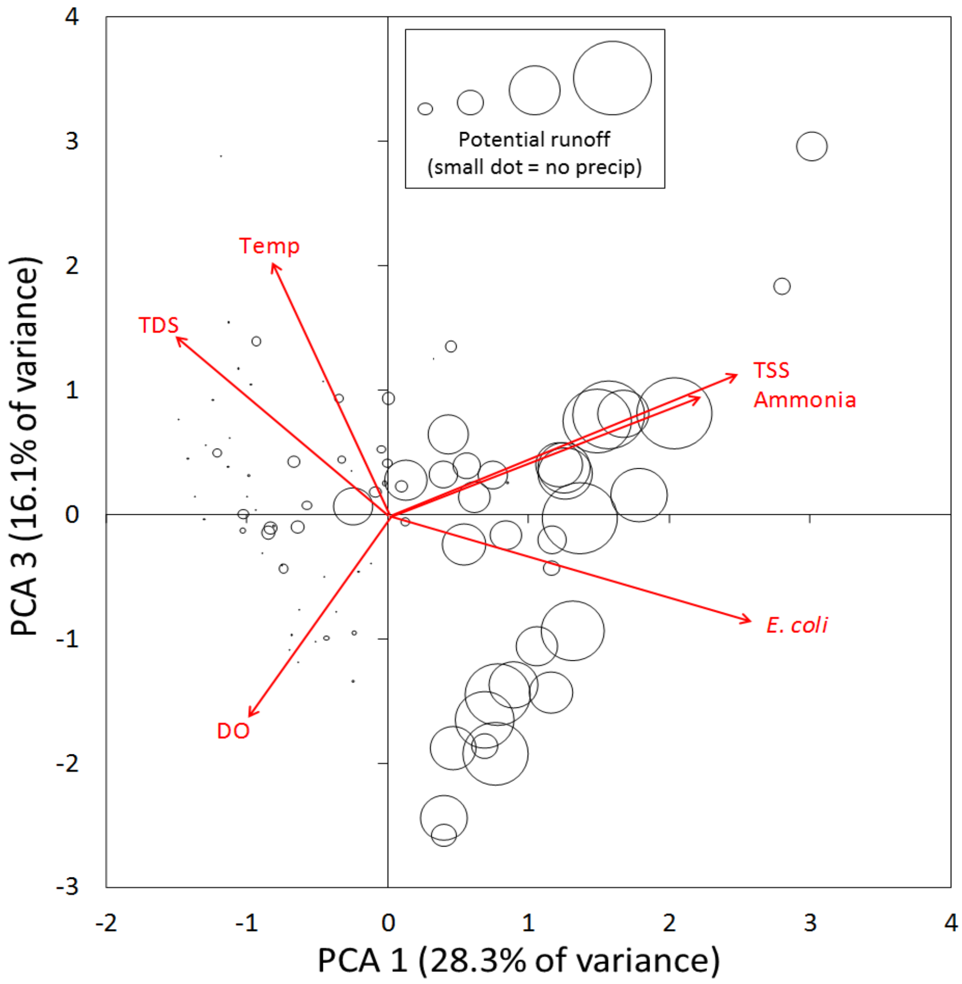


Figure 46: Association of potential runoff from impervious surfaces with PCA 1 and PCA3

Impervious surfaces include road, parking lots, rooftops, sidewalks, paved surfaces and other impermeable areas. These areas can create faster storm flows and greater runoff that washes all types of pollutants and increases the concentrations of nutrients and other pollutants into surface water. This might be the reason behind the increase in concentration of ammonia, TSS, *E.coli* and Coliform in the Mill Creek watershed during high flow. Similar results were found with *E.coli* and coliform bacteria at the Likangala River of southern Malawi, and with at Ciliwung River in Jakarta (Pallanikatil et.al 2015, Permatasari et al 2017).

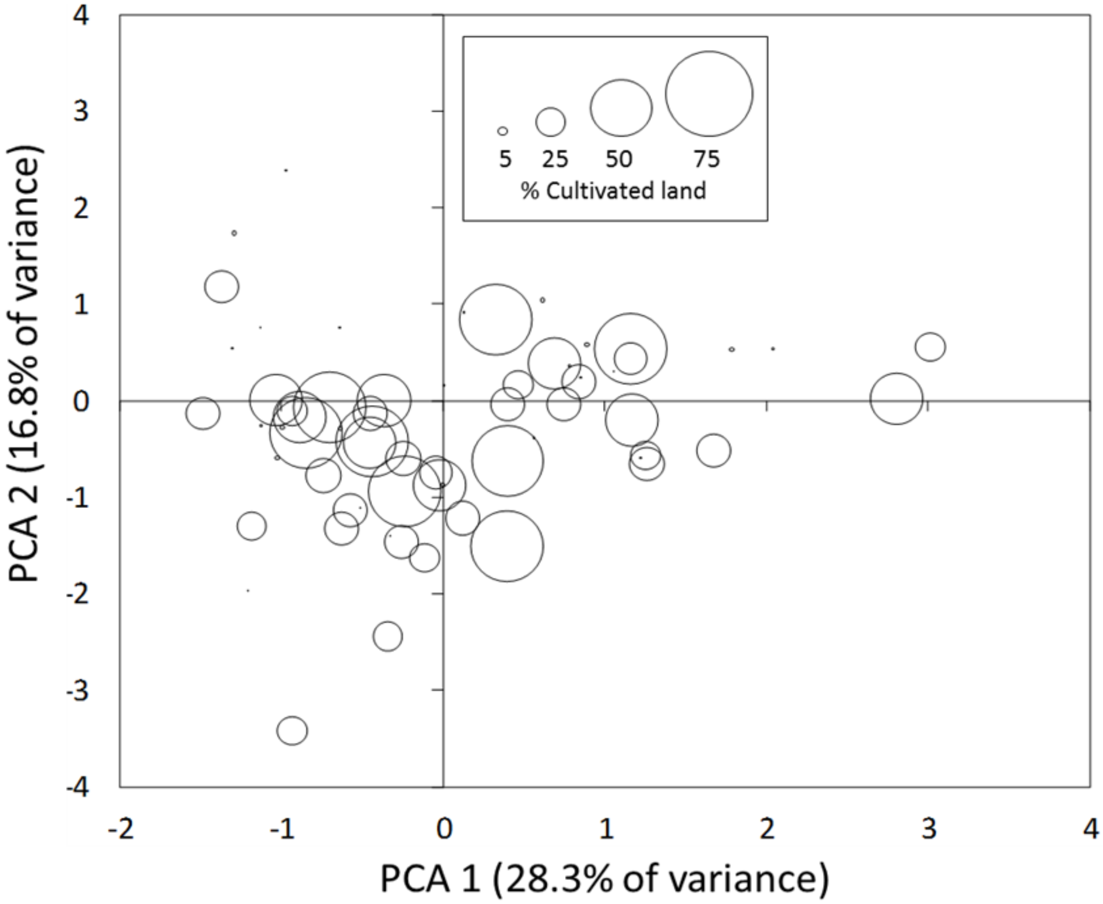


Figure 47: Association of percentage of cultivated land with PCA 1 and PCA2

Figure 47 shows the variation of the percentage of cultivated land with the first and the second principal components. The larger the size of the bubbles, the larger is the percentage of cultivated land. The graph implies a very weak negative association, of PCA1 and PCA2 with cultivated areas. Similarly, Figure 48 also indicates a weak negative correlation if any between PCA3 and percentage of cultivated land.

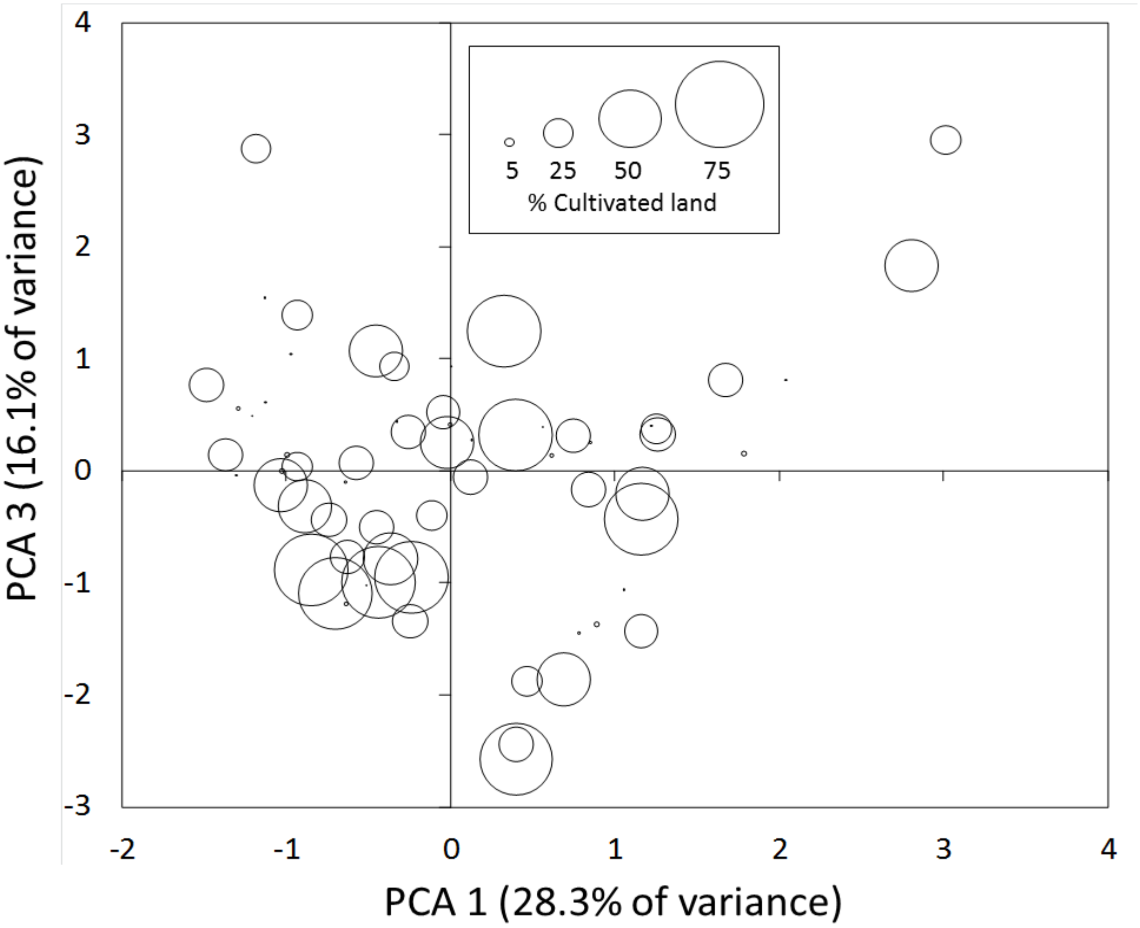


Figure 48: Association of percentage of cultivated land with PCA1 and PCA3

Figure 49 shows the variation of potential runoff factor with the first principal component (PCA1) and the second (PCA2). The size of the bubbles in the graph represents the potential runoff factor, which is the product of rainfall and the proportion of cultivated land. The dots indicate zero runoff. As depicted in the graph, there is a positive correlation between potential runoff and PCA1. The graph (Figure 49) shows the strong positive correlation between PCA1 and the different water quality parameters (Ammonia, TSS, VSS, Coliform and E.coli), it implies a positive correlation of runoff with each of these variables.

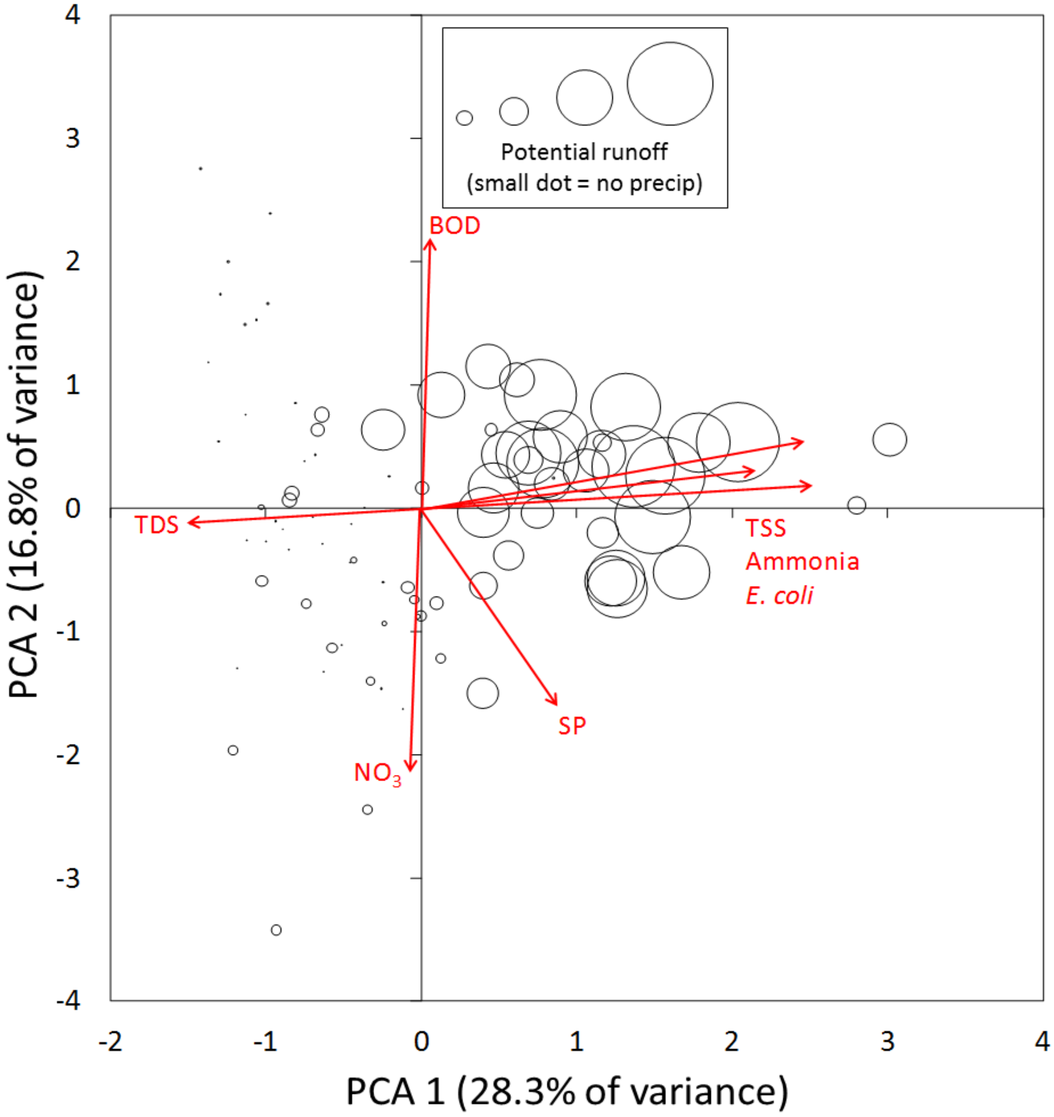


Figure 49 Association of potential runoff from cultivated land with PCA1 and PCA2

The graph below (Figure 50) does not provide any evidence of a pattern of relationship between PCA3 and potential runoff. Whereas, the graph shows (Figure 50) strong positive correlation between PCA1 and the different water quality parameters (Ammonia, TSS, VSS, Coliform and E.coli), it implies a positive correlation of runoff with PCA1 with each of these variables.

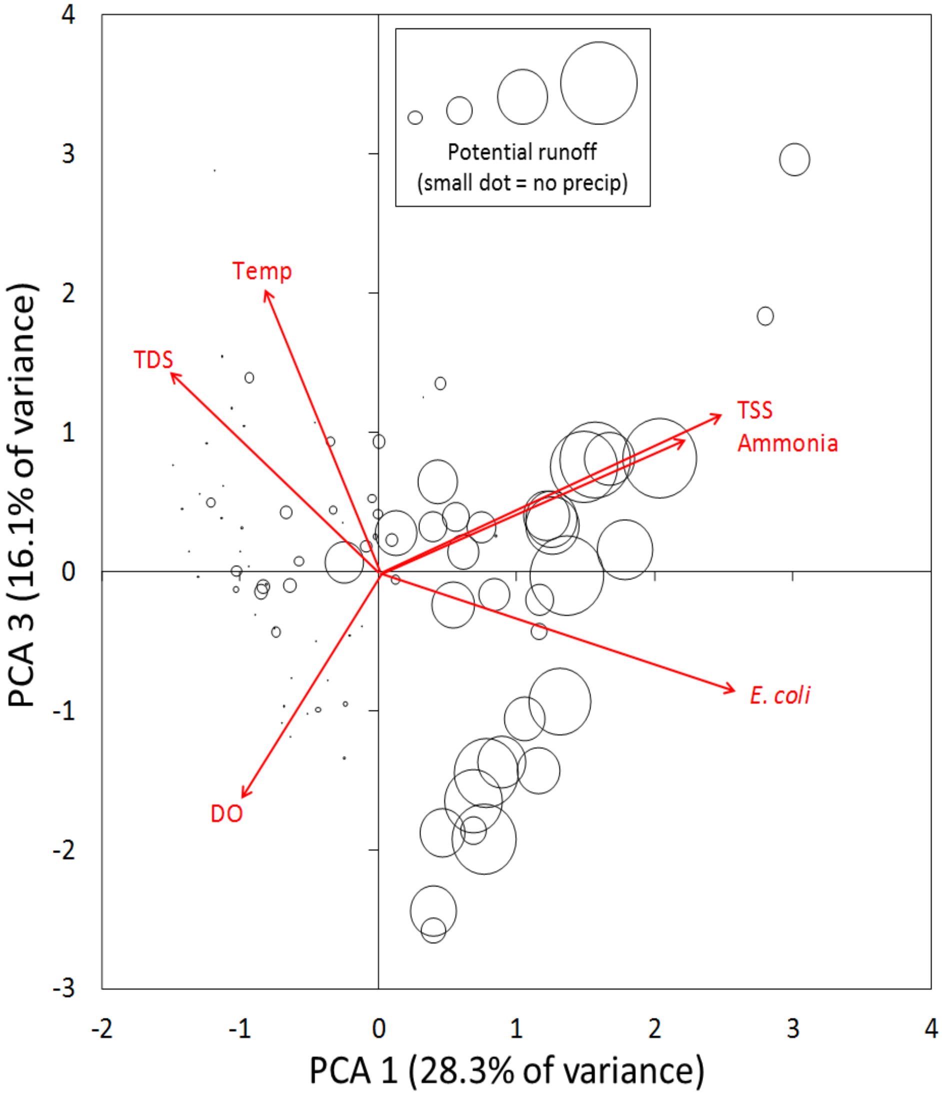


Figure 50 Association of potential runoff from cultivated land with PCA1 and PCA2

It was hypothesized that during high flow period the agricultural land increase input of nutrients (nitrogen and phosphorous), bacteria and sediment in the Mill Creek Watershed. The results from PCA show the positive correlation between Ammonia, TSS, VSS Coliform and *Ecoli* bacteria with crude runoff factor. Farmers apply chemical fertilizer, manure and bio solids directly to the agricultural land. Thus, pollutants like sediments, fertilizer, pesticides are often attached to the soil particles and wash into the water bodies during heavy rainfall. Similar results were found with ammonia in Chaohu Lake basin of China (Huang et.al. 2013).

The analysis until now is based on the data collected within the one-year interval from May 2017 to May 2018. The results of the principal component analysis using additional data that date back to May 2016 is presented below. The variables included in the analysis along with their descriptive are shown in Table 15 below.

Table 17: Descriptive statistics of the variables used in the Principal Component Analysis including data from 2016in addition to 2017-2018

Variables	Mean	Minimum	Maximum	Standard deviation
Rainfall (cm)	2.35	0	10.13	2.92
Temperature (^{0}C)	19.14	8.3	28	4.3
DO (mg/L)	6.96	3.43	11.6	1.85
pH	7.57	6.15	9	0.5
TSS (mg/L)	23.65	0	212	30.04
TDS(mg/L)	355.62	52	707	141.67
TVS (mg/L)	118.24	0	406	75.22
Total Coliform(MPN/100mL)	1706.13	300	2419.6	932.13
BOD5 (mg/L)	5.7	-0.14	33.67	4.1

The eigen values corresponding to each of the 7 different principal components and their shares of variance are shown in Table 16. The first 3 principal components, which collectively contain more than 62% of the total variance in the data are chosen for the analysis. The component matrix that shows the association of each of these three principal components with the original seven variables are presented in Table 18.

Table 18: Eigen values of the principal components and the variance they contain

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	1.809	25.84	25.84	1.809	25.84	25.84
2	1.435	20.50	46.34	1.435	20.50	46.34
3	1.121	16.02	62.36	1.121	16.02	62.36
4	0.845	12.07	74.43			
5	0.779	11.13	85.56			
6	0.603	8.617	94.18			
7	0.408	5.822	100.0			

Table 19: Principal components and their association with different water parameters

	Component		
	1	2	3
Temp	0.620	-0.339	-0.492
DO	-0.370	0.764	0.222
pH	0.566	0.473	-0.232
TSS	-0.285	-0.532	0.295
TDS	0.436	0.284	0.498
TVS	0.347	-0.373	0.627
Coliform	-0.759	-0.104	-0.221

As the component matrix shows, the first principal component is strongly positively correlated with temperature and pH, and moderately positively correlated with TDS. On the other hand it is negatively strongly correlated with Coliform. So the first component is basically a measure of these four variables. Similarly, the second component is positively correlated with DO and negatively correlated with TSS. There is a strong positive correlation of the third principal component with TVS, while its correlation with TDS is moderately positive.

Figure 51 shows plots the first principal component (PCA1) and the second (PCA2) with precipitation, the amount of which is represented by the size of the bubbles. The color of the bubbles differentiates the date that the samples were collected. The graph shows that high precipitation events are clustered. Especially interesting was that the two HP events from summer 2016 (1st Aug and 2nd Sept) diverged on the graph from events in the fall (1st and 21st Oct). If those two high precipitation events from summer 2016 are not included, the graph for 2016 looks similar to that of 2017-18. It seems quite apparent that the summer 2016 events were producing a water chemistry signature that was not distinguishable from water quality at low precipitation conditions. In contrast, the fall events in 2016 seemed to influence water chemistry directly, much as is apparent in the 2017-2018 graphs that includes more water quality variables. Figure 52 shows the variation in water quality parameters with precipitation. The top half of the graph includes all the observations while the bottom half excludes the events of high precipitation in the summer. The implications of the two plots are not qualitatively different.

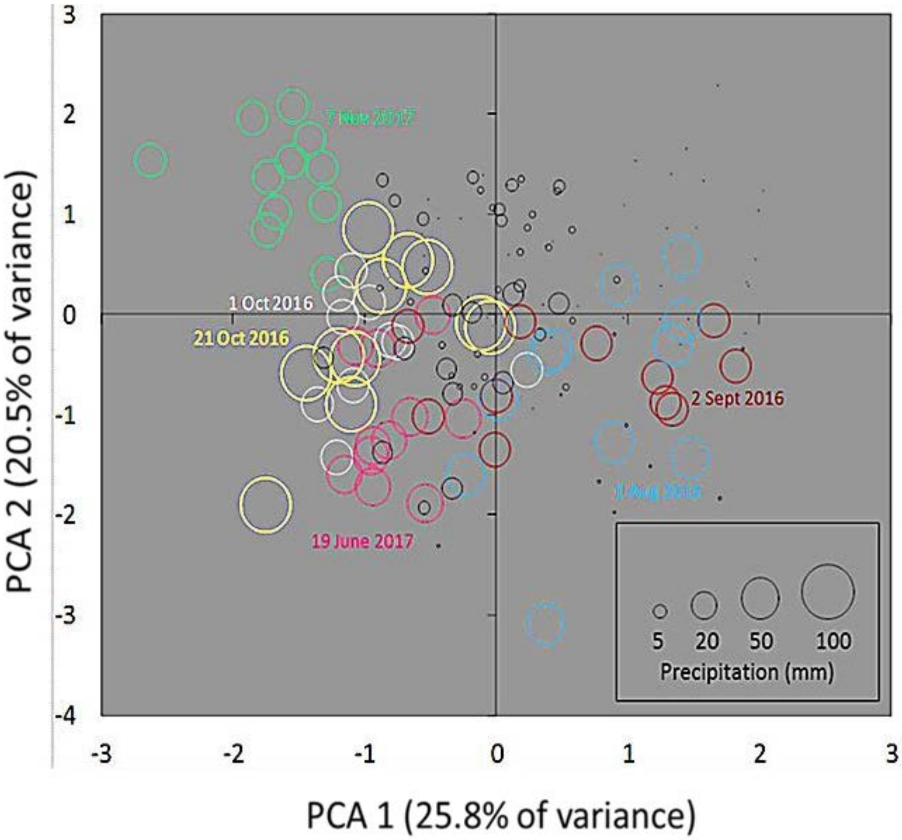


Figure 51: Association of Precipitation with principal components 1 and 2

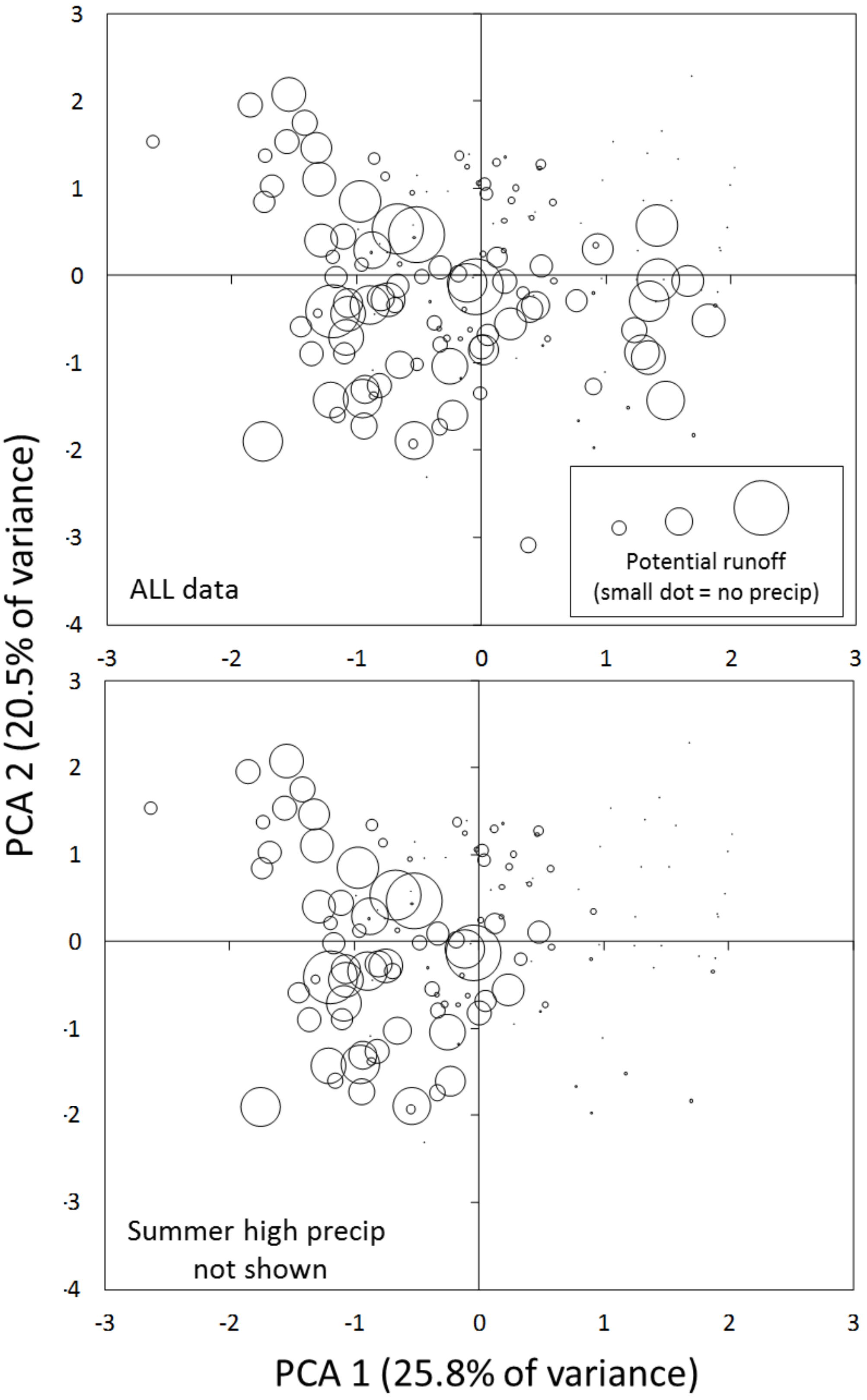


Figure 52: Association between potential runoff and the first two principal components

Chapter 5 Conclusion

This thesis is a study of the influence of the various land use practices on water quality parameters of Mill Creek watershed. Samples were taken from 11 different sites of the Mill Creek Watershed from head waters to the out flow during pre and post rain events. Post rain samples were collected 24-48 hours after the significant rain (<2cm) events. These samples were used to measure various physical, chemical and biological water quality parameters in the laboratory.

Even simple bar diagrams show that the average of water quality parameters vary before and after rain events, which imply that water quality is affected by precipitation. The average concentrations of ammonia, *E.coli*, TSS, VSS and Total coliform are higher post rainfall events while that of TDS and VDS were lower each sites. In all Sites except Site 5, the concentration of Nitrate is lower after rainfall events, which also happens to be close to the Boardman WWTP. This, in general, applies to that of Phosphorous as well. Similarly, the results from spatial dispersion show the increase in concentration of solids, nutrient and bacteria with rain fall events.

Principal Component Analysis shows that the runoff from the impervious surfaces impacts the water quality of the Mill Creek Watershed. The potential runoff from impervious surfaces and from cultivated area are found to be positively correlated with the concentrations of ammonia, TSS, E.coli, VSS and Coliform. Principal Component Analysis with whole data covering 2016-2018 result in ordination plots in which high precipitation events are clustered. Interestingly high precipitation events in summer 2016 diverged from high precipitation events in the fall. Excluding the high precipitation events from summer of 2016 results implications that are similar to that of 2017-18. Thus, high precipitation events of summer 2016 apparently produced water parameters similar to that of low conditions. In contrast, the fall events seemed to influence water chemistry in the similar way to that of 2017-2018 which are based on a large number of water quality variables.

This study shows that the runoff from agricultural areas and impervious surfaces has negative impact on the water quality of the watershed. Beside runoff factor there might be other factors like input of nutrients, bacteria and solids from the tributaries of the Mill Creek River. It is recommended to expand the sampling into the tributaries of the Mill Creek River.

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Appendix

Average of water quality variables for the years 2016-2018

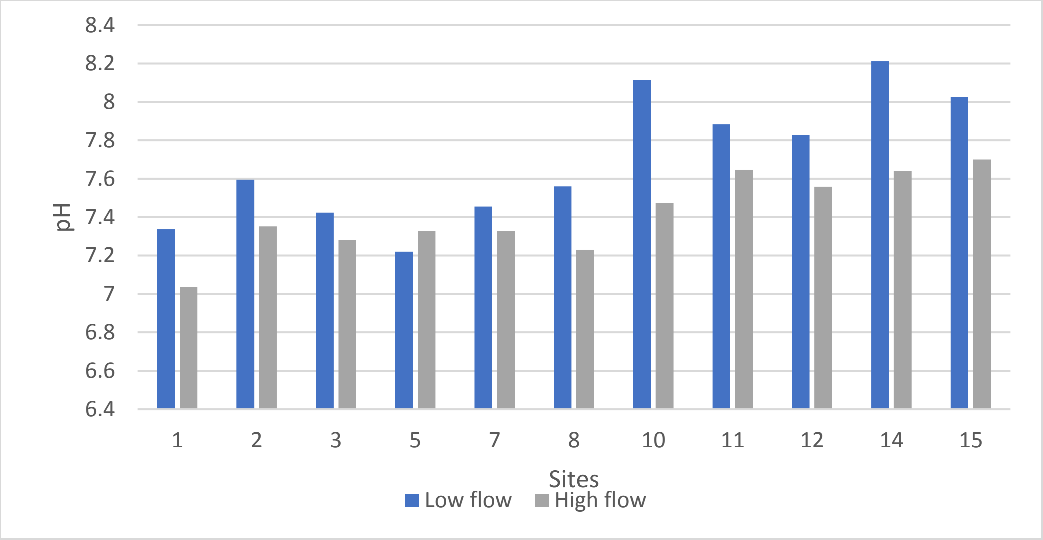


Figure 53: Average pH before and after rainfall for different sites for the year 2016-2018

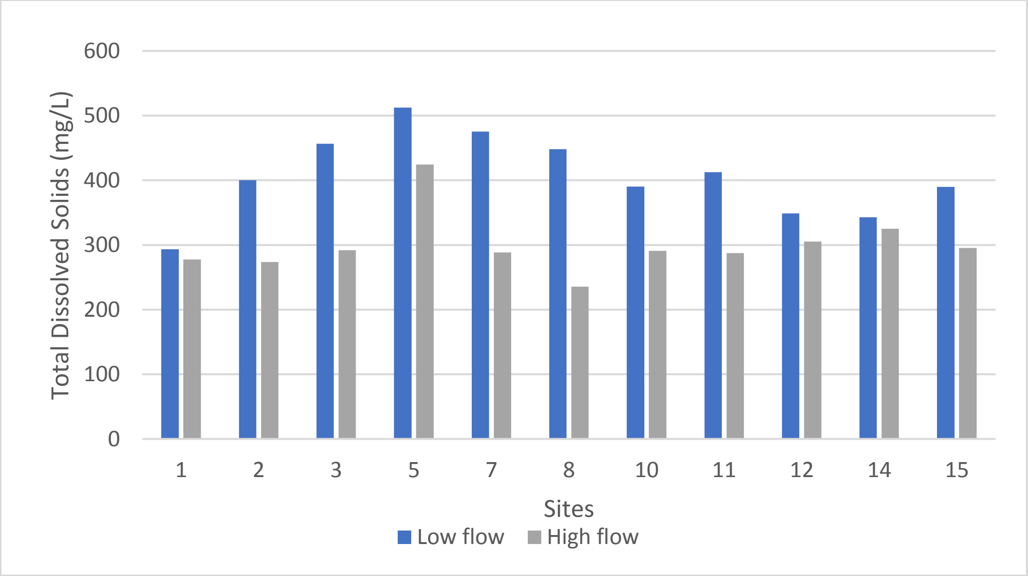


Figure 54: Average TDS before and after rainfall for different sites for the year 2016-2018

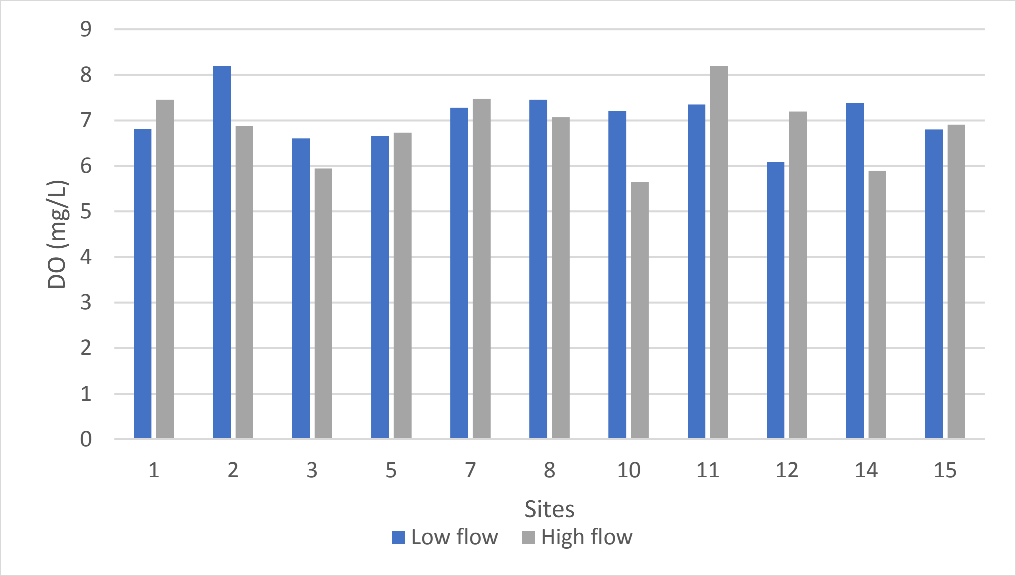


Figure 55: Average DO before and after rainfall for different sites for the year 2016-2018

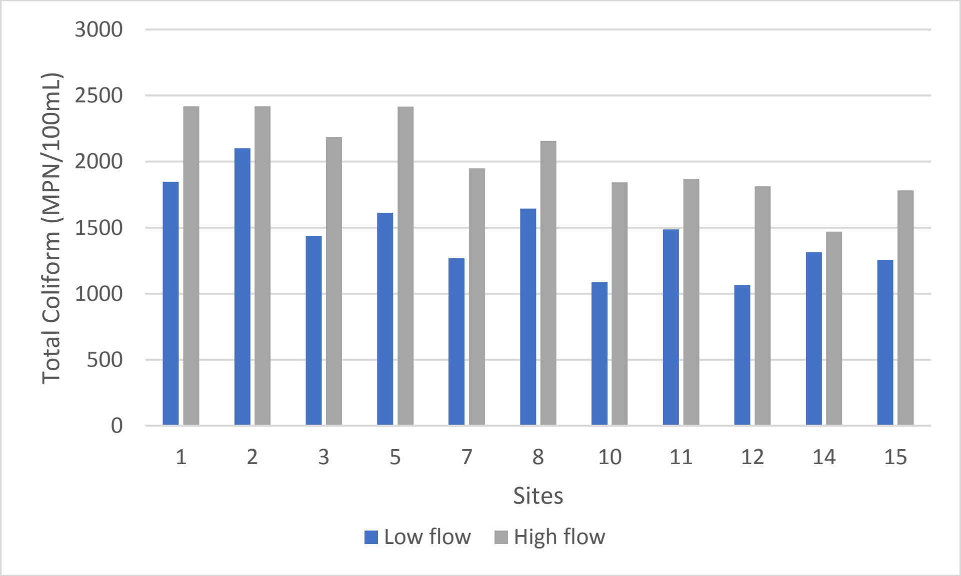


Figure 56: Average total coliform before and after rainfall for different sites for the year 2016-2018

Total Drainage Area of Each Sites

Table 20: Land use practices at Watershed 1 (Site1)

Land use	Drainage Area in acres	Percentages
Herbaceous	25.13 acres	1.45%
Open space and low intensity developed areas	199.71 acres	11.50%
Medium intensity developed areas	5.12 acres	0.29%
Hay, pasture, Cultivated crops	1119.98 acres	64.48%
Forests	377.40 acres	21.73%
Open water	6.89 acres	0.40%
Wetlands	2.67 acres	0.15%

Table 21: Land use practices at Watershed 2 (Site 2

Land use	Drainage area in acres	Percentages
Herbaceous and barren land	113.20	2.0
Forest	1198.26	20.30
Medium and high intensity developed areas	413.88	7.01
Open space and low intensity developed areas	1703.32	28.86
Hay, pasture and cultivated crops	2390.96	40.51
Open water	47.15	0.80
Wetlands	35.14	0.60

Table 22: Land use practices at Watershed 3 (Site 3)

Land use	Drainage area in acres	Percentages
Herbaceous and barren land	313.58	2.36
Forest	3677.07	27.69
Medium and high intensity developed areas	503.50	3.79
Open space and low intensity developed areas	2523.73	19.00
Hay, pasture and cultivated crops	5873.88	44.23
Open water	120.54	0.91
Wetlands	268.87	2.02

Table 23: Land use practices at Watershed 5 (Site5)

Land use	Drainage area in acres	Percentages
Herbaceous and barren land	551.76	2.39
Forest	6150.54	26.64
Medium and high intensity developed areas	1502.05	6.51
Open space and low intensity developed areas	5237.84	22.69
Hay, pasture and cultivated crops	8431.20	36.52
Open water	369.17	1.60
Wetlands	842.43	3.65

Table 24: Land use practices at Watershed 7 (Site 7)

Land use	Drainage area in acres	Percentages
Herbaceous and barren land	557.99	2.36
Forest	6396.07	27.00
Medium and high intensity developed areas	1512.50	6.39
Open space and low intensity developed areas	5452.22	23.02
Hay, pasture and cultivated crops	8439.87	35.63
Open water	370.51	1.56
Wetlands	959.19	4.05

Table 25: Land use practices at Watershed 8 (Site8)

Land use	Drainage area in acres	Percentages
Herbaceous and barren land	795.06	2.36
Forest	9061.69	26.92
Medium and high intensity developed areas	2291.33	6.81
Open space and low intensity developed areas	8540.17	25.37
Hay, pasture and cultivated crops	11372.14	33.78
Open water	426.55	1.27
Wetlands	1178.47	3.50

Table 26: Land use practices at Watershed 10 (Site 10)

Land use	Drainage area in acres	Percentages
Herbaceous and barren land	796.17	2.10
Forest	9164.21	24.22
Medium and high intensity developed areas	2708.32	7.16
Open space and low intensity developed areas	12124.06	32.04
Hay, pasture and cultivated crops	11372.14	30.06
Open water	430.11	1.14
Wetlands	1242.52	3.28

Table 27: Land use practices at Watershed 11 (Site 11)

Land use	Drainage area in acres	Percentages
Herbaceous and barren land	887.35	2.09
Forest	9850.30	23.21
Medium and high intensity developed areas	2824.19	6.65
Open space and low intensity developed areas	15549.60	36.64
Hay, pasture and cultivated crops	11550.06	27.22
Open water	498.61	1.17
Wetlands	1277.43	3.01

Table 28: of Land use practices at Watershed 12 (Site12)

Land use	Drainage area in acres	Percentages
Herbaceous and barren land	887.35	2.05
Forest	9902.34	22.91
Medium and high intensity developed areas	2905.14	6.72
Open space and low intensity developed areas	16193.21	37.46
Hay, pasture and cultivated crops	11550.06	26.72
Open water	511.73	1.18
Wetlands	1277.43	2.96

Table 29: Land use practices at Watershed 14 (Site14)

Land use	Drainage area in acres	Percentages
Herbaceous and barren land	898.92	1.93
Forest	10009.98	21.45
Medium and high intensity developed areas	3162.89	6.78
Open space and low intensity developed areas	19214.44	41.18
Hay, pasture and cultivated crops	11550.06	24.75
Open water	541.09	1.16
Wetlands	1281.88	2.75

Table 30: Land use area at Watershed 15 (Site 15)

Land use	Drainage area in acres	Percentages
Herbaceous and barren land	917.38	1.81
Forest	10200.57	20.09
Medium and high intensity developed areas	3762.25	7.41
Open space and low intensity developed areas	22405.13	44.12
Hay, pasture and cultivated crops	11626.56	22.89
Open water	583.56	1.15
Wetlands	1291.44	2.54

Photographs of the Sampling Sites


Site1

Intersection of the Matz Rd and Camelot Dr


Site 2

Near Renkenberger Rd


Site 3

Intersection of Lynn and


Site 5

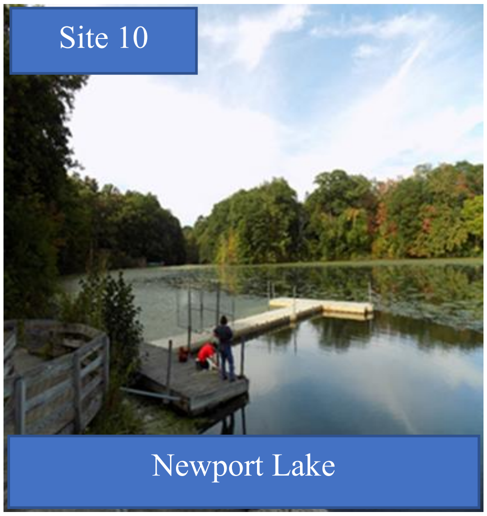
Near Boardman WWTP


Site 7

Near Mill Creek Golf Course


Site 8

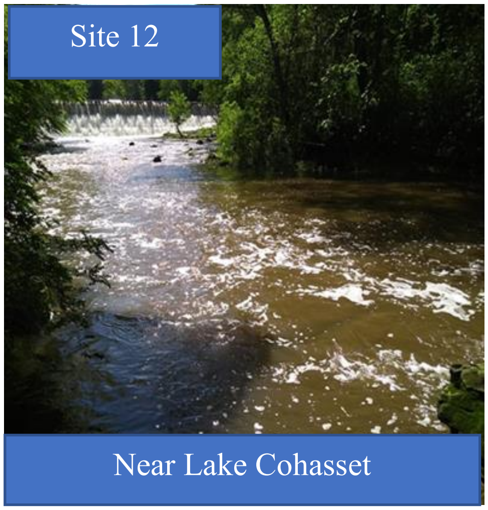
Near Cranberry run


Site 10

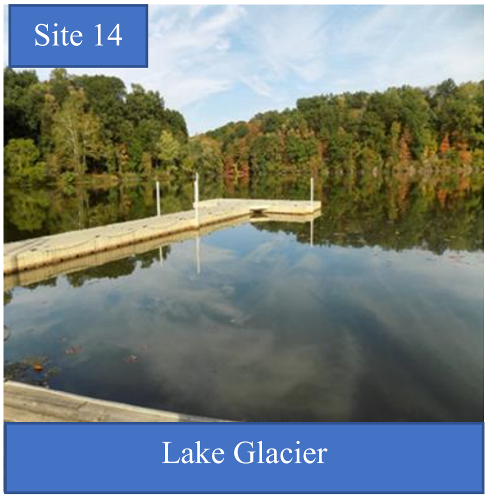
Newport Lake


Site 11

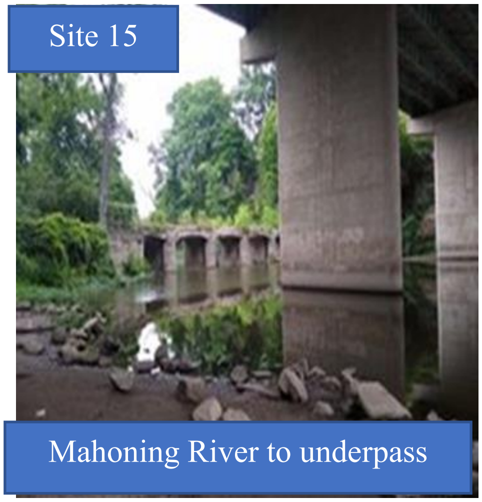
Near Lanterman’s Mill


Site 12

Near Lake Cohasset


Site 14

Lake Glacier


Site 15

Mahoning River to underpass

Data from 2016-2018

Table 31: Water Quality Variables Data from 2016-2018

Site	Date	Rainfall (cm)	Temp. (°C)	DO (mg/L)	pH	TSS (mg/L)	TDS (mg/L)	TVS (mg/L)	Total coliform ,(MPN/100 mL)
15	23-May-18	1.63	21.7	5.88	8.3	25.50	406.50	94	2419.6
15	9-May-18	0.00	20.7	6.24	8.87	15.00	513.00	110	183.9
15	7-Nov-17	3.78	10.9	8.37	7.8	20.50	263.50	49	2419.6
15	24-Sep-17	0.00	23	6.5	7.74	7.00	509.00	207	771.7
15	11-Aug-17	0.15	23.2	6.89	8.38	9.00	463.00	38	2419.6
15	6-Jul-17	0.13	25.2	7.07	7.58	15.50	310.50	74	1161.6
15	19-Jun-17	4.95	22.5	6.69	7.28	92.00	194.00	70	2419.6
15	19-May-17	0.00	22.4	6.29	7.33	56.00	119.00	52	2419.6
15	4-Nov-16	0.53	12.1	9.34	7.56	11.00	380.00	203	533.3
15	21-Oct-16	10.13	16.3	8.55	7.66	34.50	437.50	329	2419.6
15	1-Oct-16	4.06	17.4	5.9	6.9	30.50	268.50	60	2419.6
15	2-Sep-16	3.86	22.5	4.1	7.93	17.50	203.00	162	276.0
15	1-Aug-16	5.72	26.5	8.87	8.04	11.50	295.00	138	100.0
15	16-Jun-16	0.03	23.9	6.67	8.29	13.50	355.00	235	2419.6
15	25-May-16	0.00	23.1	5.43	8.46	21.00	468.00	106	150.0
14	23-May-18	1.63	20.3	6.49	7.92	16.00	406.00	100	2419.6
14	9-May-18	0.00	20.7	7.3	8.71	13.50	466.50	66	214.3
14	7-Nov-17	3.78	10.7	9.16	7.92	15.50	250.50	49	2419.6
14	24-Sep-17	0.00	22.7	8.33	7.77	6.00	514.00	125	236.4
14	11-Aug-17	0.15	23.8	6.04	8.5	16.00	465.00	100	2419.6
14	6-Jul-17	0.13	24.9	7.64	7.63	7.00	299.00	48	2203.0
14	19-Jun-17	4.95	23.9	5.33	7.42	39.50	247.50	64	2419.6
14	19-May-17	0.00	23.5	10.4	8.87	22.00	99.00	65	2419.6
14	4-Nov-16	0.53	12	8.9	7.53	9.00	175.00	0	654.5
14	21-Oct-16	10.13	15.7	7.7	7.65	20.00	356.00	91	2419.6
14	1-Oct-16	4.06	18.2	5.12	6.82	16.00	353.00	60	178.2
14	2-Sep-16	3.86	24.9	4.01	8.35	21.50	389.00	0	340.0
14	1-Aug-16	5.72	25.3	3.48	7.41	15.50	272.00	148	94.0
14	16-Jun-16	0.03	24.2	4.15	8.16	20.00	238.00	310	2200.0
14	25-May-16	0.00	22.5	6.32	8.53	16.00	487.00	149	170.0
12	23-May-18	1.63	19.8	7.1	7.72	31.00	353.00	78	2419.6
12	9-May-18	0.00	21.5	6.26	8.58	8.50	469.50	86	748.6
12	7-Nov-17	3.78	10.8	11	7.99	15.50	238.50	30	2419.6

Site	Date	Rainfall (cm)	Temp. (°C)	DO (mg/L)	pH	TSS (mg/L)	TDS (mg/L)	TVS (mg/L)	Total coliform ,(MPN/100 mL)
12	24-Sep-17	0.00	22.6	7	7.72	8.00	499.00	151	652.4
12	11-Aug-17	0.15	21.7	8.49	7.74	4.33	411.67	79	1715.4
12	6-Jul-17	0.13	24.5	5.7	7.01	10.50	317.50	46	2419.6
12	19-Jun-17	4.95	22.1	8.32	7.55	63.00	187.00	54	2419.6
12	19-May-17	0.00	21.6	5.7	8.37	16.00	99.00	43	2419.6
12	4-Nov-16	0.53	12.3	6.75	7.53	4.50	408.50	48	427.3
12	21-Oct-16	10.13	16.5	7.67	7.6	22.00	413.00	102	2419.6
12	1-Oct-16	4.06	18.6	5.93	6.46	53.00	309.00	103	2419.6
12	2-Sep-16	3.86	22.7	3.66	7.85	25.50	312.00	102	400.0
12	1-Aug-16	5.72	26.9	6.7	7.74	7.50	325.00	100	203.3
12	16-Jun-16	0.03	22.3	4.5	7.54	3.50	126.00	406	42.0
12	25-May-16	0.00	22.2	4.35	8.13	19.50	460.50	100	100.0
11	23-May-18	1.63	20.3	7.17	7.82	33.00	347.00	106	2419.6
11	9-May-18	0.00	21.7	6.42	9	8.50	501.50	90	336.5
11	7-Nov-17	3.78	10.4	10.6	7.92	22.50	283.50	78	2419.6
11	24-Sep-17	0.00	21.7	8.34	7.37	5.00	575.00	102	1553.1
11	11-Aug-17	0.15	22.6	8.5	7.75	6.67	453.33	128	2419.6
11	6-Jul-17	0.13	25.3	6.68	7.2	11.50	336.50	60	2419.6
11	19-Jun-17	4.95	22.1	8.74	7.4	63.00	174.00	49	2419.6
11	19-May-17	0.00	21.2	9.57	8.19	6.00	136.00	46	2419.6
11	4-Nov-16	0.53	11.9	10.14	7.78	7.50	430.50	287	300.0
11	21-Oct-16	10.13	16.7	9.96	7.6	40.50	357.50	92	2419.6
11	1-Oct-16	4.06	18.2	7.23	7.18	30.00	312.00	95	2419.6
11	2-Sep-16	3.86	21.9	5.43	7.82	14.50	246.00	196	333.3
11	1-Aug-16	5.72	25.5	8.22	7.79	11.50	291.00	118	660.0
11	16-Jun-16	0.03	23.4	4.92	7.66	16.00	387.00	155	2419.6
11	25-May-16	0.00	21.9	4.22	8.12	15.00	479.00	126	30.0
10	23-May-18	1.63	22.1	5.05	7.53	25.50	374.50	88	2419.6
10	9-May-18	0.00	21.7	10.58	8.94	13.00	509.00	112	100.3
10	7-Nov-17	3.78	11	6.36	7.54	18.00	244.00	36	2419.6
10	24-Sep-17	0.00	22.9	9.53	7.84	4.50	507.50	64	2419.6
10	11-Aug-17	0.15	23.5	9.16	8.14	13.00	426.00	100	2419.6
10	6-Jul-17	0.13	28	5.28	7.72	18.00	329.00	70	2419.6
10	19-Jun-17	4.95	22.7	3.49	7.05	45.00	178.00	58	2419.6
10	19-May-17	0.00	21.8	6.9	8.56	14.00	141.00	55	744.2
10	4-Nov-16	0.53	12.7	5.01	7.25	10.50	421.50	158	493.3

Site	Date	Rainfall (cm)	Temp. (°C)	DO (mg/L)	pH	TSS (mg/L)	TDS (mg/L)	TVS (mg/L)	Total coliform ,(MPN/100 mL)
10	21-Oct-16	10.13	16	7	6.73	30.50	359.50	91	2419.6
10	1-Oct-16	4.06	18.6	6.81	7.16	19.50	295.50	92	2419.6
10	2-Sep-16	3.86	23.8	4.12	8.33	25.00	318.00	118	86.7
10	1-Aug-16	5.72	26.8	6.68	7.98	14.50	268.00	157	713.3
10	16-Jun-16	0.03	24.9	6.08	8	7.00	334.00	223	82.0
10	25-May-16	0.00	22.7	5.09	8.48	19.50	454.50	80	30.0
8	23-May-18	1.63	19.1	5	7.28	39.50	424.50	86	2419.6
8	9-May-18	0.00	19.4	8.15	8.51	6.00	554.00	86	331.4
8	7-Nov-17	3.78	9.3	8.5	7.54	26.50	259.50	35	2419.6
8	24-Sep-17	0.00	21.3	9.45	7.7	5.50	699.50	143	362.6
8	11-Aug-17	0.15	20.7	8.8	7.57	12.67	616.33	67	2419.6
8	6-Jul-17	0.13	22.3	6.24	6.74	12.00	455.00	92	2419.6
8	19-Jun-17	4.95	21.5	5.7	7.1	85.00	201.00	89	2419.6
8	19-May-17	0.00	20.2	8.12	7.53	1.75	124.25	82	2419.6
8	4-Nov-16	0.53	11.1	8.5	7.66	2.50	420.50	149	2419.6
8	21-Oct-16	10.13	14.9	8.43	7.54	20.00	243.00	170	2419.6
8	1-Oct-16	4.06	17.9	6.25	6.15	9.50	291.50	77	2419.6
8	2-Sep-16	3.86	17.8	7.78	7.52	6.00	125.00	186	2419.6
8	1-Aug-16	5.72	22.1	7.8	7.49	11.00	105.00	194	590.0
8	16-Jun-16	0.03	20.4	5.7	7.28	16.50	216.00	233	2419.6
8	25-May-16	0.00	18	4.7	7.5	9.00	501.00	86	360.0
7	23-May-18	1.63	18.7	5.76	7.38	39.00	409.00	98	2419.6
7	9-May-18	0.00	19.3	8.63	8.17	4.00	532.00	92	561.0
7	7-Nov-17	3.78	9.3	9.26	7.39	38.00	280.00	90	2419.6
7	24-Sep-17	0.00	21.4	9.01	7.27	6.00	651.00	94	220.3
7	11-Aug-17	0.15	20.3	8.93	7.64	1.33	673.67	122	1986.3
7	6-Jul-17	0.13	22.6	5.78	6.71	9.00	456.00	92	2203.0
7	19-Jun-17	4.95	21.4	5.73	6.95	45.50	226.50	81	2419.6
7	19-May-17	0.00	21	8.42	7.59	3.50	90.50	58	2419.6
7	4-Nov-16	0.53	12.5	8.5	7.57	7.00	518.00	124	726.7
7	21-Oct-16	10.13	15	7.22	7.45	66.50	297.50	119	2419.6
7	1-Oct-16	4.06	15.8	8.34	7.36	56.00	305.00	100	2419.6
7	2-Sep-16	3.86	18.5	8.99	7.49	7.00	245.00	404	686.7
7	1-Aug-16	5.72	22.4	7.03	7.28	15.00	256.00	140	860.0
7	16-Jun-16	0.03	21	3.5	7.27	8.50	365.00	282	1883.3
7	25-May-16	0.00	18.6	5.44	7.43	2.00	518.00	166	160.0

Site	Date	Rainfall (cm)	Temp. (°C)	DO (mg/L)	pH	TSS (mg/L)	TDS (mg/L)	TVS (mg/L)	Total coliform ,(MPN/100 mL)
5	23-May-18	1.63	18.6	4.92	7.27	137.00	693.00	120	2419.6
5	9-May-18	0.00	17.8	6.72	7.69	4.50	557.50	96	1715.4
5	7-Nov-17	3.78	11.1	9.8	7.56	18.25	314.75	23	2419.6
5	24-Sep-17	0.00	22	7.65	7.11	9.00	707.00	339	1044.7
5	11-Aug-17	0.15	21.2	8.9	7.2	6.33	706.67	179	2076.3
5	6-Jul-17	0.13	22	5.57	6.57	4.50	601.50	99	2419.6
5	19-Jun-17	4.95	20.6	4.84	6.86	15.00	269.00	61	2419.6
5	19-May-17	0.00	20.9	6.6	7.2	11.00	124.00	54	2419.6
5	4-Nov-16	0.53	12.5	7.23	7.54	212.00	530.00	222	700.0
5	21-Oct-16	10.13	17.4	6.62	7.31	8.00	478.00	183	2400.0
5	2-Sep-16	3.86	19.6	8.05	7.5	7.50	431.00	281	2419.6
5	1-Aug-16	5.72	21.8	6.16	7.46	35.50	360.00	179	2419.6
5	16-Jun-16	0.03	21.3	4.09	7.17	10.00	345.00	383	1866.7
5	25-May-16	0.00	18.6	6.55	7.28	49.50	528.50	105	660.0
3	23-May-18	1.63	18.2	5.23	7.23	80.00	308.00	88	2419.6
3	9-May-18	0.00	16.8	6.37	7.89	3.50	500.50	110	2419.6
3	7-Nov-17	3.78	8.6	8.93	7.55	13.50	256.50	27	2419.6
3	24-Sep-17	0.00	19.7	6.39	7.08	10.00	554.00	97	677.4
3	11-Aug-17	0.15	18.6	9.49	7.69	7.67	570.33	111	1700.0
3	6-Jul-17	0.13	20.6	6.65	6.84	15.00	495.00	89	2419.6
3	19-Jun-17	4.95	21.1	4.6	6.64	32.00	111.00	33	2419.6
3	19-May-17	0.00	19.8	6.4	7.76	7.50	128.50	19	1476.6
3	4-Nov-16	0.53	11.8	6.36	7.5	12.00	490.00	198	1160.0
3	21-Oct-16	10.13	14.6	7.24	7.3	86.50	335.50	173	2419.6
3	1-Oct-16	4.06	15.5	8.53	7.36	43.50	349.50	142	2419.6
3	2-Sep-16	3.86	17.6	3.5	7.41	20.50	317.00	196	2419.6
3	1-Aug-16	5.72	21.6	3.58	7.42	33.00	367.00	131	786.7
3	16-Jun-16	0.03	20	3.61	7.27	25.00	428.00	143	460.0
3	25-May-16	0.00	16.8	7.57	7.36	18.50	484.50	221	1200.0
2	23-May-18	1.63	17.9	6.32	7.35	28.50	295.50	84	2419.6
2	9-May-18	0.00	14.8	7.87	7.96	11.00	389.00	102	2419.6
2	7-Nov-17	3.78	9	10.58	7.6	8.50	255.50	17	2419.6
2	24-Sep-17	0.00	18.5	8.9	7.51	8.00	527.00	108	2419.6
2	11-Aug-17	0.15	18.3	8.88	7.71	3.33	556.67	95	2419.6
2	6-Jul-17	0.13	19.3	7.68	7.01	18.00	450.00	74	2419.6
2	19-Jun-17	4.95	21.7	6.11	7.05	68.00	228.00	61	2419.6

Site	Date	Rainfall (cm)	Temp. (°C)	DO (mg/L)	pH	TSS (mg/L)	TDS (mg/L)	TVS (mg/L)	Total coliform ,(MPN/100 mL)
2	19-May-17	0.00	17.7	7.71	7.81	10.50	93.50	21	2419.6
2	4-Nov-16	0.53	11.2	8.11	7.57	0.00	386.00	66	509.1
2	21-Oct-16	10.13	14.6	8.41	7.36	180.50	248.50	204	2419.6
2	1-Oct-16	4.06	15.9	8.77	7.26	23.00	302.00	98	2419.6
2	2-Sep-16	3.86	16.8	3.75	7.49	6.50	361.00	158	2419.6
2	1-Aug-16	5.72	20.8	4.17	7.36	41.50	225.00	154	2419.6
1	23-May-18	1.63	16.8	6.87	6.87	24.50	213.50	64	2419.6
1	9-May-18	0.00	15.9	7.64	7.8	5.00	325.00	76	2419.6
1	7-Nov-17	3.78	8.3	11.6	6.55	5.00	239.00	39	2419.6
1	24-Sep-17	0.00	19.7	3.43	7.46	18.00	471.00	120	2419.6
1	11-Aug-17	0.15	17.6	6.9	7.44	5.33	387.67	49	2419.6
1	6-Jul-17	0.13	19.1	7.87	6.93	2.00	348.00	54	2419.6
1	19-Jun-17	4.95	19.8	7.745	7.33	20.50	349.50	123	2419.6
1	19-May-17	0.00	18.8	8.9	7.42	4.25	179.75	89	1587.6
1	4-Nov-16	0.53	10.1	8.83	7.11	3.00	346.00	148	620.0
1	21-Oct-16	10.13	14.4	8.52	6.97	58.00	232.00	190	2419.6
1	1-Oct-16	4.06	15.5	9.25	7.09	32.00	312.00	150	2419.6
1	2-Sep-16	3.86	15.9	3.84	7.25	16.00	274.00	123	2419.6
1	1-Aug-16	5.72	19.8	4.35	7.2	166.00	323.00	235	0.0
1	16-Jun-16	0.03	18.2	3.84	7.14	33.00	52.00	291	2419.6
1	25-May-16	0.00	14.8	7.1	7.4	28.50	237.50	163	480.0

Data from 2017-2018

Table 32: Water Quality Variables Data from 2017-2018

Site	Date	Rainfall (cm)	Ammonia (ug/L)	Phosphorous (ug/L)	NO3-N (mg/L)	Temp. (°C)	DO (mg/L)	pH	TSS (mg/L)	VSS (mg/L)	TDS(mg/L)	VDS (mg/L)	Total coliform (mpn/100 ml)	E-coli (mpn/100 mL)	BOD$_5$ (mg/L)
15	23-May-18	1.63	127.57	80.72	0.89	21.7	5.88	8.3	25.50	12.00	406.50	82.00	2419.6	1516	3.56
15	9-May-18	0.00	133.50	50.88	0.48	20.7	6.24	8.87	15.00	13.00	513.00	97.00	183.9	40.7	6.51
15	7-Nov-17	3.78	334.55	155.75	0.44	10.9	8.37	7.8	20.50	7.00	263.50	42.00	2419.6	2420	2.36
15	24-Sep-17	0.00	269.23	18.85	0.47	23	6.50	7.74	7.00	6.00	509.00	201	771.7	5.75	3.80
15	11-Aug-17	0.15	124.32	111.69	3.67	23.2	6.89	8.38	9.00	5.33	463.00	32.67	2419.6	19.1	5.43
15	6-Jul-17	0.13	257.43	308.85	5.73	25.2	7.07	7.58	15.50	13.50	310.50	60.50	1161.6	166	3.23
15	19-Jun-17	4.95	378.23	239.88	3.72	22.5	6.69	7.28	92.00	16.50	194.00	53.50	2419.6	2420	3.88
15	19-May-17	0.00	84.90	239.88	4.89	22.4	6.29	7.33	56.00	15.50	119.00	36.50	2419.6	314	4.11
14	23-May-18	1.63	106.17	30.73	1.21	20.3	6.49	7.92	16.00	10.50	406.00	89.50	2419.6	551	3.49
14	9-May-18	0.00	121.97	60.53	0.45	20.7	7.30	8.71	13.50	11.00	466.50	55.00	214.3	9.9	3.29
14	7-Nov-17	3.78	362.64	137.48	0.49	10.7	9.16	7.92	15.50	6.50	250.50	42.50	2419.6	2420	2.44
14	24-Sep-17	0.00	203.34	17.13	0.51	22.7	8.33	7.77	6.00	5.00	514.00	120.00	236.4	8.5	9.39
14	11-Aug-17	0.15	119.56	56.55	3.47	23.8	6.04	8.5	16.00	6.33	465.00	93.67	2419.6	318	4.01
14	6-Jul-17	0.13	276.44	359.76	8.36	24.9	7.64	7.63	7.00	5.50	299.00	42.50	2203.0	359	3.34
14	19-Jun-17	4.95	412.76	237.49	6.64	23.9	5.33	7.42	39.50	15.00	247.50	49.00	2419.6	2420	2.30
14	19-May-17	0.00	33.38	237.49	5.25	23.5	10.40	8.87	22.00	5.50	99.00	59.50	2419.6	55.2	4.04
12	23-May-18	1.63	197.53	76.31	1.37	19.8	7.10	7.72	31.00	10.50	353.00	67.50	2419.6	2202	2.53
12	9-May-18	0.00	93.15	23.68	0.17	21.5	6.26	8.58	8.50	7.00	469.50	79.00	748.6	32.5	4.27
12	7-Nov-17	3.78	375.87	146.22	0.48	10.8	11.00	7.99	15.50	8.50	238.50	21.50	2419.6	2420	4.31
12	24-Sep-17	0.00	195.27	26.48	0.63	22.6	7.00	7.72	8.00	6.50	499.00	144.50	652.4	11.5	7.53
12	11-Aug-17	0.15	162.35	150.57	3.71	21.7	8.49	7.74	4.33	3.33	411.67	75.67	1715.4	24.8	3.63
12	6-Jul-17	0.13	233.66	181.31	3.82	24.5	5.70	7.01	10.50	7.50	317.50	38.50	2419.6	78.1	0.98

Site	Date	Rainfall (cm)	Ammonia (ug/L)	Phosphorous (ug/L)	NO3-N (mg/L)	Temp. (°C)	DO (mg/L)	pH	TSS (mg/L)	VSS (mg/L)	TDS(mg/L)	VDS (mg/L)	Total coliform (mpn/100 ml)	E-coli (mpn/100 mL)	BOD$_5$ (mg/L)
12	19-Jun-17	4.95	252.74	260.67	4.09	22.1	8.32	7.55	63.00	14.00	187.00	40.00	2419.6	2420	3.58
12	19-May-17	0.00	33.90	260.67	4.71	21.6	5.70	8.37	16.00	7.00	99.00	36.00	2419.6	22.5	3.83
11	23-May-18	1.63	204.12	90.28	1.39	20.3	7.17	7.82	33.00	12.00	347.00	94.00	2419.6	2420	5.50
11	9-May-18	0.00	95.07	47.37	0.39	21.7	6.42	9	8.50	8.50	501.50	81.50	336.5	5.2	3.83
11	7-Nov-17	3.78	337.85	187.54	0.64	10.4	10.60	7.92	22.50	13.50	283.50	64.50	2419.6	2420	2.41
11	24-Sep-17	0.00	164.34	66.20	0.71	21.7	8.34	7.37	5.00	4.00	575.00	98.00	1553.1	21.3	0.92
11	11-Aug-17	0.15	102.92	138.56	4.32	22.6	8.50	7.75	6.67	2.00	453.33	126.00	2419.6	18.2	2.09
11	6-Jul-17	0.13	256.24	342.60	3.73	25.3	6.68	7.2	11.50	6.00	336.50	54.00	2419.6	46.6	1.78
11	19-Jun-17	4.95	280.69	258.28	5.70	22.1	8.74	7.4	63.00	21.50	174.00	27.50	2419.6	2420	3.84
11	19-May-17	0.00	86.96	258.28	5.43	21.2	9.57	8.19	6.00	2.50	136.00	43.50	2419.6	26.2	2.91
10	23-May-18	1.63	210.70	52.79	1.39	22.1	5.05	7.53	25.50	11.50	374.50	76.50	2419.6	1210	6.79
10	9-May-18	0.00	155.29	39.47	0.65	21.7	10.58	8.94	13.00	9.00	509.00	103.00	100.3	6.3	9.22
10	7-Nov-17	3.78	463.47	135.09	0.54	11	6.36	7.54	18.00	10.00	244.00	26.00	2419.6	2420	4.28
10	24-Sep-17	0.00	169.71	32.71	0.67	22.9	9.53	7.84	4.50	6.00	507.50	58.00	2419.6	16.2	3.28
10	11-Aug-17	0.15	69.65	120.18	4.24	23.5	9.16	8.14	13.00	7.00	426.00	93.00	2419.6	14	3.29
10	6-Jul-17	0.13	307.34	338.60	3.45	28	5.28	7.72	18.00	13.50	329.00	56.50	2419.6	229	6.43
10	19-Jun-17	4.95	328.91	260.67	4.75	22.7	3.49	7.05	45.00	11.50	178.00	46.50	2419.6	2420	5.32
10	19-May-17	0.00	60.17	260.67	6.95	21.8	6.90	8.56	14.00	5.00	141.00	50.00	744.2	15.1	5.52
8	23-May-18	1.63	154.73	138.07	1.40	19.1	5.00	7.28	39.50	11.50	424.50	74.50	2419.6	2076	1.63
8	9-May-18	0.00	109.80	94.74	0.76	19.4	8.15	8.51	6.00	5.50	554.00	80.50	331.4	81.1	3.51
8	7-Nov-17	3.78	220.50	246.34	0.51	9.3	8.50	7.54	26.50	14.00	259.50	21.00	2419.6	2420	2.80
8	24-Sep-17	0.00	149.54	202.49	0.99	21.3	9.45	7.7	5.50	5.00	699.50	138.00	362.6	38.4	0.66
8	11-Aug-17	0.15	142.14	320.94	9.96	20.7	8.80	7.57	12.67	5.00	616.33	62.00	2419.6	137	2.19

Site	Date	Rainfall (cm)	Ammonia (ug/L)	Phosphorous (ug/L)	NO3-N (mg/L)	Temp. (°C)	DO (mg/L)	pH	TSS (mg/L)	VSS (mg/L)	TDS(mg/L)	VDS (mg/L)	Total coliform(mpn/100 ml)	E-coli (mpn/100 mL)	BOD$_5$ (mg/L)
8	6-Jul-17	0.13	201.57	159.00	10.27	22.3	6.24	6.74	12.00	4.00	455.00	88.00	2419.6	994	5.30
8	19-Jun-17	4.95	310.83	288.66	8.72	21.5	5.70	7.1	85.00	11.00	201.00	78.00	2419.6	2420	2.64
8	19-May-17	0.00	40.59	288.66	12.30	20.2	8.12	7.53	1.75	1.50	124.25	80.50	2419.6	74.3	2.68
7	23-May-18	1.63	191.77	290.99	1.18	18.7	5.76	7.38	39.00	9.50	409.00	88.50	2419.6	1426	1.36
7	9-May-18	0.00	169.38	94.74	0.64	19.3	8.63	8.17	4.00	3.50	532.00	88.50	561.0	57.5	1.73
7	7-Nov-17	3.78	182.48	267.80	0.65	9.3	9.26	7.39	38.00	14.00	280.00	76.00	2419.6	2420	3.21
7	24-Sep-17	0.00	201.99	239.88	1.07	21.4	9.01	7.27	6.00	5.00	651.00	89.00	220.3	36.2	0.76
7	11-Aug-17	0.15	82.72	456.67	16.3	20.3	8.93	7.64	1.33	0.67	673.67	121.33	1986.3	163	2.31
7	6-Jul-17	0.13	233.66	141.27	6.18	22.6	5.78	6.71	9.00	2.50	456.00	89.50	2203.0	217	0.23
7	19-Jun-17	4.95	252.19	245.48	7.96	21.4	5.73	6.95	45.50	11.00	226.50	70.00	2419.6	2420	2.68
7	19-May-17	0.00	27.20	245.48	9.98	21	8.42	7.59	3.50	3.50	90.50	54.50	2419.6	86.1	1.75
5	23-May-18	1.63	800.00	496.84	0.82	18.6	4.92	7.27	137.00	19.00	693.00	101.00	2419.6	2470	3.76
5	9-May-18	0.00	118.13	205.26	0.54	17.8	6.72	7.69	4.50	1.50	557.50	94.50	1715.4	126	2.74
5	7-Nov-17	3.78	155.21	235.62	0.67	11.1	9.80	7.56	18.25	5.25	314.75	17.75	2419.6	2420	3.53
5	24-Sep-17	0.00	227.54	543.22	1.14	22	7.65	7.11	9.00	7.75	707.00	331.25	1044.7	44.3	0.93
5	11-Aug-17	0.15	95.79	756.40	20.4	21.2	8.90	7.2	6.33	3.67	706.67	175.33	2076.3	231	-0.14
5	6-Jul-17	0.13	234.85	292.84	15.9	22	5.57	6.57	4.50	3.00	601.50	96.00	2419.6	116	0.52
5	19-Jun-17	4.95	359.60	347.03	4.28	20.6	4.84	6.86	15.00	11.00	269.00	50.00	2419.6	2420	2.60
5	19-May-17	0.00	31.32	347.03	14.4	20.9	6.60	7.2	11.00	5.75	124.00	48.25	2419.6	88.4	1.99
3	23-May-18	1.63	693.83	778.41	0.79	18.2	5.23	7.23	80.00	18.50	308.00	69.50	2419.6	2420	4.10
3	9-May-18	0.00	77.13	101.75	0.77	16.8	6.37	7.89	3.50	2.00	500.50	108.00	2419.6	155	1.99
3	7-Nov-17	3.78	223.80	176.41	0.48	8.6	8.93	7.55	13.50	9.00	256.50	18.00	2419.6	1986	3.16
3	24-Sep-17	0.00	165.68	490.65	0.50	19.7	6.39	7.08	10.00	8.50	554.00	88.50	677.4	65.3	2.07

Site	Date	Rainfall (cm)	Ammonia (ug/L)	Phosphorous (ug/L)	NO3-N (mg/L)	Temp. (°C)	DO (mg/L)	pH	TSS (mg/L)	VSS (mg/L)	TDS(mg/L)	VDS (mg/L)	Total coliform (mpn/100 ml)	E-coli (mpn/100 mL)	BOD$_5$ (mg/L)
3	11-Aug-17	0.15	93.42	176.73	3.98	18.6	9.49	7.69	7.67	3.00	570.33	108.00	1700.0	417	4.29
3	6-Jul-17	0.13	222.96	149.28	2.64	20.6	6.65	6.84	15.00	7.00	495.00	82.00	2419.6	488	0.62
3	19-Jun-17	4.95	152.46	223.89	4.00	21.1	4.60	6.64	32.00	8.00	111.00	25.00	2419.6	2420	4.50
3	19-May-17	0.00	36.99	223.89	5.07	19.8	6.40	7.76	7.50	5.00	128.50	14.00	1476.6	330	2.96
2	23-May-18	1.63	270.78	191.00	0.46	17.9	6.32	7.35	28.50	8.50	295.50	75.50	2419.6	2420	3.23
2	9-May-18	0.00	75.85	334.21	0.72	14.8	7.87	7.96	11.00	6.00	389.00	96.00	2419.6	207	2.93
2	7-Nov-17	3.78	233.72	190.72	0.61	9	10.58	7.6	8.50	3.00	255.50	14.00	2419.6	2420	2.25
2	24-Sep-17	0.00	180.47	785.05	0.65	18.5	8.90	7.51	8.00	5.50	527.00	102.50	2419.6	233	1.36
2	11-Aug-17	0.15	99.36	232.57	6.09	18.3	8.88	7.71	3.33	2.33	556.67	92.67	2419.6	903	2.30
2	6-Jul-17	0.13	221.77	278.54	6.27	19.3	7.68	7.01	18.00	6.50	450.00	67.50	2419.6	852	0.70
2	19-Jun-17	4.95	151.36	322.25	8.91	21.7	6.11	7.05	68.00	9.50	228.00	51.50	2419.6	2420	3.20
2	19-May-17	0.00	28.75	322.25	5.34	17.7	7.71	7.81	10.50	3.50	93.50	17.50	2419.6	116	2.28
1	23-May-18	1.63	297.12	146.15	0.49	16.8	6.87	6.87	24.50	11.00	213.50	53.00	2419.6	2420	5.19
1	9-May-18	0.00	110.44	28.95	0.78	15.9	7.64	7.8	5.00	2.00	325.00	74.00	2419.6	27.1	1.63
1	7-Nov-17	3.78	208.93	127.15	1.00	8.3	11.60	6.55	5.00	2.00	239.00	37.00	2419.6	2420	2.17
1	24-Sep-17	0.00	246.37	112.15	0.51	19.7	3.43	7.46	18.00	14.50	471.00	105.50	2419.6	194	5.25
1	11-Aug-17	0.15	81.53	29.69	2.29	17.6	6.90	7.44	5.33	2.67	387.67	46.33	2419.6	772	1.01
1	6-Jul-17	0.13	217.02	57.20	2.64	19.1	7.87	6.93	2.00	1.00	348.00	53.00	2419.6	923	0.27
1	19-Jun-17	4.95	138.21	311.85	21.17	19.8	7.75	7.33	20.50	10.00	349.50	113.00	2419.6	2420	3.62
1	19-May-17	0.00	28.75	43.54	7.84	18.8	8.90	7.42	4.25	4.00	179.75	85.00	1587.6	91	2.73

Metal Data *(ICP)*

Table 33 Soluble Metals

Date	Site	Arsenic (ug/L)	Barium (ug/L)	Beryllium (ug/L)	Calcium)mg/L)	Cadmium (ug/L)	Cobalt (ug/L)	Chromium (ug/L)	Copper (ug/L)	Iron (ug/L)	Potassium (mg/L)	Magnesium (mg/L)	Manganese (ug/L)
5/19/2017	1	3.05	84.4	0.8	62.8	1.3	0	0.15	0	0	3.24	14.60	41.9
5/19/2017	2	2.40	113	1.4	102	1.65	0	0	0	984	4.53	24.23	418
5/19/2017	3	3.75	89.5	0.5	99.3	1.95	0.25	4.3	0	355	4.07	25.07	530
5/19/2017	5	4.15	69.2	0.95	104	1.3	0	0	4.45	67	8.80	24.92	404
5/19/2017	7	3.65	101	1.15	102	0.45	0	0	15.1	216	7.65	24.79	175
5/19/2017	8	2.35	59.9	0.75	77.2	1.25	0	1.25	0	353	6.60	19.11	100
5/19/2017	10	2.95	47.4	1.3	68.3	0.65	0	0	0	0	4.74	16.84	248
5/19/2017	11	2.55	49.4	1	72.6	0.4	1.5	0	0	278	4.99	17.55	146
5/19/2017	12	3.60	78.0	0.5	68.3	2.55	1.4	0	0	0	4.78	16.47	213
5/19/2017	14	1.45	44.6	0.65	43.9	1.9	0.9	22.55	11.1	1974	4.78	10.81	273
5/19/2017	15	0	31.5	0.3	25.6	0.35	1	7.35	27.5	2264	4.55	4.79	469
5/19/2017	16	0	52.8	0.4	26.6	1.05	0.8	16.4	1.15	2213	4.86	5.28	287
6/26/2017	1	0	33.5	0.15	32.9	1.05	1	14.9	9.55	2323	6.30	6.94	185
6/26/2017	2	0	40.6	0.4	29.8	0.1	1.25	16.6	0	1919	6.44	6.25	162
6/26/2017	3	0	34.1	0.95	25.2	0.3	0	36.45	22.4	1213	6.18	4.93	185
6/26/2017	5	0	68.5	0.55	30.7	1	1.9	8.2	6.35	2215	6.36	6.40	214
6/26/2017	7	0	99.6	0.95	47.6	0	1.15	35.65	2.90	2529	9.51	10.28	228
6/26/2017	8	0	50.6	0.8	48.9	0.25	0	16.3	10.8	324	9.09	11.54	66.4
6/26/2017	10	0	49.3	0.8	58.9	0.05	1.4	14.6	23.0	1009	6.50	14.41	296
6/26/2017	11	0	53.6	1.05	68.9	0	0	16	22.4	524	5.65	16.57	316
6/26/2017	12	0	40.4	0.45	65.8	0.5	1.45	0.9	36.5	0	5.85	15.71	194
6/26/2017	14	0	62.8	0.4	28.4	1.4	2.15	22.55	26.9	3484	5.19	5.60	426
6/26/2017	15	0	31.5	0.3	25.6	0.35	1	7.35	27.5	2264	4.55	4.79	469
6/26/2017	16	0	52.8	0.4	26.6	1.05	0.8	16.4	1.15	2213	4.86	5.28	287
7/6/2017	1	0	48.6	0.45	60.0	0	0	0	32.9	0	5.95	13.41	66.2
7/6/2017	2	0	94.8	0.85	98.7	0.35	0.25	0	40.7	947	6.75	23.29	445
7/6/2017	3	0	53.7	0.65	71.9	0	0	0	51.8	17.6	7.30	16.39	314
7/6/2017	5	0	39.4	0.4	75.6	0	0	0	61.5	165	9.09	16.67	328

Date	Site	Arsenic (ug/L)	Barium (ug/L)	Beryllium (ug/L)	Calcium)mg/L)	Cadmium (ug/L)	Cobalt (ug/L)	Chromium (ug/L)	Copper (ug/L)	Iron (ug/L)	Potassium (mg/L)	Magnesium (mg/L)	Manganese (ug/L)
7/6/2017	7	0	75.8	0.8	76.7	0.3	0	0	44.0	122	6.19	16.11	59.5
7/6/2017	8	0	48.3	0.5	69.8	0.15	0.8	10.2	15.9	63.3	6.55	15.99	167
7/6/2017	10	0	11.9	0.3	45.1	0	7.06	4.03	11.5	90.9	4.59	9.75	935
7/6/2017	11	0	0.0	0	45.7	0	11.7	4.6	3	145	3.99	9.90	928
7/6/2017	12	0	0.0	0	43.9	0	17.7	0	0	248	3.53	9.26	256.4
7/6/2017	14	0	0.0	0	41.3	0	19.5	0	0	176	3.73	8.78	1651
7/6/2017	15	0	0.0	0	41.3	0	18.65	0	2.65	0	3.68	8.61	413
8/11/2017	1	0	109	0.7	87.5	0	1	0	0	96.0	3.99	20.96	203
8/11/2017	2	0	78.6	0.95	90.2	0.85	0.2	0	87.1	0	6.13	18.63	66.7
8/11/2017	3	1.20	68.6	0.75	92.3	2.7	2.25	4.15	58.2	144	5.53	21.66	560
8/11/2017	5	0	35.4	0.5	75.9	1.15	0.65	0	90.0	0	13.1	15.05	263
8/11/2017	7	0	40.7	0.55	78.3	1	1.05	0	82.4	0	10.5	17.06	159
8/11/2017	8	0.500	46.8	0.75	77.4	1.75	1.75	0	64.4	172	8.95	17.16	132
8/11/2017	10	0.950	40.0	0.75	53.9	0.7	1.45	0	90.6	15.5	6.28	11.73	186
8/11/2017	11	0.400	41.5	1.3	55.1	0.7	1	0	80.0	0	6.29	12.39	162
8/11/2017	12	0.200	43.3	0.05	53.6	0.95	0.55	0.45	62.9	0	5.99	12.10	280
8/11/2017	14	0	44.0	0.55	55.2	0.65	0.8	0	107.2	31.4	5.80	12.62	206
8/11/2017	15	0.600	50.5	0.25	57.3	2.8	0	2.6	61.9	57.5	6.10	13.01	213
8/11/2017	16	0.100	28.0	0.95	42.8	1.9	1	13.45	65.5	37.0	5.68	11.99	76.8
9/22/2017	1	2.15	118	0.15	86.0	0	2.5	0	0	0	5.37	19.40	262
9/22/2017	2	0.700	70.0	0.3	94.3	0.85	0.75	3.45	2.55	0	7.47	19.89	156
9/22/2017	3	2.55	56.1	0.35	91.8	0	2.15	12.45	0	0	6.76	20.52	227
9/22/2017	5	0.350	30.4	0	78.6	1.4	1.3	6.3	0	0	16.3	14.31	128
9/22/2017	7	0	37.0	0.5	78.5	0.2	1.5	0	1	0	14.9	14.87	36.9
9/22/2017	8	0.850	37.9	0.1	77.8	1.75	0	0	0	0	14.0	15.14	30.3
9/22/2017	10	0.850	40.0	0.1	64.3	0.55	1.3	5.25	0	0	9.07	13.51	22.9
9/22/2017	11	0.050	44.6	0.2	67.2	0.55	2.25	0	0	0	9.28	13.77	25.3
9/22/2017	12	0.650	42.2	0.15	65.5	0	2.8	6.65	0	0	7.56	13.38	18.9
9/22/2017	14	0.550	44.5	0	65.8	0	2.45	0	2.50	0	7.99	13.60	38.0
9/22/2017	15	0.350	46.0	0.25	66.6	0.05	1.9	8.55	0.550	0	8.16	13.70	111
9/22/2017	16	0	22.6	0.2	36.6	0.55	1.8	7.05	10.4	0	5.49	9.35	6.20
11/7/2017	1	0	50.8	0	44.8	0	2.35	6.85	0	0	7.85	9.49	11.9
11/7/2017	2	0.350	48.7	0	46.2	1.4	0.85	10.4	0	43.9	5.20	8.76	37.3
11/7/2017	3	0.250	38.8	0.3	44.0	1.85	1.15	2.7	0	33.8	5.93	9.93	261

Date	Site	Arsenic (ug/L)	Barium (ug/L)	Beryllium (ug/L)	Calcium)mg/L)	Cadmium (ug/L)	Cobalt (ug/L)	Chromium (ug/L)	Copper (ug/L)	Iron (ug/L)	Potassium (mg/L)	Magnesium (mg/L)	Manganese (ug/L)
11/7/2017	5	0.600	30.4	0.15	42.7	1.3	0.8	13.05	5.50	219	8.37	8.85	132
11/7/2017	7	0.800	35.1	0.1	41.3	0.9	1.5	2.05	0	441	7.27	8.97	191
11/7/2017	8	0	37.0	0	41.2	0	0.9	0	0	610	6.97	9.57	245
11/7/2017	10	0	25.7	0.3	35.0	0.15	1.3	0	0	185	4.61	6.97	64.7
11/7/2017	11	0	29.1	0.2	38.3	0	0	0	14.9	311	5.50	8.09	121
11/7/2017	12	0	27.5	0	36.0	0.7	0.45	0	0	261	5.04	7.23	113
11/7/2017	14	0	24.2	0	34.9	0.25	0	0	9.40	0	4.65	6.71	20.8
11/7/2017	15	0.800	26.0	0	33.9	0.15	0.55	0	0	201	4.39	6.49	90.9
11/7/2017	16	0	22.1	0.15	40.2	0	0	0	0	0	5.14	9.66	13.8
5/9/2018	1	0	51.9	0	52.0	0	0	0	84.7	0	0.00	12.29	653
5/9/2018	2	0	51.9	0	72.2	0	0	0	76.2	0	0.00	14.83	424
5/9/2018	3	0	38.1	0	77.4	0	0	0	15.8	0	0.00	18.86	3381
5/9/2018	5	0	28.0	0	74.1	0	0	0	65.2	0	0.00	16.71	4246
5/9/2018	7	0	30.3	0	70.3	0	0	0	47.2	0	0.00	16.11	2286
5/9/2018	8	0	29.1	0	69.4	0	0	0	69.7	0	0.00	15.62	1017
5/9/2018	10	0	25.4	0	61.7	0	0	0	57.2	0	0.00	13.75	3920
5/9/2018	11	0	22.0	0	61.0	0	0	0	88.9	0	0.00	13.57	1013
5/9/2018	12	0	32.2	0	61.4	0	0	0	44.7	0	0.00	13.56	2534
5/9/2018	14	0	54.9	0	59.3	0	0	36.5	0	130	3.42	13.83	3620
5/9/2018	15	0	54.9	0	58.1	0	0	0	0	0	3.21	12.88	3163
5/9/2018	16	0	15.7	0	33.1	0	0	11.95	39.5	124	3.34	8.33	989
5/23/2018	1	0	0.0	0	31.2	0	0	0	55.1	353	5.68	7.03	149
5/23/2018	2	1.40	0.0	0	43.6	0	0	33.45	3.40	441	4.79	8.78	647
5/23/2018	3	0.400	0.0	0	42.8	0	0	9.75	23.1	388	5.51	9.56	483
5/23/2018	5	0.800	0.0	0	45.3	0	0	53.2	0	472	6.79	8.69	350
5/23/2018	7	1.95	0.0	0	46.6	0	0	17	29.0	192	3.60	10.39	559
5/23/2018	8	2.55	0.0	0	47.7	0	0	24.4	17.8	249	3.38	9.85	517
5/23/2018	10	3.45	0.0	0	41.5	0	0	31.25	9.60	66.4	3.36	8.21	347
5/23/2018	11	2.80	0.0	0	38.4	0	0	5.35	6.10	212	3.34	7.52	430
5/23/2018	12	2.25	0.0	0	38.7	0	0	11.5	25.3	198	3.19	7.54	544
5/23/2018	14	3.60	0.0	0	44.7	0	0	34.8	31.4	0	3.14	8.86	868
5/23/2018	15	3.35	0.0	0	44.3	0	0	0	6.00	107.8	3.29	8.72	1449
5/23/2018	16	6	0.0	0	37.0	0	0	39.6	0	234	3.44	7.70	468

Date	Site	Molybdenum ug/L)	Sodium (mg/L)	Nickel(ug/L)	Phosphorus (ug/L)	Lead (ug/l)	Sulfur (mg/L)	Antimony (ug/L)	Selenium (ug/L)	Tin (ug/L)	Titanium (ug/L)	Vanadium (ug/L)	Tungsten (ug/L)	Zinc (ug/L)
5/19/2017	1	0	20.14	0	234.1	6.95	10.72	94.2	488	7.35	7.00	29.2	0	5.35
5/19/2017	2	0	60.05	0	881.1	24.6	32.29	3.4	478	54.9	17.2	0	0	38.8
5/19/2017	3	123	52.67	0	501.6	5.45	35.47	14.5	463	24.6	7.65	0	0	4.30
5/19/2017	5	8.60	105.7	57.6	873.6	29.9	36.52	10.6	755	34.8	6.45	0	0	188.5
5/19/2017	7	927	104.0	0	736.2	0	34.68	78.2	767	36.5	5.25	1.15	0	94.7
5/19/2017	8	0.500	90.27	0	422.7	0.95	27.43	128	396	29.4	11.8	0	0	14.0
5/19/2017	10	53.0	78.44	0	227.9	12.4	22.06	0	462	60.9	4.10	0	0	0.850
5/19/2017	11	0	81.72	0	481.9	31.0	23.63	0	405	9.3	4.20	0	0	9.75
5/19/2017	12	50.0	76.55	0	404.6	27.5	22.15	0	258	25.4	7.00	18.2	0	10.1
5/19/2017	14	39.2	51.55	0	386.9	28.7	18.70	205	253	28.6	19.3	0	5.60	20.6
5/19/2017	15	35.1	26.42	0	410.8	108	11.58	501	230	66.7	6.65	33.3	3.60	45.8
5/19/2017	16	100	25.50	0	284.9	110	16.71	675	416	1.4	9.05	1.8	24.6	47.0
6/26/2017	1	104	27.53	0	468.2	58.2	14.67	514	463	13.5	1.40	0	0	50.3
6/26/2017	2	81.0	25.71	0	502.2	101	20.80	529	119	42.7	16.4	15.1	0	40.6
6/26/2017	3	165	20.41	0	475.9	42.3	17.31	575	0	0	6.35	7.30	14	40.4
6/26/2017	5	105	14.17	0	728.9	26.8	14.47	505	393	0	15.4	100	0	32.5
6/26/2017	7	159	19.02	1.05	777.3	39.1	18.96	608	0	0	5.90	62.9	15.4	45.3
6/26/2017	8	221	32.32	0	708.6	58.3	25.46	822	0	66.7	7.60	41.3	0	32.4
6/26/2017	10	158	66.51	0	744.4	81.0	42.16	632	0	0	7.20	7.25	9.40	74.0
6/26/2017	11	176	81.12	0	543.9	41.1	47.96	553	7.20	28.8	0.55	10.5	0	28.8
6/26/2017	12	244	75.61	0	517.9	70.2	45.65	456	0.350	0	2.95	9	0	32.7
6/26/2017	14	29.5	28.41	0	389.2	51.6	14.67	393	270	22.1	26.7	0	9.25	76.4
6/26/2017	15	35.1	26.42	0	410.8	108	11.58	501	230	66.7	6.65	33.3	3.60	45.8
6/26/2017	16	100	25.50	0	284.9	110	16.71	675	416	1.40	9.05	1.8	24.6	47.0
7/6/2017	1	88.7	52.53	0	600.7	14.5	20.96	255	0	0	13.7	0	24.2	41.8
7/6/2017	2	24.0	73.43	0	301.2	22.9	12.09	450	0	42.1	31.7	23.3	0	20.6
7/6/2017	3	117	75.42	0	701.0	0.0	35.98	538	0	0	20.9	17.9	8.05	39.5
7/6/2017	5	148	94.89	3.30	1233	19.4	38.45	558	97.2	0	15.4	57.8	0	72.4
7/6/2017	7	279	70.40	0	909.2	18.2	25.29	357	0	0	3.50	0	0	58.9
7/6/2017	8	79.7	84.10	0	489.9	30.6	40.74	351	22.4	29.9	4.50	0	15.8	34.0
7/6/2017	10	16.3	40.83	0	245.7	11.4	7.566	96.7	0	42.3	0.933	9.07	7.9	0.700
7/6/2017	11	4.9	38.23	0	24.80	0.0	2.199	0	0	0	0	24.5	0	0

Date	Site	Molybdenum ug/L)	Sodium (mg/L)	Nickel(ug/L)	Phosphorus (ug/L)	Lead (ug/l)	Sulfur (mg/L)	Antimony (ug/L)	Selenium (ug/L)	Tin (ug/L)	Titanium (ug/L)	Vanadium (ug/L)	Tungsten (ug/L)	Zinc (ug/L)
7/6/2017	12	7	33.81	0	28.00	0.0	1.956	0	0	0	0	55.8	3.85	0
7/6/2017	14	4.3	29.22	0	25.80	0.0	1.671	0	0	1.45	0	0	4.10	0
7/6/2017	15	4.9	30.59	0	35.50	0.0	1.694	0	0	0.350	0	25.4	2.55	0
8/11/2017	1	8.3	22.35	131	78.50	0.0	20.85	0	548	17.8	0	0	0	0
8/11/2017	2	7.2	72.36	110	350.9	0.0	26.21	39.9	356	23.3	31.6	5.35	8.2	10.2
8/11/2017	3	3.5	59.33	110	282.1	2.25	41.21	0	230	0	19.7	0	0	0.400
8/11/2017	5	0	130.7	104	879.5	0.0	45.85	0	271	10.9	5.95	0	0	8.65
8/11/2017	7	5	111.1	107	261.9	9.35	42.78	0	48.6	31.8	23.7	22.1	0.4	1.95
8/11/2017	8	0	103.0	104	255.4	0.70	41.64	51.0	149	15.4	17	0	28.2	4.90
8/11/2017	10	0	66.04	107	176.7	0.0	28.02	0	505	27.9	4.3	0	0	1.60
8/11/2017	11	0	68.21	105	216.8	15.8	30.45	0	179	25.8	16.0	0	19.8	0
8/11/2017	12	0	65.94	105	223.3	18.4	26.53	0	96.9	6.05	9.75	0	0	0
8/11/2017	14	0	73.71	106	123.4	10.1	25.97	0	188	21.7	9.95	0	0	0
8/11/2017	15	5.1	76.96	107	230.7	1.0	24.13	0	132	101	15.2	0	0	2.30
8/11/2017	16	0	42.91	109	164.5	0.0	17.32	0	242	44.6	19.2	0	2.1	3.90
9/22/2017	1	25.7	22.34	75.9	95.35	42.3	11.56	0	0	0	0.650	0	0	9.90
9/22/2017	2	15.1	59.41	76.8	1013	3.50	27.55	73.4	66.3	0	1.00	0.750	13.1	0
9/22/2017	3	5.9	53.28	77.5	662.3	3.55	32.77	79.7	183	0	0	49.9	0	0
9/22/2017	5	33.5	131.0	79.4	481.4	7.45	39.47	234	108	0	0	0	8.55	12.9
9/22/2017	7	0	125.5	80.1	316.3	0.0	36.55	161	0	0	0	0	1.75	6.90
9/22/2017	8	20.1	116.7	76.0	137.1	0.0	37.98	31.5	146	0	0	0	62.8	17.6
9/22/2017	10	67.7	93.92	72.5	208.3	6.10	30.44	118	321	0	0	0	13.7	0
9/22/2017	11	40.9	92.19	73.7	132.00	0.0	28.68	0	0	0	0	0	132	0
9/22/2017	12	20.7	80.22	79.7	239.3	0.0	26.86	197	133	0	0	0	7.45	0
9/22/2017	14	8	81.24	76.3	83.30	44.4	27.01	63.3	0	0	0	0	17.5	0
9/22/2017	15	0	82.16	76.3	89.50	0.0	27.28	81.3	98.7	0	0	5.10	10.7	0
9/22/2017	16	24.2	34.60	74.4	310.2	27.3	10.74	0	0	0	0	0	28.9	0
11/7/2017	1	30.3	16.88	75.7	412.3	0.0	10.81	93.3	258	0	0	32.1	59.4	0
11/7/2017	2	18.9	26.89	76.9	208.2	1.0	10.33	0	0	0	0	0	32.3	0
11/7/2017	3	15.7	22.89	74.7	195.3	6.60	20.49	8.55	0	0	4.85	0	26.0	0
11/7/2017	5	32.3	43.53	81.1	255.5	0.15	22.11	92.5	0	0	0	0	60.4	6.05
11/7/2017	7	0.55	30.95	77.8	145.8	35.3	21.21	97.8	0	0	0.250	12.2	29.6	11.8
11/7/2017	8	15.9	31.87	74.3	40.15	31.2	12.03	114	98.4	0	20.6	15.0	29.6	5.95

Date	Site	Molybdenum ug/L)	Sodium (mg/L)	Nickel(ug/L)	Phosphorus (ug/L)	Lead (ug/l)	Sulfur (mg/L)	Antimony (ug/L)	Selenium (ug/L)	Tin (ug/L)	Titanium (ug/L)	Vanadium (ug/L)	Tungsten (ug/L)	Zinc (ug/L)
11/7/2017	10	8.45	35.38	74.0	225.3	62.0	8.947	39.8	168	0	5.45	28.5	94.7	0
11/7/2017	11	0	35.61	75.0	196.9	83.8	10.28	114	87.2	0	12.1	16.1	0	0.950
11/7/2017	12	0	35.88	73.7	219.6	42.3	9.403	45.5	11.2	0	12.9	0	0	5.20
11/7/2017	14	3.95	37.26	75.7	237.8	11.4	8.874	296	124	20.2	8.40	0	0	1.70
11/7/2017	15	11.3	36.26	73.2	83.15	81.8	8.252	223	98.6	14.0	10.3	0	0	9.00
11/7/2017	16	17.5	42.01	72.1	172.0	47.2	10.41	128	0	0	15.1	27.1	0	6.75
5/9/2018	1	44.2	21.39	40.5	8.950	6.35	3.139	43.5	40.3	0	0	199	158.1	0
5/9/2018	2	19.9	47.09	29.9	76.65	16.5	2.799	29.6	114	26.8	0	59.6	126.8	0
5/9/2018	3	15.9	39.11	41.3	46.95	27.0	5.833	0	0	51.7	0	127	71.5	0
5/9/2018	5	13.1	72.01	33.4	42.00	39.3	5.603	12.2	8.30	4.10	0	37.5	166	0
5/9/2018	7	28.7	70.65	35.9	47.40	13.5	5.767	0	57.6	28.8	0	164	84.7	0
5/9/2018	8	10.2	77.18	28.5	18.15	1.00	6.107	84.6	0	0	0	188	187	0
5/9/2018	10	8.40	67.69	34.0	55.15	28.6	5.470	0	78.7	32.8	0	153	124	0
5/9/2018	11	43.9	67.74	29.2	38.55	14.1	5.266	120.2	119	3.90	0	170	105	0
5/9/2018	12	30.2	66.74	34.5	21.60	18.5	5.199	78.7	68.1	34.2	0	0	92.2	0
5/9/2018	14	12.6	64.36	0	19.90	0.0	9.402	0	0	0	10.8	6.65	0	39.3
5/9/2018	15	21.8	66.12	0	17.60	0.0	2.895	0	0	0.350	12.7	0	0	28.5
5/9/2018	16	37.3	31.30	0	21.35	0.0	1.903	22.1	0	9.90	10.9	0	0	13.4
5/23/2018	1	19.9	9.463	0	50.35	1.85	1.052	18.5	0	17.4	12.9	0	5.5	0
5/23/2018	2	18.3	25.66	0	52.65	0.0	1.225	28.9	0	16.3	24.7	0	41.7	0
5/23/2018	3	19.5	18.99	0.150	48.40	0.0	1.951	0	0	19.7	3.70	0	0	0
5/23/2018	5	10.2	48.25	0	62.60	0.0	2.168	37.0	0	15.9	11.3	0	60.9	0
5/23/2018	7	31.4	42.18	0	29.55	0.0	2.239	0	0	10.8	8.60	0	10.5	0
5/23/2018	8	13.3	47.74	0	27.55	12.5	2.029	62.8	0	33.0	0	0	54.5	4.50
5/23/2018	10	18.5	45.77	0	22.95	11.4	1.642	0	0	24.4	8.55	0	8.40	0
5/23/2018	11	21.0	42.03	0	16.20	0.0	1.608	0	0	18.4	4.75	0	61.3	15.2
5/23/2018	12	12	42.30	0.050	16.00	0.0	1.531	0	0	27.4	4.40	0	32.1	0
5/23/2018	14	14.7	46.15	0	19.60	0.0	1.815	0	2.85	6.60	0	0	0.200	0
5/23/2018	15	19.0	47.29	0	14.40	0.0	1.779	0	0	40.5	11.4	0	72.4	0
5/23/2018	16	26.1	38.06	0	9.40	5.50	1.536	0	0.900	18.2	7.35	0	65.8	37.2