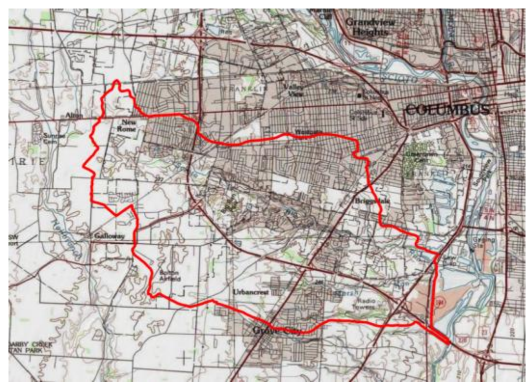
SCIOTO BIG RUN:
ASSESSING THE IMPACTS OF WETLANDS ON AN URBAN STREAM



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Scioto Big Run: Assessing the Impacts of Wetlands on an Urban Stream

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Executive Summary

The relationship between wetlands and stream quality was examined in the urbanized HUC 12 Scioto Big Run watershed located in Franklin County, central Ohio. Specifically, wetland ecological condition and abundance and stream biocriteria, nutrient loadings, and flood flows were investigated. In addition, the potential to restore wetlands in the watershed, and the effect of such restoration activities on water quality were examined.

The Scioto Big Run watershed is approximately 24.6 square miles (15,744 acres). The watershed has been heavily impacted by urban development, and is composed of 29.38 percent impervious cover. Of the 2,786 acres of wetlands estimated to be historically present in the watershed, only ten wetlands, totaling 7.574 acres, or 0.05 percent of the watershed, remain. Nine wetlands have a hydrogeomorphic (HGM) classification of depressional and one is riverine. Historic wetland loss in the Scioto Big Run watershed is 99.4 percent, which exceeds the percent of wetland loss for all but 70 of Ohio's 1,538 HUC 12s.

Scioto Big Run is designated as a warmwater habitat (WWH) stream in Ohio's Water Quality Standards, but it is in partial attainment of that designation. While fish and benthic macroinvertebrate communities have actually improved since 1992, macroinvertebrate communities remain below the biological criteria necessary to attain the WWH use designation. In-stream concentrations of nitrate + nitrite (NO2+3) exceeded the statewide target of 1.0 mg/l and ammonia exceeded the ecoregional target of 0.05 mg/l during late spring and early summer. Total phosphorus (TP) exceeded the statewide headwater TP target of 0.08 mg/l and TSS exceeded the ecoregional target of 69.95 mg/l mainly during high flow events. Causes of biological impairment include flow alteration, organic enrichment, sedimentation and embeddedness from flashy stream flows and urban runoff, which is consistent with an urbanized watershed. Scioto Big Run's failure to attain WWH is also consistent with previous studies that observe the loss of use at 25 percent impervious cover.

Ten identified wetlands were evaluated using the Ohio Rapid Assessment Method (ORAM) version 5.0. On a scale of 0 to 100, ORAM scores ranged from 19 to 51.5, with a mean score of 31, which is considered a modified Category 2 wetland. The mean ORAM score of 31 is lower than the mean ORAM score of 37 observed for natural wetlands recorded throughout Ohio. The Landscape Disturbance Index, (LDI) score for the Scioto Big Run watershed was 6.91, which is more degraded than all but 16 other HUC 12s in Ohio.

Approximately 748 acres, representing 4.75 percent of the watershed, could potentially be restored to wetlands. No wetlands would be restored adjacent to or near the main stem of Scioto Big Run, and only 150 acres of restorable wetlands are located within 100 meters of a Scioto Big Run tributary. The location of restorable wetlands was based on areas having predominantly hydric soils on agricultural land that exhibited a high probability for restoration and was not based on modeling of strategic locations for installing wetlands as best management practices (BMPs) for flood control and nutrient management.

The 7.6 acres of existing wetlands potentially store 0.66 MGD of water, or 0.79 percent of the volume of the flow of Scioto Big Run, during a 1.5" storm event which was the highest recorded storm during the study. Restoration of 748 acres would increase the volume of water potentially stored by wetlands to71.8 MGD which represents 85 percent of the flow during a 1.5" storm event. The conversion of 748 acres from agriculture to wetlands could potentially reduce the sediment load to the stream by an average of 330 metric tons (330,000 kg) per year, the total phosphorus load by 530 kg/year and the total nitrogen load by 6500 kg/year. These reductions are due to the land use conversion only and do not take into account any additional filtering functions wetlands can provide for runoff from upland drainage areas.

A separate TMDL study was performed for the Scioto Big Run upstream from river mile 2.0. The amount of restorable wetland area in the watershed upstream from river mile 2.0 is 242 acres or 2 percent of the total drainage area upstream from river mile 2.0. Converting this 2 percent of the watershed from agriculture to wetland reduces the nonpoint source total phosphorus load by 40 percent and achieves 70 percent of the TMDL total phosphorus nonpoint source reduction goal.

The paucity of wetlands remaining in the watershed is consistent with literature that reports a minimum of 7-10 percent of a watershed should be composed of wetlands to perform flood control and nutrient management functions. Estimates that 4.75 percent of the watershed could be restored to wetlands remain below 7-10 percent threshold cited for wetlands functions to be effective. In addition, wetlands in the Scioto Big Run watershed exhibited diminished ecological condition. However, it is not clear whether the lack of wetlands or their diminished ecological condition are a direct cause of the non-attainment in Scioto Big Run or simply an artifact of the degree of urbanization of the watershed. Additional analysis is required to determine if the impairments are a result of watershed conditions at the regional landscape level, land use immediately adjacent to Scioto Big Run and its tributaries, or more localized habitat variables, or some combination thereof.

Finally, an analysis of alternative land use mapping techniques was conducted to compare the results of three approaches with the standard National Land Cover Data Set (NLCD) generated from LANDSAT 7 data by the United States Geological Survey. Both a supervised and an unsupervised classification of the Scioto Big Run watershed was run using current Ohio Statewide Imagery Program (OSIP) high resolution orthophotography in conjunction with standard ArcGIS 10.0 software tools. Additionally, a subsequent supervised classification was also performed on SPOT satellite imagery using MultiSpec 9.2011, a freeware multispectral image data analysis system. MultiSpec provided landuse classification results with equal or greater resolution than the NLCD which could potentially enable the creation of more accurate land use and impervious surface maps and at more regular intervals than the commonly used NLCD layer, making temporal change studies much easier to conduct at the watershed scale.

Introduction

The purpose of this study was to examine the relationship between wetland abundance and ecological condition and stream condition within a small urban watershed. Specifically, this study, a) examined the ability of wetlands to attenuate flood flows and reduce nutrient loadings and b) evaluated the potential to restore wetlands within the watershed and the potential water quality benefits resulting from that restoration.

The project study area is the Scioto Big Run watershed, a HUC12 subwatershed of the Scioto River located in southwest Franklin County in central Ohio (Figure 1). Scioto Big Run is located in the 8 digit Scioto River watershed HUC (050600012301). The watershed is located entirely within the municipal jurisdictions of Columbus and Grove City. Scioto Big Run is located within a 24.6 square mile (15,744 acres) watershed and discharges directly into the main stem of the Scioto River downstream from Columbus. The watershed is predominated by urban and suburban land uses. While portions of the watershed are highly developed, open space is present in the headwaters and along the riparian corridor located in the middle portions of the watershed within the Scioto Big Run Park.

Urbanization and Stream Quality

The relationship between urbanization and stream quality has been previously investigated. Urbanized watersheds, which exhibit higher percentages of impervious cover types such as concrete, asphalt and roof tops, are characterized by flashier hydrographs, elevated concentrations of pollutants, altered channel morphology and reduced biotic integrity (Belluci, 2007). Urbanization is generally understood to adversely impact urban streams by lowering base flows and causing more frequent flashy flows at smaller storm events and increasing pollutant loadings associated with storm water discharges (Booth, et al., 2004).

Nutrient enrichment is a commonly cited cause of stream impairment and can be seen in urbanized watersheds. Nutrients rarely approach concentrations in the ambient environment that are toxic to aquatic life, and nutrients, in small amounts, are essential to the functioning of healthy aquatic ecosystems. However, excess nutrient concentrations can shift fish species composition away from functional assemblages comprised of intolerant species, benthic insectivores and top carnivores typical of high quality streams towards less desirable assemblages of tolerant species, niche generalists, omnivores and detritivores typical of degraded streams (Ohio EPA, 1999). Such a shift in community structure lowers the diversity of the system. The Index of Biotic Integrity (IBI) and Invertebrate Community Index (ICI) scores reflect this shift and a stream may be precluded from achieving its aquatic life criteria.

Previous studies are in general agreement that stream degradation can be observed at percentages of impervious cover as low as 7-10 percent (Yoder et al., 2000; Klein, 1979; Belluci, 2007; Schueler, 2003). Severe degradation and loss of attainment of Clean Water Act goals for aquatic life, as measured by the Index of Biotic Integrity (IBI), have been observed at 25-30 percent impervious cover, and when impervious cover exceeds 40 percent, attainment of aquatic life uses for Warmwater Habitat may be irretrievably lost (Yoder et al., 2000; Zielinski, 2002; Booth and Jackson, 1997; Schueler, 2003).

However, Yoder et al. (2000) caution against reliance on single dimension land use indicators such as impervious cover, because other factors, such as legacy pollutants, sewage discharges, combined sewer overflows and habitat modification may also account for non-attainment of biological criteria. Further, Booth and Jackson (1997) discriminate between *total impervious area* (TIA) and *effective impervious area* (EIA) wherein TIA includes all non-infiltrating surfaces such as concrete, asphalt and rooftops, but EIA consists of only those impervious surfaces with a direct hydraulic connection to the stream drainage network. Additionally, Miltner et al.

(2003) observed undeveloped riparian zones and floodplains at sites where biological integrity was maintained despite levels of urbanization greater than 30 percent.

Ecological Services Performed by Wetlands

Given the known influences of urbanization on streams described above, can wetlands influence water quality in urbanized watersheds? Can the abundance and ecological condition of wetlands in an urban watershed offset or ameliorate the detrimental impacts of urbanization on stream health?

Wetlands are known to perform numerous ecological functions including flood control, nutrient transformation and cycling, removal of sediment and other pollutants, providing habitat for fish and wildlife including threatened and endangered species, ground water recharge and providing recreational and educational opportunities (NRC, 1995). In fact, wetlands are often referred to as "nature's kidneys" because of their ability to store flood waters and filter pollutants (Mitsch and Gosselink, 2000). Wetlands located in urban areas may be particularly valuable at performing these functions given the changes to aquatic systems observed in urban areas (USEPA, 1995). A brief description of wetlands' functions related to this study is provided below.

Nutrient Transformation and Cycling

Nutrient removal is a primary function of wetlands (Wright et al., 2006). Nutrients have been implicated in algal blooms, decreased water clarity, anoxia and fish kills. Therefore, the ability of wetlands to reduce nutrient loadings to streams may have policy ramifications for stream restoration including the development of TMDLs. In fact, several states are developing TMDLs specifically for wetlands (Kusler, 2011).

Wetlands receive phosphorus and nitrogen from both natural and anthropogenic sources including agricultural runoff and effluent discharges such as storm water. Wetlands remove nutrients through physical, biological and chemical processes by encouraging sediment deposition, sorbing to sediments, plant uptake and enhancing denitrification (Fischer and Acreman, 2004). A review of the literature reveals that actual nutrient removal rates are highly variable from wetland to wetland. Factors influencing the ability of wetlands to process and remove nutrients include hydrogeomorphic location in the watershed (Mitsch and Gosselink, 2000), whether it is an open or closed system, types of vegetation present (Fischer and Acreman, 2004), presence and depth of standing water and water level fluctuations and water retention time (Whigam et al., 1988)(Kadlec and Kadlec, 1978).

Nitrogen removal is achieved through a combination of settling, denitrification, microbial assimilation and plant uptake. Phosphorus removal is a function of physical processes including deposition and adsorption onto soil particles, precipitation and biological uptake (Wright, et al., 2006). Phosphorus is not removed through biogeochemical processes because it does not have a gaseous phase.

Flood Flows

Another important function wetlands perform is to capture and store storm water, reducing peak flows and flooding (Mitsch and Gosselink, 2000). This storage function minimizes downstream flooding, slows erosive stream flows and delays peak discharges. Because urban areas are composed of greater percentages of impervious cover, the presence of wetlands may assume added importance in these watersheds (Wright et al., 2006).

Factors cited in the literature that influence the ability of wetlands to attenuate flood flows include their location in the watershed, basin morphometry and connectivity to a receiving stream or water body (Mitsch and Gosselink, 2000). Kotze (2000) compiled the following list of wetland characteristics that contribute to flood flow attention: topography, size, shape, surface hydraulic roughness, location in catchment, water regime and soil permeability. U.S. EPA (2006) cites the wetland area, slope, location of the flow path within the wetland and soil saturation prior to flooding as contributing to effectiveness at reducing flood damage. As an example of site specific considerations, the Oregon Watershed Assessment Manual (NWP, 1999) cistes that wetlands located in the middle elevations of a watershed are more effective at reducing flood flows because they are located in a landscape position to intercept greater volumes of storm water than wetlands located in headwaters. Wetlands located in lower elevations may not reduce flooding in upstream reaches.

Linking Wetlands and Stream Quality

Several studies have reported correlations between the percentage of a watershed composed of wetlands and the watershed's ability to attenuate flood flows and reduce nutrients. The reported percentages of wetlands necessary to perform these functions vary. Novitski (1979) reports that watersheds composed of 40 percent wetland or lake habitat resulted in an 80 percent reduction in flood flows. Hey and Philippi (1995) report that restoration of 13 million acres of wetlands in the upper Mississippi and Missouri river basins, equaling 7 percent of the total watershed area, would have provided enough flood water storage to prevent the disastrous 1993 floods. Historical records indicate the 9-11 percent of the watershed was composed of wetlands prior to European settlement. Mitsch and Gosselink (2000) report that 3-7 percent of temperate zone watersheds should be composed of wetlands to provide flood control. In this same study, they suggest that watersheds with fewer remaining wetlands may not imply greater value for those remaining wetlands as their functions may be overwhelmed by anthropomorphic impacts.

Johnson et al. (1990) reported in a Minnesota study that incremental wetland losses in watersheds with less than 10 percent wetlands decreases their ability to reduce flood flows. Johnson et al.(1990) also reports that watersheds with less than 10 percent wetlands will experience higher peak flows.

Mitch and Gosselink (2000) estimate that 3.4-8.8 percent of the Mississippi River basin would need to be converted to wetlands and riparian forest to reduce nitrogen loads to the Gulf of Mexico by 20-40 percent. Wang and Mitsch (1998) report that 15 percent. In a study of an 80 acre Lake Erie watershed, Wang and Mitsch (1998) concluded that 15 percent of the watershed would need to be composed of wetlands in order to reduce phosphorus loadings. Oberts (1981) reports that retention of 10 percent of wetlands in a watershed maximizes nutrient loading reductions. Tonderski et al. (2005), developed a model that predicts a nearly linear increase in the removal efficiency of nitrogen and phosphorus as the percentage of watershed area composed of wetlands increases.

Researchers have expressed concerns that the ability of wetlands to remove nutrients may be degraded over time (Mitsch and Gosselink, 2000). Storm water flows and pollutants alter the assimilative capacity of these wetlands to retain organic matter and sediment (Wright et al., 2006).

Ohio EPA Urban Wetland Study Results

During 2006 and 2007, Ohio EPA studied 100 urban wetlands located in Franklin County within central Ohio to determine the level of functioning of urban wetlands. Studying a subset of 22 of these urban wetlands, Gamble et al., (2007) calculated that a one acre depressional wetland stored 0.4 acre-feet of water when inundated to the boundary, compared to 0.8 acre-feet of water for a one acre riverine wetland. However, based on annual precipitation falling within the delineated footprints of the wetlands, depressional wetlands captured 11 times their maximum basin volume compared to riverine wetlands which captured less than 7 times their maximum basin volume. This difference was attributed to the slower release of water and higher rate of evapotranspiration occurring in depressional wetlands.

As a result of this study, which also included an examination of amphibian populations, Mack and Micacchion (2007) concluded that the average condition of urban wetlands are best characterized as being of overall “fair” quality rather than “poor”.

Stream Restoration

Booth et al. (2004) concludes that few urban streams can be completely restored, but rehabilitation to an improved biological condition is feasible if the stressors are first understood. Given the vast array of potential stressors on urban streams, the watershed characteristics and functions must be understood to determine the efficacy of wetlands in achieving stream restoration. Wetlands, or the lack thereof, may be one additional stressor to be considered. The Federal Interagency Stream Restoration Working Group (1998), includes wetlands restoration as a consideration when evaluating stream restoration options.

The Scientific and Technical Advisory Committee of the Chesapeake Bay Program (CBP, 2008) undertook a study of the potential to restore wetlands as a Best Management Practice (BMP) to reduce nutrient and sediment loadings to the Chesapeake Bay. They conclude that the efficiency of removal of nitrogen and phosphorus by restored wetlands can be predicted by the percentage of the watershed occupied by wetland receiving discharge from the entire watershed, but that actual removal efficiencies will vary based on landscape and local influences.

Methods

Wetland Assessment Methods

Wetland Identification and Mapping

Wetlands in the Scioto Big Run watershed were identified through a process involving both desktop analysis and field verification. Potential wetlands were first identified by examining National Wetland Inventory maps (NWI, 2006-2007). Mapped wetlands located under structures or parking lots visible on the mapping layer were eliminated from consideration. Remaining potential wetlands were then field verified using the U.S. Army Corps of Engineers’ wetland determination form (Environmental Laboratory, 1987) to determine if wetland criteria for soils, hydrology and hydrophytic vegetation were met. When it was determined that all three criteria met, the wetland was included in the assessment study. The wetland determination forms were not submitted to the Corps for a formal jurisdictional determination.

Assessment of Wetland Ecological Condition

The ecological condition of all identified wetlands was determined by obtaining an Ohio Rapid Assessment Method (ORAM) score. The ORAM was conducted in accordance with the *Ohio Rapid Assessment Method for Wetlands v. 5.0 User’s Manual and Scoring Forms*, Ohio EPA Technical Report WET/2001-1 (Mack, 2001). The ORAM is a Level 2 wetland categorization tool. By way of comparison, Level 1 assessments are considered to be rapid assessment methods generally conducted as desktop reviews. Level 2 assessment methods involve field work including semi-qualitative, or rapid assessments methods, while Level 3 assessments involve intensive field work and quantitative sampling (Mack, 2006).

ORAM measures wetland condition along a human disturbance gradient (Mack, 2001). ORAM scores range from 0 (very poor) to 100 (excellent condition). The ORAM score is derived by evaluating the six metrics and assigning a maximum number of points per metric: area (6 points), buffer width and intensity of land use outside the buffer (14 points), hydrologic characteristics (30 points), substrate and habitat characteristics (20 points) plant community composition and characteristics (20 points), and special wetlands such as bogs, fens, mature or old growth forest (10 points). Because the ORAM score is a measure of wetland condition, a higher score indicates a more intact wetland. Conversely, a lower score represents a more disturbed wetland.

Based on the ORAM score, a wetland is placed into one of three categories. Category 1 wetlands (ORAM 0- 29.5) are considered low quality wetlands and support minimal functions and values. Category 2 wetlands (ORAM 35 – 59.5) are considered moderate quality wetlands. Wetlands with ORAM scores from 35 to 44.5 are considered *modified* Category 2 wetlands, meaning they are degraded but restorable. Category 3 wetlands (ORAM ≥ 65) are considered superior quality wetlands with high functions and values. Wetlands falling into gray zones between categories are automatically assigned to the next highest category unless a Level 3 biological assessment is conducted to confirm the appropriate category. ORAM scores were obtained for all ten wetlands identified during field assessments conducted on June 30, 2009 and July 1, 2009.

Hydrogeomorphic Classification

The hydrogeomorphic class (HGM) for each wetland was also determined in the field at the same time the ORAM was obtained. HGM, first described by Brinson (1993) characterizes wetlands by their dominant landscape position, hydrologic regime including geomorphology and water sources, and hydrodymanics, and plant community class.

Stream Assessment Methods

Hydrology Methods

Hydrology monitoring was conducted from May 2008 through September 2008 to determine the stream flow, or discharge. Hydrology data was collected by deploying Isco brand ultrasonic level recorders within Scioto Big Run at the Norton Road (RM 9.68), Big Run Park (RM 6.58) and Quarry (RM 2.00) sites. Stage data was recorded at 15-minute intervals.

Stream discharge was also measured at the level recorder sites approximately weekly from late April through early September 2008, following the Ohio EPA Surface Water Field Sampling Manual protocol (Ohio EPA, 2012). Ohio EPA used SonTek FlowTracker meters to measure the stream discharge in units of cubic feet per second (cfs).

To conduct a discharge measurement, the location on the stream channel, characterized by a straight, non-eddied, and edge-to-edge flow, was identified. The cross section at that location was established and divided into approximately twenty equally wide subsections. When flow was not equally distributed across the channel, subsections with greater flow were narrower, and subsections with less flow were wider. The width and depth of each subsection was then measured and entered into the FlowTracker. The product of the width and depth of each subsection was that subsection's area. FlowTracker then measured velocity at the center of each subsection. Discharge was computed for each subsection by an Acoustic Doppler Current Profiler (ADCP) using *discharge* = *area* × *velocity*. The sum of all subsection's discharges represented the stream's total discharge at that location. Velocity was measured by the FlowTracker tool using ADCP technology.

Utilizing the strong relationship between stage and streamflow (USGS, 1984), the level recorder stage data was correlated to field stream discharge measurements. Determining discharge from stage required defining the stage-discharge relationship by measuring discharge at a wide range of river stages.

Water Quality Methods

Following Ohio EPA's Surface Water Field Sampling Manual Draft Version 4.0 (Ohio EPA, 2012), 67 water quality samples were collected between May 2008 through September, 2008 at the three Scioto Big Run assessment sites. All water quality samples were obtained as grab samples at the water surface directly into LPDE cubitainers while wading the stream. Each water quality sample included lab analysis for 18 metal parameters preserved with nitric acid, 5 nutrient parameters preserved with sulfuric acid and 4 demand parameters (chloride, total hardness, total dissolved solids and total suspended solids) that did not receive acid preservation. After field acid preservation, if applicable, all samples were put on ice and chilled to 4° C. All samples were delivered to Ohio EPA's Division of Environmental Services (DES) lab within 48 hours of sampling. The DES lab adheres to Standard Methods and/or U.S. EPA methods for all parameters. Data generated from this lab achieves the State of Ohio Level 3 Credible Data designation which is the state's highest level for scientific rigor and methods.

Biological Assessment

Ohio EPA obtained data on the biological communities residing in Scioto Big Run by assessing historic data dating to 1992 on fish and benthic macroinvertebrates. Sampling was conducted at seven locations along the length of Scioto Big Run in years 1992, 1994, 2005, 2007, 2008, and 2010 (Figure 2). Sampling undertaken in 2010 was conducted as part of the development of the technical support document (TSD) for the Middle Scioto River to confirm the appropriateness of the WWH aquatic life use for Scioto Big Run (OEPA, 2012). Fish and benthic macroinvertebrate communities were assessed using the methods described below.

Benthic macroinvertebrates: Qualitative multihabitat composite sampling of benthic macroinvertebrates was conducted using a triangular ring frame 30 mesh dip net and forceps. Collections were conducted by at least two persons for a minimum of 30 minutes apiece at each sampling location until no new taxa were identified. This sampling effort included all major macrohabitat types (e.g., riffle, run, pool, and margin) present at each sampling location. Both a preliminary biological community assessment and a station description sheet were completed for each site. Samples were preserved and returned to the laboratory for identification down to the lowest taxonomic level.

Fish: Fish were sampled using pulsed DC electroshocking methods, with sampling distances of 160-200 meters at each site. Fish were processed in the field, identifying each individual to species, weighing, and recording external abnormalities.

Fish communities were assessed and an Index of Biotic Integrity (IBI) was calculated and compared to numeric standards for attainment of tiered aquatic life uses. Benthic macroinvertebrate communities were assessed and a narrative score calculated in lieu of an Invertebrate Community Index (ICI) score because only qualitative sampling was conducted. In order to calculate a formal ICI score, quantitative sampling through the deployment of Hester-Dendy multi-plate samplers would be required. However, Scioto Big Run did not support the deployment of HD samplers due to its small drainage area (< 20 mi^2). A detailed discussion of the fish and macroinvertebrate field and laboratory procedures is contained in Biological Criteria for the Protection of Aquatic Life: Volume III, Standardized Biological Field Sampling and Laboratory Methods for Assessing Fish and Macroinvertebrate Communities (Ohio EPA 1989c, Ohio EPA 2008b).

In-Stream and Riparian Habitat Assessment

Assessments of in-stream and riparian were conducted using Ohio EPA's Qualitative Habitat

Evaluation Index (QHEI) (Rankin, 1989). Similar to the ORAM, the QHEI assigns a maximum number of points to six interrelated stream metrics: substrate (20), in-stream cover (20), channel quality (20), riparian habitat and bank erosion (10), pool riffle quality (20), and gradient (10) to assign a score from 1 to 100. These macro-habitat features have been shown to be highly positively correlated to fish communities. The higher the QHEI score, the more likely the stream possessed necessary habitat and riparian features to support fish communities. Streams with QHEI scores of 60 or greater possess habitat features necessary to support fish communities meeting the *warmwater habitat* aquatic life use designation. While strongly correlated to the IBI and ICI, the QHEI indicates only the ability of stream to meet CWA goal based on habitat features. Actual use attainment can only be determined by sampling of fish and benthic macroinvertebrate communities as described above. See Rankin (1989) for a full explanation of the QHEI rationale and methods.

Watershed Characterization Methods

A watershed characterization was conducted using ESRI's ArcGIS 9.3.1 software analysis tools (Environmental Systems Research Institute, 1998-2009) in conjunction with a wide variety of GIS data layers. Watershed characteristics quantified were impervious cover, forest area, wetlands status and trends, Landscape Development Intensity (LDI) Index (Brown and Vivas, 2005), population density, and home sewage treatment system density.

Landscape Development Intensity (LDI) Index

The LDI is an index of human disturbance which is used in conjunction with land use GIS data layers to quantify the overall intensity of land use for a given geographic area (Brown and Vivas, 2005). An LDI score was calculated for each HUC12 watershed in Ohio by using the USGS National Land Cover Database (NLCD) from 1992, 2001, and 2006. The NLCD is a standard GIS layer of land cover derived using LANDSAT imagery. As an example, Figure 3 shows the 2006 NLCD data for Ohio within the Scioto Big Run HUC12 watershed. For each of these NLCD data layers, all 30 meter x 30 meter LANDSAT pixels were classified into a discrete Anderson level II land use category (Anderson et al., 1972; Vogelman et al., 2001; Homer et al., 2004; Fry et al., 2011). LDI coefficients were assigned to each land use category by interpreting intensity descriptions from Florida (Brown and Vivas, 2005). These LDI coefficient assignments were made for the 1992, 2001, and 2006 NLCD datasets (Table 1 and Table 2). Calculation of an LDI score for each HUC12 watershed is straightforward. The number of raster cells falling within a HUC12 boundary for each 1992, 2001, 2006 NLCD land use category was multiplied by the associated LDI coefficient. The sum total of all LDI/land use calculations was then divided by the total number of raster cells associated with each watershed.

Wetland Status and Trends Analysis

Using available GIS data layers, trends for the changes in wetland acreage, impervious cover, forest cover, population density were examined.

Three parameters were calculated related to the presence of wetland habitat for Scioto Big Run: 1) current wetlands, 2) historic wetlands, and 3) percent wetland loss. Current wetlands were estimated by comparing HUC12 watershed boundaries to the most recent GIS layer of the National Wetlands Inventory (NWI) for Ohio (National Wetlands Inventory, 2006-2007). Only polygons identified as emergent, scrub-shrub, or forested wetlands were included in the analysis. Historic wetlands were estimated by using the digital NRCS soil surveys for Ohio (Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture, accessed 2009). Each soil polygon on the digital soil surveys is assigned an estimated value for percent hydric soils. It was assumed that soils exhibiting hydric characteristics were formed under true wetland conditions. ArcGIS 9.3.1 tools (Environmental Systems Research Institute, 1998-2009) were used to multiply the percent hydric value with the area of each soil polygon. These values were then summed for the entire watershed to estimate the total area of each HUC12 that is likely to have been wetland habitat in pre-settlement times. Subtracting current wetland area from historic wetland area provides an estimate of wetland loss for each HUC12 watershed.

Impervious Cover

Impervious surface has been an ancillary product of the NLCD data layers since 2001 (Xian et al., 2011). The 2006 version of the NLCD was used to calculate a mean impervious percent estimate for each Ohio HUC12 watershed. Each 30 meter x 30 meter LANDSAT pixel was assigned a value between 0 and 100 based on the total proportion of the 900 square meter area estimated to be covered by pavement or some other impervious surface (Yang et al., 2003). Standard ArcGIS 9.3.1 analysis tools were used to quantify the overall percent imperviousness for each HUC12 watershed in Ohio.

Forest Cover

The 2001 NLCD included a "percent forest canopy" ancillary data product, in which each 30 meter x 30 meter LANDSAT pixel was assigned a value between 0 and 100 based on the total proportion of the 900 square meter area was estimated to be covered by trees (Huang et al., 2003). As with the impervious surface analysis, each HUC12 watershed was assigned a mean percent forested value by using standard ArcGIS 9.3.1 analysis tools (Environmental Systems Research Institute, 1998-2009).

Population Density

ArcGIS 9.3.1 software tools were used with U.S. Census Bureau data from 1990 and 2000 to estimate population density values from both of these nationwide census events (U.S. Census Bureau, 1992; 2003).

Home Sewage Treatment System Density

Information provided by the Franklin County Soil and Water Conservation District (SWCD) was used to generate a probability map of potential home sewage treatment system failure density map for the Scioto Big Run HUC12 Watershed. Field location data was recorded by the SWCD, along with information as to the likelihood each system was failing. ArcGIS 9.3.1 Spatial Analyst extension was then used to generate an interpolated surface probability (Environmental Systems Research Institute, 1998-2009).

Wetland Functions Assessment

Flood Water Storage Calculations

An analysis of the wetlands capacity to store water was conducted using the methods described in Ohio EPA's *An Ecological and Functional Assessment of Urban Wetlands*, *Volume 2: Morphometric Surveys, Depth-Area-Volume Relationships and Flood Storage Functions of Urban Wetlands in Central Ohio* (Gamble et al, 2007). Based on an evaluation of twenty-two urban wetlands, separate regression curves were developed to determine the volume of water that could be stored, expressed in acre-feet, for depressional and riverine wetlands. A detailed description of the methodology can be read in the Volume 2 report. A key conclusion of the report is the development of equations calculating volume of water stored in wetlands that can be applied across the state.

Depressional wetlands:

$$\text{volume} = 0.3557 \times \text{area}^{0.8045} \qquad \text{Equation 1}$$

Riverine wetlands:

$$\text{volume} = 0.6468 \times \text{area}^{1.0992} \qquad \text{Equation 2}$$

where volume = acre-feet, and area = wetland acreage.

The following steps were conducted to calculate the volume of water that could be stored by wetlands in the watershed and what percentage of flow during a 335 cfs storm event that volume represented that largest recorded storm event.

Step 1: Determine current wetland acreage using the NWI mapping layer;

Step 2: Calculate the volume of water that may be stored by entering the acreage into the appropriate equation, depending upon whether the wetland was depressional or riverine;

Step 3: Convert the acre-feet of water storage to millions of gallons per day (MGD);

Step 4: Calculate peak discharge recorded in Scioto Big Run using methods described in the *Hydrology Methods* section above. Convert the discharge from cfs to MGD.

Step 5: Calculate the percentage of volume of flow stored in the wetlands by dividing by the volume in MGD from Step 3 by the volume in of flow calculated in Step 4;

Step 6: Steps 1 through 5 were repeated using the acreage of wetlands that could potentially be restored based on the methods described in *Wetland Restoration Potential* section above.

Step 7: Compare the results between the volume of water that could be stored under current conditions to those based on potentially restorable wetlands to determine the difference in the percentage of volume of stream flow that could be stored.

Nutrient Removal

Potential nutrient removal was determined by using the BasinSim 1.0 model (Dai et al, 2000) to calculate the theoretical amount of nutrients that could be processed by each wetland. BasinSim is a based on the Generalized Watershed Loading Function (GWLF) watershed model, and uses land use, population, soils, water discharge, water quality, climate, and point sources discharge inputs to simulate nutrient and sediment loadings under various scenarios. No field measurements of actual nutrient input or output were obtained.

Alternative Land Use Mapping Approaches

Several alternate approaches to land use mapping were explored as part of this study. The standard USGS National Land Cover Dataset (NLCD) is useful as a tool for watershed characterization in that it is based on a consistent image source (LANDSAT 7) and it is generated roughly every five to ten years to allow for temporal change analyses (Fry, et., al., 2011). However, detailed studies of individual watersheds frequently require data at a higher resolution than the NLCD can accommodate, as it is based off of the 30 meter by 30 meter pixel LANDSAT data. Fortunately, in Ohio, there is an abundance of high quality GIS data that has been created in the past decade as part of the Ohio Statewide Imagery Program (OSIP), including 1 foot resolution true color orthophotography, 1 meter resolution color infrared orthophotography, and detailed digital surface elevation models derived from LiDAR data (Ohio Statewide Imagery Program, 2006-2007). Using these and other data sources in conjunction with ESRI ArcGIS 10.0 Image Classification tools (Environmental Systems Research Institute, 2011), both a supervised and an unsupervised classification were run to create simple land use maps for Scioto Big Run.

Additionally, an open source software package, called MultiSpec (Biehl and Landgebe, 2002) was also used to investigate its potential utility for generating detailed land use maps within HUC12 watershed areas using the image sources other than LANDSAT. Multispec, a freeware multispectral image data analysis system developed and maintained by Purdue University, was one of the alternate approaches to land use mapping that was explored as part of this study (Biehl Larry and David Landgrebe. 2011). The primary purpose of the system is to make new algorithms resulting from our research into hyperspectral data analysis conveniently available for others to try, although it has found additional uses in other circumstances, such as university and K-12 education, and in the government and commercial sectors. MultiSpec Application version 3.3 was used for the analysis along with SPOT imagery (CNES, 2011). Both MutliSpec software and SPOT imagery are described in Appendix 1.

Results

Wetland Assessment

Wetland Identification and Mapping

A total of ten separate wetlands meeting all three jurisdictional criteria were identified in the Scioto Big Run watershed. Two wetlands, referred to as the Dispatch – Emergent wetland collectively, were considered as a single wetland for the purpose of this analysis because of their small size, proximately to each other and shared vegetation and hydrology characteristics.

All wetlands had a combined total of 7.6 acres (3.065 ha), which represents 0.05 percent of the total watershed area (15,744 acres). The wetlands ranged in area from 0.09 to 2.46 acres with a mean area of 0.76 acres. A summary of the wetland attributes can be seen in Table 3.

The wetlands are not evenly distributed throughout the watershed. Five wetlands, the Dispatch-forested, Dispatch-emergent, Norton Road-east, Norton Road-west and the Bolton Field wetlands, composing 5.887 acres, are located in the headwaters of an unnamed tributary that discharges into Scioto Big Run just above river mile (RM) 7.0. They are generally located in the southwest portion of the watershed. Three wetlands, the Raccoon Creek Apartment, Big Run vernal pool and Big Run dugout wetland, making up 1.135 acres, are located in the middle of the watershed, all just slightly below RM 7.0. Finally, two wetlands, the Big Run Quarry and I-270 Marsh, composing .552 acres, are located in the lower watershed below RM 2.0. The wetland locations may be seen in Figure 4.

ORAM Score

ORAM scores ranged from a low score of 19 to a high score of 51.5. The mean ORAM score is 31.9, which falls in the gray zone between Category 1 and Category 2, just above the break point of 29.9 which is the highest score for a Category 1 wetland.

Based on the ORAM scores, wetlands in the Scioto Big Run watershed are characterized as either *poor* or *fair*. Four wetlands, totaling 3.931 acres, were classified as Category 1, while six wetlands, totaling 3.643 acres, were classified as Category 2 wetlands. The Norton Road-west and Big Run Quarry wetlands, which scored in the grey zone, were classified as Category 2.

HGM Classification

The predominant HGM classification for wetlands in the Scioto Big Run watershed is depressional, which comprise 7.064 acres. Of this acreage, 1.821 acres are emergent and 5.243 are forested. The 0.51 acre Raccoon Creek Apartment wetland is the only non-depressional wetland, which was classified as a slope wetland. Even at that, it was assigned a secondary HGM class of depressional with an emergent component.

Scioto Big Run Characterization

Stream Flow

Stream flow and water quality data were collected for this project to determine what flow conditions water quality targets were exceeded in Scioto Big Run, and if wetland restoration would help to address these conditions.

Scioto Big Run is an ungaged stream without current USGS stream flow information. Stream flow records were created at two sites on Scioto Big Run by developing flow to stage curves using USGS protocol (USGS, 1984). Stage measurements were recorded at 15-minute intervals using Isco brand ultrasonic level recorders deployed at the Big Run Park (drainage area 6.58 square miles) and at a quarry (drainage area 18.4 square miles) from April to September 2008. Stream discharge measurements were measured at the level recorder sites using SonTek FlowTracker meters following the Ohio EPA Surface Water Field Sampling Manual protocol (Ohio EPA, 2012).

All of the observed flow and associated stage data was plotted and a regression equation for flow based on stage was developed for each site. Figures 1 and 7 in Appendix 2 show the flow development curves for the Scioto Big Run Park site and quarry site respectively. Figure 11 of Appendix 2 shows the calculated flow record and the observed flows for each site over the study period. The flow record was calculated by entering the recorded stage measurements into the flow-stage regression equations.

The June 4, 2008, storm caused a peak in the park site's stream flow that was calculated to exceed 500 cfs. The stage to stream flow relationship was not calibrated to a stream flow anywhere nearly this high, and the calculated stream flow for the downstream quarry site has a much lower calculated stream flow for this event. Therefore, this high flow calculation is likely incorrect.

A more detailed discussion of the methods used to calculate stream flow and the uncertainty associated with the calculations is included in Appendix 2.

Water Quality Analysis

An analysis of in-stream concentrations for selected water quality parameters, that includes consideration of stream flow, was conducted. In-stream concentrations of nitrate + nitrite (NO2+3) exceeded the statewide target of 1.0 mg/l and ammonia exceeded the ecoregional target of 0.05 mg/l during late spring and early summer. Total phosphorus (TP) exceeded the statewide headwater TP target of 0.08 mg/l, mainly during high flow events. This result indicates that nutrients are slightly elevated.

Total suspended solids (TSS) exceeded the statewide target value of 69.95 only during high flows. This result is not unexpected as greater quantities of sediment would be mobilized during high flow events. Total dissolved solids (TDS) was always below the target value of 1,500 mg/l; however, an interesting observation noted from Figure 44 of

Appendix 2 is the relationship between TDS and the percentage of watershed area developed among the Scioto Big Run sites. While the relationship between TDS and urbanization is well known (Schoonover, 2005), the strong correlation is striking and possibly worth further evaluation.

Figures 13-17 of Appendix 2 show measured in-stream concentrations in mg/l for ammonia, nitrate plus nitrite (NO_2+$_3$), total dissolved solids (TDS), total phosphorus (TP), and total suspended solids (TSS), respectively.

Figure 18 of Appendix 2 presents that same data for ammonia, nitrate plus nitrite (NO_2+$_3$), total dissolved solids (TDS), and total phosphorus (TP) using box plots for each month during the sampling period. The box plots consist of data grouped from all three 2008 sampling locations on Scioto Big Run. For each box, the middle line is the median concentration. The top and the bottom of the box are the 75th and 25th percentile respectively. The top and bottom tails are the maximum and minimum observed values for each moth. Finally the black diamond inside each box is the mean value for each month.

The box plots reveal that the median measured in-stream concentrations for NO_2+$_3$ were 0.59 mg/l in May, spiking to 1.02 mg/l in June, then gradually decreasing to 0.7 mg/l, 0.23 mg/l, and 0.2 mg/l in July, August and September respectively. From these plots a trend in the NO2+3 can be observed as being higher in late May and early June and lower in late July and early September which confirms that NO2+3 normally enters Scioto Big Run waters above ambient concentrations when runoff from springtime fertilizer applications occur.

Variations in the measured concentrations of ammonia, TP and TDS are less noticeable. Median ammonia concentrations ranged from a high of 0.11 mg/l in May to a low of 0.05 mg/l in September. Total phosphorus concentrations remained between 0.04 to 0.09 mg/l during the sampling period. Total dissolved solids ranged from a high of approximately 510 to 310 mg/l.

In order to determine what flow conditions water quality targets were exceeded in Scioto Big Run, load duration curves (LDC) for nitrate plus nitrite (NO_2+$_3$), total dissolved solids (TDS), total phosphorus (TP) and total suspended solids (TSS), and concentration duration curves (CDC) for TDS were plotted. Figures 19-28 of Appendix 2 show these curves for the Park and Quarry sites. Due to TDS data being well below the standard, a CDC for TDS is presented instead of a LDC to allow for better examination of the results.

LDCs associate the observed in-stream load and the loading capacity to the cumulative frequency of the flow data over a specified period. This allows a visual comparison of measured in-stream data to the allowable loading capacity of the stream over the range of stream flows. Data in exceedance at the right side of the graph occur during low flow conditions, and significant sources might include wastewater treatment plants, malfunctioning home sewage treatment systems, illicit sewer connections and/or animals depositing waste directly to the stream. Any exceedance on the left side of the graph occurs during higher flow events and potential sources are likely land uses and management practices. The LDC approach helps determine which implementation practices are most effective for reducing loads.

The nitrate + nitrite LDC show exceedences under both moderate and high flows. Total phosphorus exceeded its loading capacity mainly under high flow events, and TSS exceeded only during high flow events. No significant exceedences were observed for any parameter under lower flow conditions. These results indicate that high flow runoff events are the main concern in the Scioto Big Run watershed, and implementation options need to focus on treating and controlling runoff. Because wetland restoration can reduce the quantity and quality of runoff, it is an appropriate treatment option to consider for watershed improvement in the Scioto Big Run. A more detailed discussion of the water quality results and analysis is included in Appendix 2.

Biological Assessment

Overall, biological sampling of Scioto Big Run conducted to support the TSD for the Middle Scioto River confirmed the appropriateness of the WWH aquatic life use designation for Scioto Big Run. Because the drainage area for Scioto Big Run is less than 20 square miles biological criteria for headwater streams applies.

Benthic Macroinvertebrates

Scioto Big Run was sampled extensively as part of special assessments that were conducted in 2007, 2008 and 2010. Seven total sites were evaluated from RM 11.00 to RM 1.80 over the two year period and compared to data collected since 1992 (Table 4).

Scioto Big Run was impacted by sanitary sewer overflows, failing septic systems and urban runoff. Blackflies were the predominant taxon in Scioto Big Run at Big Run Road (RM 4.4), which can indicate organic enrichment. The sampling station was located in an unsewered area, which lends credence to failing septic systems as a source of the degradation to the benthos. Downstream at RM 2.9 on Scioto Big Run, boulder and cobble substrates were present but were largely immovable and therefore provided little interstitial space for colonization. Incised stream banks also indicated that flashy, scouring flows were frequent in this reach. As such, the macroinvertebrate community remained in the fair range, with only one sensitive taxon present.

Overall, total taxa ranged from 14- 30, with a mean of 21, while EPT taxa ranged from 1-6, with a mean of 3.5. These numbers corresponded with an average community assessment of *fair*. While the two sites from 2010 yielded total and EPT taxa numbers that were slightly higher than those of 2007 and 2008, the narrative assessments still remained in the fair range. The urbanized nature of the Scioto Big Run watershed, resulting in runoff, flashy flows and unsewered areas, was responsible for the underperformance of the benthos in all three sampling years.

Fish

Scioto Big Run has shown general improvement in the fish community over time (Ohio EPA, 2012). Fish communities performed at levels meeting the WWH criteria. Fish communities sampled at the RM 4.4 and RM 2.9 achieved IBI scores of 48 and 52, respectively. An IBI score of 40 is required to attain WWH.

However, the significant increase in impervious surfaces associated with increased developed land (43 percent in 1994 to 86 percent in 2006) has likely contributed to the dip in IBI scores between RMs 3.5-4.5 (NLCD, 1994 and 2006). Historic fish community scores may be seen in Table 5. A summary of macroinvertebrate and fish sampling conducted in 2008 and 2010 may be seen in Table 6.

In-Stream and Riparian Habitat Assessment

A total of 12 QHEI scores were obtained during sampling events conducted from 1992-2010. Eight QHEIs were above the threshold score of 60 that indicates a stream exhibits sufficient habitat attributes to support the WWH use designation. Scores ranged from a low of 40.4 to a high of 71. The mean score was 61.78, which again is above 60. Sampling locations scoring below 60 were at RM 3.6 in 2007 with a score of 48, RMs 10.8 and 11.00 in 2008 with scores of 54 and 40.5, and RM 4.5 with a score of 55.8 obtained in 2010.

Lower scores in the upper reaches of the watershed are not totally unexpected due to the reduced size of the drainage area. The drainage area for RMs 10.8 is 0.7 square miles. In fact, Ohio EPA has observed changes in aquatic communities from fish to amphibians in streams with drainage areas below 1.0 square miles. These lower scores may be explained, in part, by the low number of WWH attributes, higher number of high and moderate modified Warmwater Habitat (MWH) influence attributes such as channelization, silt cover and substrate embeddedness and reduced flow velocities in these reaches. Lower QHEI scores in the vicinity of RMs 3.6-4.5 corresponds the density of failing home sewage treatment systems.

Watershed Characterization

Scioto Big Run is located in a 12-digit Hydrologic Unit Code (HUC12=050600012301) which drains directly into the Scioto River, on the south end of the Columbus metropolitan area (Figure 1). This watershed is approximately 24.6 square miles in size, which is close to the mean HUC12 watershed size of 26.8 square miles (Standard Deviation = 11.3 Sq. mi.) for the 1,538 HUC12 watersheds which cover at least part of Ohio. However, in terms of overall human disturbance as measured by a number of different watershed-scale parameters, Scioto Big Run is clearly much more highly degraded than most other HUC12 watersheds in Ohio (Table 7). These specific parameters are described in detail below.

Landscape Development Intensity (LDI) Index

The LDI index scores generated from both the earliest available NLDC data (1992) and the most recent NLCD (2006) shows a similar pattern for the Scioto Big Run HUC12. The 1992 LDI Index score for this watershed was 5.66, which is much higher than the average LDI value for all HUC12 watersheds in Ohio (3.36 ± 1.09). This placed the Scioto Big Run LDI value in the highest 10 percent of all HUC12 watersheds in terms of overall intensity of human disturbance. In fact, only 34 of the 1,538 HUC12 watersheds in Ohio had a higher overall LDI Index score for the 1992 data. The more recent NLCD data generated similar results. The LDI score for Scioto Big Run from 2006 was 6.91, which was also substantially higher than the statewide average LDI score (3.64 ± 1.18). For these 2006 NLCD data, the intensity of land use in the Scioto Big Run watershed was higher than all but 16 of Ohio’s HUC12 watersheds.

One final LDI analysis was to calculate change over time. This analysis required a simple subtraction of 1992 LDI values from those generated using 2006 NLCD data for each HUC12 watershed. The larger the change in LDI score, the larger the increase in human disturbance that occurred within the intervening years. The LDI change score for Scioto Big Run was +1.25, which again was larger than the mean score for all Ohio HUC12 watersheds (0.28 ± 0.28). Even though the Scioto Big Run watershed was highly degraded relative to virtually all other Ohio HUC12 watersheds in 1992, this increase in human disturbance from that time to 2006 was also larger than all but 23 of the 1,538 HUC12s in Ohio.

Impervious Surface

The percent impervious value for the Scioto Big Run HUC12 was 29.38 percent, which was well above the mean impervious surface percent for all Ohio HUC12 watersheds (3.33 percent ± 6.37 percent). The Scioto Big Run percent impervious value was larger than 1,514 of the 1,538 HUC12 watersheds in Ohio. Figure 5 shows the percent impervious surface across Scioto Big Run watershed. Although the percent overall impervious surface is extremely large for this watershed, certain areas are devoid of this particular disturbance, including Big Run Park along and a few smaller parks, riparian areas associated with Scioto Big Run and its tributaries, and some agricultural areas located in the southwestern portion of the watershed.

Forest Areas

Historically, it is likely that a vast majority of the Scioto Big Run HUC12 was composed of forest habitat (Gordon, 1969). Most of these forested lands have long since been eliminated for agricultural, residential or urban development. Some areas do remain, however. Figure 6 displays the percentage of forested areas for Scioto Big Run Watershed. The overall percentage of forest cover for Scioto Big Run based on this analysis is 9.84 percent which is substantially less than the mean value of 28.74 percent (± 22.61 percent) for all 1,538 HUC12 watersheds in Ohio. This is less than about 70 percent of all HUC12 watersheds in Ohio (1,076 of 1,538).

A calculation of "historic forested" land was generated using information contained within the digital USGS 7.5 minute topographic quadrangles, referred to as Digital Raster Graphics (DRG) (U.S. Geological Survey, digital 1:24,000 topographic maps, multiple dates). All areas mapped as forested (having a green color) were separated out as a new statewide raster file using ArcGIS 9.3.1 Spatial Analyst extension (Environmental Systems Research Institute, 1998-2009). Most of the USGS topographic quadrangles used to create the Ohio DRGs were generated approximately 30-40 years ago, so extracting out the forested areas using these data provides some indication of the percentage of the Scioto Big Run watershed that was forested at that time. It is not, however, an estimate of original forest percentage for this area, which was undoubtedly much higher in pre-settlement times. Figure 7 shows the distribution of "historic forest" across Scioto Big Run Watershed, as defined by this data layer. The overall percentage of historic forest for the Scioto Big Run HUC12 watershed is 6.88 percent which is less than 1,194 of the 1,538 HUC12 watersheds in Ohio (77.6 percent).

For the most part, this map is similar to Figure 6, indicating there has been little change in the amount of forest over the last several decades. Subtracting the estimated forest cover value generated by these two separate GIS layers provides an estimate for approximately how much forest has been lost or gained for each HUC12 watershed. For most of these watersheds (1,178 of 1,538 = 76.6 percent) there has been at least a modest increase in the amount of forest. Scioto Big Run Watershed fell into this category, with an estimated increase of 2.96 percent, which is less than the mean increase of 6.72 percent (± 8.78 percent) for all HUC12s.

Wetlands

Figure 1 shows the location of all mapped NWI wetlands within the Scioto Big Run Watershed. The total area of these wetlands, as estimated by the NWI dataset, is 7.6 acres, which is approximately 0.05 percent of the overall watershed area. This is less than all but 89 of the 1,538 HUC12 watersheds in Ohio (5.8 percent). The estimate of historic wetlands within Scioto Big Run suggested that approximately 17.7 percent of this watershed had consisted of wetland habitat originally, which is close to the mean value of historic wetland percent of 19.8 percent (± 20.4 percent) calculated for all 1,538 HUC12 watersheds. However, the estimate of percent wetland loss calculated for Scioto Big Run (99.4 percent) is larger than all but 70 of the 1,538 HUC12 watersheds in Ohio (4.6 percent).

Population Density

In 1990, Scioto Big Run Watershed had a population density of approximately 2,584 people per square mile, which is much larger than the Ohio HUC12 mean from that census (267 ± 642). This is a higher population density value than all but 2 percent of the Ohio HUC12 watersheds (31 of 1,538). The 2000 U.S. Census yielded similar results, with the Scioto Big Run value of 3,314 people per square mile being larger than all but 18 of the remaining HUC12 watersheds (1.2 percent). Additionally, the population density increased at a rate within Scioto Big Run; 730 people per square mile over the 10 year period; than all but one other HUC12 watershed in the State of Ohio (City of Gahanna - Big Walnut Creek).

Home Sewage Treatment Systems (HSTS)

Macroinvertabrate data collected in Scioto Big Run indicated the presence of taxa typically found in areas of organic enrichment. Additionally, visual observations of bank erosion areas verified the presence of failing septic structures adjacent to the stream itself. Figure 8 displays areas identified by the Franklin County Soil and Water Conservation District as having a high probability of home sewage treatment system failures. Bacteriological sampling and field observations revealed impairment from sewage which is consistent with high failure rates of home sewage treatment systems. However, the LDC for the Scioto Big Run did not indicate a loading capacity issue associated with these failing systems for total phosphorus or nitrate and nitrite.

Wetland LDI Comparison

Each of these 11 wetlands was assessed using the Ohio Rapid Assessment Method for Wetlands (ORAM). The mean ORAM score for these Scioto Big Run wetlands was 31.86. Comparing these results to the mean ORAM scores for the Ohio EPA Wetland Ecology Group's reference data set of natural wetlands illustrates the point that the few small wetlands located in this target watershed were also generally in poor to fair ecological condition (Figure 9). To examine the relationship between the wetlands and the affect the intensity of surrounding land uses may be having on their condition, a detailed assessment was conducted for two areas immediately outside the defined boundary of these resources: from the edge of the wetland to 100 meters ("inner zone") and from 100 meters to 350 meters ("outer zone"). For both the inner and outer zones, an LDI calculation based on 2001 NLCD data was made to quantify the overall level of human disturbance surrounding each wetland (Brown and Vivas, 2005). The results for both of these areas were compared to an identical LDI assessment of natural wetlands. Figure 10 shows this comparison for the inner zone, and Figure 11 is the outer zone comparison. It is clear from these figures that, in general, the ecological condition of wetlands as defined by ORAM scores decreases as the overall level of human disturbance increases in both of the zones surrounding these wetlands. Likewise, the extremely low overall mean ecological condition of the wetlands assessed in this study conforms to this relationship, as the overall land use intensity scores were very high for both the inner and outer zones in the Scioto Big Run Watershed wetlands.

Wetland Restoration

Analysis of the Scioto Big Run Watershed suggests that approximately 17.7 percent of this area had been wetland habitat in pre-settlement times (Table 7). A vast majority of these wetland areas have been eliminated from the watershed, mainly due to land conversion for agricultural or urban development, leaving less than 0.05 percent of this original wetland area. Areas within the Scioto Big Run watershed were identified as having a high probability for wetland restoration included if they met the following criteria: 1) mapped as both predominantly hydric soil (>50 percent hydric soil map unit on NRCS SSURGO data [(Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture, accessed 2009]) (Figure 12) and 2) consists of agricultural land use, based on 2001 USGS NLCD data (Homer et al., 2004). These potential wetland restoration areas of Scioto Big Run are illustrated on Figure 13. Due to historic conversion to highly developed, urban land uses in most of these historic wetlands, the total wetland restoration potential represents only 4.75 percent of the entire Scioto Big Run Watershed, which is substantially less than our estimate of historic wetland (4.75 percent versus 17.7 percent).

The restored wetlands would be located entirely in the southwest and far west undeveloped areas of the watershed. Only 150 acres would be located within 100 meters of a Scioto Big Run tributary. No wetlands would be restored adjacent to or near the main stem of Scioto Big Run. The location of restorable wetlands was based on areas mapped as predominantly hydric soils and agricultural land that exhibited a high probability for restoration, and not modeling of strategic locations for installing wetlands as best management practices (BMPs) for flood control and nutrient management.

Wetland Functions Assessment

Flood Storage Calculations

Using the linear regression equations from the Urban Wetlands Study, the flood water storage capacity of the wetlands under both current conditions and full restoration of 748 acres of wetlands was calculated. The linear regression equations calculated the acre feet of water each wetland could store. Acre-feet was then converted to MGD and compared to the flow during a 500 year storm, which was the highest storm event recorded during the period that hydrology data was collected.

The volume of water that could be stored in the ten existing wetlands located in the Scioto Big Run watershed was calculated to be 2.022 acre-feet (0.66 MGD) which represents 0.206 percent of the flow of a 500 cfs storm event. Restoration of 748 acres of wetlands would provide 220 acre-feet (71.8 MGD) of storage capacity. Storage volumes are seen in Table 8.

Load and Runoff Calculations

A watershed loading model was developed for the Middle Scioto River TMDL of which Scioto Big Run is a part. The Scioto Big Run watershed TMDL model was utilized for this grant project as well. The TMDL model for Scioto Big Run stopped at river mile 2.0 where monitored impairment ended.

The model used was the Generalized Watershed Loading Function or GWLF model (Haith, 1992) through the desktop simulation called BasinSim 1.0 (Dai, 2000). The model predicts stream flow based on precipitation, evapotranspiration, land uses, ground water and soil characteristics.

GWLF simulates runoff, ground water recharge and stream flow by a water-balance method using measurements of daily precipitation and average temperature. Runoff is calculated using the Natural Resources Conservation Service's Runoff Curve Number method (USDA, 1986). This method determines the amount of precipitation that runs off the surface and is adjusted for antecedent soil moisture before the precipitation event, the growing or dormant season, the detention potential and soil characteristics. The predicted surface runoff flow is the quick response flow including interflow and drainage from tiles.

The GWLF model predicts dissolved and solid-phase nitrogen and phosphorus loads by source category. Dissolved loads are calculated by multiplying the model predicted runoff from each source area by its user defined concentration. Erosion is computed for rural areas using the Universal Soil Loss Equation. Sediment yield is the product of erosion and the sediment delivery ratio and rural solid phase nutrient loads are determined by the sediment yield and user defined sediment nutrient concentrations. Urban loads are determined using exponential accumulation and wash-off functions.

Hydrology calibration for the Middle Scioto River watershed was carried out for a 30-year period. An R^2 value of 0.66 and predicted to observed ratio of 0.74 were determined for hydrology of this calibrated GWLF model.

Land use and weather data are critical components of hydrology functions of GWLF. The National Land Cover Dataset (NLCD) was used as the land cover resource for this study (Homer, 2004). Daily precipitation and air temperature data acquired from the Midwestern Regional Climate Center for the Columbus Valley Crossing (station ID 331783) weather station was used for the Scioto Big Run model. Other inputs to the GWLF model were determined using reference values from the model’s user’s guide, values published in the literature augmented by any known values available. For more information about the GWLF model please refer to Appendix D of the Middle Scioto TMDL report located on the Ohio EPA web site.

The 30-year average annual load for various water quality parameters were calculated under existing wetland conditions and the loading reductions that could be achieved if 748 acres of potential wetlands could be restored.

Under current land use for the Scioto Big Run watershed upstream of RM 2.0 (drainage area 11,606 acres), including 5.2 acres of existing wetlands, dissolved phosphorus (DP) and total phosphorus average annual loads were calculated at 523 kg/year and 4,200 kg/year, respectively. Total nitrogen (TN) average annual loading was calculated to be 34 metric tons (MT) per year, and the average annual sediment load was calculated as 267 MT per year. The Scioto Big Run TMDL focused on total phosphorus as a parameter of concern and determined that nonpoint source loads need to be reduced by 57 percent.

Modeling was used to calculate the annual runoff loading reductions that would be achieved for DP, TP, TN, and sediment if the 242 acres of potential wetlands in the TMDL modeled area could be restored. This acreage represents 2 percent of the watershed above RM 2.0. The results indicate that for every acre converted from row crop agriculture to restored wetland in the Scioto Big Run watershed, annual loading reductions of DP would be 0.14 kg/acre, TP would be reduced by 0.71 kg/acre, TN reduced by 8.7 kg/acre and sediment by 445 kg/acre. Runoff would be reduced by 5.9 cm/acre. Converting this 2 percent of the watershed from agriculture to wetland reduces the nonpoint source total phosphorus load by 40 percent and achieves 70 percent of the TMDL total phosphorus nonpoint source reduction goal.

Multiplying the average annual loading reductions described above by the 748 acres of potential wetland restoration area in the entire Scioto Big Run watershed could potentially reduce the sediment load to the stream by an average of 330 metric tons (330,000 kg) per year, the total phosphorus load by 530 kg/year and the total nitrogen load by 6500 kg/year. These reductions are due to the land use conversion only and do not take into account any additional filtering functions wetlands can provide for runoff from upland drainage areas.

Since the entire Scioto Big Run watershed was not included in the TMDL model utilized for this grant project, the percent these load reductions represent of the current existing watershed load could not be calculated.

Alternative Land Use Mapping Procedures

Supervised Classification – ArcGIS 10.0

In order to reduce the processing time typically associated with classification of high resolution photography, the area of Scioto Big Run Watershed was clipped from the Franklin County, Ohio 2006 OSIP true color orthophoto map. The clipped image was then resampled from 1 foot to 3 foot pixels, also reducing image processing time. The ArcGIS 10.0 Image Classification toolbar was used to develop a training sample in which 3-5 sample areas were digitized, from each of five different land use categories: forest, grass, impervious, water, and agriculture (ESRI, 2011). These samples were used develop a signature file that defined the appropriate image signature for each of these land use classes. The maximum likelihood classification tool was then used to produce the final unsupervised classification (Figure 14).

In order to check the accuracy of this approach, a set of 100 random points was generated (Figure 15) for the Scioto Big Run watershed using Geospatial Modelling Environment software (Beyer, 2009-2012). The “correct” land use was confirmed at each of these locations through visual examination of the source orthophotography. The land use category selected on the supervised classification was then compared to the actual land use to determine an overall accuracy of the procedure. For the random point layer, the supervised classification produced correct results 65 percent of the time. A similar accuracy analysis was then run using the USGS 2006 NLCD data. To produce a true “apples to apples” comparison, each of the NLCD land use categories that commonly occur in Scioto Big Run Watershed were placed into one of the five simplified categories (Figure 16) as follows:

Impervious = Developed, Low Intensity; Developed, Medium Intensity; Developed, High Intensity; Barren Land
Water = Open Water
Grass = Developed, Open Space; Hay/Pasture
Forest = Deciduous Forest; Mixed Forest; Woody Wetlands
Agriculture = Cultivated Crops

When compared to the true color orthophotography, the accuracy of this simplified 2006 NLCD layer was 63 percent. Even though the overall accuracy of the supervised classification was very similar to the NLCD, it appears that much of the error associated with the NLCD is due to the coarseness of the 30 meter x 30 meter pixels. For this analysis, all low intensity developed land use pixels were placed in the "impervious" land use category, however, most of these areas are residential developments, having both impervious surface (houses and driveways) and substantial amounts of grass (residential lawn) included. Due to the large pixel size of the NLCD, lumping these areas into either "grass" or "impervious" was going to produce an error one way or the other, based on how the categories were being defined. Of the 39 pixels that clearly fell on impervious surface, based on the orthophotography, the NLCD was correctly classified 85 percent of the time (33 of 39). Conversely, 43 pixels are located on grassed areas, and the NLCD only was correct 44 percent of the time, with 22 of the 24 erroneous pixels classified as "impervious," due to this lumping effect. The errors associated with the supervised classification, however, were due to discrepancies in how the sample locations were defined and limitations to the digital signature of the imagery itself (e.g., brown, murky water looks very similar to bare soil and was frequently classified incorrectly). A more sophisticated classification approach, which included additional remotely sensed information sources would have likely reduced the error rate and produced a much more accurate overall land use classification.

Unsupervised Classification – ArcGIS 10.0

A second land use classification approach was also used on the 2006 OSIP true color orthophotography for Scioto Big Run watershed (Figure 17). This approach involved the use of unsupervised classification tools, which are also included on the ArcGIS 10.0 image classification toolbar (Environmental Systems Research Institute, 2011). In addition to the true color orthophoto, NAIP 2010 leaf-on imagery and color infrared OSIP data were also included as input bands in the analysis. The ArcGIS 10.0 "ISO Cluster Unsupervised Classification" tool was used to generate 50 different classes based on the specific image signatures of the input photography layers. The selected classes were then evaluated in conjunction with the source photography to lump each into one of four simplified land use classes: forest, grass, impervious and agriculture (Figure 17). Water was not included as a class, as none of the 50 classes clearly identified the few, small water bodies present within this HUC12 watershed. This is probably due to the fact that most of these ponds were extremely murky, and superficially resembled bare soil areas, such as agricultural fields and development projects. When compared to the actual pixel values for each of the 100 random point locations, the accuracy of this unsupervised classification was 72 percent, which is slightly better than the accuracy values for both the supervised classification (65 percent) and the 2006 NLCD layer (63 percent). However, the accuracy values for selecting impervious areas was slightly lower for the unsupervised classification (75 percent) when compared to these other two land use layers (77 percent and 85 percent, respectively).

While neither the supervised nor the unsupervised land use layers created using ArcGIS 10.0 tools improved substantially on the already existing NLCD GIS layer, based on this demonstration study, it does appear there is some utility to fleshing out this concept further. Using readily available, current remote sensing data for Ohio does allow for higher resolution land use analysis and also could provide a means for more detailed temporal studies, assuming these state-specific data are available at more regular intervals that the current 5 to 10 year cycle associated with USGS NLCD updates.

MultiSpec 9.2011

Multispec, a freeware multispectral image data analysis system developed and maintained by Purdue University, was one of the alternate approaches to land use mapping that was explored as part of this study (Biehl Larry and David Landgrebe. 2011.). See Appendix 1 for an introduction to MultiSpec. The system is designed to be used with multiple layer satellite imagery such as LANDSAT. As mentioned above, the NLCD is the standard USGS National Land Cover Dataset and is based off of the 30 x 30 meter pixel LANDSAT data.

It was decided to use higher resolution imagery than afforded by LANSAT. SPOT imagery was used with a 20 x 20 meter resolution (CNES, 2011.). Recent imagery was obtained from the USGS Earth Explorer web application. Imagery was chosen that was cloud free, of excellent quality and that had a footprint that encompassed the entire Scioto Big Run HUC 12. From the 4 possibilities that ensued, the image used was selected because it appeared to have slightly better visual quality than the other images.

The SPOT imagery allowed for fairly detailed and accurate training with a resultant greater accuracy than if LANDSAT imagery was used. In addition, using high resolution imagery in ArcGIS to help determine training fields in conjunction with MultiSpec to also increase accuracy

Classification

The area of Scioto Big Run Watershed, along with a 500 foot buffer, was clipped from the selected SPOT imagery using ArcGIS.

Land use categories that what were used in classification were based on those used in the 2006 NLCD (Anderson level 1). Several minor categories were lumped in with other categories. Grassland/Heraceous were included with either: cultivated crops; deciduous, forests or developed; open space; mixed forest was included with deciduous forest; and woody wetlands were included with deciduous forests. As none of the random dots fell on these small classifications (which were of very small acreage) it was decided that the NLCD did not need to be reclassified.

The final list of categories used for MultiSpec was:

Barren Land (Rock/Sand/Clay)
Cultivated Crops
Deciduous Forest
Developed, High Intensity
Developed, Low Intensity
Developed, Medium Intensity
Developed, Open Space
Open Water

The original SPOT imagery used is seen in Figure 18. The classified land use map developed using MultiSpec for the Big Run watershed is shown in Figure 19. The NLCD map for the area is shown in Figure 3.

In order to check the accuracy of this approach, the set of 100 random points that was previously generated (Figure 12) for the Scioto Big Run watershed was used. The method of checking was similar to that done for the ArcGIS 10 approach. The "correct" land use was identified at each of these locations through visual examination of the source orthophotography. The land use category selected on the supervised classification was then compared to the actual land use to determine an overall accuracy of the procedure. The initial check for the MultiSpec classification layer was 71 percent. This compared with a 59 percent accuracy level for the 2006 NLCD layer.

A subsequent second check was done to see how the random points fit within the category classification on the map. With a land use classification, the map is divided up similar to a jigsaw puzzle. Until one obtains a visual image for how the patterns occur, it is easy to miss those patterns which produce error in the accuracy check.

In addition, in a few cases a discrepancy was found between the high resolution imagery and the classification pattern due to the classification pattern being slightly shifted. If it was approximately less than 100 feet, it was included as accurate (e.g., the random point was 30 feet from the forest edge). The algorithm fit the different pieces of the classification together in the watershed area, and rarely is there a perfect fit of what is shown on the imagery and in the resultant classification patterns – there would be a “shift affect” where the entire woods would be shown in the classification map but it might be shifted slightly from the actual image. However, the amount of forested land use for the area would be accurate.

After the second check, the accuracy for the MultiSpec classification layer was 91 percent and the accuracy level for the 2006 NLCD layer was 85 percent. According to the USGS factsheet, The *National Land Cover Database* (USGS, 2012), “For the conterminous United States, NLCD 2001 has an improved Anderson Level I class accuracy of 85.3 percent and an Anderson Level II class accuracy of 78.7 percent” (the accuracy check for the 2006 NLCD is currently underway). Although this would vary by region or local areas, it still indicates that the second check was probably fairly close in accuracy although probably a bit on the high side. Together, the two iterations of accuracy checks and the accuracy check mentioned in the NLCD factsheet would indicate a level of accuracy in between the two checks but somewhat closer to the second check.

The results demonstrate that the MultiSpec classification produced a fairly accurate classification, similar to or more accurate than the NLCD. Use of imagery such as SPOT, with higher resolution than LANDSAT, that is also available on at least an annual basis, if not more often, would allow for more detailed temporal studies with a fair degree of accuracy.

Some examples of possible studies that might be done with a method such as this are:

a. Looking at how development affects stream quality, one could select a watershed in a rapidly developing watershed with associated biological data and see how buildup over time affects stream water quality.

b. This method could have a number of wetland applications. For example, it could be used as a tool, in conjunction with other tools, to help make a more accurate NWI. It could also potentially be used to help differentiate a few basic wetland types based on vegetation (e.g, Typha wetlands vs. non-Typha wetlands).

Discussion

The primary purpose of this study was to evaluate the influence of wetlands on water quality and quantity in an urbanized watershed. The wetland attributes used in the study included wetland abundance and ecological condition. Wetland abundance was calculated using the National Wetland Inventory data for Ohio (NWI, 2006-2007) to determine the acreage and percentage of wetlands within the Scioto Big Run watershed. The ecological condition of the wetlands was determined using the ORAM, a level 2 wetland assessment tool. Streams were assessed using biocriteria, hydrology, and in-stream concentrations of nutrients. The Scioto Big Run watershed upstream of river mile (RM) 2.0 was assessed using the GWLF watershed hydrology and loading model.

Flood Flow Attenuation

The ability of the existing 7.6 acres of wetlands and the 748 acres of potentially restorable wetlands to store floodwater in the Scioto Big Run watershed was calculated using linear regression equations developed by Ohio EPA (Gamble et al., 2008). These calculated floodwater volumes were then compared to the flow volume of Scioto Big Run after a 1.5 inch rain event to estimate how much flood flow attenuation potential wetlands could achieve in the watershed. The 1.5“ rain event was used because Gamble et al. (2008) determined that wetlands in Central Ohio generally fill to capacity during a storm of this magnitude.

A rain event of this magnitude occurred on June 16, 2008, and resulted in an average daily flow of 130 cfs (84 MGD) at the Quarry site in-stream monitoring location (RM 2.0).

The storage capacity for the 7.6 acres of existing wetlands was 2 acre-feet (0.66 MG), which translates to 0.8 percent of the total volume of stream flow during a 1.5” storm event flow event and 0.3 percent during a 3.5” storm event, which was the largest storm event recorded during the study period.

The remaining 7.6 acres of wetlands are simply too scarce, both in terms of number of acres and as a percentage of the watershed, to make any significant contributions to floodwater storage or flood desynchronization. Although percentages reported in the literature vary, many agree that 7 to 10 percent of a watershed should be composed of wetlands to perform an effective flood control function. The existing wetlands represent only 0.05 percent of the watershed. The area of a wetland has also been implicated as a factor determining the ability of a wetland to store floodwater. Existing wetlands have a mean area of 0.76 acres.

Given the urbanized nature of the watershed with 29 percent impervious cover, the small amount of existing wetlands are not able to significantly contribute to flood water storage or flood flow desynchronization. Any flood storage functionality performed by these wetlands would be overwhelmed by the other land uses and altered hydrology.

The water storage capacity of the 748 acres of potential wetland restoration areas was also calculated using the same procedures for the existing wetlands. The same linear regression equations used to calculate the water storage capacity for existing conditions were repeated for the restored wetlands scenario.

The storage capacity for the 748 acres of restored wetlands was 220 acre-feet (71.8 MG), which translates to 85 percent of the total volume of stream flow during a 1.5” storm event and 33 percent during a 3.5” storm event.

Conversion of 748 acres of agricultural land to wetland represents only 4.75 percent of the watershed. While this figure is below the 7 to 10 percent threshold appearing in the literature, storage of 85 percent of the flow during a 1.5” rain event is expected to have a significant positive contribution on flood desynchronization.

Calculating the volume and percent of overall stream flow captured in wetlands during a particular storm event is useful in gauging the overall effect of wetlands at a broad watershed level scale. However, it may be an oversimplification of the hydrologic processes at work within the watershed.

Evaluation of stream flow characteristics of Scioto Big Run would have been enhanced by obtaining stream flow data over a longer time period. Detrimental impacts on urban stream hydrology include increased stage variability, stream flashiness and the duration of extreme-stage conditions (McMahon, 2003). Sampling over a five month period did not provide enough of a record to determine stream flow characteristics such as flashiness. We recommend collecting data over multiple years to develop the necessary hydrologic record to characterize the stream.. Therefore, we cannot fully predict how restoration of 748 acres of wetlands would affect stage height and stream flashiness based on current data.

Nutrients

The affect of wetlands on nutrient loadings was modeled using the GWLF watershed loading model that was developed for the Scioto Big Run TMDL. The TMDL model for Scioto Big Run stopped at RM 2.0 where monitored impairment ended. Modeled results were calculated, then converted to loading rates per acre which could then be applied to the entire watershed area. Literature values for wetland-related inputs were used, as site specific wetland chemical data was not available.

Modeling was used to calculate the annual runoff loading reductions that would be achieved for DP, TP, TN and sediment if the 242 acres of potential wetlands in the modeled area could be restored. This acreage represents 2 percent of the watershed above RM 2.0. The results indicate that for every acre converted from row crop agriculture to restored wetland in the Scioto Big Run watershed, annual loading reductions of DP would be 0.14 kg/acre, TP would be reduced by 0.71 kg/acre, TN reduced by 8.7 kg/acre and sediment by 445 kg/acre. Runoff would be reduced by at least 5.9 cm/acre. Converting this 2 percent of the watershed from agriculture to wetland reduces the nonpoint source total phosphorus load by 40 percent and achieves 70 percent of the TMDL total phosphorus nonpoint source reduction goal.

Multiplying the average annual loading reductions described above by the 748 acres of wetland restoration area in the entire Scioto Big Run watershed could potentially reduce the sediment load to the stream by an average of 330 metric tons (330,000 kg) per year, the total phosphorus load by 530 kg/year and the total nitrogen load by 6,500 kg/year. These reductions are due to the landuse conversion only and do not take into account any additional filtering functions wetlands can provide for runoff from upland drainage areas.

Since the entire Scioto Big Run watershed was not included in the TMDL model utilized for this grant project, the percentage these load reductions represent of the current existing watershed load could not be calculated. However, the potential loading reductions calculated by the model are significant and would improve the water quality of the Scioto Big Run.

Similar to the affect of the wetlands on flood flow, the remaining 7.475 acres of wetlands ability to remove nutrients or improve water quality is negligible and masked by the degree of urbanization of the watershed.

Comparing Wetland Condition to Function

This study also included collection of ORAM data to determine wetland ecological condition. The existing wetlands in the Scioto Big Run watershed were characterized as poor or fair. The mean wetland condition was considered a modified Category 2 wetland. While wetland ecological condition has been postulated to be positively correlated to function (Fennessey et al., 2004), we were not able to test this correlation. The existing wetlands were too few to make any meaningful inferences as to whether the ORAM score was correlated to their influences the wetlands ability to store flood flow and remove nutrients. The the ability of restored wetlands potential ability to remove nutrients was based on a literature review to determine wetland related inputs for the GWLF model assumptions built. We were not able to ascertain the various wetland attributes, beyond acreage and percentage of the watershed they composed, to test this correlation.

In addition, measures of ecological condition may not fully characterize a wetland's ability to perform a specific function.

Modeled results for nutrient removal rates are only as accurate as the model and data being used. Some models treat wetlands as storm water ponds, and would undervalue their ability to perform flood flow attenuation (Gamble et al., 2008). Modeling results can be hampered when the assumptions built into the model do not reflect actual processes or conditions in the field. A shortcoming of modeling is that it does not always accurately represent the actual wetlands as they are functioning in the environment.

In this case, field data such as nutrient loads to or discharging from the wetlands, water retention times, water flow paths through the wetland and other site specific parameters were not collected. While such data is likely to be more accurate than values used in the model or gleaned from the literature, obtaining actual field data is timely and expensive. In light of these constraints, researchers have attempted to use measures of ecological condition and/or functional assessment measures as surrogates for costly field data collection.

Further data collection that includes both measures of wetland ecological condition and actual field data for water storage and nutrient removal is recommended.

Literature Cited

Anderson, James R., Hardy, Ernest E., and Roach, John T. 1972. *A Land-use Classification System for Use with Remote-sensor Data*. U.S. Geological Survey pg. 671, 16 p., refs.

Biehl, Larry and David Landgrebe. 2002. "MultiSpec—a Tool for Multispectral–Hyperspectral Image Data Analysis." *Computers & Geosciences*, (Volume 28, Issue 10, December 2002), pp. 1153-1159.

Biehl Larry and David Landgrebe. 2011. *An Introduction & Reference For MultiSpec© Version 9.2011.*

Belluci, Christopher. 2007. "Stormwater and Aquatic Life: Making the Connection between Impervious Cover and Aquatic Life Impairments for TMDL Development in Connecticut Streams." In proceedings of the Water Environment Federation TMDL Conference, Belluvue WA, Alexandria VA: Water Environment Federation 1003-1018.

Booth, Derek and C. Rhett Jackson. 1997. "Urbanization of Aquatic Systems: Degradation Thresholds, Stormwater Detection, and the Limits of Mitigation." *Journal of the American Water Resources*, American Water Resources Association, (Volume 33, No. 5.), pp. 1077-1090.

Booth, Derek B, James R. Karr, Sally Schauman, Christopher P. Conrad, Sarah A. Morley, Marit G. Larson, and Stephen J. Burges. 2004. "Reviving Urban Streams: Land Use Hydrology, Biology, and Human Behavior." *Journal of the American Water Resources Association,* (Volume 40 Issue 5), pp. 1351-1364.

Brinson, M. M. 1993. *A Hydrogeomorphic Classification for Wetlands*. U.S. Army Corps of Engineers Waterways Experimental Station. Wetlands Research Program Technical Report WRP-DE-4. Vicksburg, MS.

Brown, Mark T. and M. Benjamin Vivas. 2005. "A Landscape Development Intensity Index." *Environmental Monitoring and Assessment*, (volume 101 issue 1-3), pp. 289-309.

Chesapeake Bay Program. November 2008. *Quantifying the Role of Wetlands in Achieving Nutrient and Sediment Reductions in Chesapeake Bay*. STAC Publication 08-006. retrieved from: http://www.chesapeake.org/pubs/Pubs/wetlandsbmpreport.pdf

CNES (Centre National d'Etudes Spatiales). 2011. 06/29/2011. SPOT 4 North America Data Buy - Path: 609 Row: 270. Scene: 46092701106291557412I0.

Dai, T., R.L. Wetzel, T.R.L. Christensen, and E.A. Lewis. 2000. *BasinSim 1.0: A Windows-Based Watershed Modeling Package, User's Guide*. Virginia Institute of Marine Science and School of Marine Science, College of William & Mary, Gloucester Point, VA.

Environmental Laboratory. 1987. *Corps of Engineers Wetland Delineation Manual*, Technical Report Y-87-1. U.S. Army Corps of Engineers, Vicksburg, MS.

Environmental Systems Research Institute. ArcGIS: Release 9.3.1 [software]. Redlands, California: Environmental Systems Research Institute, 1999-2009.

Environmental Systems Research Institute. 2011. ArcGIS: Release 10.0 [software]. Redlands, California: Environmental Systems Research Institute.

Federal Interagency Stream Restoration Working Group, (10/98). *Stream Corridor Restoration, Principles, Processes, and Practices*. GPO Item No. 0120-A SuDocs No. A 57.6/2 EN3/PT.653.

Fennessey, M. Siobhan, John J. Mack, Abby rokosch, Martin Knapp, and Mick Micacchion. 2004. Integrated Wetland Assessment Program. Part 5: Biogeochemical and Hydrological Investigations of Natural and Mitigation Wetlands. Ohio EPA technical Report WET/2004-5. Ohio EPA, Wetland Ecology Group, Division of Surface Water. Columbus, Ohio.

Fischer, J. and M.C. Acreman. 2004. "Wetland Nutrient Removal: a Review of the Evidence." *Hydrology and Earth Sciences*, (Volume 8 Issue 40), pp. 673-685.

Fry, J., Xian, G., Jin, S., Dewitz, J., Homer, C., Yang, L., Barnes, C., Herold, N., and Wickham, J., 2011. "Completion of the 2006 National Land Cover Database for the Conterminous United States," *PE&RS*, (Volume 77 Issue 9), pp. 858-864.

Gamble, D. , E. Grody, J. Undercoffer, J.J. Mack, and M. Micacchion. 2007. *An Ecological and Functional Assessment of Urban Wetlands in Central Ohio. Volume 2: Morphometric Surveys, Depth-area-volume Relationships and Flood Storage Function.* Ohio EPA Technical Report WET/2007-3B. Ohio Environmental Protection Agency, Wetland Ecology Group, Division of Surface Water, Columbus, Ohio.

Gordon, Robert B. 1966. "Natural vegetation of Ohio at the time of the earliest land surveys" (map). Ohio Biological Survey.

Haith, D.A., R. Mandel, and R.S. Wu. 1992. *GWLF, Generalized Watershed Loading Functions, Version 2.0, User's Manual*. Department of Agricultural & Biological Engineering, Cornell University, Ithaca, NY.

Hey, D.L. and N.S. Philipi. 1995. "Flood Reduction through Wetland Restoration: the Upper Mississippi River Basin as a Case Study." *Restoration Ecology,* (Volume 3 Issue 4), p. 17.

Homer, C. C. Huang, L. Yang, B. Wylie and M. Coan. 2004. "Development of a 2001 National Landcover Database for the United States." *Photogrammetric Engineering and Remote Sensing*, (Volume 70, Issue 7, July 2004), pp. 829-840.

Huang, C., Homer, C., and L. Yang. 2003, "*Regional Forest Land Cover Characterization Using Landsat Type Data*," in Wulder, M., and Franklin, S., eds., *Methods and Applications for Remote Sensing of Forests: Concepts and Case Studies*, Kluwer Academic Publishers, pp. 389-410.

Johnston, C., N. Detenbeck, and G. Niemi. 1990. "The Cumulative Effect of Wetlands on Stream Water Quality and Quantity. A Landscape Approach." *Biogeochemistry,* (Volume 10), pp. 105-141.

Kadlec, Robert H. and John A. Kadlec. 1978. “Wetlands and Water Quality.” in P.E. Greeson, J.R. and J.E. Clark [eds.] *Wetland Functions and Values: The State of our Understanding.* American Water Resources Association, Proc. Nat. Symp. on Wetlands, Lake Buena Vista, FL. American Water Resources Association, Minneapolis, MN. pp 436-456.

Klein, R. 1979. “Urbanization and Stream Quality Impairment.” *Water Resources Bulletin*, (Volume 15), pp. 948-963.

Kotze, Donovan. 2000. *The Contribution of Wetlands to the Attenuation of Floods.* available from the Mondi Wetland Programme website www.wetland.org.za

Kusler, Jon. 2011. *Issue paper: TMDLs and Wetlands.* Association of State Wetland Managers. U.S. EPA State Wetland Development Grant BG 973027-03.

Mack, John J. 2001. *Ohio Rapid Assessment Method for Wetlands v. 5.0, User’s Manual and Scoring Forms.* Ohio EPA Technical Report WET/2001-1. Ohio Environmental Protection Agency, Wetland Ecology Group, Division of Surface Water, Columbus, Ohio.

Mack, J.J. 2006. “Landscape as a Predictor of Wetland Condition: an Evaluation of the Landscape Development Index (LDI) with a Large Reference Wetland Dataset from Ohio.” *Environmental Monitoring and Assessment*, (Volume 120), pp. 221-241.

Mack, J.J. and M. Micacchion. 2007. *An Ecological and Functional Assessment of Urban Wetlands in Central Ohio. Volume 1: Condition of Urban Wetlands Using Rapid (level 2) and Intensive (level 3) Assessment Methods.* Ohio EPA Technical Report WET/2007-3A. Ohio Environmental Protection Agency, Wetland Ecology Group, Division of Surface Water, Columbus, Ohio.

Milter, Robert. Dale White, and Chris Yoder. 2004. “The Biotic Integrity of Streams in Urban and Suburbanizing Landscapes.” *Landscape and Urban Planning*, (Volume 69 2004), pp. 87-100.

Mitsch, W. and J. Gosselink. 2000. “The Value of Wetlands: Importance of Scale and Landscape Setting, in Special Issue, The Values of Wetlands: Landscape and Institutional Perspectives.” *Ecological Economics,* (Volume 35 2000), pp. 25-33.

Mitsch, W.J. and J.G. Gosselink. 2000. *Wetlands*. 3rd Edition. John Wiley & Sons, Inc., New York.

National Research Council. 1995. *Wetlands: Characteristics and Boundaries.* National Academy Press, Washington, D.C. 306 p.
National Wetlands Inventory (NWI) [GIS database], U.S. Fish and Wildlife Service, Updated by Ducks Unlimited, Inc., 2006-2007.

Network, Watershed Professionals. *Oregon Watershed Assessment Manual Component II Historical Conditions Assessment. June 1999.* Prepared for the Governor’s Watershed Enhancement Board. Salem, Oregon, 1999.

Novitski, R. 1979. “Hydrologic Characteristics of Wisconsin’s Wetlands and their Influence on Floods, Stream Flow, and Sediment, in Wetland Functions and Values: The State of Our Understanding.” in P.E. Greeson, J.R. Clark, eds, *American Water Resources Association*, Minneapolis, MN, pp. 377-388.

Oberts, G.L. 1981. “Impacts of Wetlands on Watershed Water Quality.” pp. 213-226 in B. Richardson (ed.), *Selected Proceedings of the Midwest Conference on Wetland Values and Management.* Freshwater Society, Navarre, Minnesota.

Ohio Statewide Imagery Program (OSIP). 2006-2007. Ohio Office of Information Technology, Ohio Geographically Referenced Information Program (OGRIP). http://ogrip.oit.ohio.gov/.

Rankin, Edward, T. 1989. *The Qualitative Habitat Evaluation Index [QHEI] Rationale, Methods, and Application*. Ohio Environmental Protection Agency, Div. of Water Quality Planning and Assessment. Columbus, Ohio.

Schoonover, J.E.; Lockaby, B.G.; Pan, S. 2005. Changes in chemical and physical properties of stream water across an urban-rural gradient in western Georgia. Urban Ecosystems. 8: 107–124.

Schueler, Thomas R., 2003. "Impacts of Impervious Cover on Aquatic Systems." *Watershed Protection Research Monogram* (Volume 1). Ellicot City, MD. Center for Watershed Protection.

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Soil surveys for each Ohio County available online from http://soildatamart.nrcs.usda.gov/Survey.aspx?State=OH [Accessed 2009].

Tonderski, K.S., B. Arheimer, and C.B. Pers. 2005. "Modeling the Impact of Potential Wetlands on Phosphorus Retention in a Swedish Catchment." *Ambio,* (Volume 34), pp. 544-551.

US EPA, 2007. *An Approach for Using Load Duration Curves in the Development of TMDLs.* EPA 841-B-07-006.

Ohio EPA. 1999. *Association Between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams.* Ohio Environmental Protection Agency Technical Bulletin. MAS/1999-1-1. Columbus, OH. http://epa.ohio.gov/portals/35/guidance/assoc_load.pdf

Ohio Environmental Protection Agency. 2008b. *2008 updates to Biological Criteria for the Protection of Aquatic Life: Volume III. Standardized Biological Field Sampling and Laboratory Methods for Assessing Fish and Macroinvertebrate communities.* Div. of Surface Water, Ecol. Assess. Sect., Columbus, Ohio.
Ohio EPA, 2012. *Surface Water Field Sampling Manual*, Draft Version 4.0
Ohio Environmental Protection Agency. 2012. *Biological and Water Quality Survey of the Middle Scioto River and Select Tributaries 2010: Delaware, Franklin, Pickaway, and Union Counties. November 2012.* OEPA Report DSW/EAS 2012-1-1. Division of Surface Water, Columbus, Ohio.

Whigham, D., C. Chittering, and B. Palmer. 1998. "Impacts of Freshwater Wetlands on Water Quality: a Landscape Perspective." *Environmental Management*. (Volume 12 Issue 5) pp. 663-671.

Wright, Tiffany, Jennifer Tomlinson, Tom Schueler, Karen Cappiella, Anne Kitchell, and Dave Hirschman. 2006. "Direct and Indirect Impacts of Urbanization on Wetland Quality." *Wetlands and Watersheds* Article #1. Center for Watershed Protection, Ellicot City, MD.

U.S. Census of Population and Housing, 1990: *Summary Population and Housing Characteristics: Ohio*. Washington: Government Printing Office, 1992.

U.S. Census of Population and Housing, 2000: *Summary Population and Housing Characteristics: Ohio*. Washington: Government Printing Office, 2003.

U.S. Environmental Protection Agency. 1995. *America's Wetlands: Our Vital Link Between Land and Water*, Office of Water, Office of Wetlands, Oceans and Watersheds. EPA843-K-95-001.

U.S. Environmental Protection Agency. 2006. *Wetlands: Protection for Life and Property from Flooding*. Office of Water, Report EPA843-F-06-001.

U.S. Geological Survey. 1984 *Discharge Ratings at Gaging Stations.* TWRI 3-A10.

U.S. Geological Survey. Digital 1:24,000 *Topographic Maps for Ohio*, multiple dates.

U.S. Geologic Survey. 2012. Fact Sheet 2012-3020. February 2012. http://pubs.usgs.gov/fs/2012/3020/fs2012-3020.pdf.

Vogelmann, J.E., S.M. Howard, L. Yang, C. R. Larson, B. K. Wylie, and J. N. Van Driel, 2001, "Completion of the 1990's National Land Cover Data Set for the conterminous United States," *Photogrammetric Engineering and Remote Sensing,* (Volume 67), pp. 650-662.

Wang N. and W. J. Mitsch. 1998. "Estimating Phosphorus Retention of Existing Wetlands in a Tributary Watershed of the Laurentian Great Lakes in Michigan, USA," *Wetlands Ecol. Manag.* (Volume 6), pp 69-82.

Xian, G., Homer, C., Dewitz, J., Fry, J., Hossain, N., and Wickham, J., 2011. "The Change of Impervious Surface Area Between 2001 and 2006 in the Conterminous United States." *Photogrammetric Engineering and Remote Sensing*, (Volume 77 Issue 8), pp. 758-762.

Yang L, Huang C, Homer C, Wylie B, and Coan M. 2003. "An Approach for Mapping Large-area Impervious Surfaces: Synergistic Use of Landsat 7 ETM+ and High Spatial Resolution Imagery." *Canadian Journal of Remote Sensing,* (Volume 29), pp. 230-240.

Yoder, CD. White. 2000. "Using Biological Criteria to Assess and Classify Urban Streams and Develop Improved Landscape Indicators," pp.32-44 in S. Minamyer, J. Dye, and S. Wilson (eds.), *National Conference on Tools for Urban Water Resource Management and Protection.* U.S. EPA, Office of Research and Development, Cincinnati, Ohio. EPA/625/R-00/001.

Zielinski, Jennifer. 2002. *Watershed Vulnerability Analysis.* Center for Watershed Protection.

Tables

Table 1. 1992 National Land Cover Dataset (NLCD) Land Use Categories (Vogelmann et.al., 2001) and corresponding Landscape Development Intensity (LDI) Coefficients (*derived from* Brown and Vivas, 2005).

Land Use Category	LDI Coefficient
11 (Open Water)	1.00
21 (Low Intensity Residential)	7.47
22 (High Intensity Residential)	7.55
23 (Commercial/Industrial/Transportation)	9.42
31 (Bare Rock/Sand/Clay)	8.32
32 (Quarries/Strip Mines/Gravel Pits)	8.32
33 (Transitional)	8.32
41 (Deciduous Forest)	1.00
42 (Evergreen Forest)	1.00
43 (Mixed Forest)	1.00
52 (Shrub/Scrub)	2.02
71 (Grassland/Herbaceous)	3.41
81 (Pasture)	3.74
82 (Row Crops)	4.54
85 (Urban/Recreational Grasses)	6.92
91 (Woody Wetlands)	1.00
92 (Emergent Wetlands)	1.00

Table 2. 2001 and 2006 National Land Cover Dataset (NLCD) Land Use Categories (Homer et al., 2004; Fry et. al., 2011) and corresponding Landscape Development Intensity (LDI) Coefficients (*derived from* Brown and Vivas, 2005).

Landuse Category	LDI Coefficient
11 (Open Water)	1.00
21 (Developed, Open Space)	6.92
22 (Developed, Low Intensity)	7.47
23 (Developed, Medium Intensity)	7.55
24 (Developed, High Intensity)	9.42
31 (Barren Land)	8.32
41 (Deciduous Forest)	1.00
42 (Evergreen Forest)	1.00
43 (Mixed Forest)	1.00
52 (Shrub/Scrub)	2.02
71 (Grassland/Herbaceous)	3.41
81 (Pasture/Hay)	3.74
82 (Cultivated Crops)	4.54
90 (Woody Wetlands)	1.00
95 (Emergent Herbaceous Wetlands)	1.00

Table 3. Ecological Attributes of Existing Wetlands in the Scioto Big Run watershed ranked by ORAM score

Wetland name	Acres (HA)	Drainage Area	HGM Class/ Plant community Class	JD/Iso[1]	ORAM	Category	Hydroperiod (from ORAM)[2]	Nutrient loading (qualitative determination from ORAM scoring sheet)[3]
Dispatch-emergent	0.09 (.03) 0.126 (.05)[4]	0.2 0.13	IC (Depression - Regular)/ 2A (EM - Marsh)	ISO	19 20	1	Seasonal inundation	Yes Source unspecified
Bolton Field	2.46 (.995)	5.2	IA (Depression – Permanent)/ 1A (FO- Swamp)	ISO	21	1	Seasonal inundation	Yes Farming, nutrient enrichment
I-270 Marsh	0.322 (.130)	3.7	IB (Depression - Regular)/ 2A (EM - Marsh)	ISO	26.5	1	Semi/Perm. Regular	Yes Source unspecified
Norton Road - East	0.933 (.378)	133.6	IC (Depression – Regular)/ 2A (EM - Marsh)	ISO	29	1	Seasonal inundation	Yes Algal mats
Big Run Quarry	0.23 (.093)	4.0	IC (Depression – Regular)/ 1A (FO- Swamp)	ISO	32	2 (grey zone)	Seasonal saturation	No
Norton Rd. West	0.888 (.359)	14.0	IC (Depression - Regular)/ 1A (FO- Swamp) (2A/3A secondary)	ISO	34	2 (grey zone)	Seasonal inundation	Yes carwash
Dispatch-forested	1.39 (.562)	4.0	IC (Depression - Regular)/ 1A (FO- Swamp)	ISO	35	2 mod.	Seasonal inundation	Yes Source unspecified
Big Run Dugout	0.35 (0.14)	32.5	IB (Depression - Regular)/ 2A (EM – Marsh)	JD	36	2 Mod.	Regular	Yes Storm water inputs
Raccoon Creek Apartments	0.51 (.206)	30.1	IIIB (Slope- Regular)/ 2B (EM – Wet Meadow)	ISO	46.5	2	Regular/Seasonal Inundation	Yes Stormwater from parking lot
Big Run Vernal Pool	0.275 (.111)	3.0	IC (Depression - Regular)/ 1A (FO- Swamp)	ISO	51.5	2	Regular	Yes Source unspecified
	7.574 (3.065)				31.9[5]			

1 Jurisdictional or isolated determination made on basis of interpretation of aerial mapping and site visit. No formal determination by U.S. Army Corps of Engineers personnel was sought. (JD status used to determine whether a direct hydraulic connectivity to Scioto Big Run exists in conjunction with HGM class)
2 Literature review indicates that fluctuating water level is an important criterion for a wetland to perform denitrification.
3 Provides insights whether the wetland has the opportunity (or potential) to reduce nutrient loading to Scioto Big Run in the absence of actual field measurements of nutrient loading reductions.
4 Due to small size and proximity to each other- these wetlands were considered a single unit for the purpose of this analysis.
5 Mean ORAM score of 31.9 (modified Category 2 wetland).

Table 4. Scioto Big Run Historic Macroinvertebrate Sampling Results

River Mile	Date Sampled	Drainage Area (sq mi)	QHEI	Narrative Criteria	Comments from field sheets
1.8	10/23/1992	18.4	61	F	Soft substrate,
1.8	10/1/2007	17.6		MG^{ns}	Municipal runoff, flow velocity
2.7	10/1/2007	17.6	64.5	HF	Embedded and compacted substrate
2.9	10/23/1992	17.6	71	P	CSOs?, embedded substrates
2.9	7/9/2010	17.6	67.8	F	Embedded substrate
3.5	10/1/2007	14.3		VP	
3.7	10/1/2007	16.5	63.5	HF	Good habitat, hydrologic issues
4.4	7/9/2010	11.8	55	LF	Highly urbanized, smothered substrates, sewage, severe bank erosion
7.1	10/1/2007	5.8	73.5	MG^{ns}	Sewage fungus, urban runoff, historically channelized
8.4	10/10/2007	2.9	80.5	LF	CSOs?, runoff, flashy embedded chunk of grease, sewage runoff
10.9	9/12/2005	0.7	63.5		
10.8	9/19/2008	0.7	54.0	HF	
11.0	9/19/2008	0.7	40.5	LF	

Table 5: Scioto Big Run Historic Fish Sampling Results

River Mile	Date Sampled	Drainage Area (sq mi)	QHEI	IBI	Narrative Criteria	Attainment Status
1.9	10/21/1992	18.4	61	46	Fair	
2.0	9/13/2007	17.6		52	Mod good	Full
				(+6)		
2.8	1/21/1992	17.6	64.5	28	Poor	
2.8	8/30/2007	17.6	71	46	High fair	
2.9	8/6/2010	17.6	67.8	52	Fair	Partial
				(+24)		
3.5	10/13/1994	16.5	63.5	30	Very poor	
3.6	8/30/2007	16.5	48	34	High fair	Non??
				(+4)		
4.5	7/9/2010	11.8	55	48	Low fair	Partial
7.0	8/9/2007	5.8	73.5	44	Mod good	Full
8.5	8/30/2007	2.9	80.5	42	Low fair	Partial
10.9	9/12/2005	0.7	63.5	22		
10.8	9/19/2008	0.7	54.0	36	High fair?	Partial
11.0	9/19/2008	0.7	40.5	38	Low fair?	Partial
				(+16)		

Table 6. Various land use parameters, with mean and standard deviation values for all Ohio HUC12 watersheds, specific values for the Scioto Big Run HUC12 watershed, and whether or not the Scioto Big Run values are in the most disturbed 10% of all watersheds.

Parameter	Mean Score	Standard Deviation	Scioto Big Run Value	Upper 10th Percentile?
Percent Impervious Surface (2006)	3.33%	6.37%	29.38%	Yes
1992 LDI Index	3.36	1.09	5.66	Yes
2006 LDI Index	3.64	1.18	6.91	Yes
1992 to 2006 LDI Change	0.28	0.28	1.25	Yes
Percent Historic Forest	22.02%	18.77%	6.88%	No (8th)
Percent Forest Canopy (2001)	28.74%	22.61%	9.84%	No (8th)
Percent Forest Change	6.72%	8.78%	2.96%	No (6th)
Percent Historic Wetland	19.77%	20.35%	17.70%	No (5th)
Percent Existing Wetland	1.90%	3.03%	0.11%	Yes
Percent Wetland Loss	71.65%	34.00%	99.40%	Yes
1990 Population Density (per sq. mile)	266.59	642.39	2584.34	Yes
2000 Population Density	278.09	627.09	3314.18	Yes
1990 to 2000 Population Density Change	11.5	72.38	729.83	Yes

Table 7. Aquatic life use attainment status for Scioto Big Run stations based on data collected June - October 2009 and June – October 2010. The Index of Biotic Integrity (IBI), Modified Index of well-being (MIwb), and Invertebrate Community Index (ICI) are scores based on the performance of the biotic community. The Qualitative Habitat Evaluation Index (QHEI) is a measure of the ability of the physical habitat of the stream to support a biotic community. The Scioto River is located in the Eastern Corn Belt Plains (ECBP) ecoregion. If biological impairment has occurred, the cause(s) and source(s) of the impairment are noted. NA = not applicable.

Location	RM[a]	Drainage Area	IBI	MIwb[b]	ICI[c]	QHEI	Status[d]	Causes	Sources
Scioto Big Run at Big Run Road	(4.40)	11.8[H]	48[H]	N/A	LF*	55.8	**PARTIAL**	Organic enrichment (sewage) biological indicators	On-site treatment systems
Scioto Big Run at Hardy Parkway	(2.90)	17.6[H]	52[H]	N/A	F*	67.8	**PARTIAL**	Other flow regime alteration Particle distribution (embeddedness)	Municipal (urban high density area) Urban runoff/storm sewers

a River Mile (RM) represents the Point of Record (POR) for the station, not the actual sampling RM.

b MIwb is not applicable to headwater streams with drainage areas ≤ 20 mi^2.

c A narrative evaluation of the qualitative sample based on attributes such as EPT taxa richness, number of sensitive taxa, and community composition was used when quantitative data was not available or considered unreliable. VP=Very Poor, P=Poor, LF=Low Fair, F=Fair, MG=Marginally Good, G=Good, VG=Very Good, E=Exceptional

d Attainment is given for the proposed status when a change is recommended.

ns Nonsignificant departure from biocriteria (≤4 IBI or ICI units, or ≤0.5 MIwb units).

* Indicates significant departure from applicable biocriteria (>4 IBI or ICI units, or >0.5 MIwb units). Underlined scores are in the Poor or Very Poor range.

H Headwater site.

Table 8. Wetland Water Storage Calculations

Wetland Type	Acres	HGM Class/ Plant Community Class	Water Storage Capacity Based on Equations from Ohio EPA Acre-feet	MG
Existing Wetland Scenario				
Riverine wetlands	0.51	IIIA (Riverine-Headwater)/ 1 or 2A (EM – Marsh or Forest)	0.31	0.10
Depressional wetlands	7.064	IA (Depression – Permanent)/ 1A (FO- Swamp)	1.71	0.56
Total	**7.57**		**2.02**	**0.66**
Percent of flow represented by a 1.5" rain event[5] (84 MGD)				0.79% of flow
Percent of flow represented by a 3.5" rain event[5] (216 MGD)				0.31% of flow
Wetland Restoration Scenario				
Slope wetlands	150	IIIA (Riverine-Headwater)/ 1 or 2A (EM – Marsh or Forest)	159	52.0
Depressional wetlands	598	IA (Depression – Permanent)/ 1A (FO- Swamp)	61	19.9
Total	**748**		**220**	**71.8**
Percent of flow represented by a 1.5" rain event[5] (84 MGD)				85% of flow
Percent of flow represented by a 3.5" rain event[5] (216 MGD)				33% of flow

Figures

Figure 1. Scioto Big Run watershed in Franklin County, Ohio (HUC12 = 050600012301).

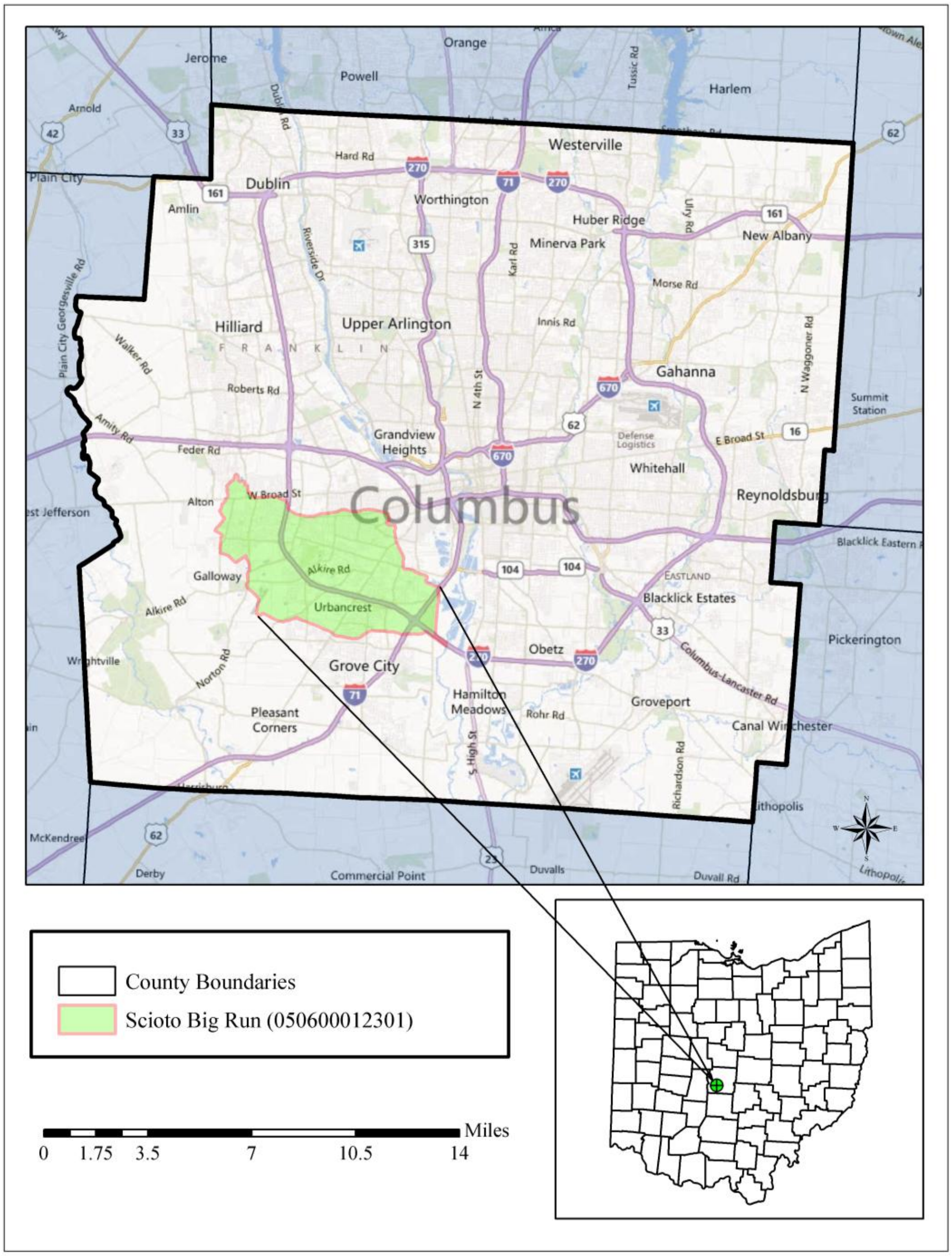


Figure 2. Hydrologic, water quality, and biological sampling locations by river mile along Scioto Big Run, Franklin County, Ohio.

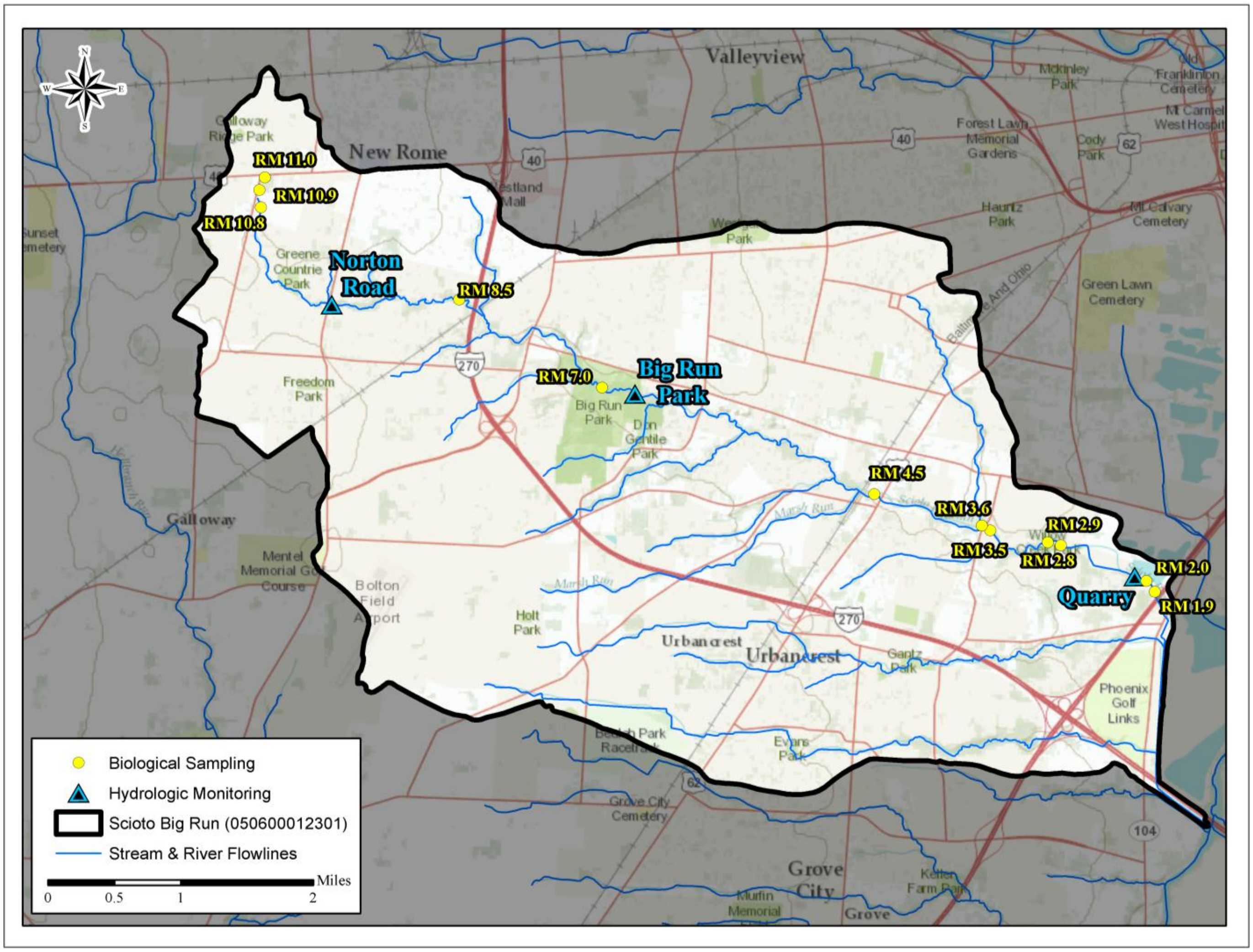


Figure 3. 2006 USGS National Land Cover Dataset for Scioto Big Run watershed, Franklin County, Ohio (HUC12 = 100600012301)

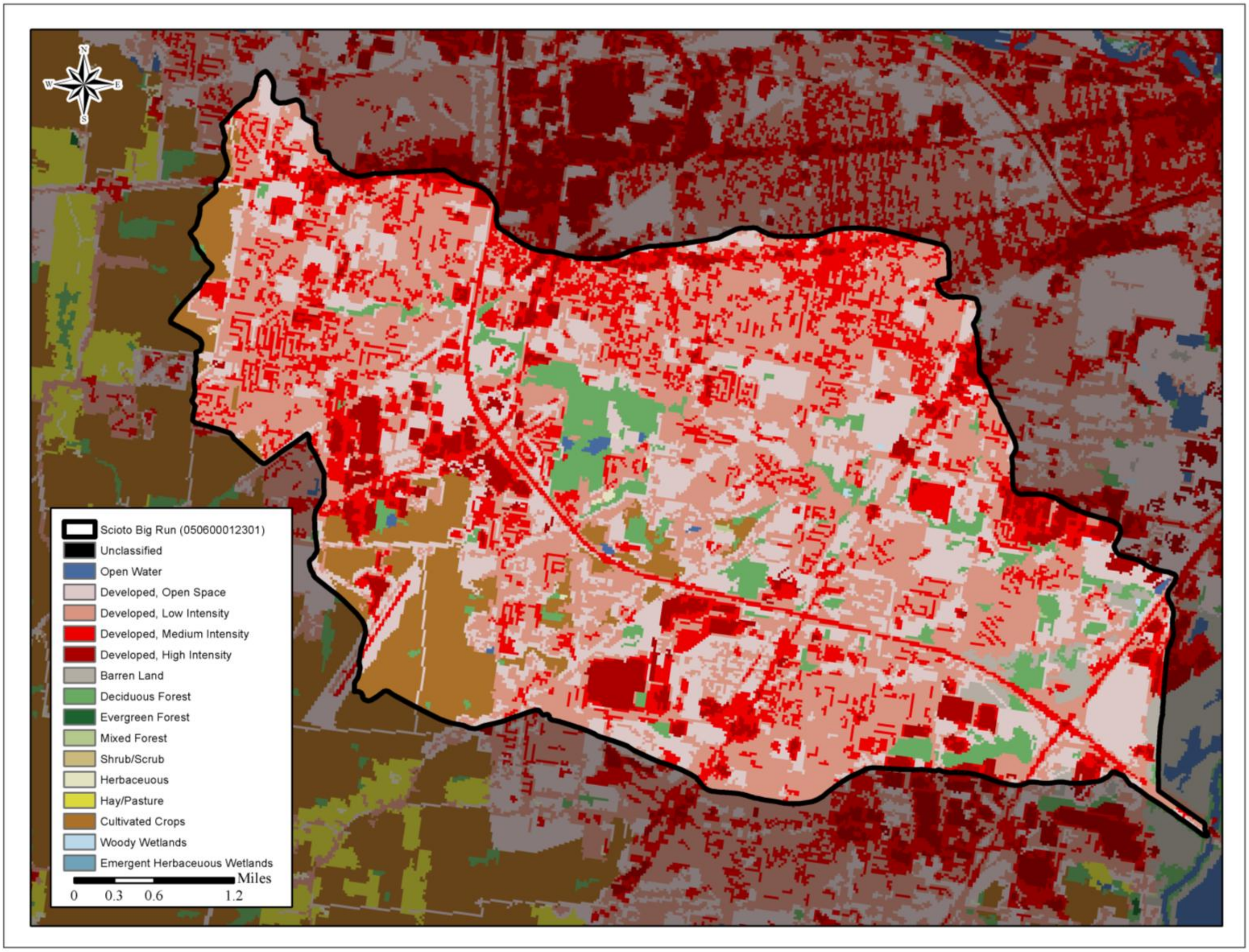


Figure 4. Location of NWI Wetlands in Scioto Big Run watershed

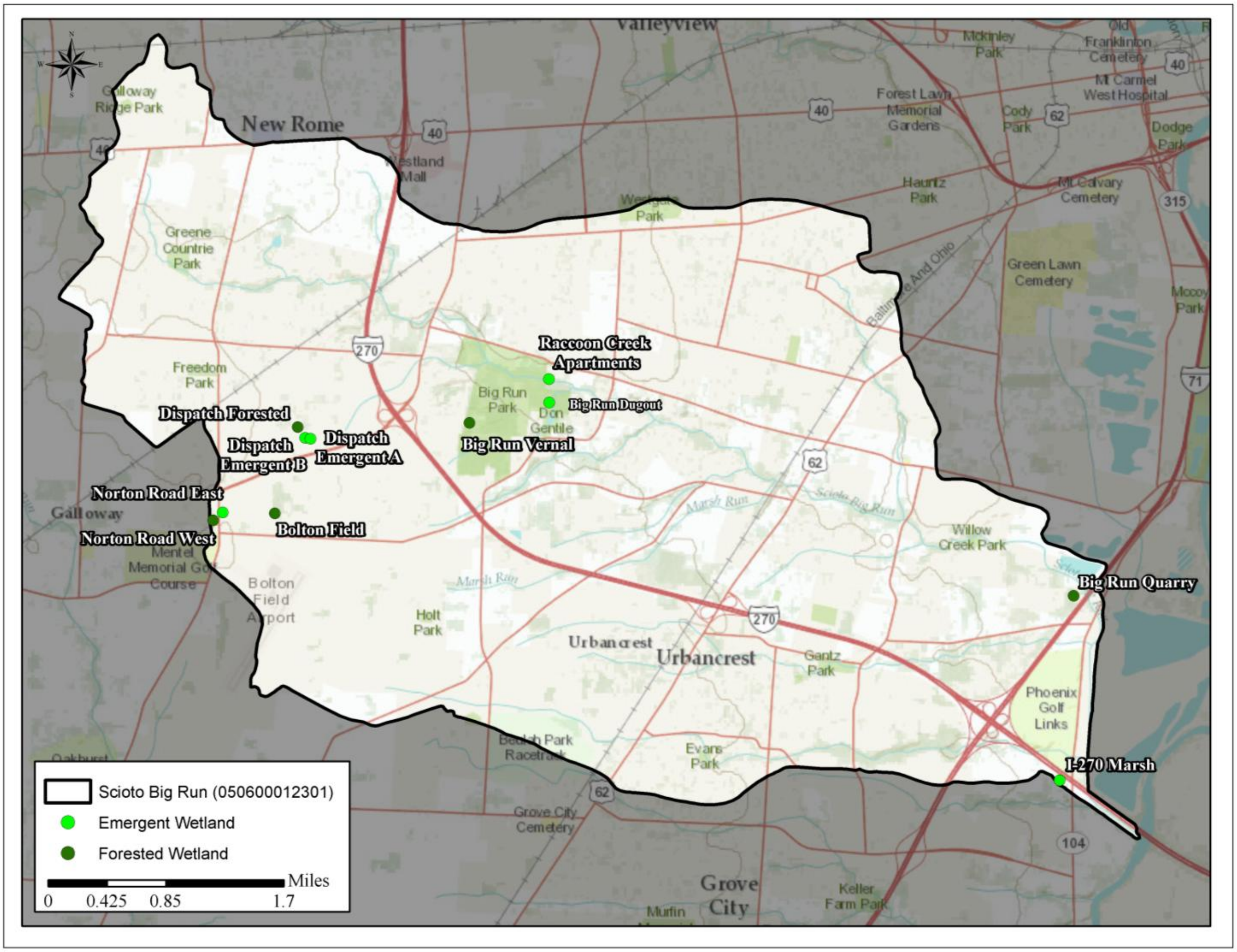


Figure 5. Percent Impervious Surface derived from the 2006 USGS National Land Cover Dataset for Scioto Big Run Watershed, Franklin County, Ohio (HUC12 = 050600012301).

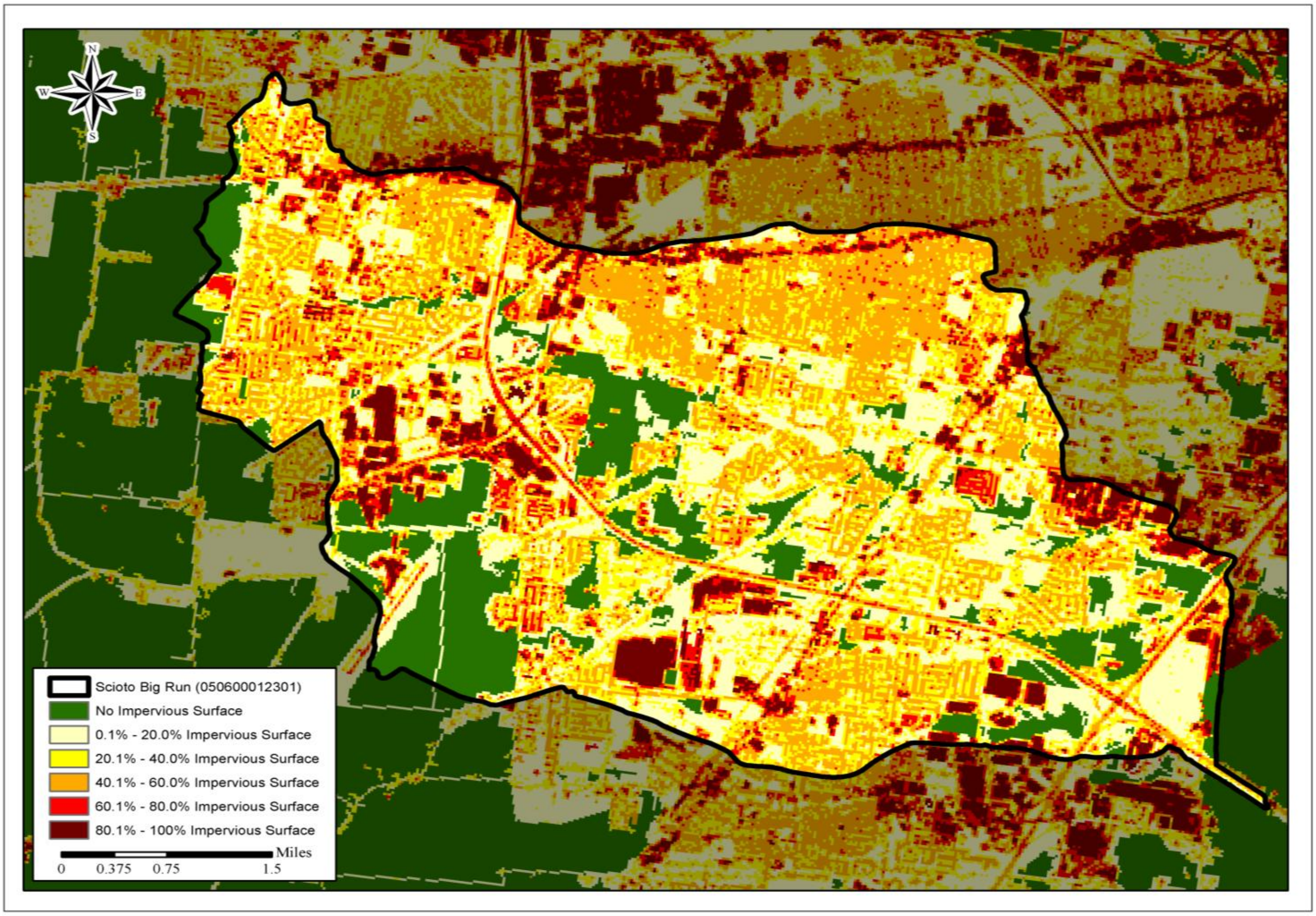


Figure 6. Percent Forest Canopy derived from the 2001 USGS National Land Cover Dataset for Scioto Big Run Watershed, Franklin County, Ohio (HUC12 = 050600012301).

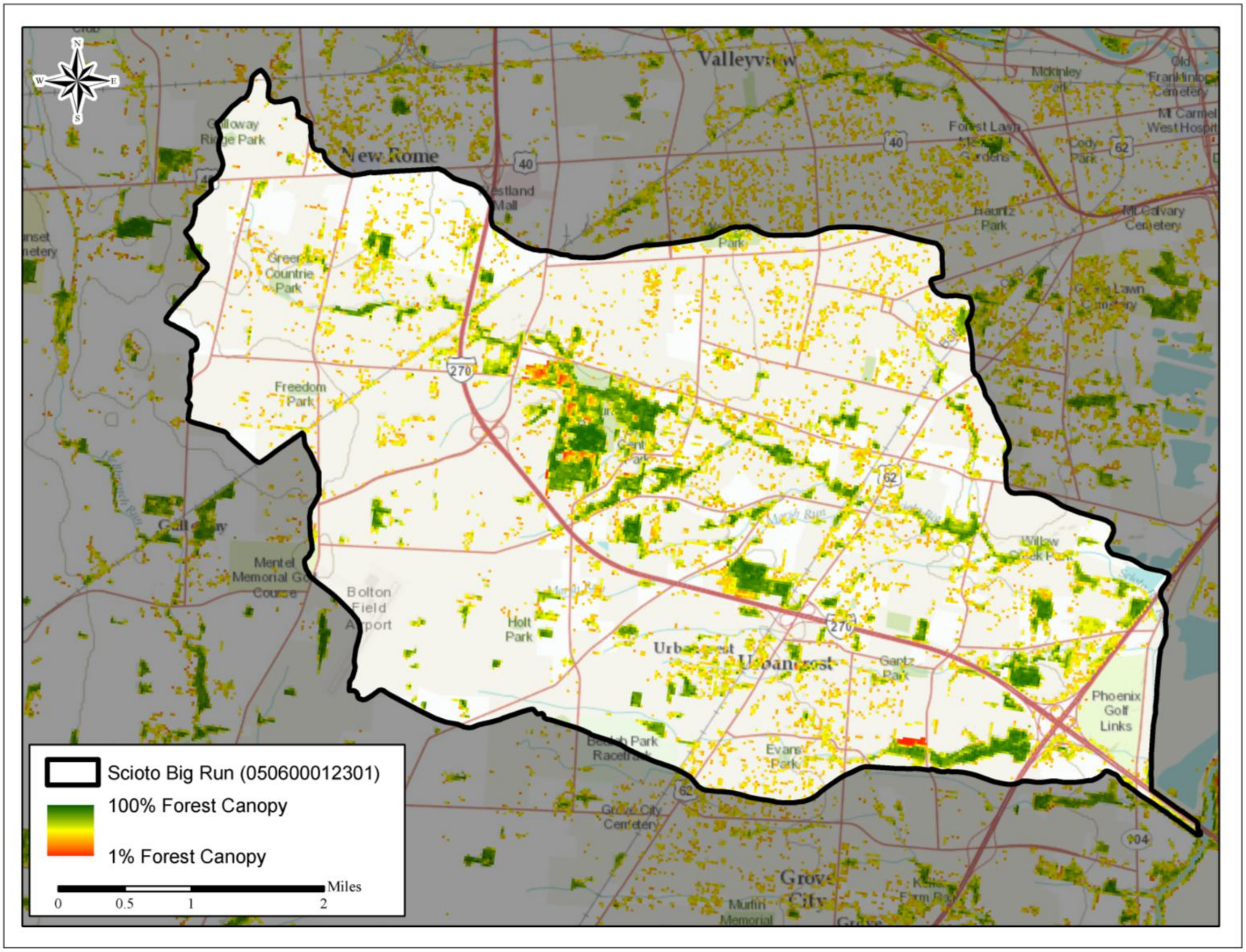


Figure 7. Percent Forest Canopy Derived from Digital USGS 1:24,000 Topographic Maps (DRGs) for Scioto Big Run Watershed, Franklin County, Ohio (HUC12 = 050600012301).

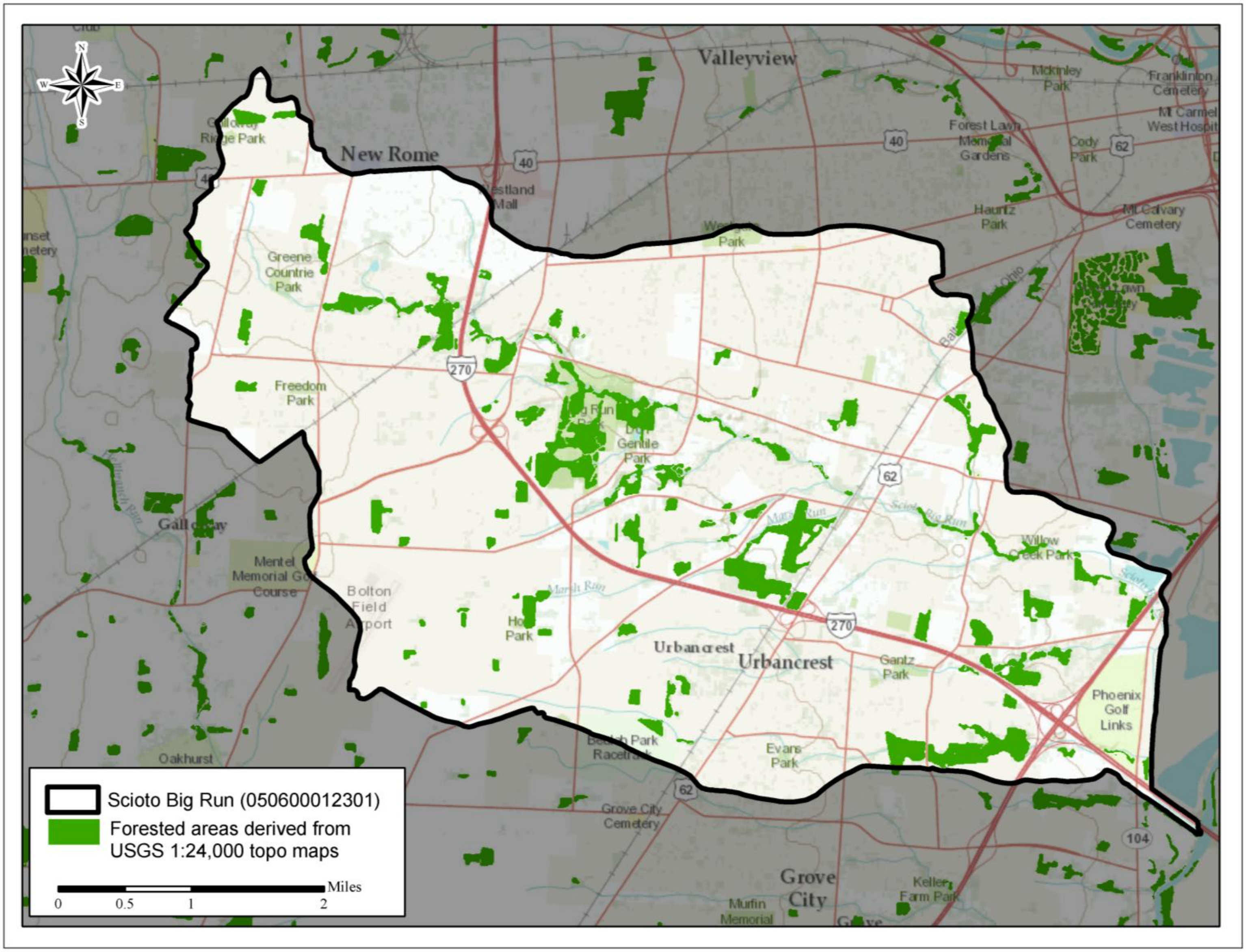


Figure 8. Density map of predicted home sewage treatment system failures in the Scioto Big Run Watershed (HUC12 = 050600012301).

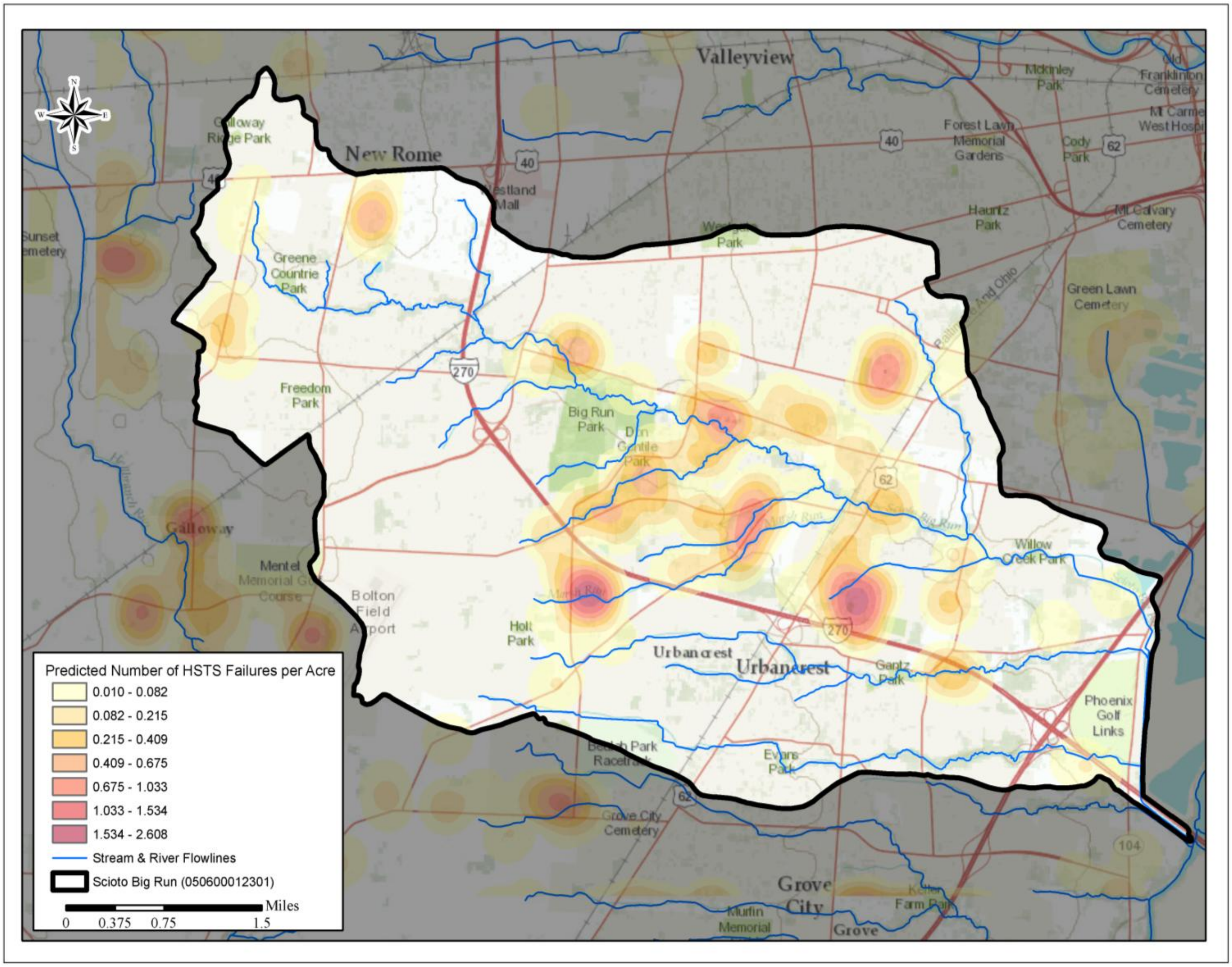


Figure 9. Box and whisker plots of mean ORAM scores for 293 natural wetlands in Ohio by ORAM anti-degradation category versus Scioto Big Run ORAM scores.

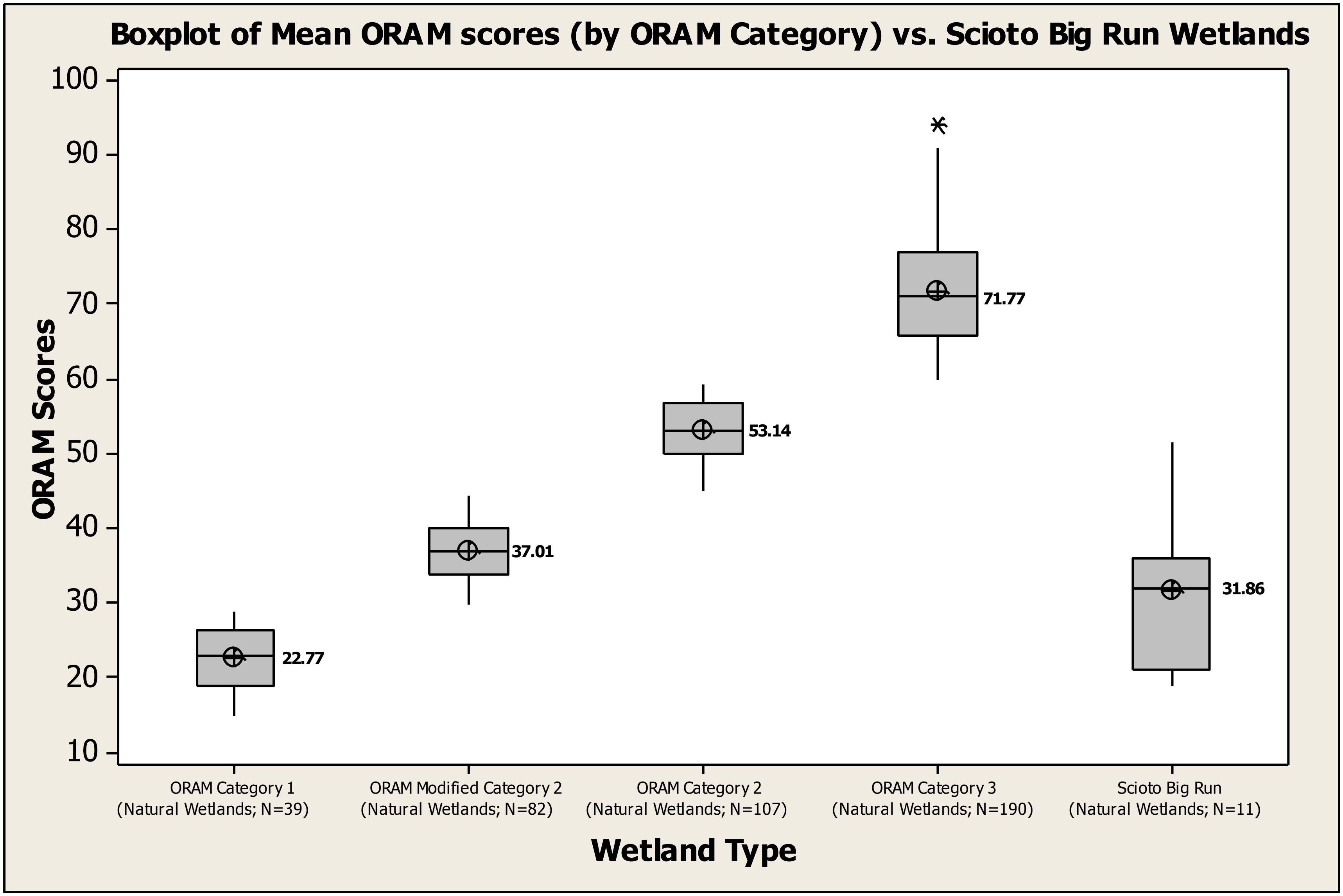


Figure 10. Box and whisker plots of mean ORAM scores for 293 natural wetlands in Ohio by LDI scores calculated for area within 100 meters of wetland boundary (organized into geometric interval tertiles) versus Scioto Big Run ORAM scores.

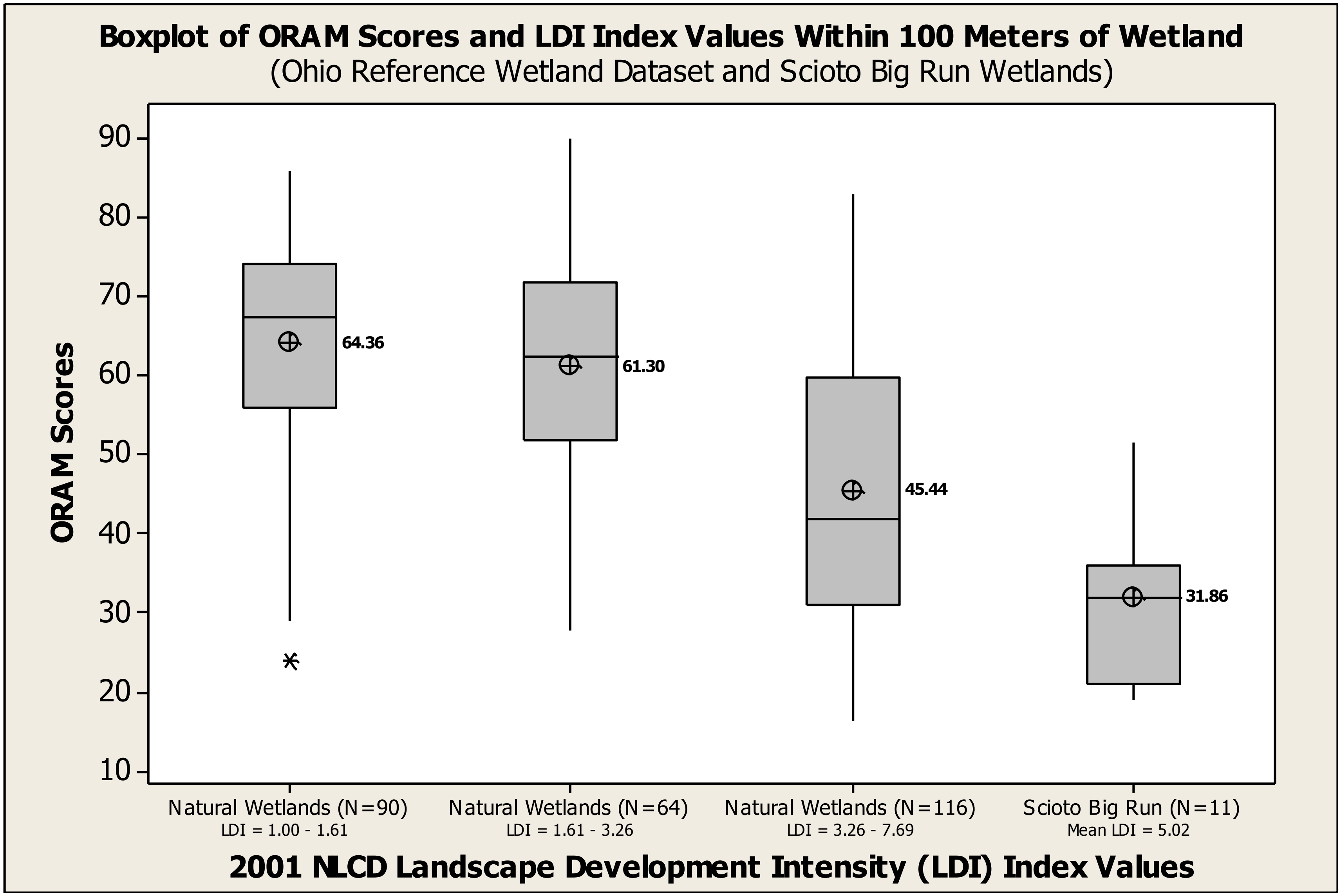


Figure 11. Box and whisker plots of mean ORAM scores for 293 natural wetlands in Ohio by LDI scores calculated for area from 100 meters to 350 meters of wetland boundary (organized into geometric interval tertiles) versus Scioto Big Run ORAM scores.

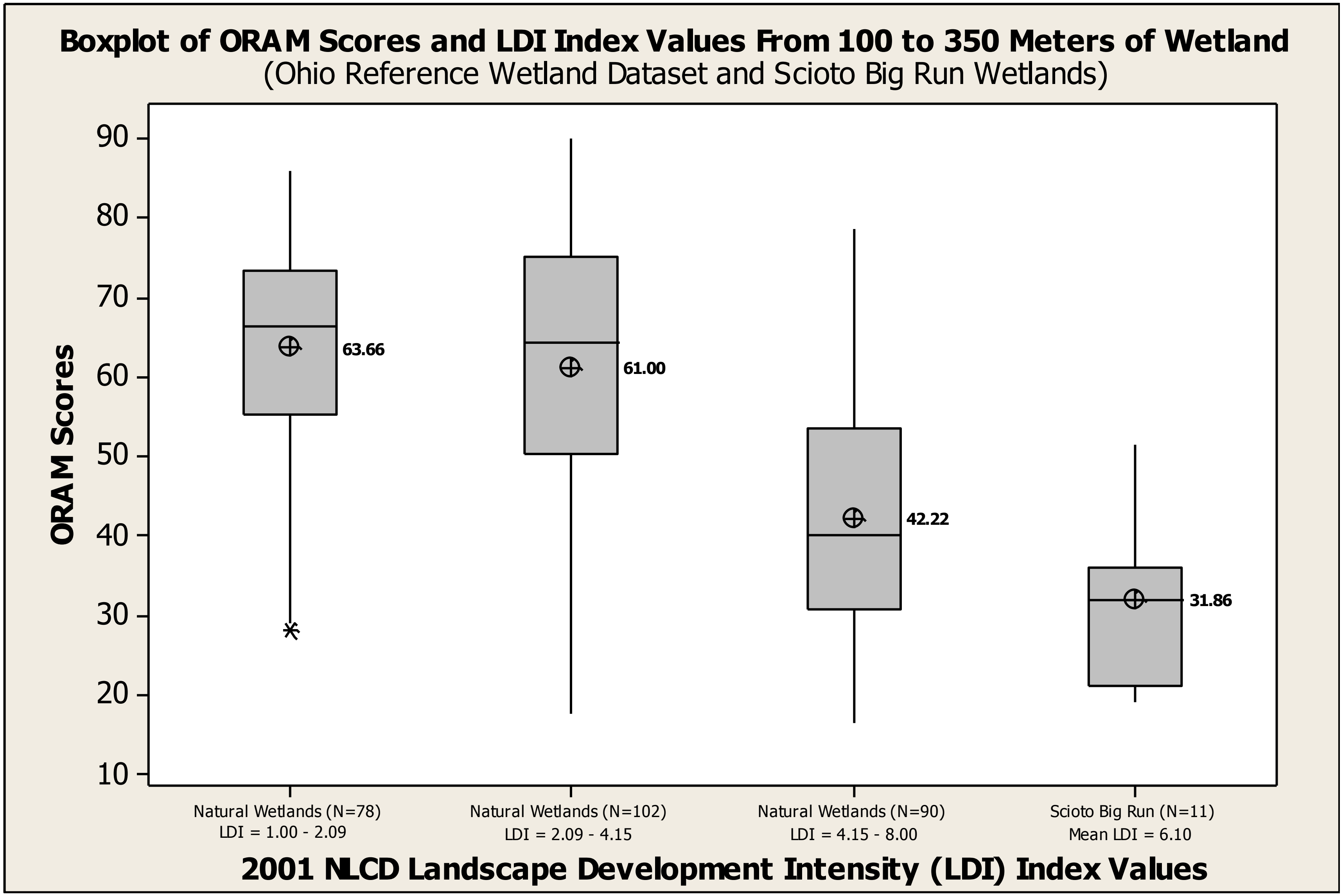


Figure 12. Partly and predominantly hydric NRCS SSURGO soil map units located in the Scioto Big Run Watershed in Franklin County, Ohio (HUC12 = 050600012301).

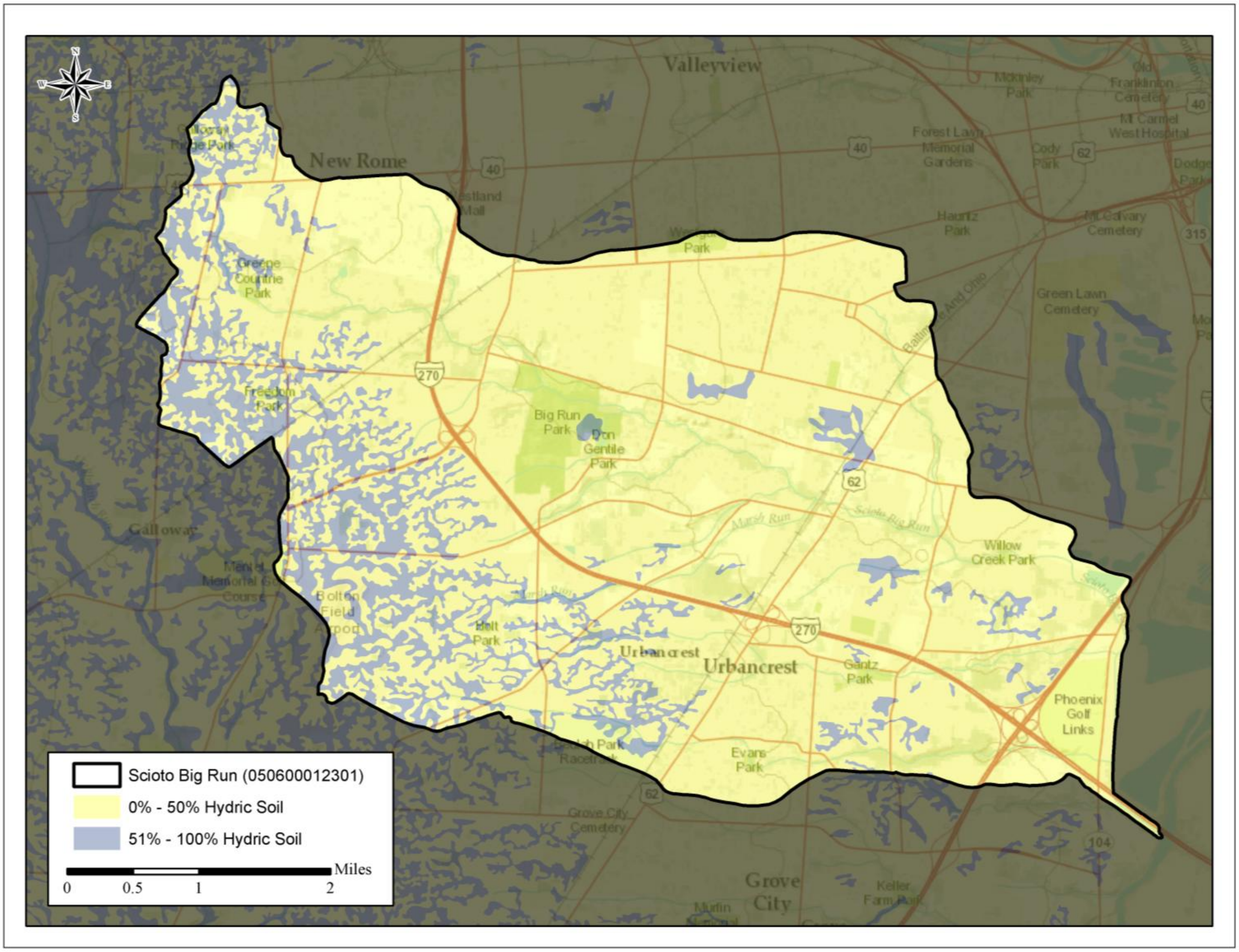


Figure 13. High probability wetland restoration locations: areas of the Scioto Big Run Watershed mapped as having predominantly hydric soil (NRCS SSURGO) and an agricultural land use (2006 USGS NLCD)

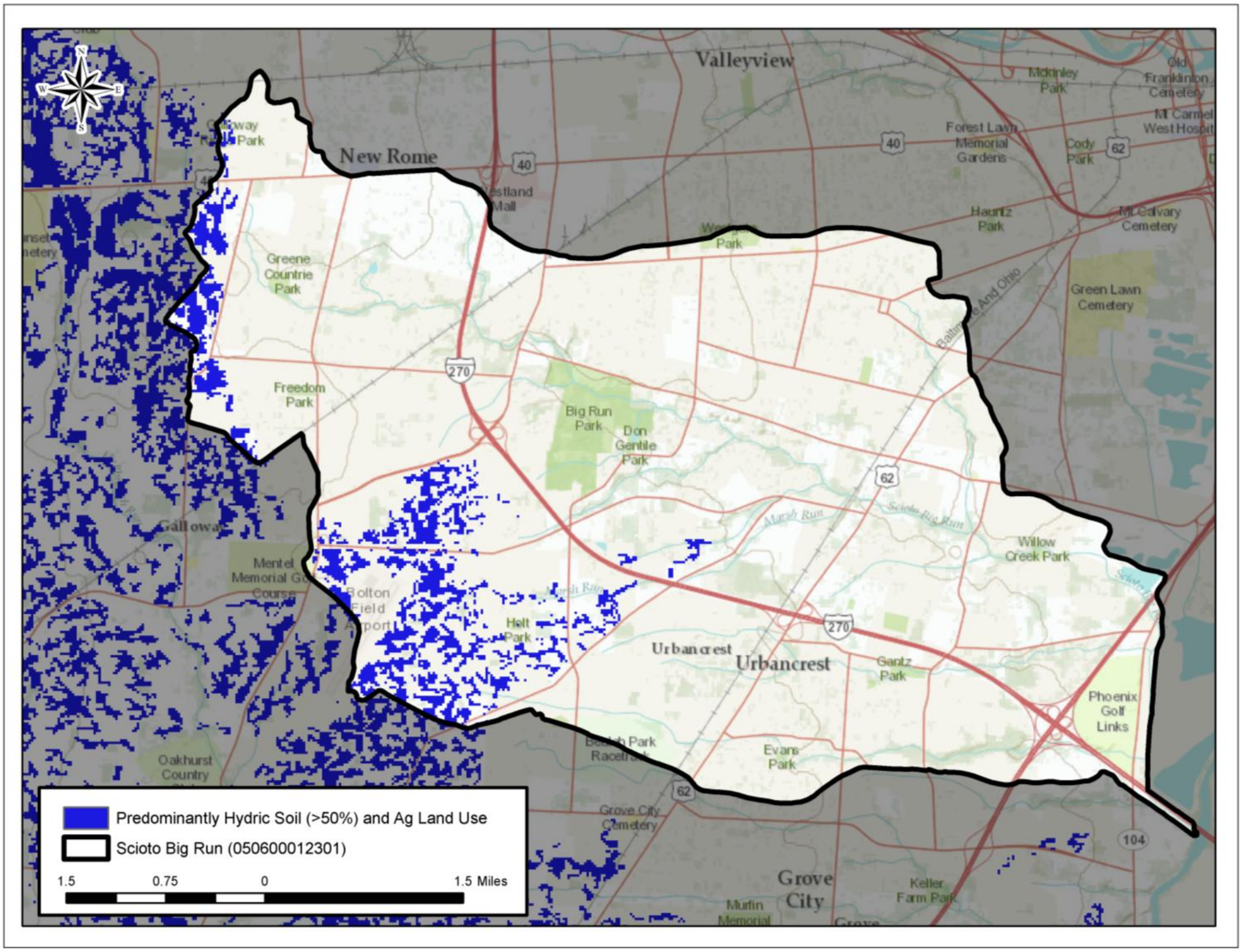


Figure 14. Alternate land use map of Scioto Big Run Watershed generated using ArcGIS 10.0 to perform a supervised classification on Ohio Statewide Imagery Program (OSIP) orthophotography from 2006.

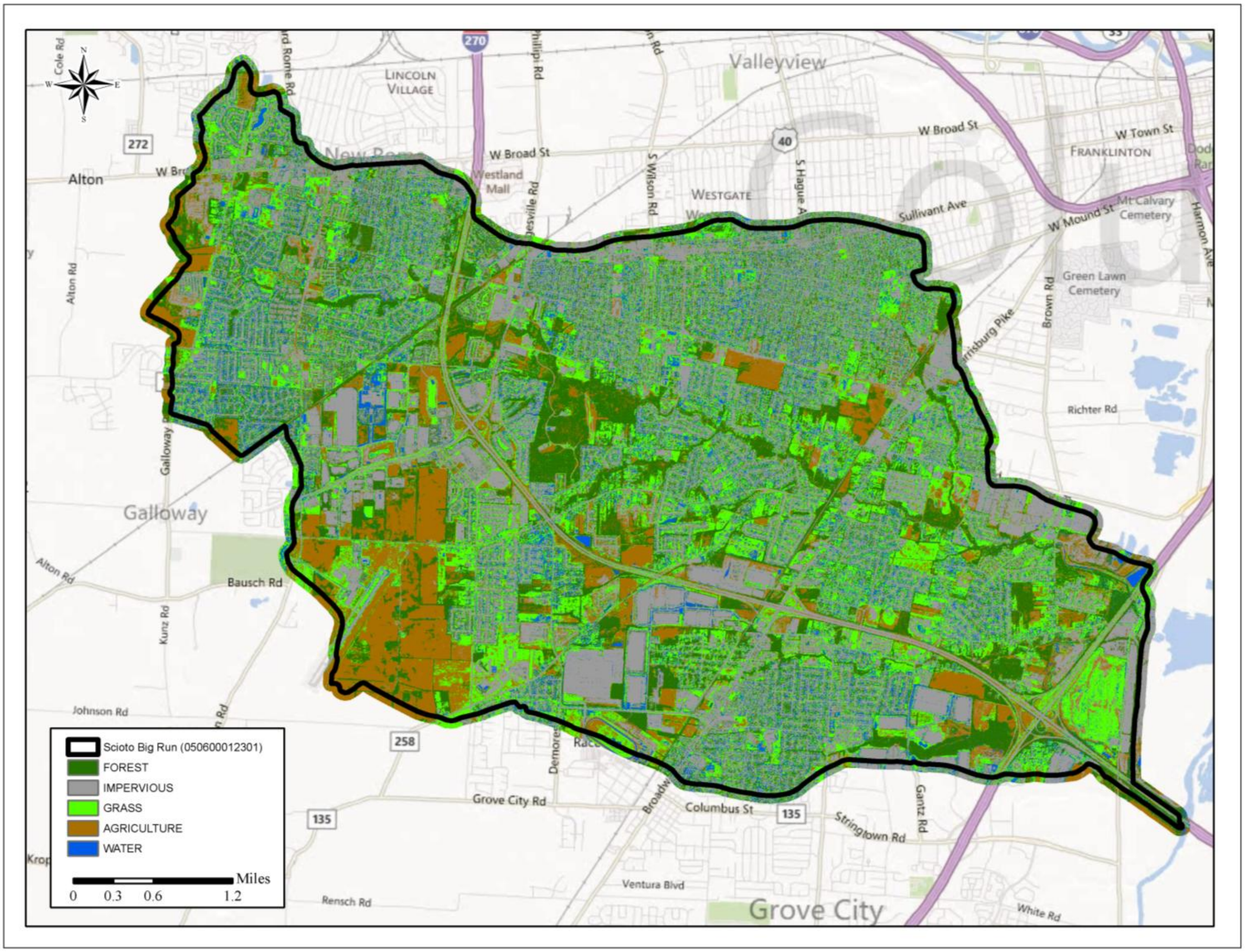


Figure 15. Random point locations (100) for testing accuracy of various land use layers in the Scioto Big Run Watershed.

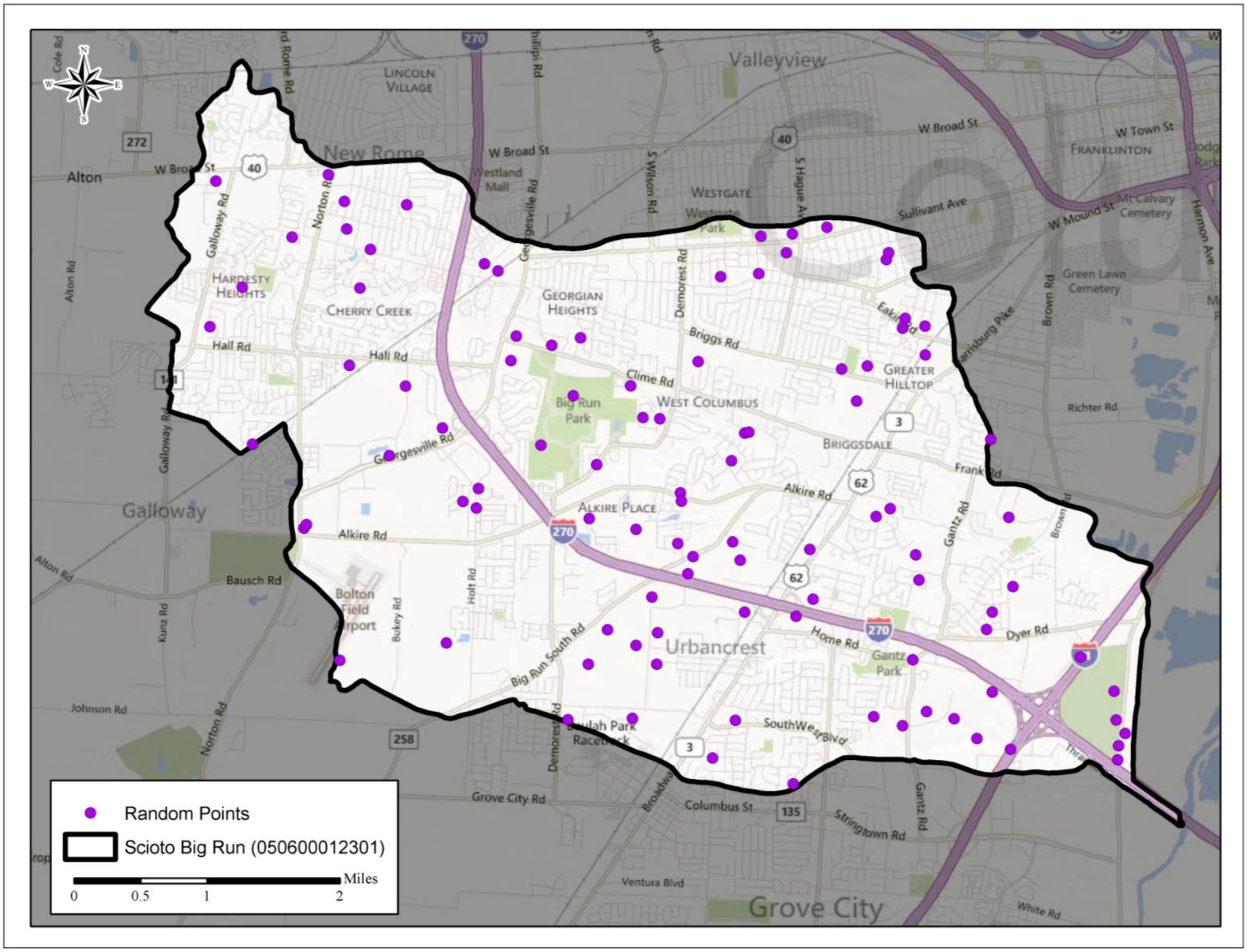


Figure 16. Simplified 2006 National Land Cover Dataset (NLCD) layer with all Anderson Level 2 classes assigned to one of five broad land use classes.

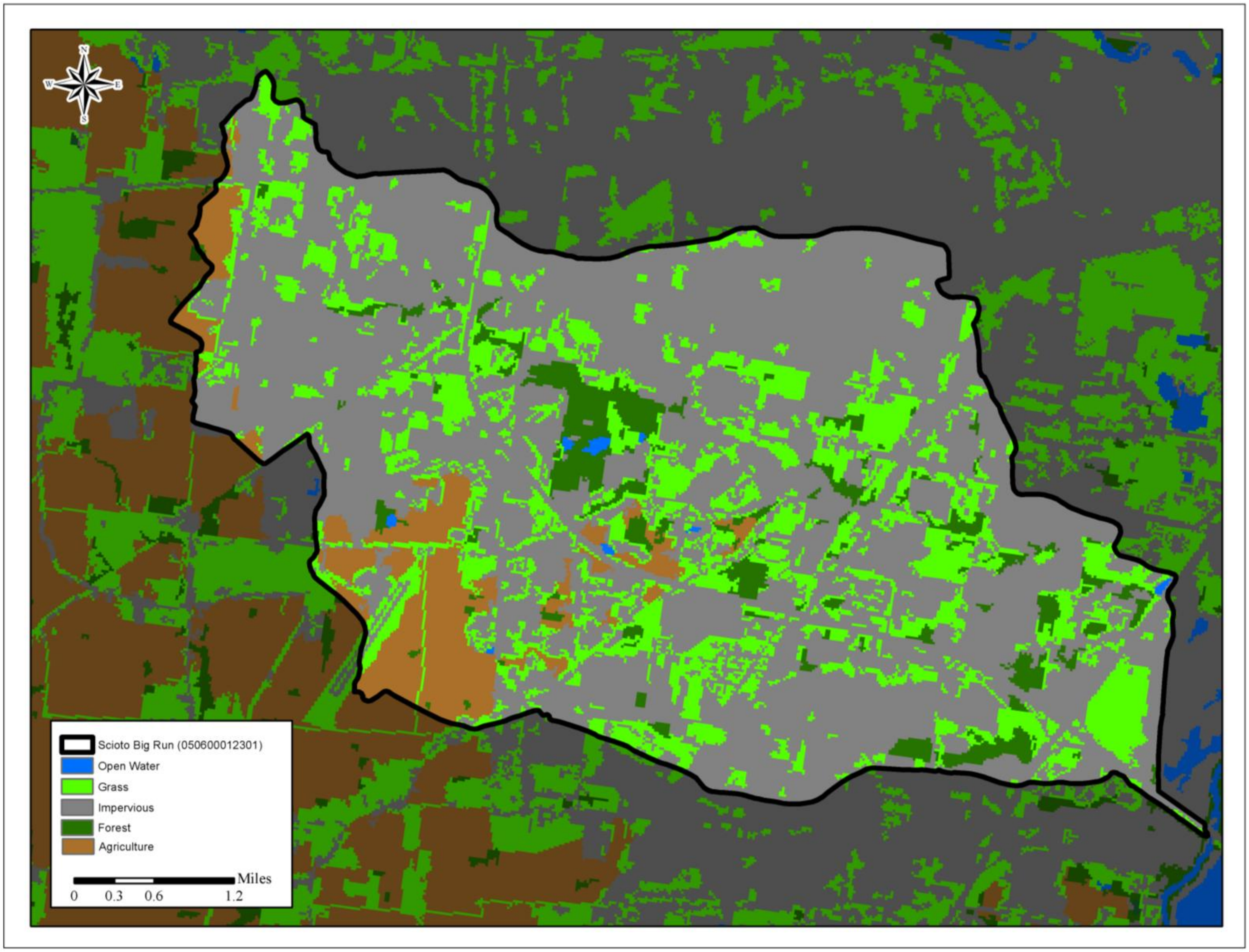


Figure 17. Alternate land use map of Scioto Big Run Watershed generated using ArcGIS 10.0 to perform an unsupervised classification on Ohio Statewide Imagery Program (OSIP) orthophotography from 2006.

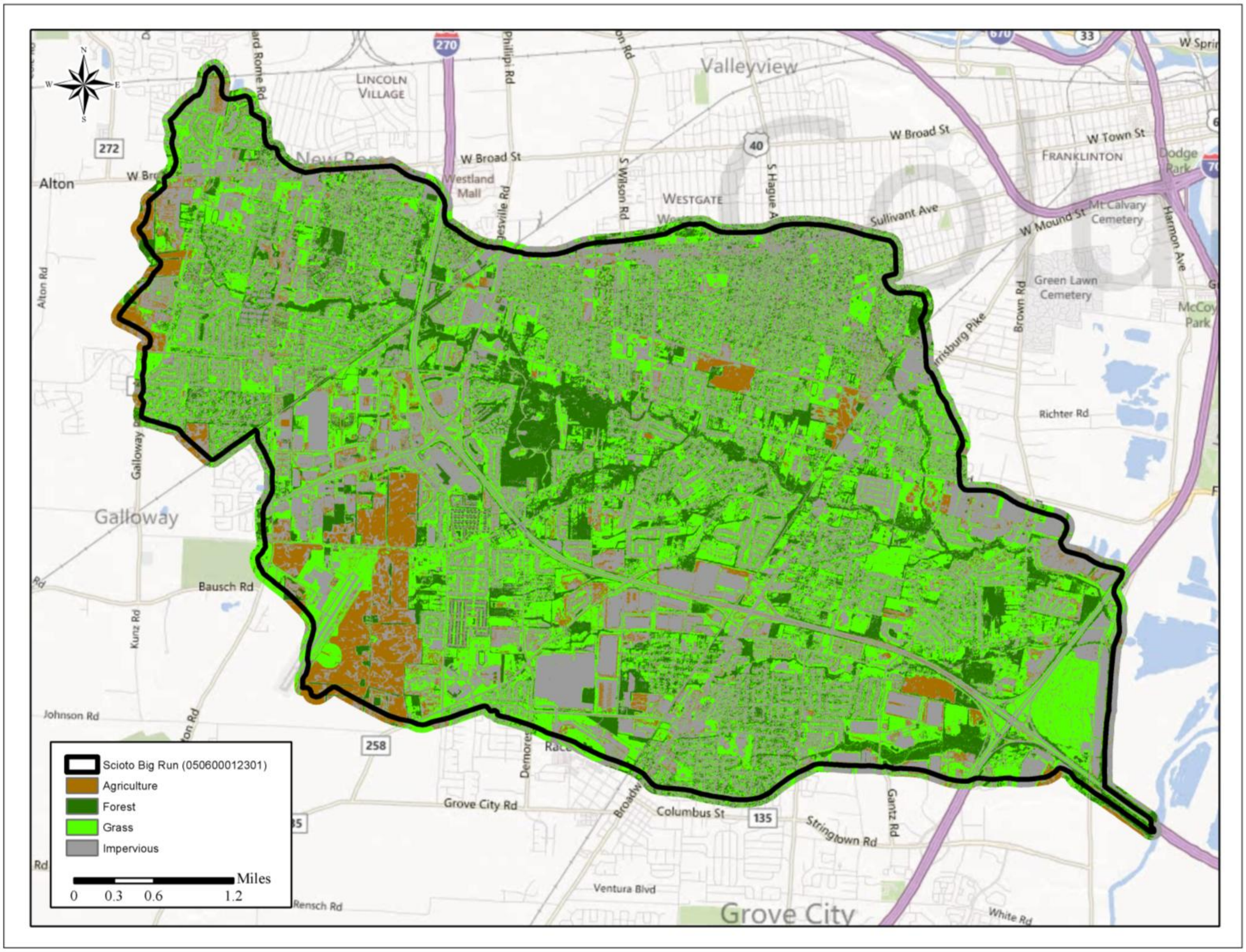


Figure 18. SPOT imagery of Scioto Big Run Watershed before being processed using MultiSpec to develop an alternate landuse map.

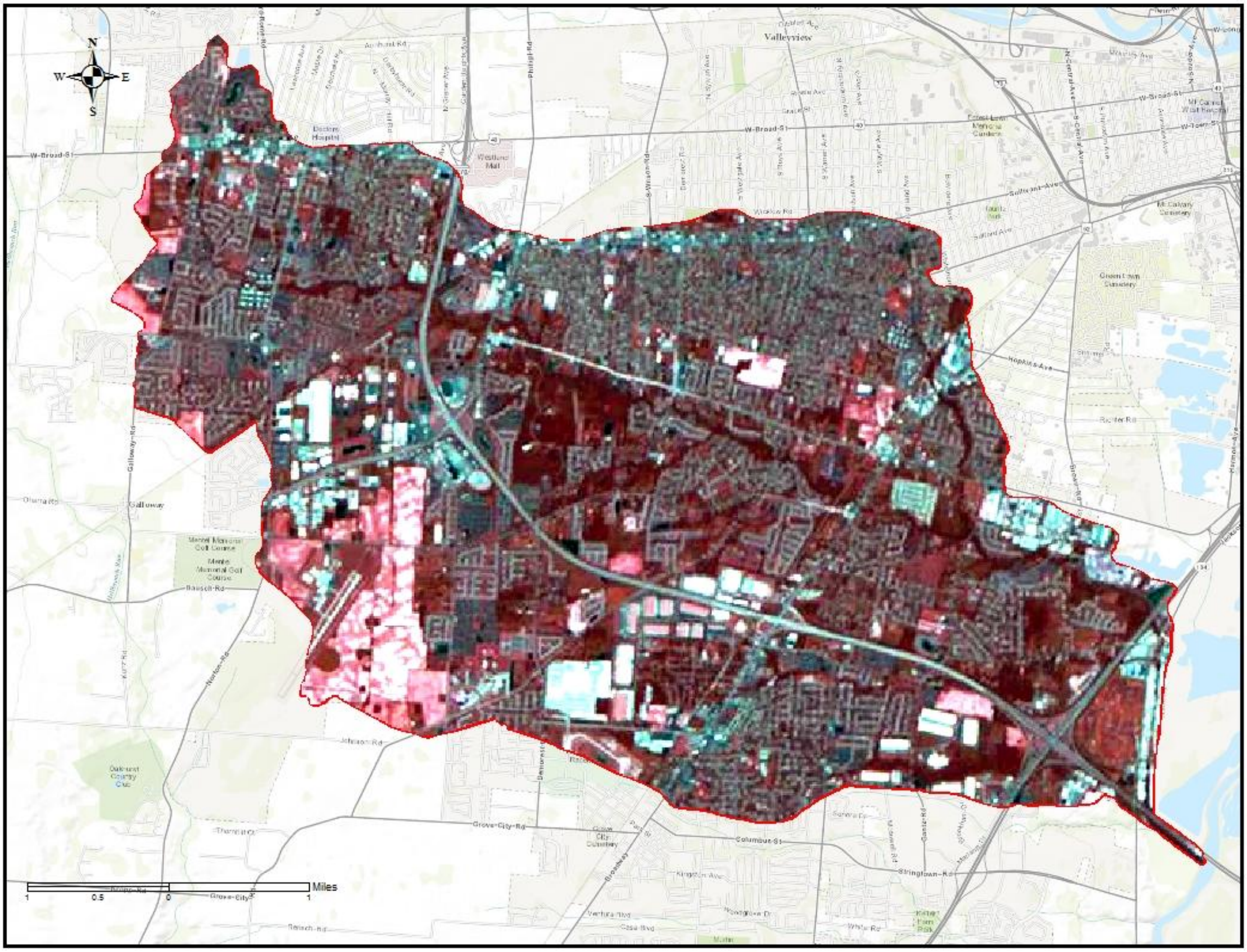
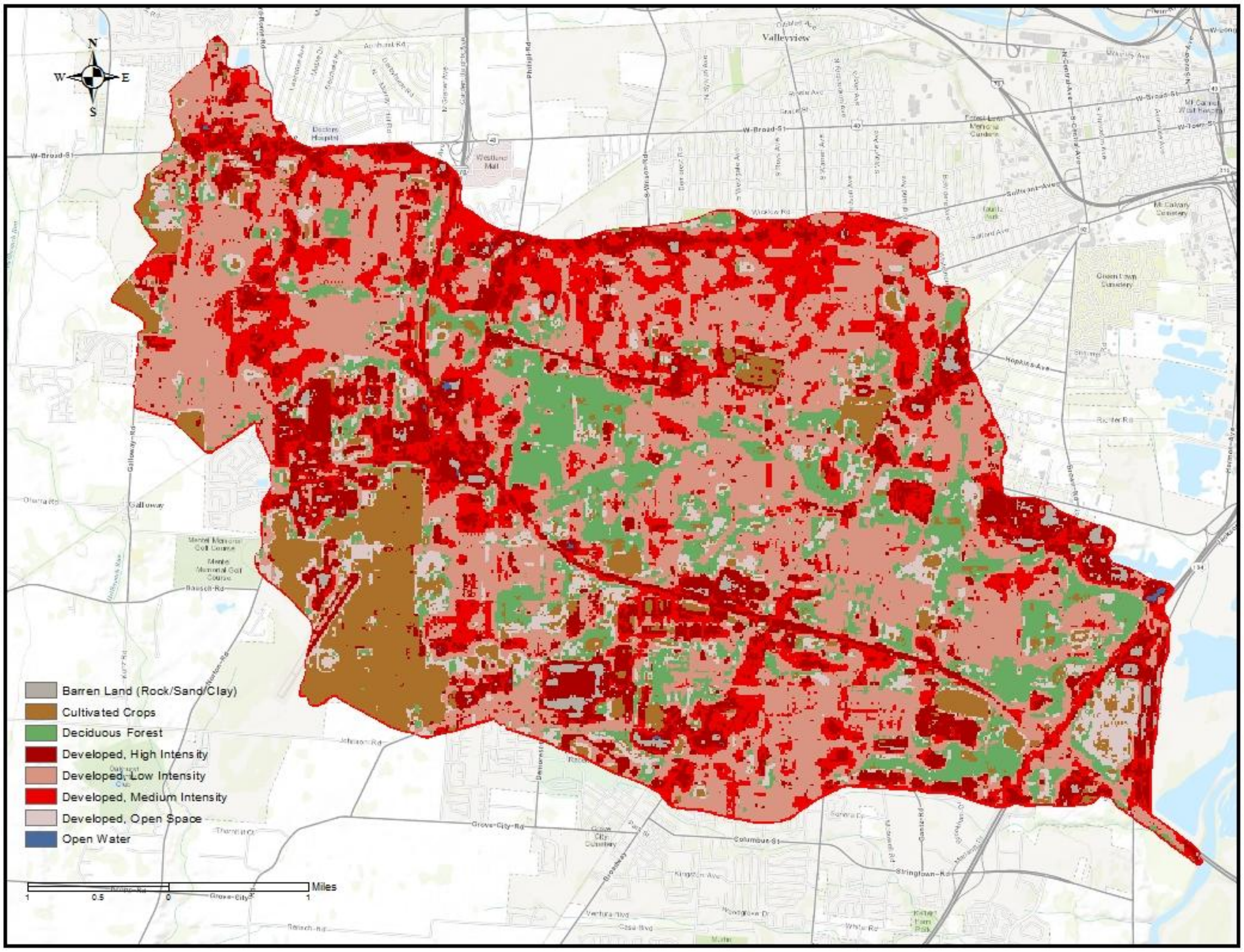


Figure 19. Alternate land use map of Scioto Big Run Watershed generated using MultiSpec to perform a supervised classification on SPOT imagery from 2011.



Appendix 1

Description of Alternative Land Use Methodolgies

A. Introduction to MultiSpec

The below is from Biehl Larry and David Landgrebe. 2011.

MultiSpec is a data analysis software system implemented for Macintosh and Windows computers. MultiSpec is intended for the analysis of multispectral image data, such as that from the Landsat series of Earth observational satellites or hyperspectral data such as from AVIRIS, MODIS, Hyperion, and other systems which contain many bands. The primary purpose of the system is to make new algorithms resulting from our research into hyperspectral data analysis conveniently available for others to try, although it has found additional uses in other circumstances, such as university and K-12 education, and in the government and commercial sectors. MultiSpec Application version 3.3 was used for the analysis along with SPOT imagery.

B. ***SPOT Imagery***

The below introduction to SPOT imagery and information about the specific image uses is taken from the metadata for the image chosen (CNES (Centre National d'Etudes Spatiales). 06/29/2011. SPOT 4 North America Data Buy - Path : 609 Row: 270. Scene: 46092701106291557412I0)

The USGS has contracted with SPOT Image Corporation to acquire and provide Satellite Pour l'Observation de la Terre (SPOT) satellite data for calendar years 2010 and 2011. Under the North America Data Buy agreement, SPOT Image will provide moderate-resolution data from their SPOT 4 and 5 satellites over the conterminous United States and parts of Canada and Mexico through the receiving capabilities at the USGS EROS Center. The French space agency, Centre National d'Etudes Spatiales (CNES), owns and operates the SPOT satellite system. SPOT Image Corporation is a subsidiary of the SPOT Image group, which provides worldwide distribution of their imagery. Under the licensing arrangements of the North America Data Buy contract, access is limited to U.S. Federal civil Government agency users and U.S. State and local government users. The 2011 contract expands usage to include U.S. tribal governments. Qualified users must be logged in to EarthExplorer to gain access to this dataset. Anexplanation of data restrictions and limitations is displayed when accessing these collections and must be agreed upon before gaining access to these data.

The USGS SPOT 4 and 5 datasets provide North American coverage between 53 deg north latitude and 23.5 deg north latitude in calendar year 2010. The coverage for 2011 extends from 55 deg north latitude to 23.5 deg north latitude.

SPOT satellites carry imaging instruments that operate with panchromatic and multispectral sensors. The SPOT 4 payload includes two High Resolution Visible and Infrared (HRVIR) sensors, and SPOT 5 utilizes two High Resolution Geometric (HRG) instruments. Each sensor has a swath of 60 km and has an oblique viewing capability of 27 deg on each side of vertical. The sensors can operate independently to observe separate targets or in tandem to cover a larger swath in a single pass. Each scene in this collection is approximately 60 km by 60 km and is referenced to World Geodetic System 84 (WGS 84) datum.

Each SPOT satellite repeats their orbit every 26 days. Earth is completely covered in a 26-day cycle. EROS began receiving data from the Canadian receiving station on December 28, 2009 and began direct reception of SPOT 4 and 5 data on April 29, 2010. EROS is acquiring over 200 scenes a day via the 5 meter antenna

C. **Data Set Attribute Attribute Values (from product metadata)**

Entity ID 46092701106291557412I0
Acquisition Date 2011/06/29
Sensor Type Multispectral
Bands 4
Scene Shift 0
File Format GEOTIFF
Satellite 4
Receiving Station WX
Geometric Process Level RAW
Radiometric Process Level SYSTEM
Processing Level Level L1T Download Available
Scene Cloud Cover Zero Percent Cloud Cover
Scene Quality Excellent
Resolution 20
Instrument HRVIR2
Scene Orientation 10.47902708
GRS K Path Number 609
GRS J Row Number 270
Center Coordinates 39°47'28.72"N, 83°17'19.42"W
NW Corner 40°06'13.71"N, 83°33'31.19"W
NE Corner 40°00'14.12"N, 82°51'30.05"W
SW Corner 39°34'39.18"N, 83°43'11.27"W
SE Corner 39°28'42.06"N, 83°01'29.01"W
Cloud Cover Quote Area 1 Zero Cloud Cover
Cloud Cover Quote Area 2 Zero Cloud Cover
Cloud Cover Quote Area 3 Zero Cloud Cover
Cloud Cover Quote Area 4 Zero Cloud Cover
Cloud Cover Quote Area 5 Zero Cloud Cover
Cloud Cover Quote Area 6 Zero Cloud Cover
Cloud Cover Quote Area 7 Zero Cloud Cover
Cloud Cover Quote Area 8 Zero Cloud Cover
Quality Quote Area 1 Excellent
Quality Quote Area 2 Excellent
Quality Quote Area 3 Excellent
Quality Quote Area 4 Excellent

D. General protocol in MultiSpec used in the classification is summarized in Biehl Larry and David Landgrebe 2011. It is reproduced below

Familiarization with the data set
Display the data in two or three color format using the Display Image processor to assess its general qualities4. Compare the displayed image with any ground reference information about the site that may be available. Compose a tentative list of classes which is adequately (but not excessively) exhaustive for this data set.

Preliminary selection of the classes and their training sets
Using the Cluster processor, cluster the area from which training fields are to be selected, saving the results to disk file. Display the resulting thematic map for use in marking training areas. Using either the display of the original data or that of the thematic cluster map (after adding it as an associated image), make a preliminary selection of training fields which adequately represent the selected classes.

Verification of the class selection and training

Use the Feature Selection processor to determine the degree of separability between the various classes. Check the modality of the classes by examining the cluster map or by clustering the training areas. Where multi-mode classes are found, it may be appropriate to define two or more sub-classes to accurately represent the entire class. It may be desirable to iterate between steps 2 and 3.

It may also be useful to examine the histograms of each class using the Statistics Processor to determine the need for subclasses. This is another means of identifying the need for subclasses.

Selection of the spectral features to be used

Once a reasonably final training set is arrived at, use the Feature Selection processor to choose the best subset of features for carrying out the classification for a given training set.

Preliminary Classification of the data

Classify the training fields only, using the spectral bands you have selected to verify their purity and separability

Final Classification, Evaluation of the classification and Extraction of the desired information

Classify the entire data set using the features selected

Mark as many fields as possible as Test Fields using the Statistics Processor. Use the List Results processor to determine the accuracy obtained on the training fields and to determine how well the classifier training generalizes beyond the training set. Make modifications to the training as required to obtain satisfactory results at this point.

Depending upon the results of these evaluations it may be necessary to repeat previous steps after modifying the class definitions and training. After becoming satisfied with the results, classify the entire data set, perhaps setting a modest threshold value, saving the classification results to a disk file, and creating a Probability Results file.

Use the Display Image processor to generate thematic map versions of the results and the Probability Results files for subjective evaluation purposes. The classification results file display is useful in determining that the classification results are appropriate and consistent from a spatial distribution standpoint. The portion of points thresholded in the results display, together with the Probability Results file helps to determine if any important modes in the data have been missed in the class definition process. Depending on the outcome, it may again be necessary to iterate using some of the above steps. The List Results processor can be used to provide a quantitative evaluation of the results based upon the accuracy figures of the training and test fields classification.

Appendix 2

Hydrology and Water Quality Methods and Results Project N134: Scioto Big Run 2008

Methods

Stream hydrology and water quality analysis were carried out at three monitoring sites on Scioto Big Run in 2008. Table 1 shows the site specific details of these three sites. The station code is the unique alpha-numeric code Ohio EPA assigns to each surface water assessment site. The river mile is the miles upstream from a stream's mouth to the sampling point.

Table 1 Scioto Big Run sampling sites

Site name	Station code	River mile	Drainage area	Lat	Long
Scioto Big Run at Columbus @ Norton Rd.	301711	9.68	1.89	39.94N	83.14W
Scioto Big Run at the City of Columbus Big Run Park	301710	6.53	6.58	39.93N	83.10W
Scioto Big Run at Quarry	V07K10	2.00	18.40	39.91N	83.03W

Hydrology methods:

The hydrology monitoring goal of this project was to determine the streamflow or discharge (the amount of water flowing in the stream) throughout the 2008 field season of the Scioto Big Run. To facilitate this goal, Isco brand ultrasonic level recorders were deployed at the Scioto Big Run at the Big Run Park and Quarry sites. These instruments record the distance form an arbitrary datum in order to monitor stream height fluctuations. The difference form the datum is called stage or gage height. Stage was recorded onto memory banks of the level recorders at a 15-minute interval from April to September 2008.

Stream discharge measurements were measured at the level recorder sites regularly throughout 2008 following the Ohio EPA Surface Water Field Sampling Manual protocol (Ohio EPA, 2012). Ohio EPA used SonTek FlowTracker meters to measure the stream discharge in the Scioto Big Run. This measurement in cubic feet per second (cfs).

To make a discharge measurement, a cross section of the channel with straight, non-eddied, and edge-to-edge flow is found. The cross section is divided into about twenty subsections. The width of these subsections are generally all the same, unless the flow appears to be not equally distributed across the channel. In this case the subsections with greater flow are closer together, and the less flow subsections are wider. The width and depth of each subsection is measured and entered into the FlowTracker. The product the width and depth of each subsection is that subsection's area. The FlowTracker then measures velocity at the center of each section. The discharge is computed for each subsection by the ADCP using *discharge* = *area* × *velocity*. The sum of all the subsection's discharges is the stream's total discharge.

Velocity is measured by the FlowTracker tool using Acoustic Doppler Current Profiler (ADCP) technology. An ADCP uses the principles of the Doppler Effect to measure the velocity of water. This is carried out by sending a sound pulse into the water and measuring the change in frequency of that sound pulse reflected back by sediment or other particulates being transported in the water. The change in frequency, or Doppler Shift, that is measured by the ADCP is translated into water velocity. The velocity that is measured for each subsection with depths of equal to or less than 2.5 feet is the average velocity of a 40 second sampling at 60% of the depth down from the water's surface. For subsection's with greater than 2.5 feet depth the velocity measured is average of the 40-second sampling at 20% and at 80% of the depth down from the water's surface.

Utilizing the strong relationship between stage and streamflow (USGS. 1984), the level recorder stage data is correlated to field stream discharge measurements. Determining discharge from stage requires defining the stage-discharge relationship by measuring discharge at a wide range of river stages. This relationship is outlined in the results and analysis section of this report.

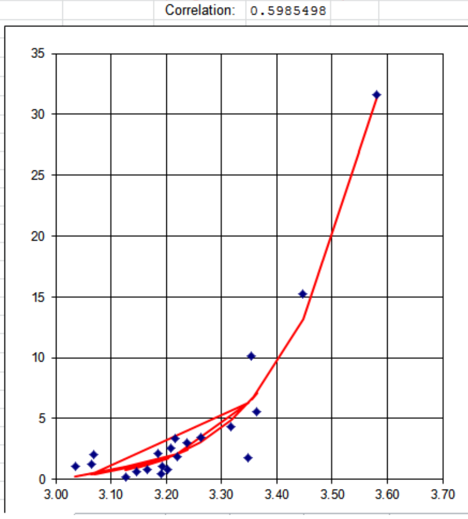
Water quality methods:

Following Ohio EPA sampling protocol (Ohio EPA, 2012), 67 water quality samples were collected in May through September, 2008 at the three Scioto Big Run assessment sites. All water quality samples were grab samples, meaning each sample was collected at the water surface directly into the sample container while wading the stream. All samples were collected in LDPE cubitainers. Each water quality sample included lab analysis for 18 metal parameters preserved with nitric acid, 5 nutrient parameters preserved with sulfuric acid and 4 demand parameters (these included chloride, total hardness, total dissolved solids and total suspended solids) that did not receive acid preservation. After field acid preservation, if applicable, all samples were put on ice to be chilled to 4 degrees C. All samples were delivered to the Ohio EPA Division of Environmental Services lab within 48 hours of sampling. The Division of Environmental Services lab follows Standard Methods and/or US EPA methods for all parameters. The data from this lab is designated State of Ohio Level 3 Credible Data. This is state's legal highest level of scientific rigor and methods.

Hydrology and water quality data analysis
Hydrology results and analysis:
Figure 1 shows the development of the flow to stage curve following USGS protocol (USGS, 1984). Figure 2 shows the same flow to stage relationships however the percent uncertainty relating to the quality of the stream discharge measurements are noted. Visually it can be detected that the lower quality measurements are responsible for the largest observation deviations from the curve.

escription: X Scioto Big Run @ Big Run Park

2247.812893
Flow = 31.32365217 (Gage Ht - 2.58) ^ 6.077876017
Correlation: 0.5985498



Description	Gage Height, feet	Flow, cfs	Calculated Flow, cfs		% Uncertainty
8/21/2008	3.13	0.223	0.8006	10:22:00 AM	14.3
9/4/2008	3.191	0.46	1.5684	10:35:00 AM	10.7
7/18/2008	3.146	0.641	0.9852	11:35:00 AM	6.9
8/13/2008	3.166	0.8	1.2167	11:57:00 AM	8.1
7/31/2008	3.203	0.817	1.7652	10:15:00 AM	5.1
5/30/2008	3.035	1.035	0.2614	1:50:00 PM	14.4
8/7/2008	3.192	1.088	1.5841	10:27:00 AM	4.2
5/7/2008	3.064	1.219	0.3805	1:00:00 PM	6.7
5/1/2008	3.35	1.7776	6.3467	1:10:00 PM	5.6
9/10/2008	3.22	1.839	2.0790	11:21:00 AM	2.7
5/22/2008	3.069	2.012	0.4051	11:05:00 AM	3.8
6/19/2008	3.185	2.158	1.4771	11:25:00 AM	2.3
4/22/2008	3.209	2.567	1.8711	9:30:00 AM	3.1
7/10/2008	3.238	3.007	2.4608	10:54:00 AM	2.6
6/11/2008	3.216	3.397	2.0013	11:35:00 AM	2.4
7/23/2008	3.262	3.471	3.0594	12:00:00 PM	2.2
7/2/2008	3.318	4.332	4.9424	11:07:00 AM	2.1
8/28/2008	3.364	5.569	7.1374	10:20:00 AM	3.1
5/16/2008	3.354	10.157	6.6017	1:05:00 PM	2.8
6/5/2008	3.447	15.235	13.1571	11:35:00 AM	2.2
6/27/2008	3.581	31.623	31.5145	11:20:00 AM	2.5
			-		
			-		
			-		
			-		

Figure 1: Scioto Big Run at park site flow development curve

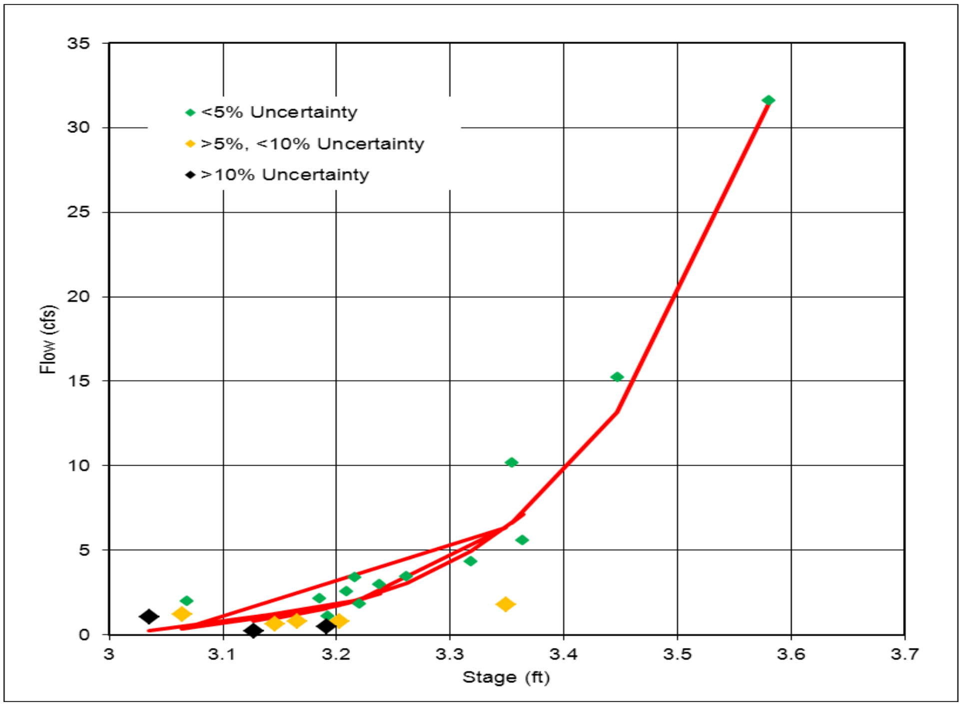


Figure 2: Scioto Big Run at park site flow development curve with discharge uncertainty marks

Using the flow to stage relationship and the level recorder data, the flow record for the entire period the Scioto Big Run level recorder was deployed can be developed. This calculated flow record is shown on Figure 3. The measured flows are also noted on Figure 3.

In order to assure that the level recorder accurately measured storm periods, a comparison to a Walnut Creek USGS stream gage (#03229796) data for the same time period is developed. The Walnut Creek watershed is another Scioto River tributary that receives similar weather as the Scioto Big Run watershed. Figure 4 shows this comparison. Most of the storm flow increases match well with the two hydrologic records. With a longer period of record, these comparisons could be used in order to determine temporal hydrologic response, or flashiness, of these watersheds.

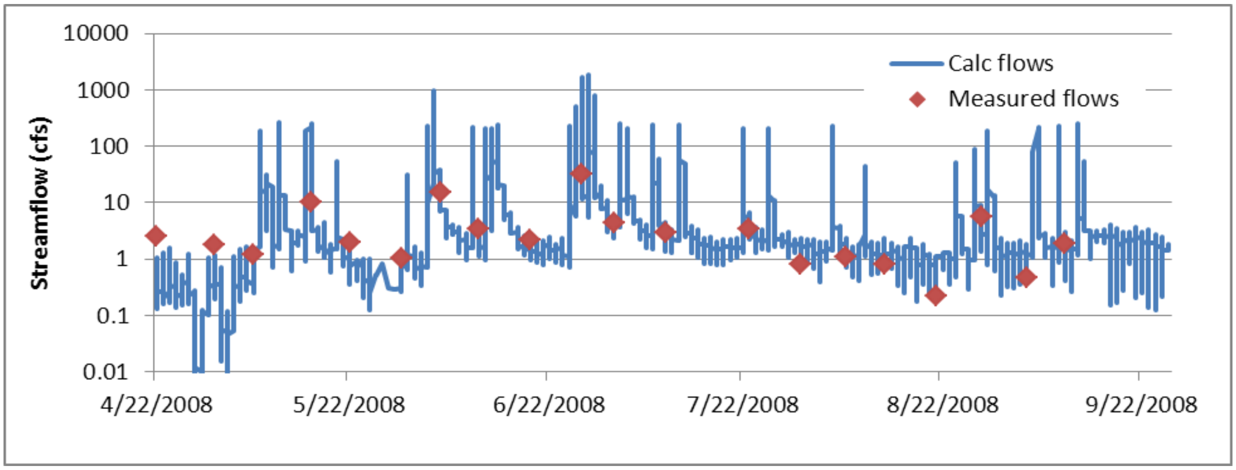


Figure 3: Scioto Big Run at park site level reorder data

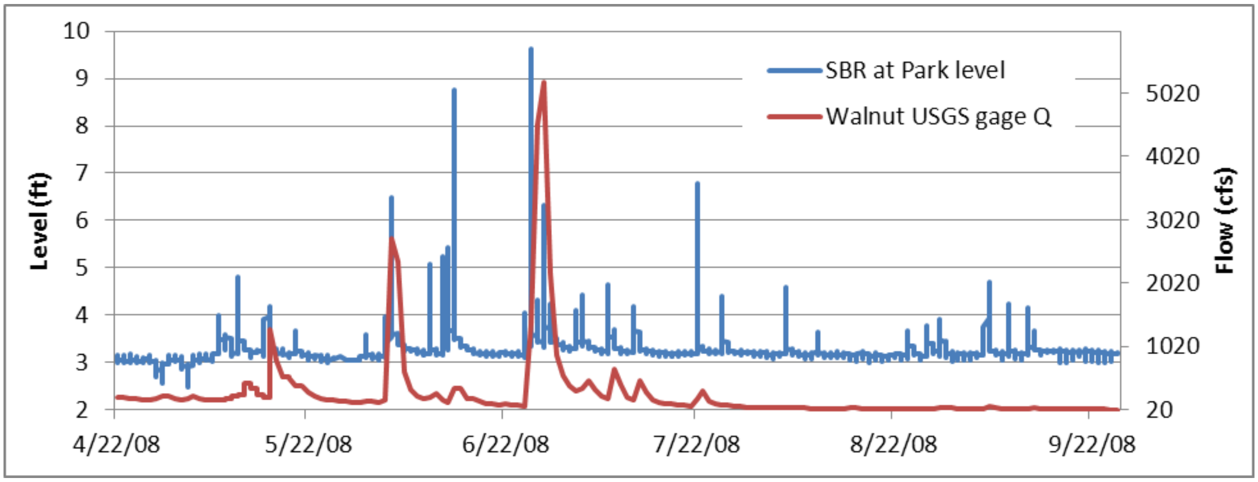


Figure 4: Scioto Big Run at park level reorder data compared to the Walnut Creek USGS gage flow

Figures 5 and 6 show the calculated stream flow record for the level recorder site; 5 in semi-log scale and 6 zoomed into flows 35 cfs and below. The measured flows are noted on both of these plots.

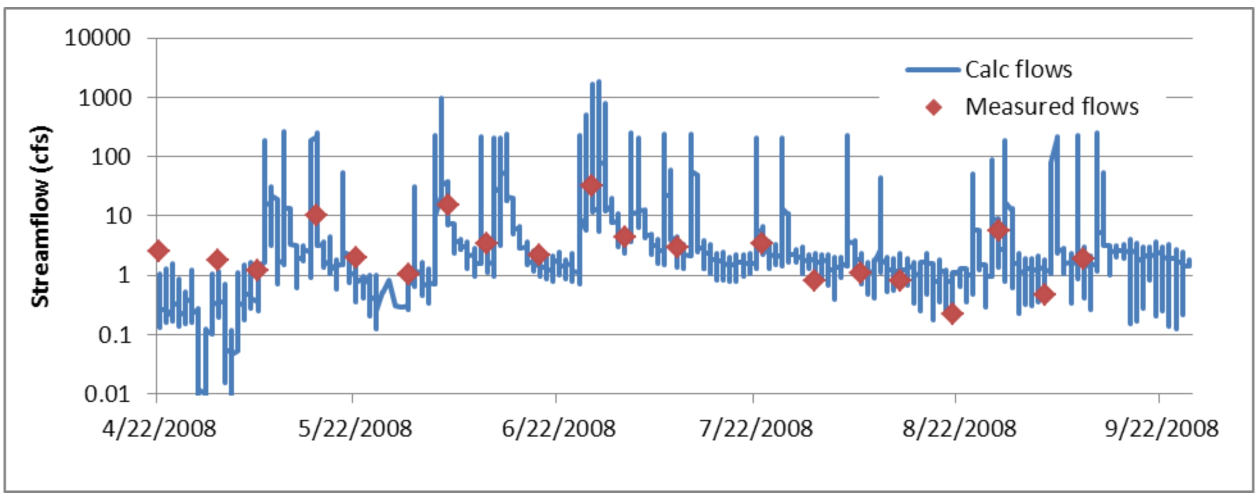


Figure 5: Calculated and measured flows at the Scioto Big Run at park site, semi-log scale

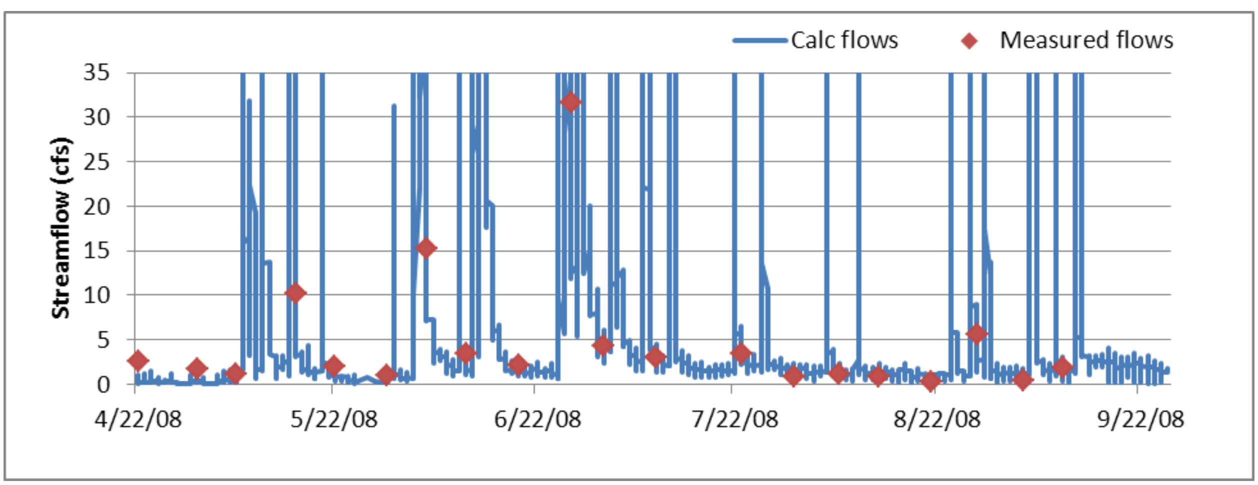
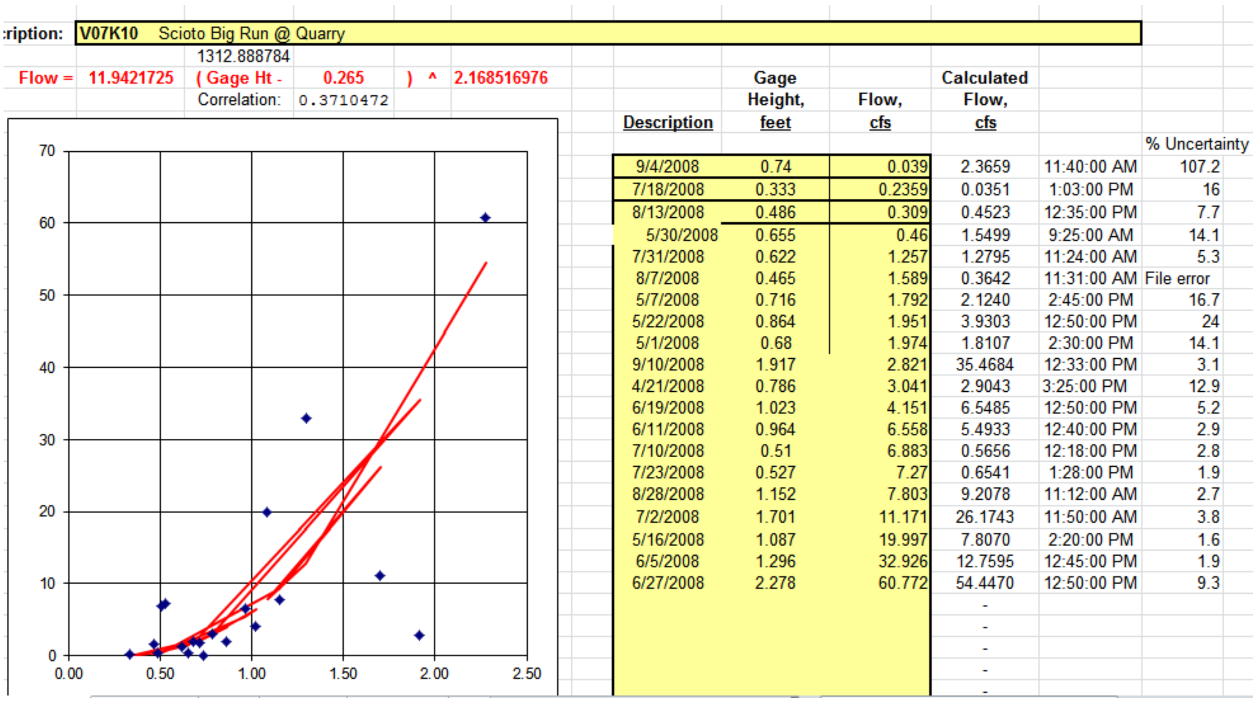


Figure 6: Calculated and measured flows at the Scioto Big Run at park site, <35 cfs flows

Figures 7 through 9 show the same information as Figures 1-3 for the quarry site. The quarry site's flow relationships matched more poorly than the park site in general. Given the existing data a reason for this match is not known.



Description	Gage Height, feet	Flow, cfs	Calculated Flow, cfs		% Uncertainty
9/4/2008	0.74	0.039	2.3659	11:40:00 AM	107.2
7/18/2008	0.333	0.2359	0.0351	1:03:00 PM	16
8/13/2008	0.486	0.309	0.4523	12:35:00 PM	7.7
5/30/2008	0.655	0.46	1.5499	9:25:00 AM	14.1
7/31/2008	0.622	1.257	1.2795	11:24:00 AM	5.3
8/7/2008	0.465	1.589	0.3642	11:31:00 AM	File error
5/7/2008	0.716	1.792	2.1240	2:45:00 PM	16.7
5/22/2008	0.864	1.951	3.9303	12:50:00 PM	24
5/1/2008	0.68	1.974	1.8107	2:30:00 PM	14.1
9/10/2008	1.917	2.821	35.4684	12:33:00 PM	3.1
4/21/2008	0.786	3.041	2.9043	3:25:00 PM	12.9
6/19/2008	1.023	4.151	6.5485	12:50:00 PM	5.2
6/11/2008	0.964	6.558	5.4933	12:40:00 PM	2.9
7/10/2008	0.51	6.883	0.5656	12:18:00 PM	2.8
7/23/2008	0.527	7.27	0.6541	1:28:00 PM	1.9
8/28/2008	1.152	7.803	9.2078	11:12:00 AM	2.7
7/2/2008	1.701	11.171	26.1743	11:50:00 AM	3.8
5/16/2008	1.087	19.997	7.8070	2:20:00 PM	1.6
6/5/2008	1.296	32.926	12.7595	12:45:00 PM	1.9
6/27/2008	2.278	60.772	54.4470	12:50:00 PM	9.3
			-		
			-		
			-		
			-		
			-		

Figure 7: Scioto Big Run at quarry site flow development curve

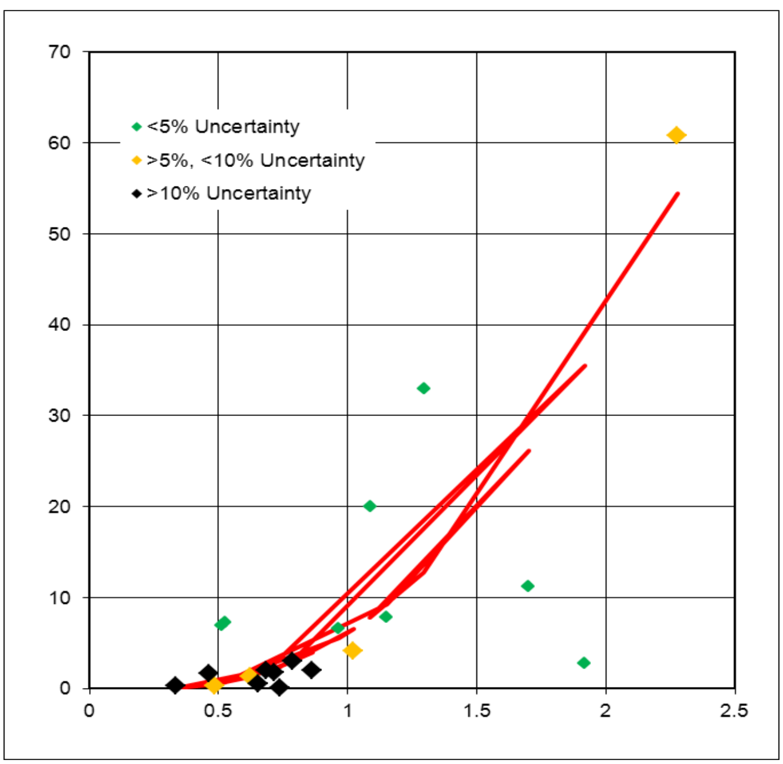


Figure 8: Scioto Big Run at quarry site flow development curve with discharge error marks

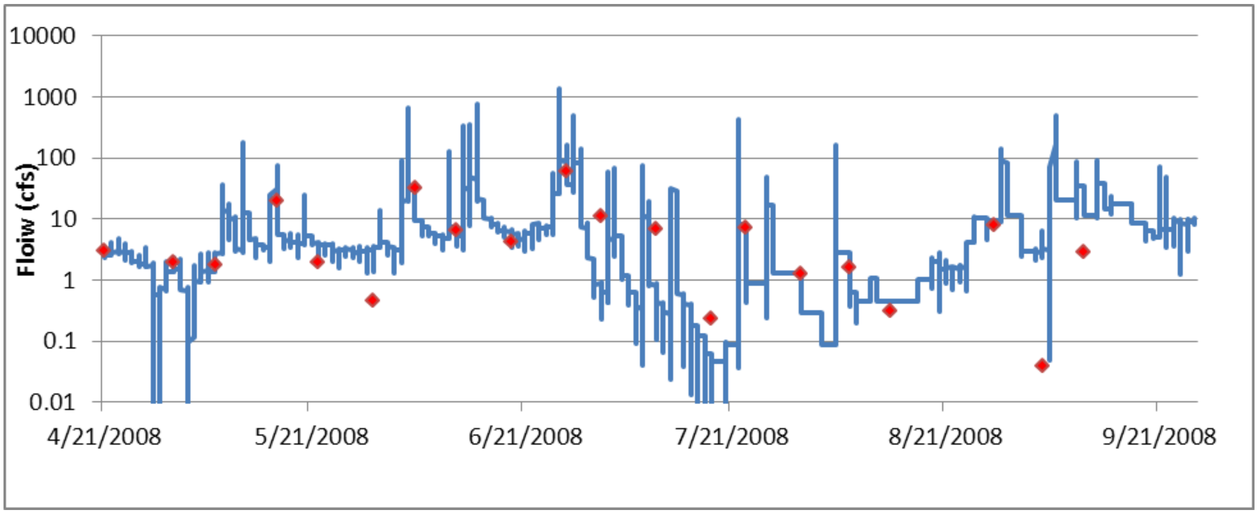


Figure 9: Scioto Big Run at quarry site level reorder data

Figures 10 through 12 compare the calculated stream flow at the two level recorder sites. Notable the June 4, 2008 storm caused a peak in the park sites stream flow that was calculated to exceed 500 cfs. The stage to stream flow relationship was not calibrated to a stream flow anywhere nearly this high. It is also noted that the calculated stream flow for the downstream quarry site has a much lower calculated stream flow for this event. Because of this, this high flow calculation is likely incorrect. More hydrology data is required in order to refine these calculations. Figures 11 and 12 show the flow measurements for each site taken plotted over time. Figure 11 includes the calculated flow records and Figure 12 does not. These plots show that flow increases from the most upstream site, Norton, to the downstream site, Quarry. As expected water withdrawal for industrial use was not observed in this watershed.

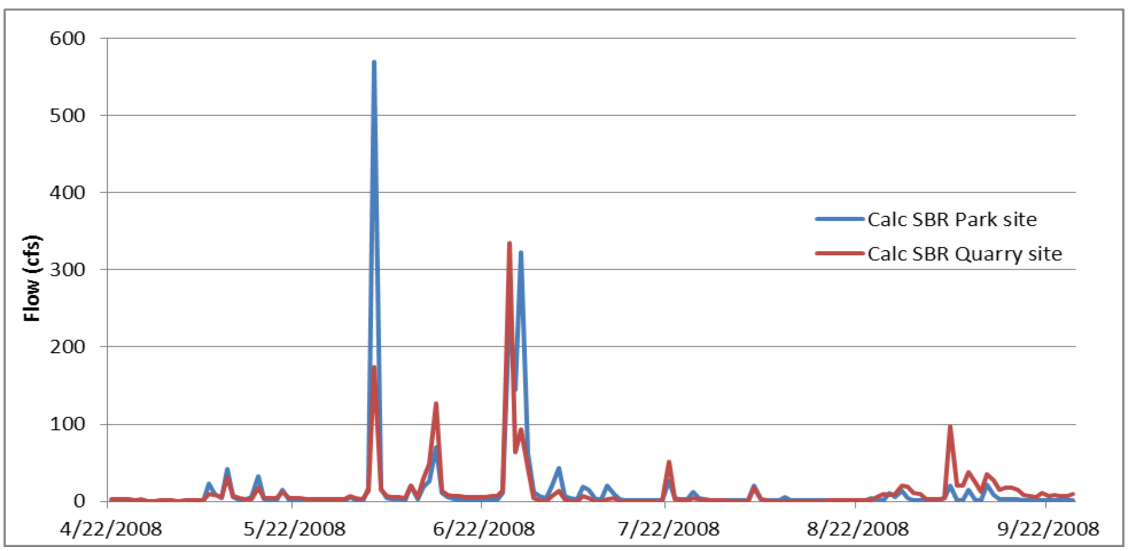


Figure 10: Comparison of calculated flows for the Scioto Big Run park and quarry sites

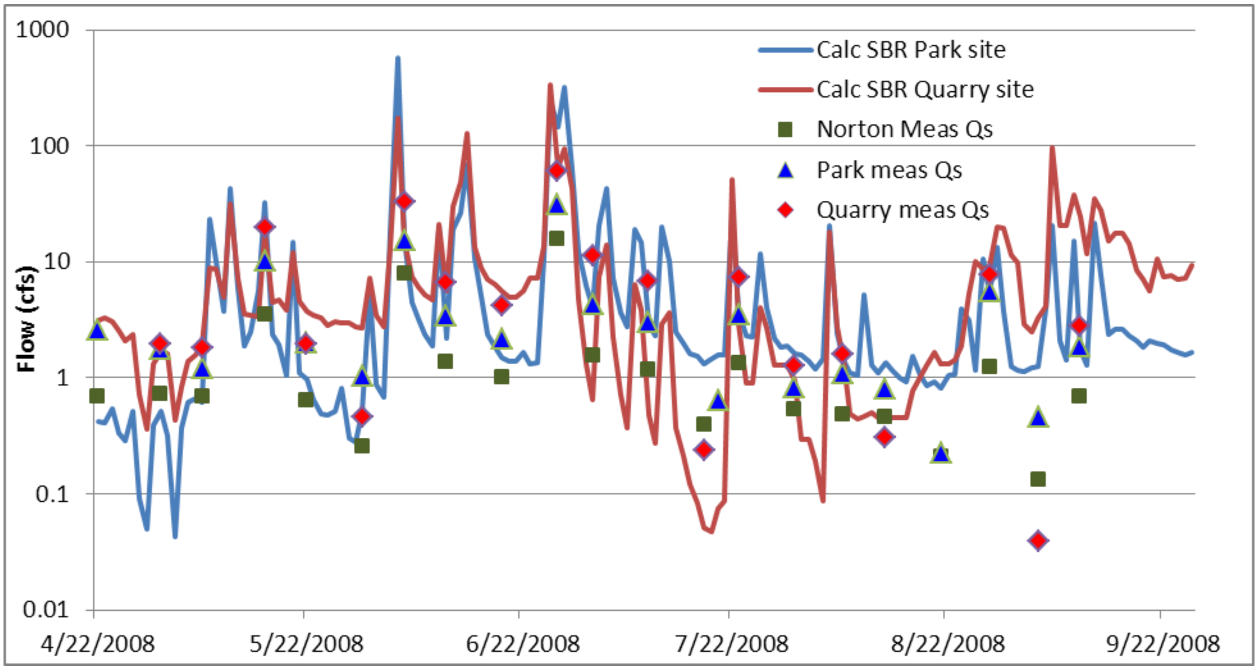


Figure 11: Calculated flows for the two Scioto Big Run level recorder sites and the observed flow measurements for all three Scioto Big Run 2008 assessment sites, log scale

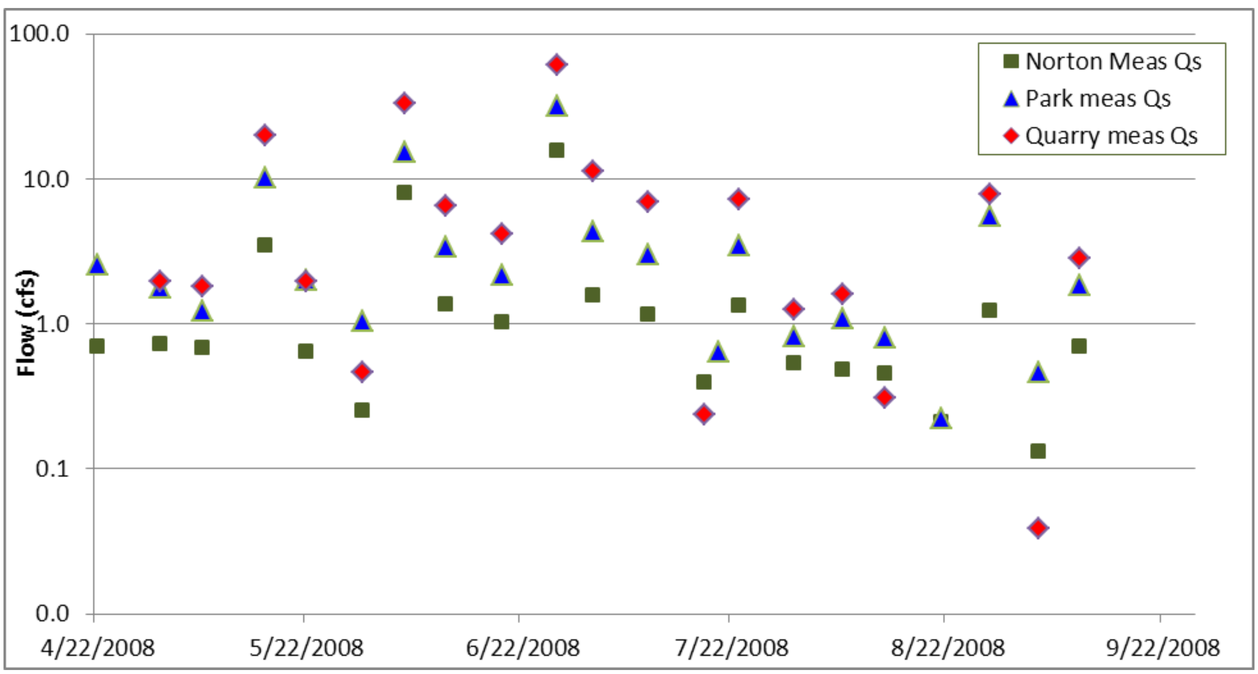


Figure 12: Scioto Big Run sites observed flow measurements only, log scale

Water quality results and analysis

An analysis of this water quality data that includes consideration of stream flow has been carried out. Figures 13-17 show observed ammonia, nitrate plus nitrite (NO2+3), total dissolved solids (TDS), total phosphorus (TP), and total suspended solids (TSS) respectively. All of these plots show the observed concentration data as a diamond, and a legend shows which site is which color of diamond. The stream flow calculated for the downstream sampling site, the "quarry" site, is shown as a gray line on each plot.

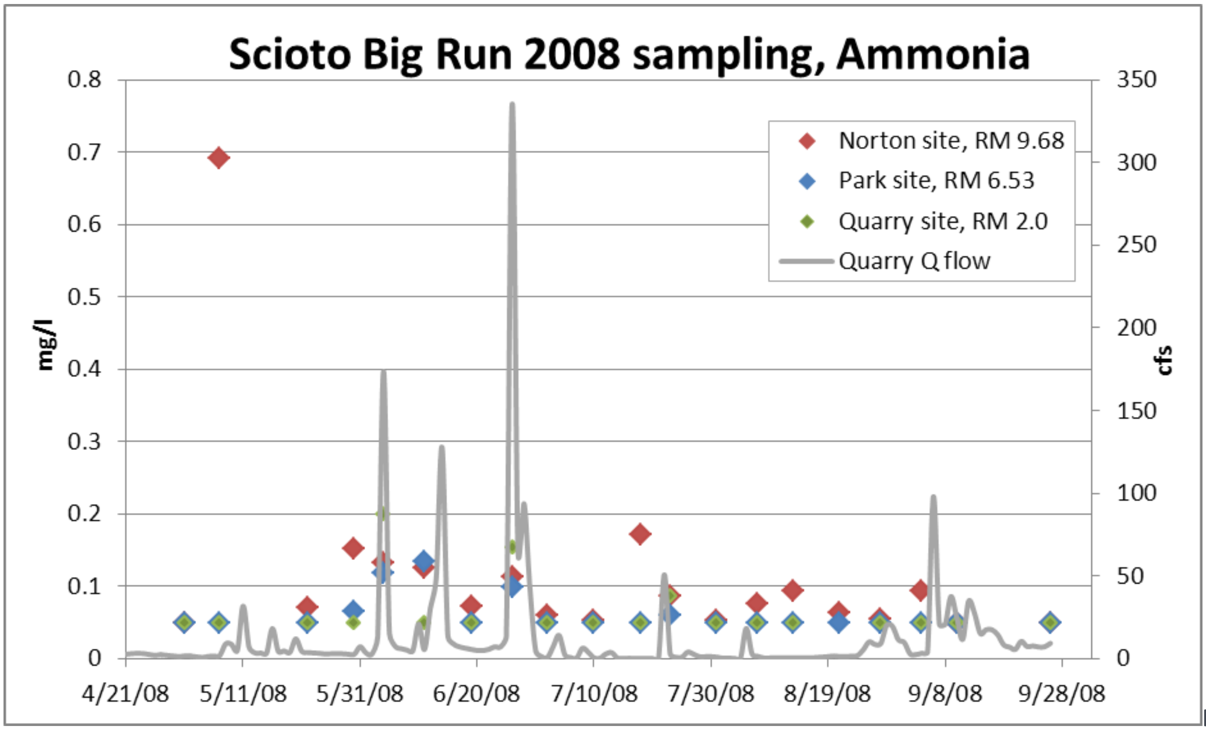


Figure 13 Ammonia concentration results for the three Scioto Big Run assessment sites with streamflow at the quarry site in gray

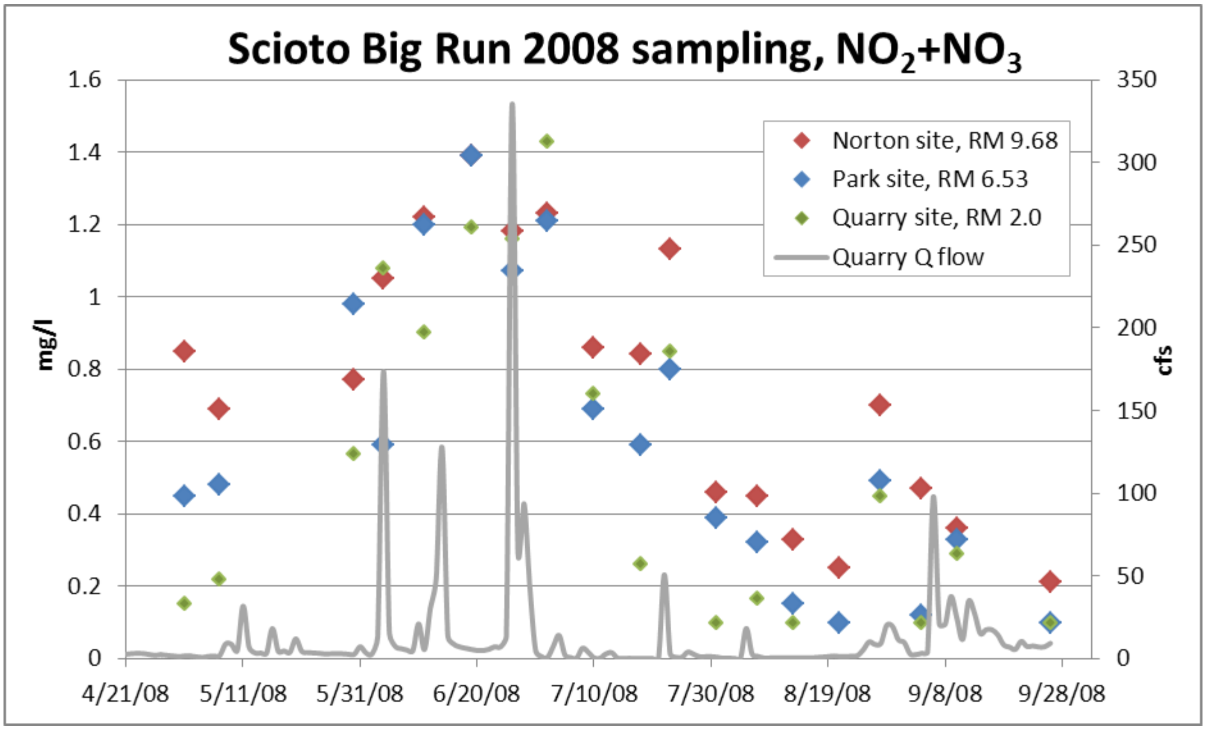


Figure 14 Nitrate-nitrite concentration results for the three Scioto Big Run assessment sites with streamflow at the quarry site in gray

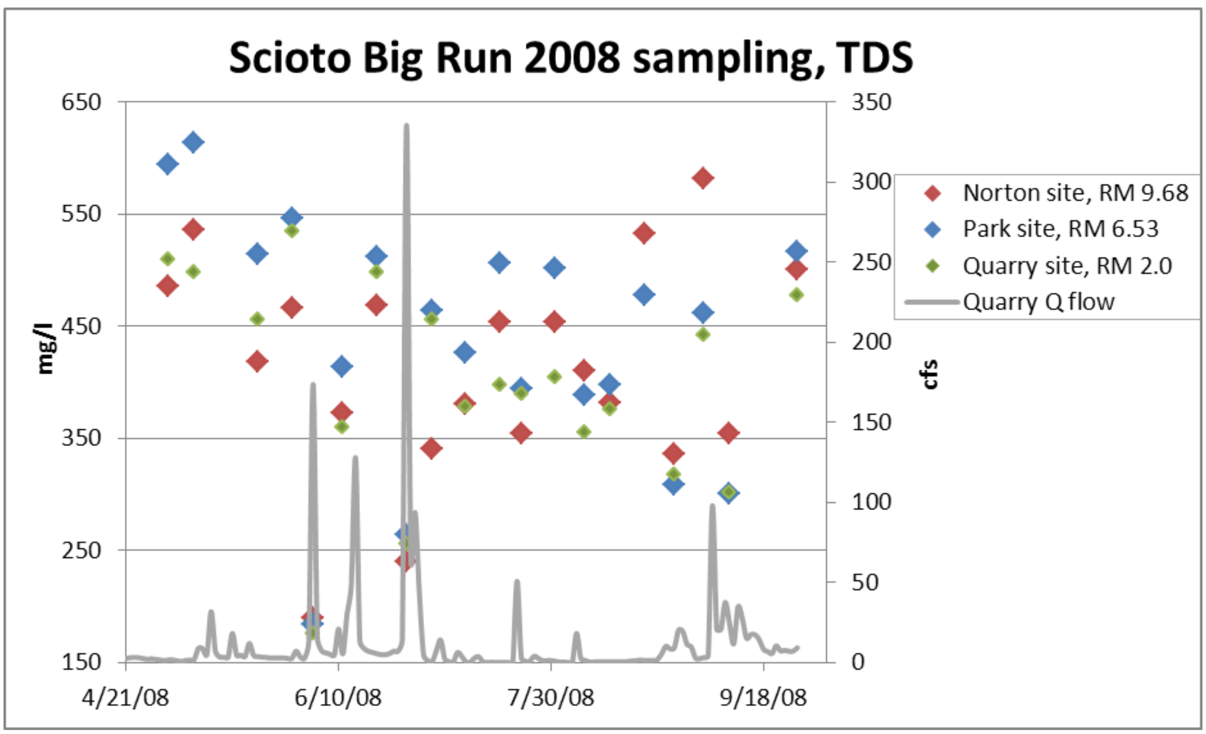


Figure 15 Total dissolved solids concentration results for the three Scioto Big Run assessment sites with streamflow at the quarry site in gray

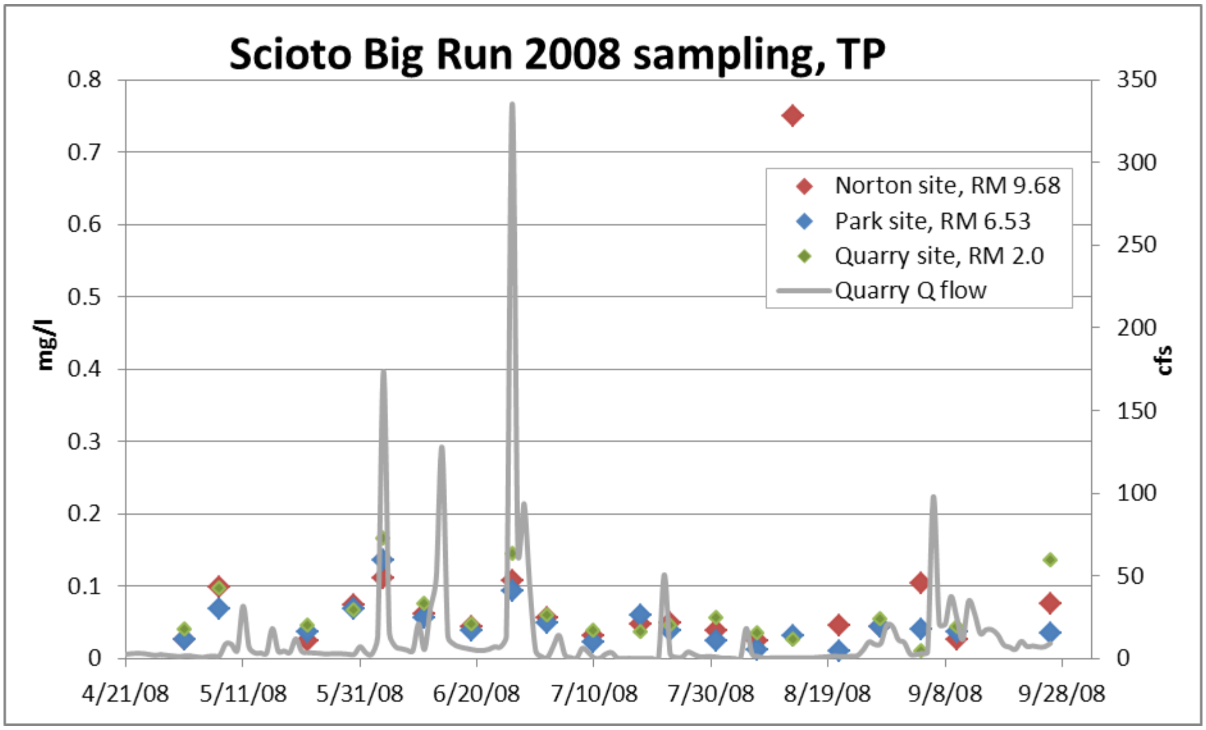


Figure 16 Total phosphorus concentration results for the three Scioto Big Run assessment sites with streamflow at the quarry site in gray

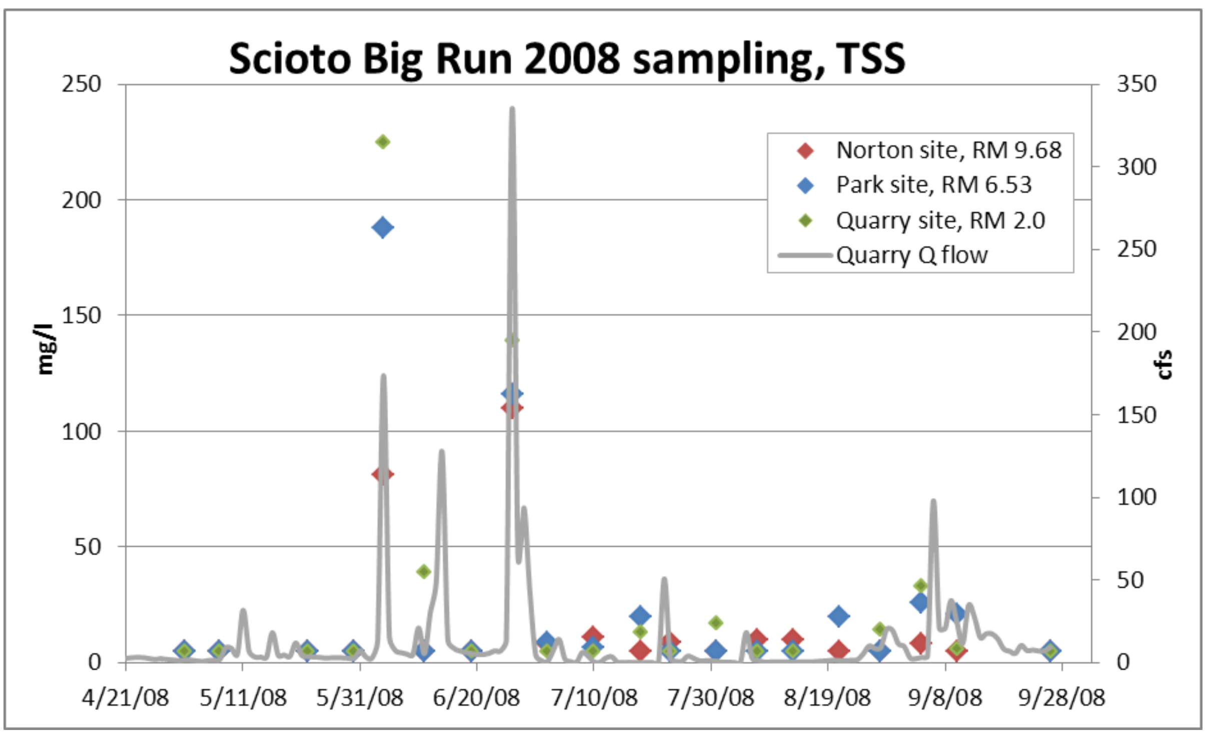


Figure 17 Total suspended solids concentration results for the three Scioto Big Run assessment sites with streamflow at the quarry site in gray

Figure 18 shows box plots of nitrate-nitrite, ammonia, total phosphorus and total dissolved solids for each month. These box plots consist of data grouped from all three 2008 sampled Scioto Big Run sites. For each box, the middle line is the median concentration. The top and the bottom of the box are the 75th and 25th percentile respectively. The top and bottom tails are the maximum and minimum observed values for each moth. Finally the black diamond inside each box is the mean value for each month.

From these plots a trend in the NO2+3 can be observed as being higher in late May and early June and lower in late July and early September. These results confirm NO2+3 normally enter waters above ambient concentrations when runoff from springtime fertilizer applications occur. Other variations are less noticeable. Because of this a load duration curve method of examination will be employed.

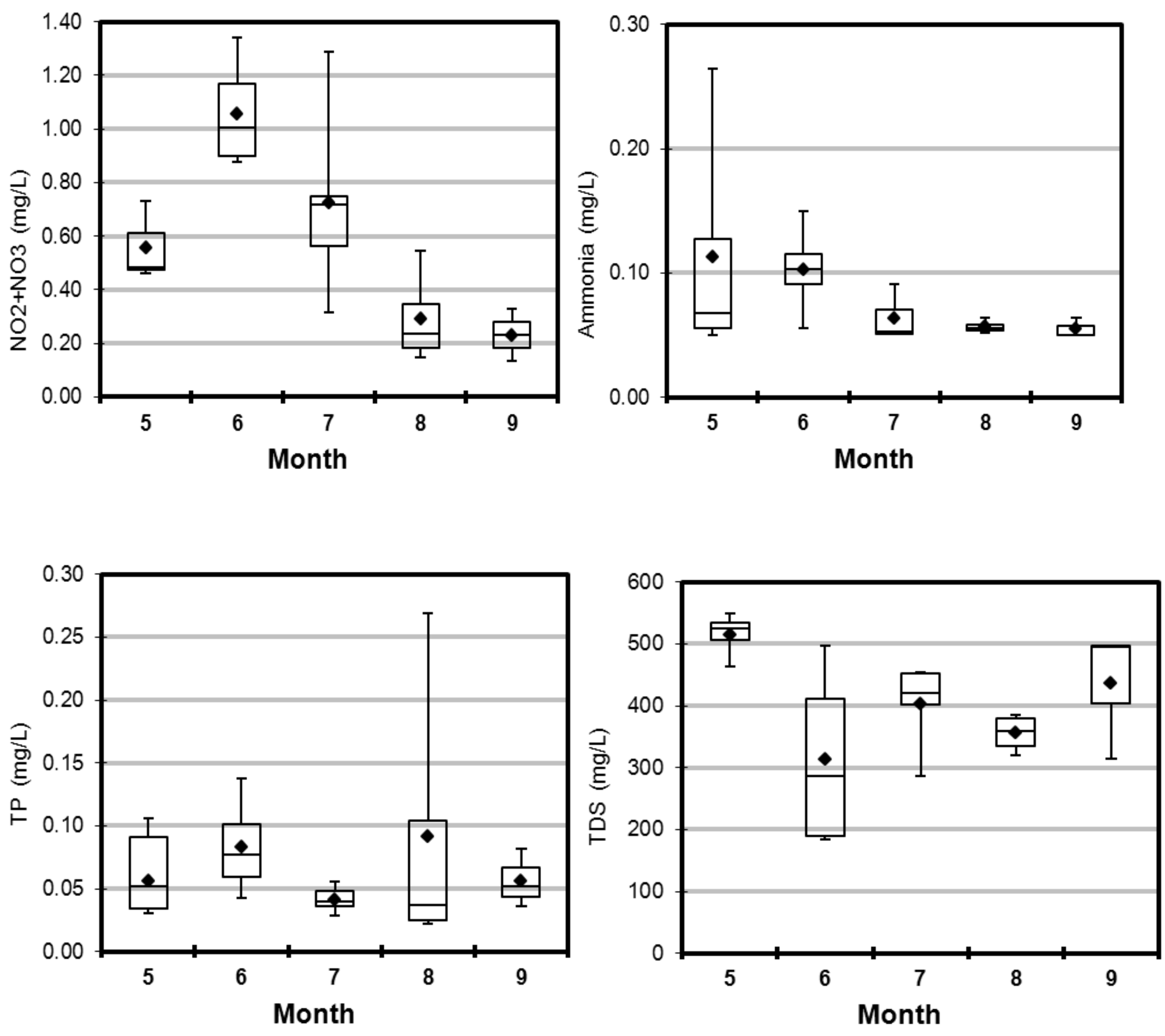


Figure 18 Temporal distribution of water quality, all 2008 Scioto Big Run data

Concentration and load duration curves

An empirical method of examining pollutant loading and pollutant reductions in order to meet specific targets is utilized with concentration and load duration curves (CDCs and LDCs respectively). The main advantage of the use of CDCs and LDCs in water quality data analysis is in this methods ability to divide load sources based on flow.

Following the guidance from US EPA, 2007 to create CDCs and LDCs, the flow duration interval for each assessment site is determined. This involves calculating the stream flow (in cfs) expected for the full range of exceedance percentile. This normalizes the flows to a range of natural occurrences from extremely high flows (0 exceedance percentile) to extremely low flows (100). The actual "curve" for each of these types of analysis is created using a specific concentration target. For CDCs the target concentration is represented by a straight horizontal line across the plot. For LDCs the curve is determined by calculating a target load. This is done by taking the product of the concentration target and of each flow values across the flow duration interval, and a conversion factor.

Depending on the parameter targets concentration used for each CDC and LDC are based on either State of Ohio water quality standards, suggested statewide criteria (from Ohio EPA 1999) or from a statistical analysis of observed concentration values in similar streams that meet their aquatic life use designation (also from Ohio EPA 1999). Priority to which source of target is used is given in the order with which the sources are presented above. For instance total phosphorus lacks a water quality standard, but does have suggested criteria and therefore that is what is used. The Total suspended solids parameter does not have either of the first two therefore a statistically derived observed value is used. Table 2 shows the target concentration for each parameter and the source of that target.

Table 2 Target concentrations for each parameter

Parameter	Target value (mg/l)	Source of target
Total dissolved solids	1500	Statewide criteria for the protection of aquatic life; OAC 3745-1-07
Nitrate + nitrite	1.0	Suggested criteria; Ohio EPA, 1999
Total phosphorus	0.08	Suggested criteria; Ohio EPA, 1999
Total suspended solids	69.95	95th percentile concentration of Eastern Corn Belt Plains, fully attaining WWH sites; Ohio EPA 1999

Within the CDCs and LDCs the observed water quality samples for each assessment site are presented. For CDCs the observed concentration is plotted. For LDCs that concentration is converted into a load by taking its product, the flow at the time the sample was collected and a conversion factor. Each calculated concentration/load is plotted as a point on the CDC/LDC plot and can then be compared to the target curve. Points that plot above the CDC/LDC curve are deviations from the target. Points that plot below the curve represent samples in compliance with target.

The water quality samples on the CDC/LDC curves are noted as diamonds. Samples taken when storm flow is greater than 50% of the flow are noted with the diamond with a red dot in the center. This flow condition is determined using the sliding-interval method for streamflow hydrograph separation contained in the USGS HYSEP program (Sloto, 1996).

The CDCs/LDCs flow durations are grouped into five flow regimes noted with vertical lines and labels. These regimes are defined as the following:

High flow zone: Stream flows in the 0 to 5 exceedance percentile range; these are related to flood flows.

Moist zone: Flows in the 5 to 40 exceedance percentile range; these are flows in wet weather conditions.

Mid-range zone: Flows in the 40 to 80 exceedance percentile range; this are the median stream flow conditions.

Dry zone: Flows in the 80 to 95 exceedance percentile range; these are related to dry weather flows.

Low flows: Flows 95 to 100 exceedance percentile range; these are extremely dry to no flow in the streams.

Within each flow regime a box plots is shown summarizing the observed data. The center line of these boxes represents the median concentration or load for that flow regime. The top and bottom of the boxes represents the 75^{th} and 25^{th} percentiles respectively. The upper and lower vertical bar tails are the maximum and minimum observed loads respectively.

For Total Maximum Daily Loads, CDCs and LDCs are used to determine where and when pollutant reductions need to occur. These analyses are also very useful in examining general loadings of streams. Samples in exceedance at the right side of the graph occur during low flow conditions, and significant sources might include wastewater treatment plants, malfunctioning home sewage treatment systems, illicit sewer connections and/or animals depositing waste directly to the stream. Any exceedance on the left side of the graph occurs during higher flow events and potential sources are likely land uses or management practices such as manure spreading or livestock production. These supply pollutants that are washed off of upland areas with runoff. The CDC/LDC approach helps determine which implementation practices are most effective for reducing loads. Table 3 shows various pollutant sources and the loads they are associated with.

On Table 3 the high, moderate and low influence of a certain source of pollution are shown as a ‘H’, ‘M’, and/or an ‘L’ in the appropriate flow regime zones. For instance, point sources can be a moderate source of pollution in dry flow and high influence in low flows.

Table 3   Load duration curve flow zones and typical contributing sources

Contributing Source Area	Duration Curve Zone				
	High	Moist	Mid-Range	Dry	Low
Point source				M	H
Livestock direct access to streams				M	H
Home sewage treatment systems	M	M-H	H	H	H
Riparian areas		H	H	M	
Storm water: Impervious		H	H	H	
Combined sewer overflow (CSO)	H				
Storm water: Upland	H	H	M		
Field drainage: Natural condition	H	M			
Field drainage: Tile system	H	H	M-H	L-M	
Bank erosion	H	M			

H = high influence; M = moderate influence; L = low influence

Figures 19 through 28 are CDC and LDC for the Park and Quarry sites. There are no ammonia plots since most of the results were below the analytical detection level. Due to always being well below the target/standard the total dissolved solids plots get both CDCs and LDCs. For this parameter the CDCs allow for better examination of the results. The rest of the parameters do not have CDCs.

The nitrate + nitrite and total phosphorus loads regularly slightly exceed the target slightly at both sites (see Figures 19, 22, 24 and 27); however the curves show that these do not happen uniformly in one flow regime. At both sites the total suspended solids exceed the target only in the high flow regime. This is expected as this parameter results from storm flows moving sediment as runoff.

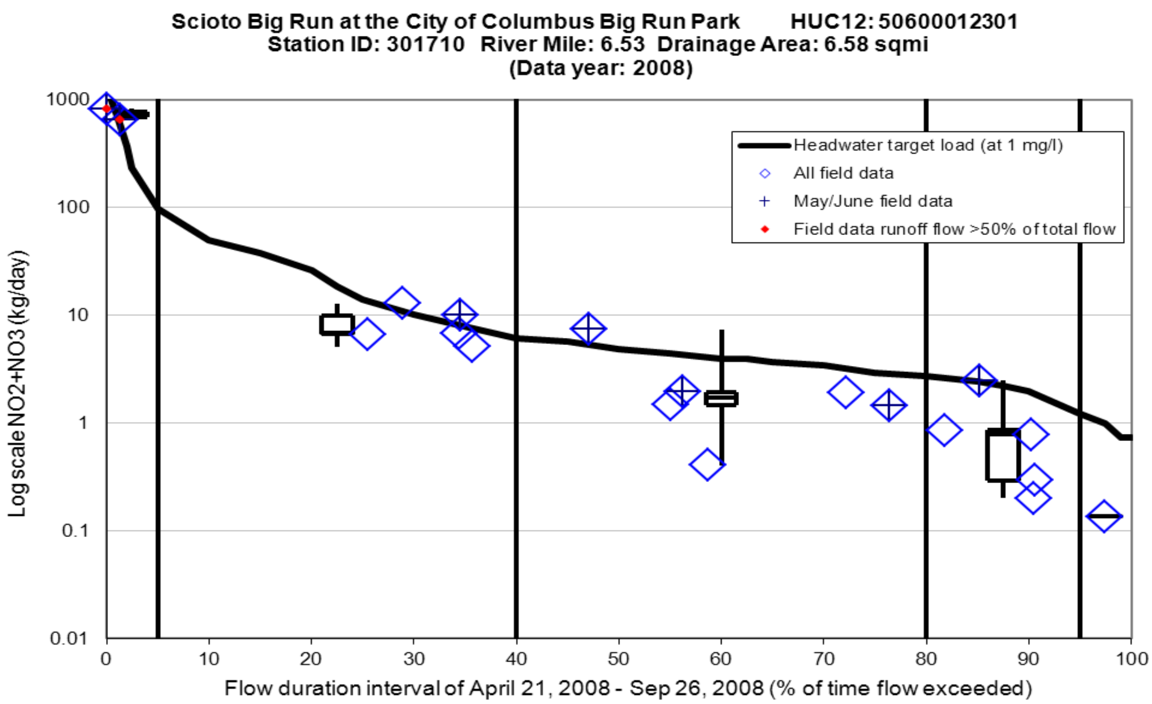


Figure 19

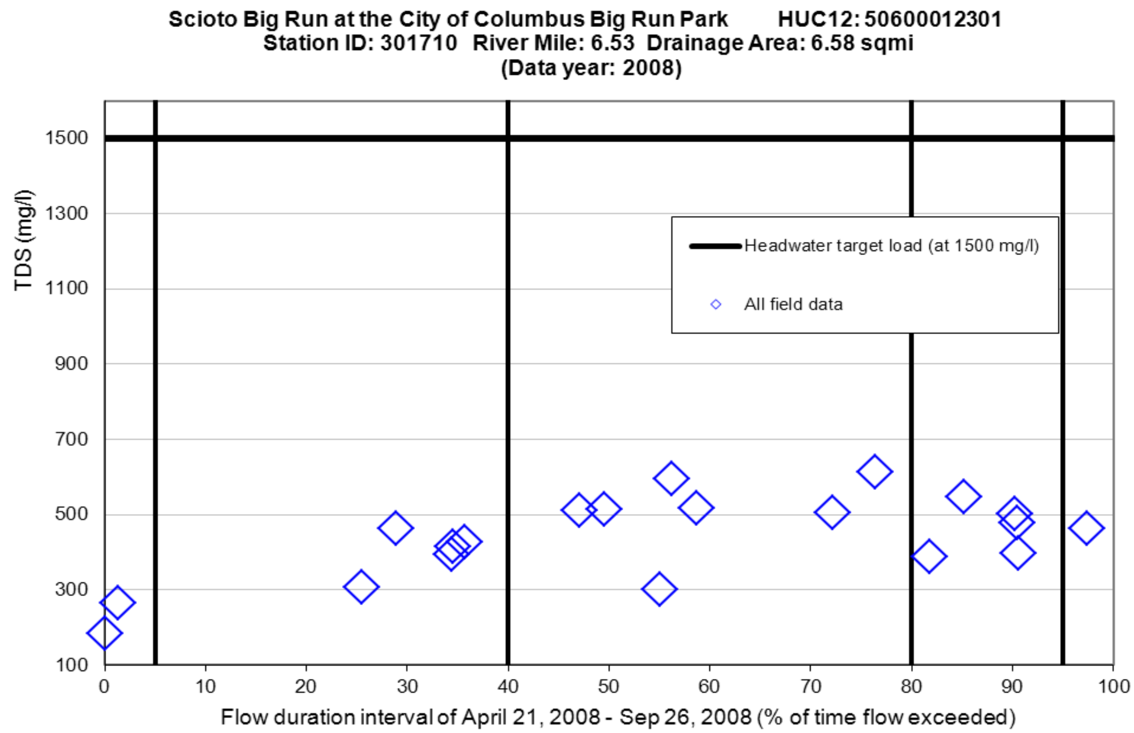


Figure 20

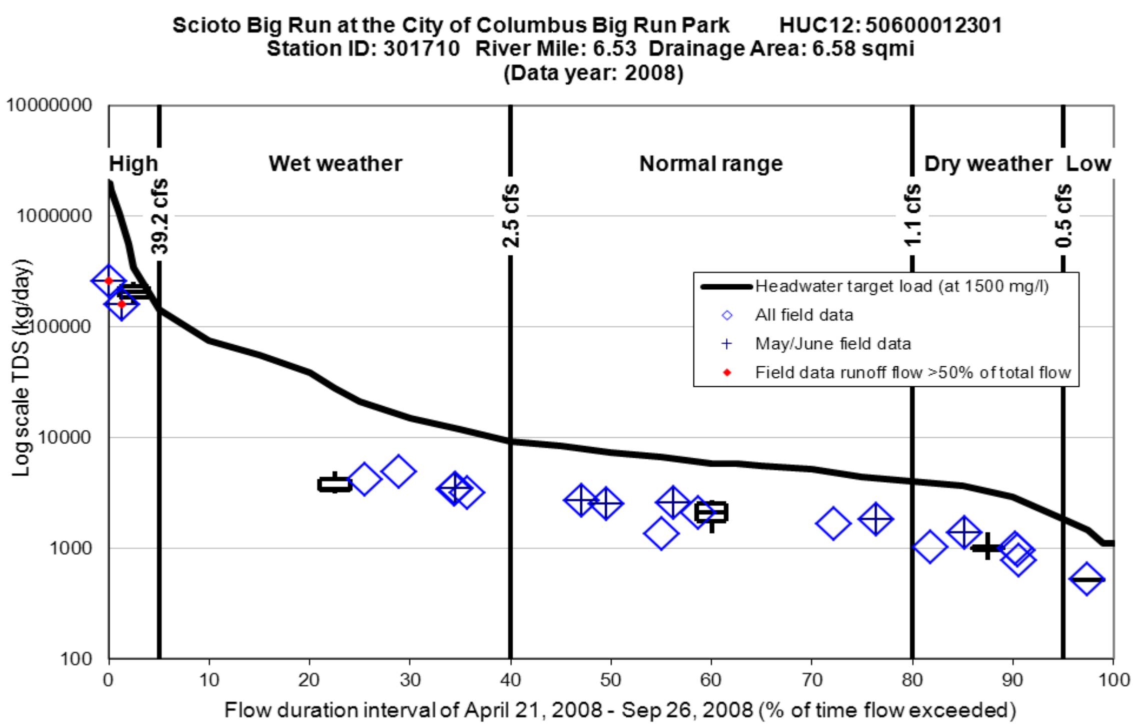


Figure 21

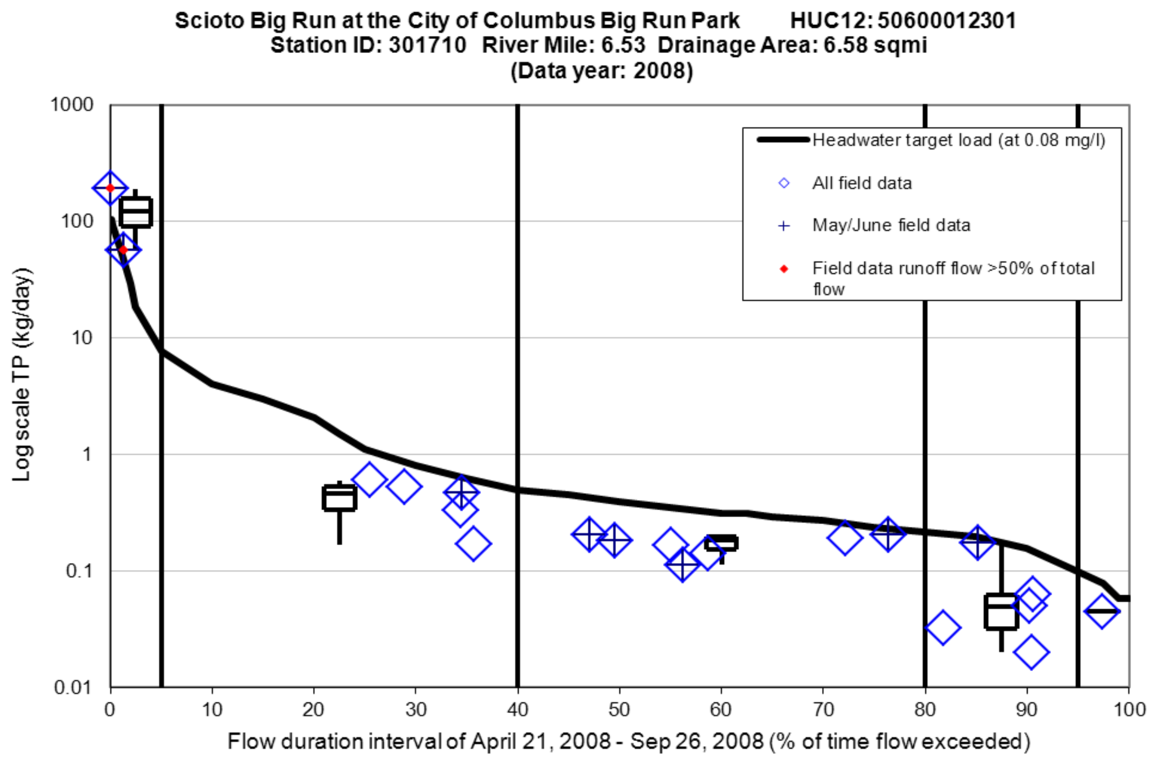


Figure 22

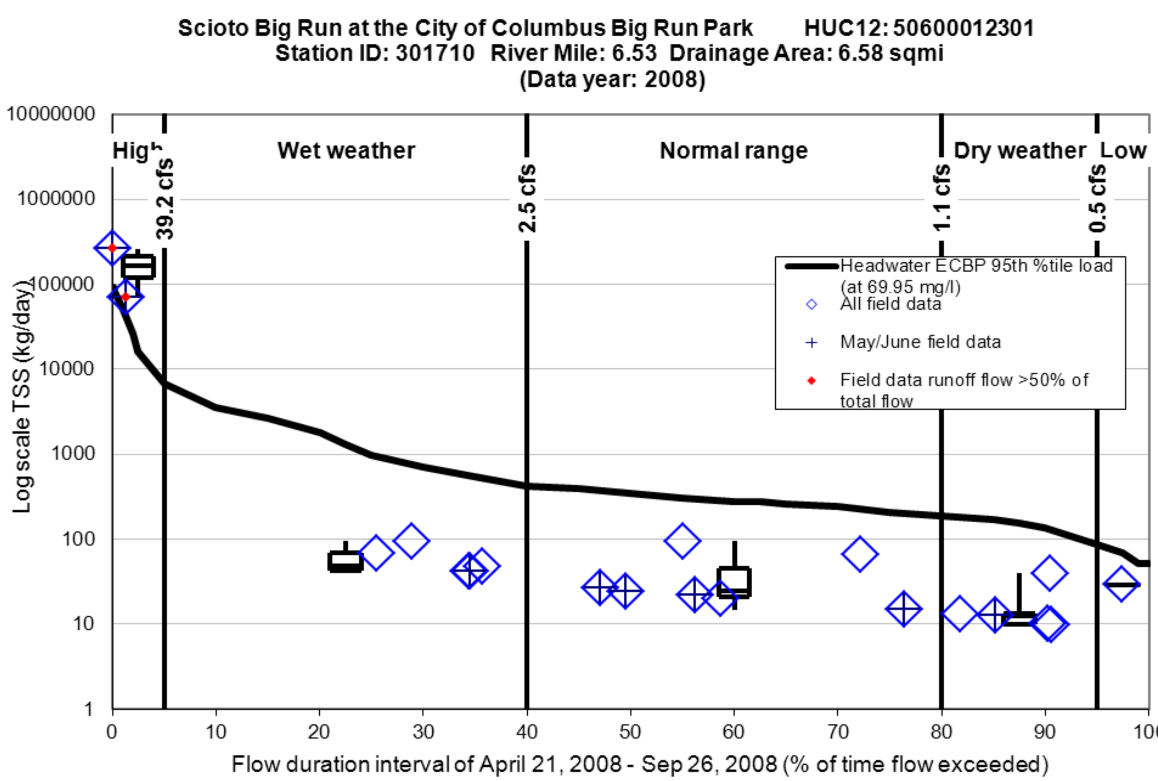


Figure 23

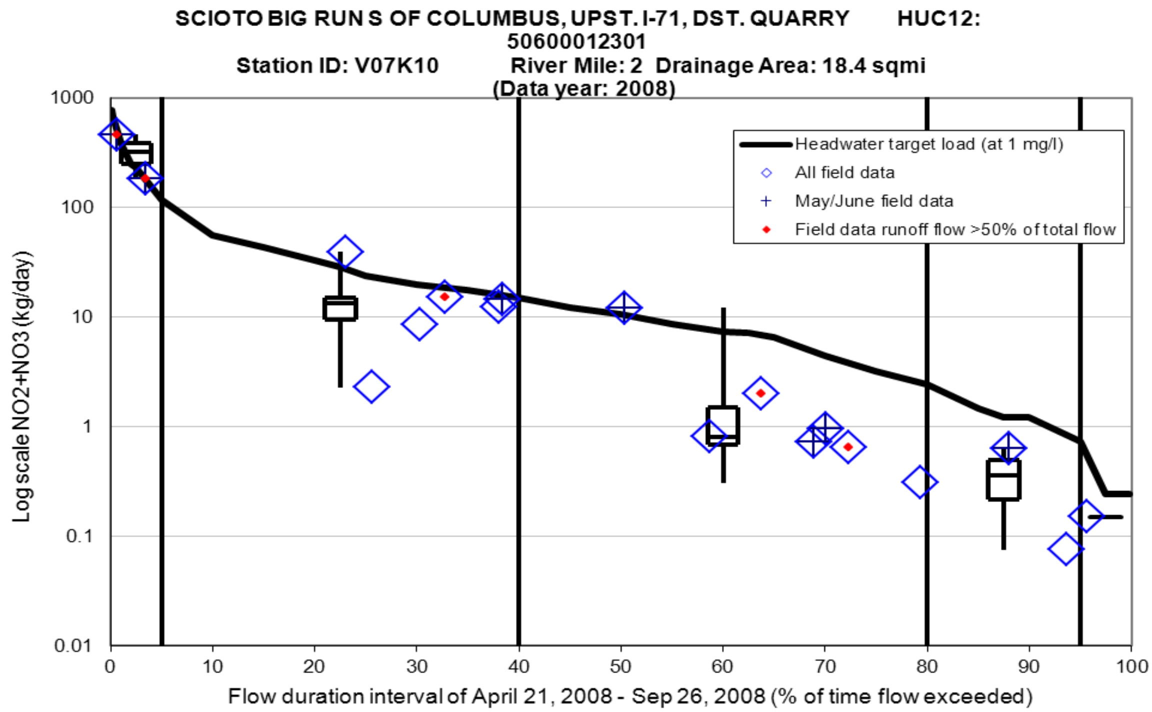


Figure 24

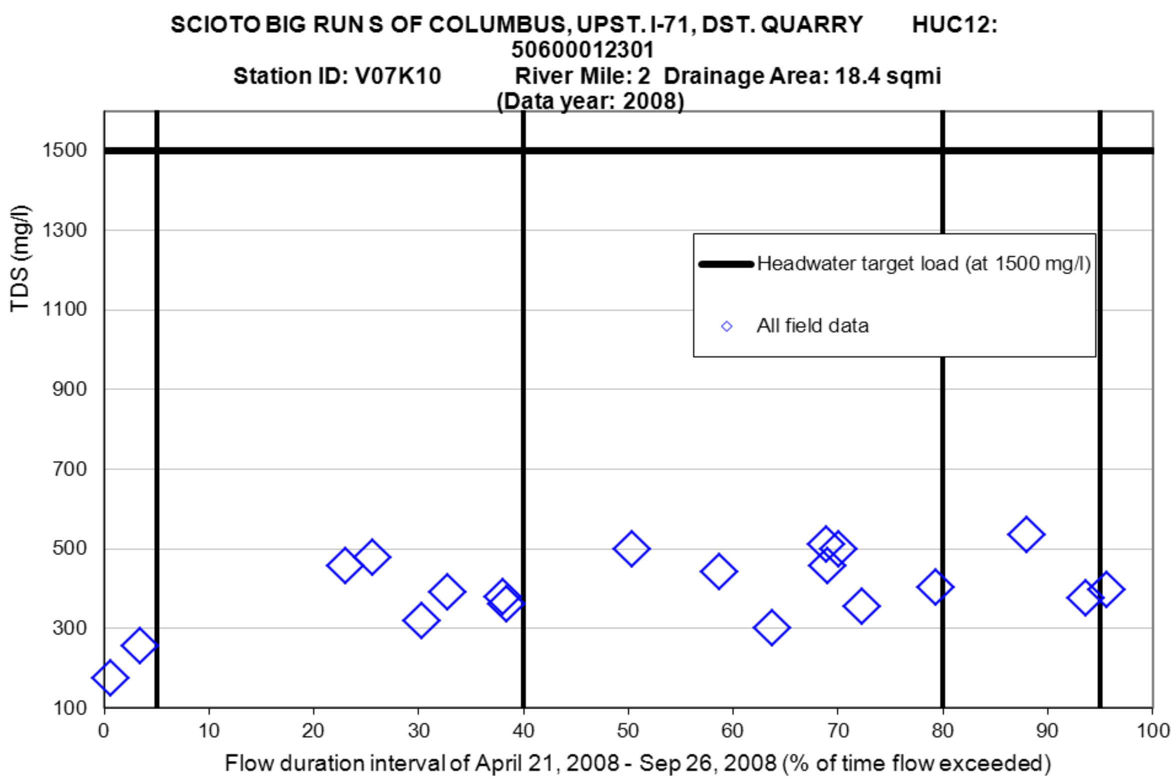


Figure 25

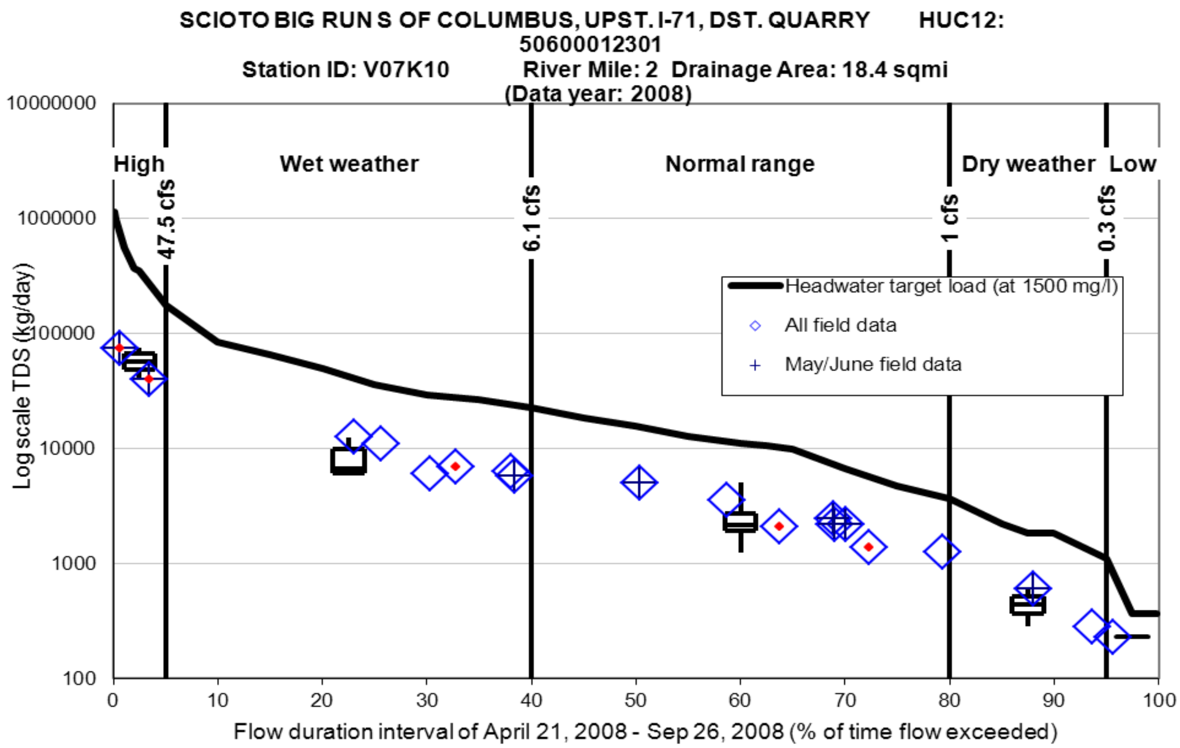


Figure 26

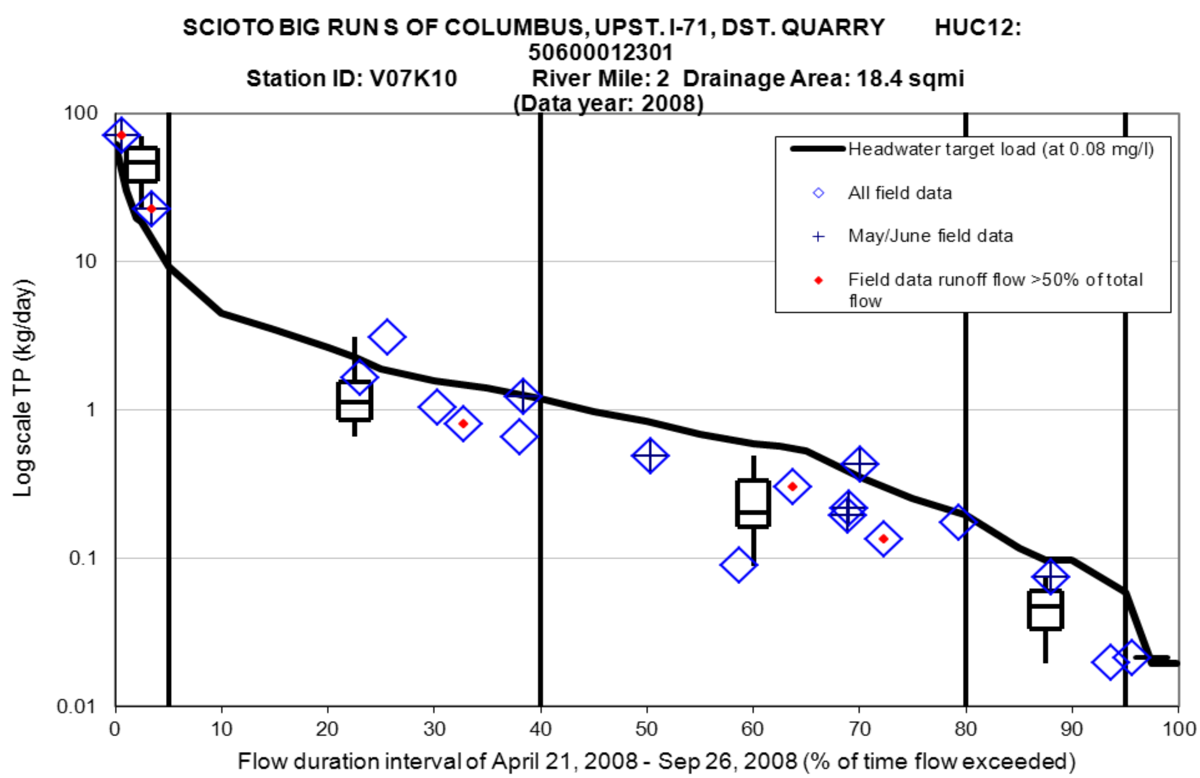
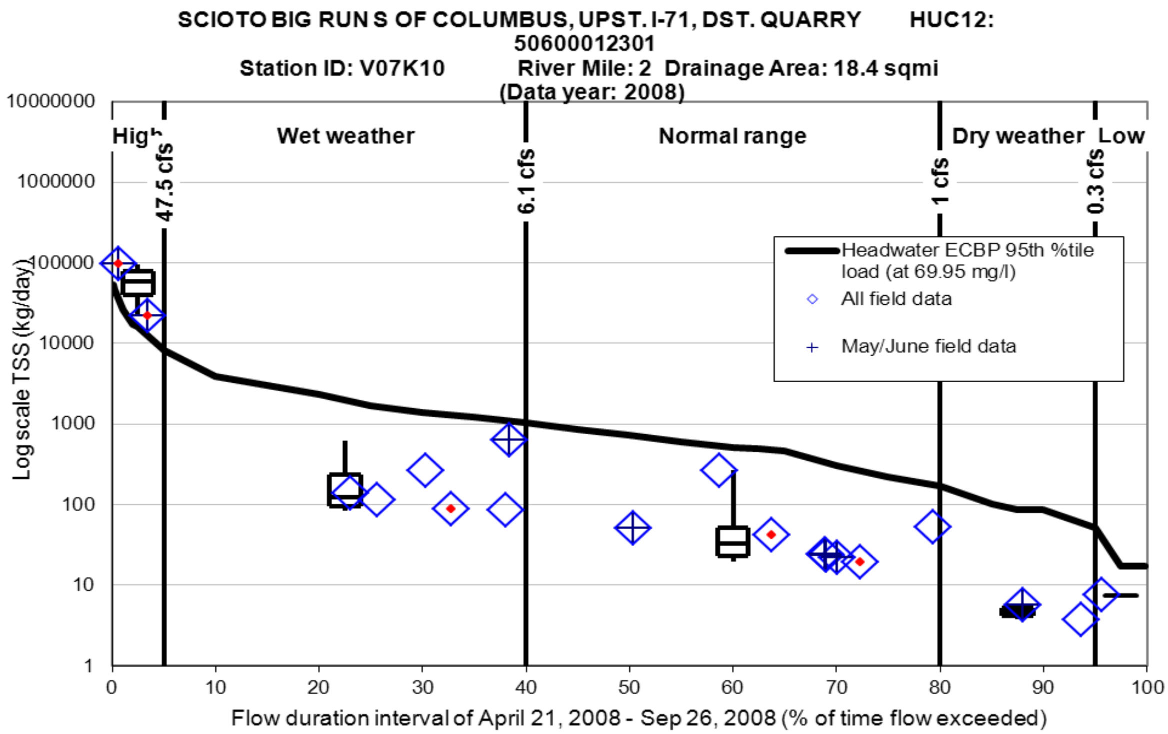


Figure 27



SCIOTO BIG RUN S OF COLUMBUS, UPST. I-71, DST. QUARRY HUC12: 50600012301
Station ID: V07K10 River Mile: 2 Drainage Area: 18.4 sqmi
(Data year: 2008)
Wet weather
Normal range
Dry weather
Low
47.5 cfs
6.1 cfs
1 cfs
0.3 cfs
Headwater ECBP 95th %tile load (at 69.95 mg/l)
All field data
May/June field data
Log scale TSS (kg/day)
Flow duration interval of April 21, 2008 - Sep 26, 2008 (% of time flow exceeded)

Figure 28

Paired watershed water quality analysis

An attempt to examine Scioto Big Run water quality versus similar, paired, watersheds has been made. Unfortunately this analysis was not envisioned at the start of the Scioto Big Run project. Because of this fact, watersheds that have been studied and have similar aspects to Scioto Big Run had to be mined from existing Ohio EPA databases. A constraint that paired watersheds must be in the same ecoregion (the Eastern Corn Belt Plain) as Scioto Big Run was put in place. An attempt to find watersheds that had been studied of similar drainage area met some challenges. Finally urban watersheds, ones with a similar amount of impervious surfaces proved unsuccessful. Hayden Run is a tributary to the Scioto River upstream of Scioto Big Run, but still within the Franklin County, City of Columbus urbanized zone. Data from a Hayden Run survey in the year 2000 is used with between 18 and 20 observations for each parameter. Pleasant Run is a tributary to the Big Darby Creek in the county to the northwest of Franklin County, Union County. Spain Creek is also a Big Darby Creek tributary in Union County. Data from the year 2001 is used for both Pleasant Run and Spain Creek with 4-5 observations for each parameter. Table 4 shows the paired watershed sites' used to make water quality comparisons to Scioto Big Run, each sites drainage area, percent land area developed and percent land area that is impervious. Scioto Big Run sites are also included in Table 4.

Table 4 Scioto Big Run and paired watershed assessment sites and key facts

Site	Drainage area (mi)	% Developed	% Impervious surfaces
Scioto Big Run at Columbus @ Norton Rd.	1.9	87.9	34.9
Scioto Big Run adj. Big Run Rd.	4.2	78.6	26.3
Scioto Big Run at the City of Columbus Big Run Park	6.6	90.9	38.2
Scioto Big Run @ Hardy Parkway	17.6	96.8	38.3
Scioto Big Run at Quarry	18.4	84.1	38.9
Hayden Run @ Hayden Run Rd adj Dexter Falls Rd	7.0	24.3	6.8
Pleasant Run @ Dunn-Burton Rd RM 4.1	4.9	3.8	0.2
Spain Cr @ Gilbert Rd RM 3.7	6.3	4.5	0.2
Spain Cr @ Mingo-Lewisburg Rd RM 5.7	4.2	4.7	0.2

From Table 4 it is clear that none of the three paired assessment sites have similar amount of development as Scioto Big Run. Because of this, analysis focused on these differences. Figures 29-33 show the Scioto Big Run and paired watersheds sites water quality average concentration versus drainage area. The figures show total phosphorous, ammonia, nitrate-nitrite, total dissolved solids and total suspended solids. The same five parameters are presented in the same fashion, but with concentration versus percent of the watershed's land area that is developed in Figures 34-38. Figures 39-43 show another similar set of data but versus percent of the watershed areas' that are covered by impervious surfaces.

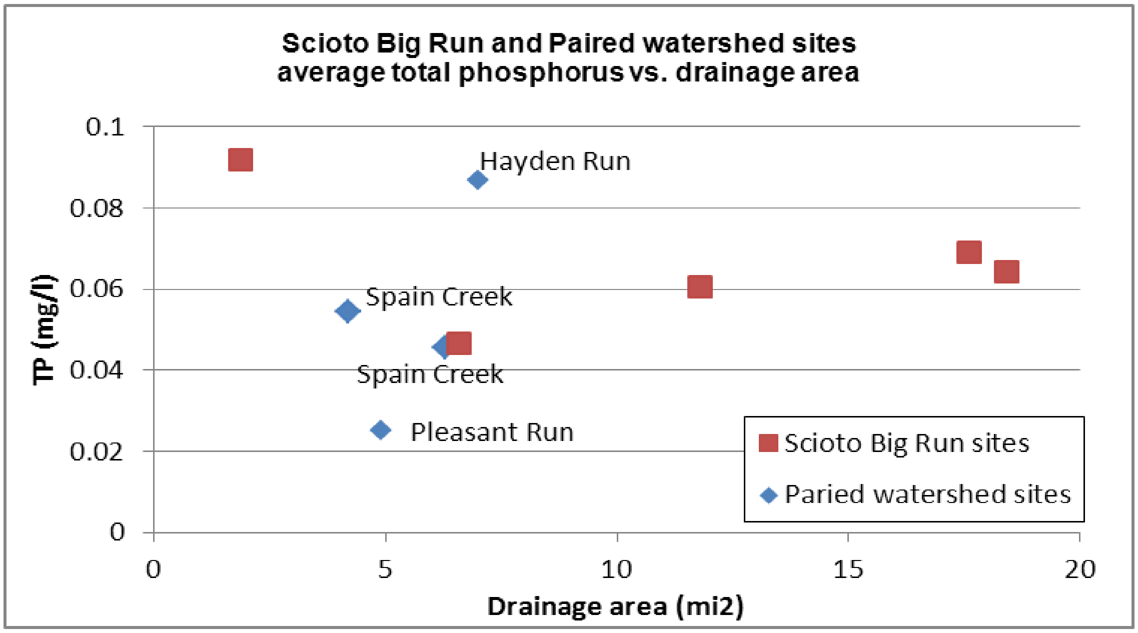


Figure 29

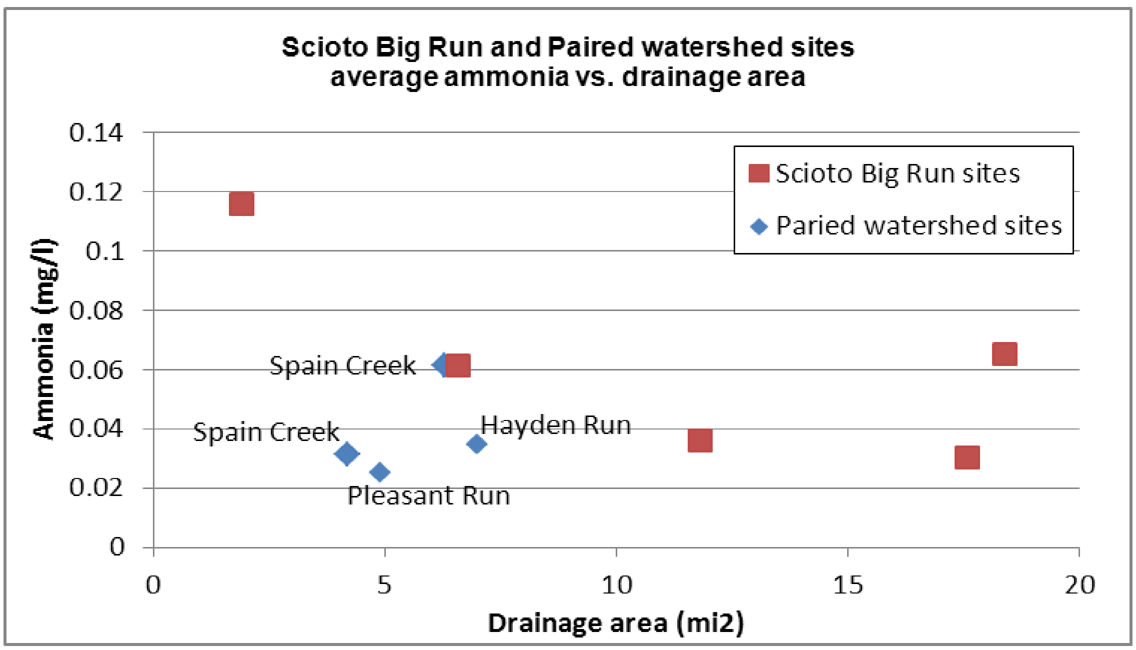
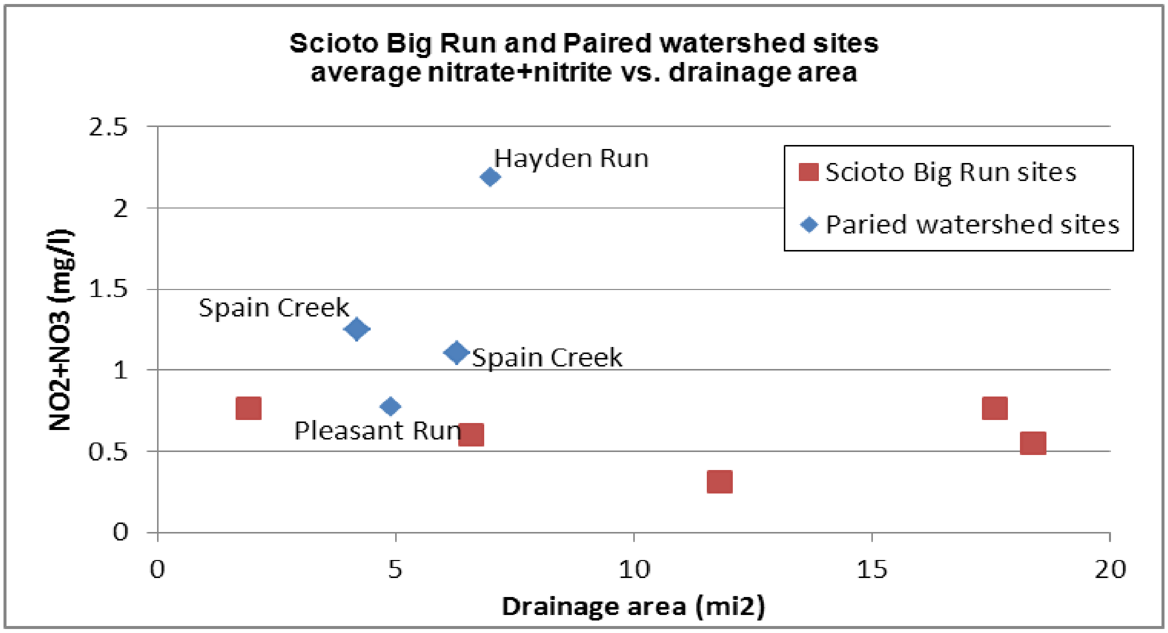


Figure 30



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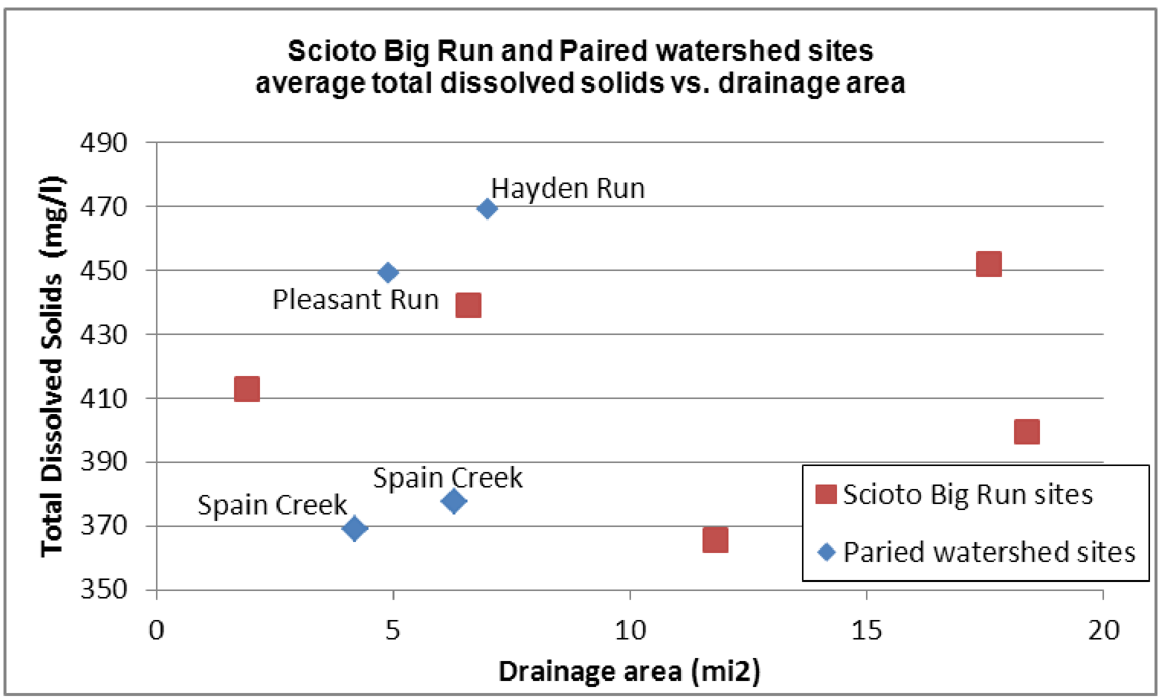
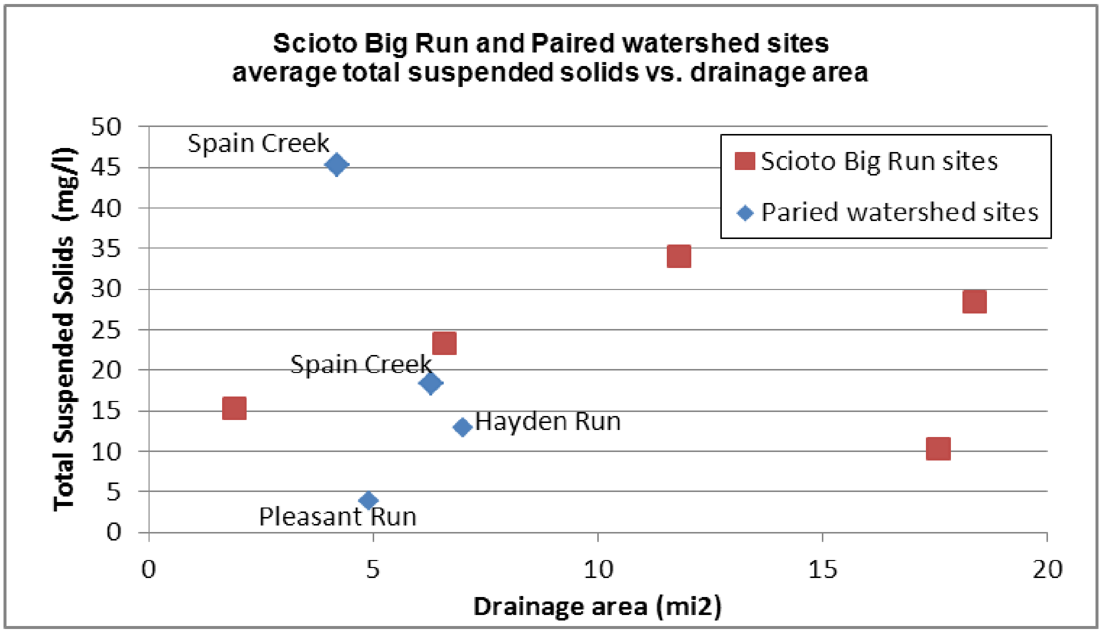


Figure 32



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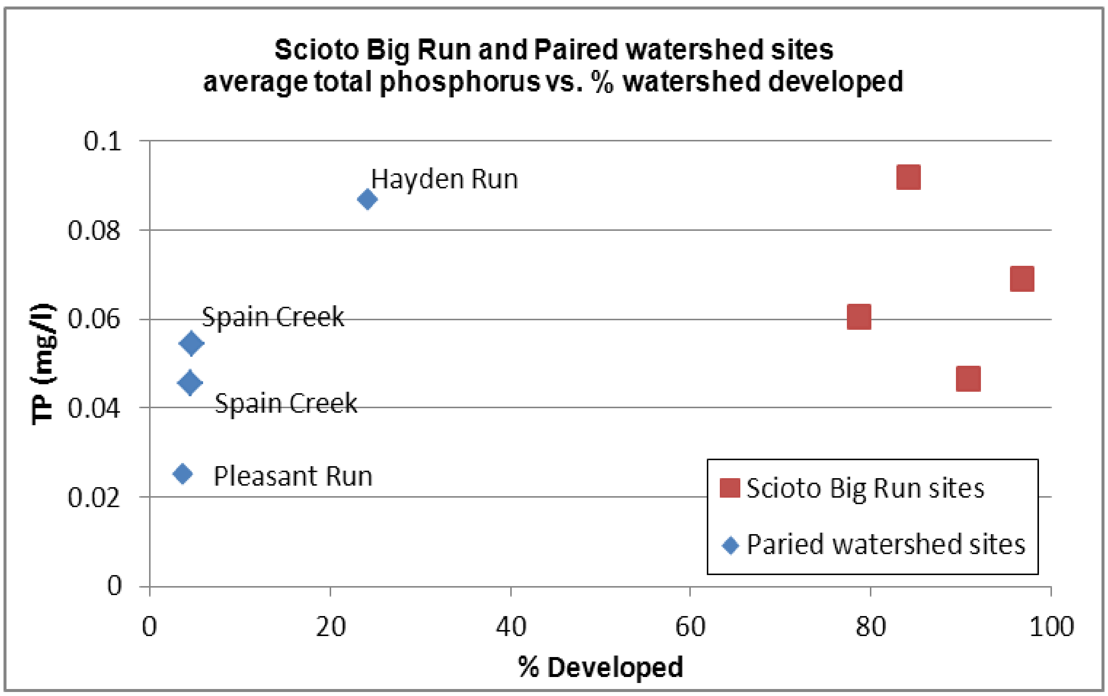

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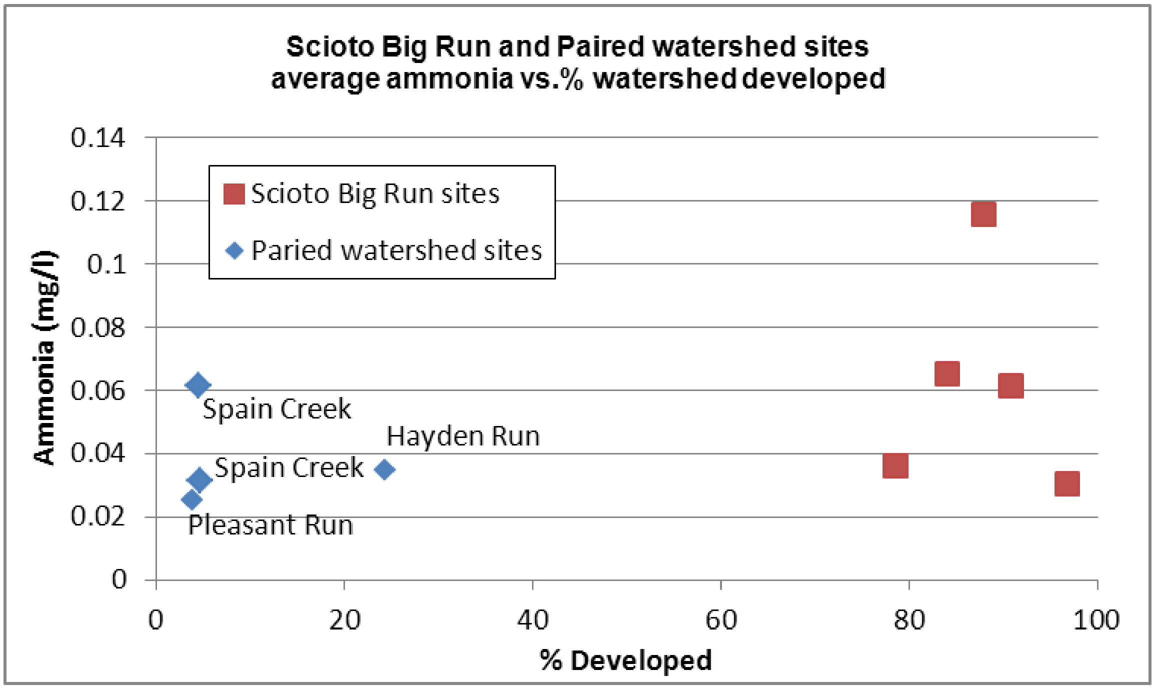

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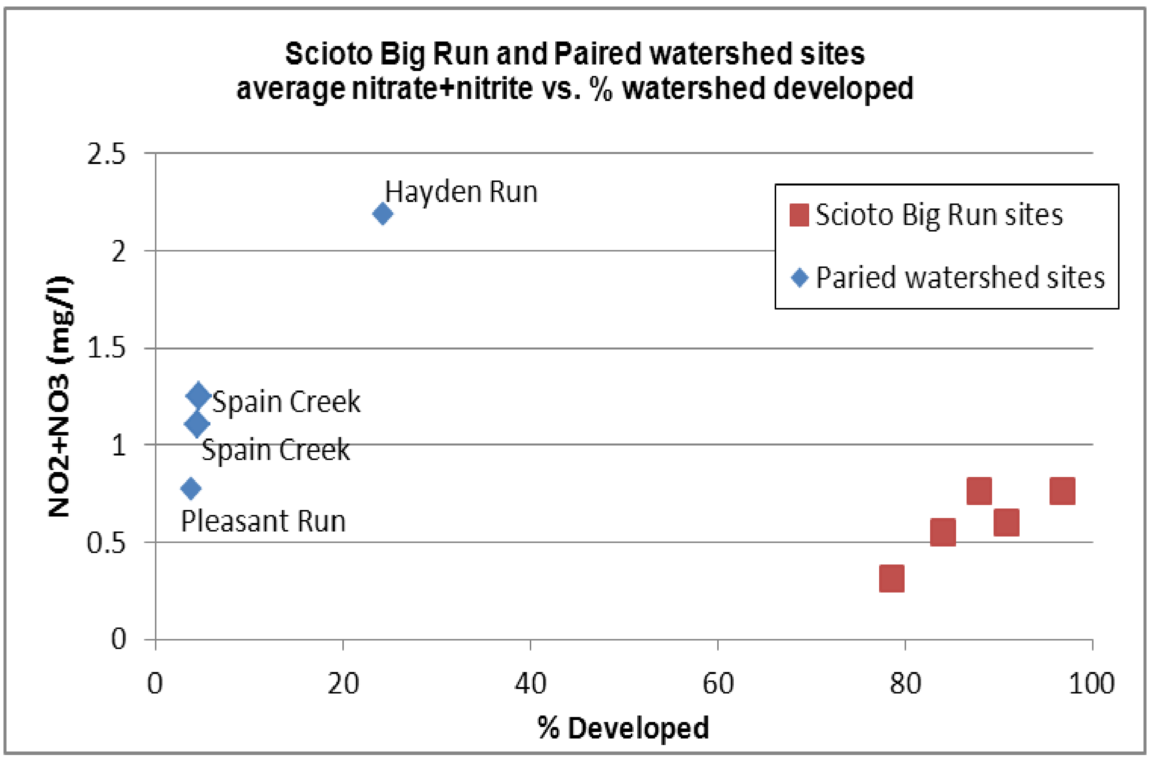


Figure 36

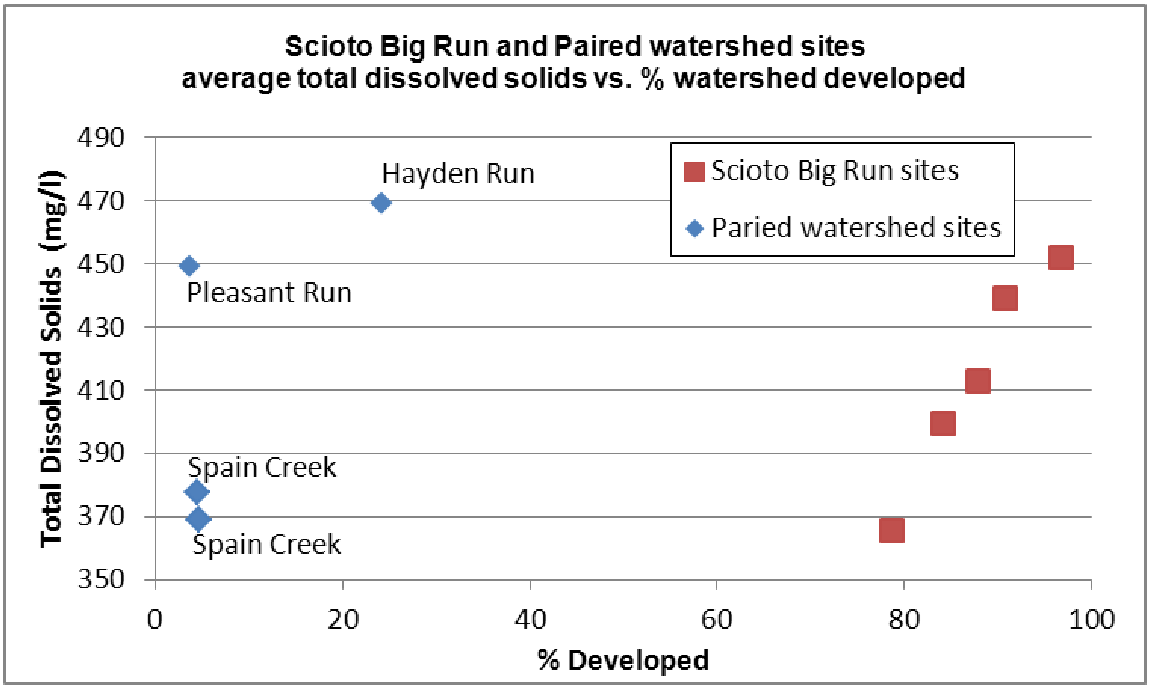


Figure 37

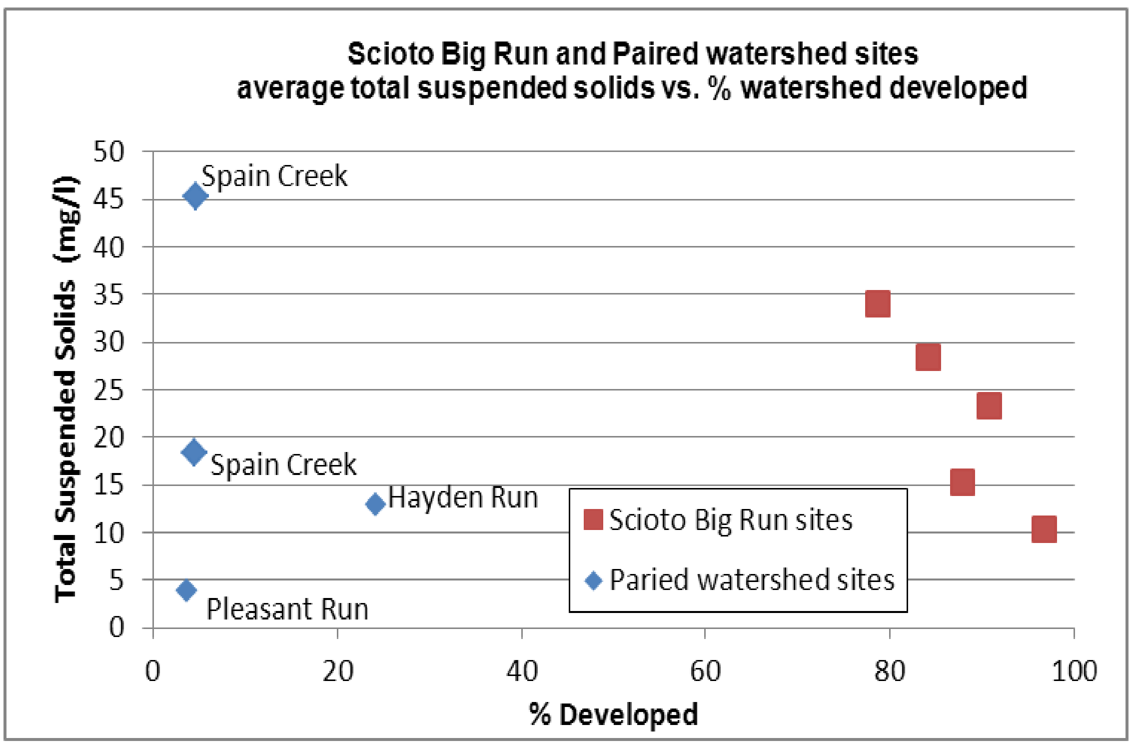
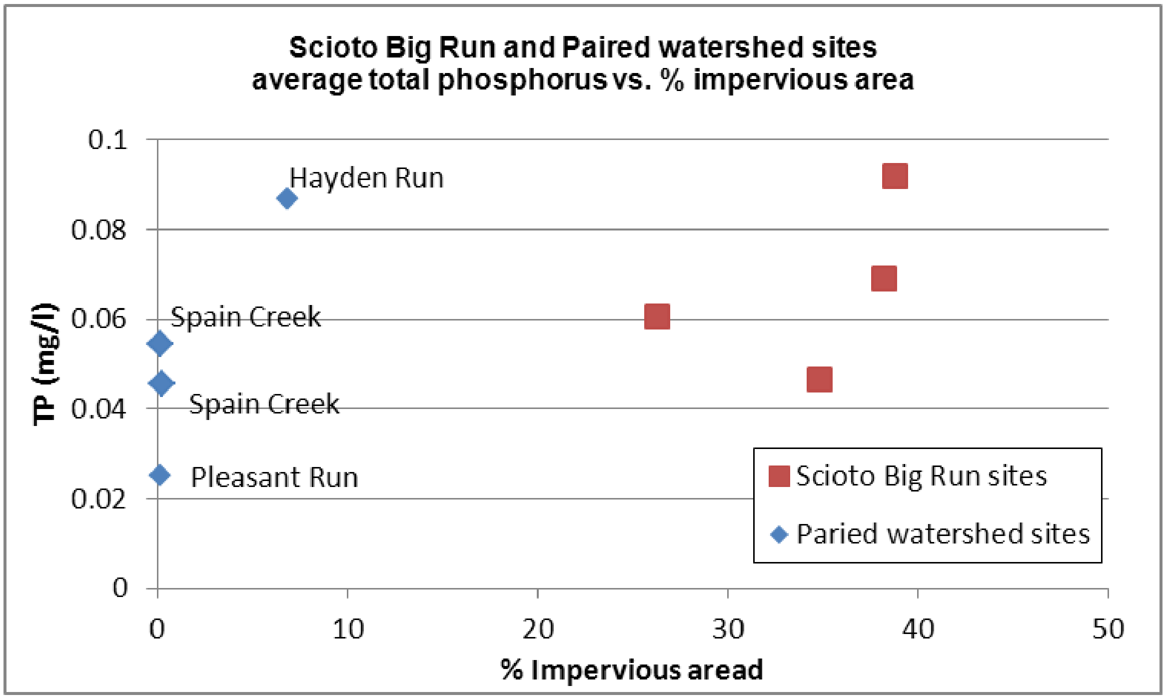


Figure 38



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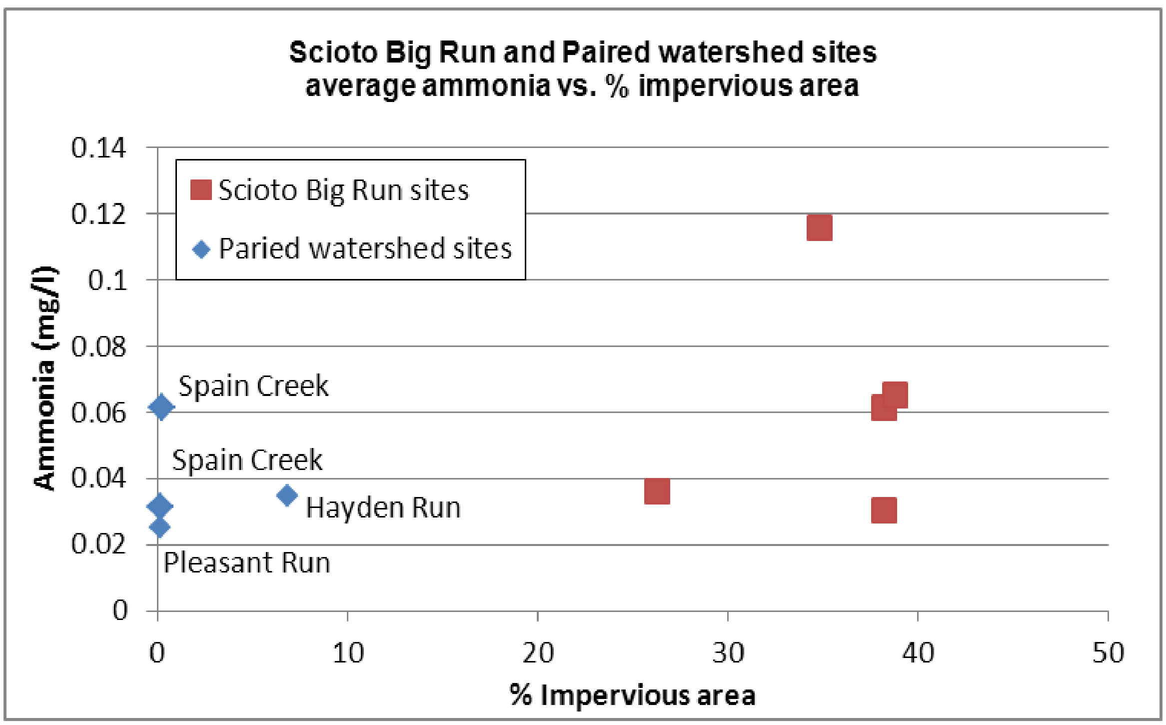

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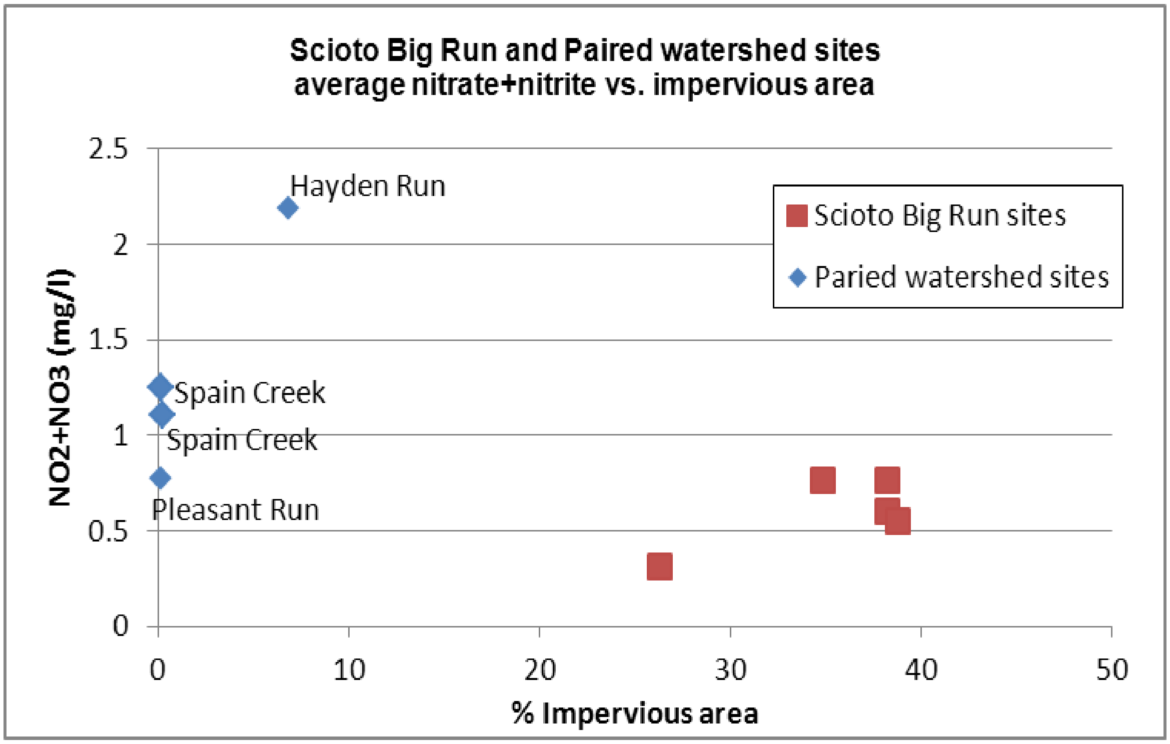

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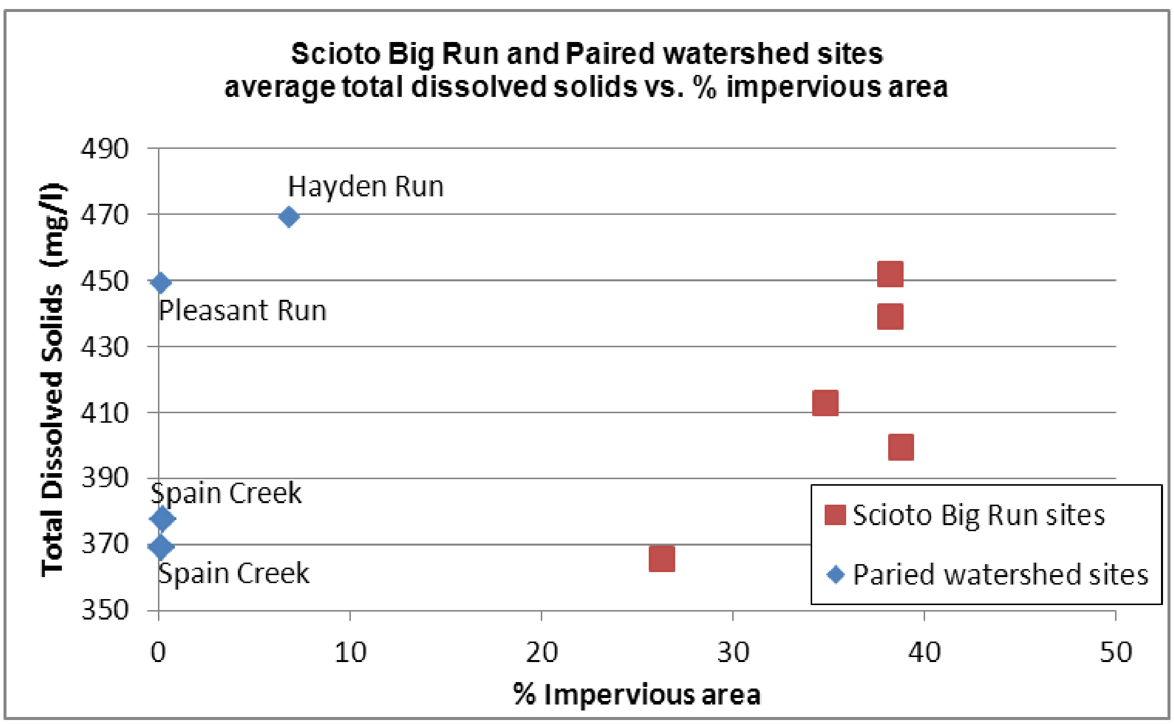

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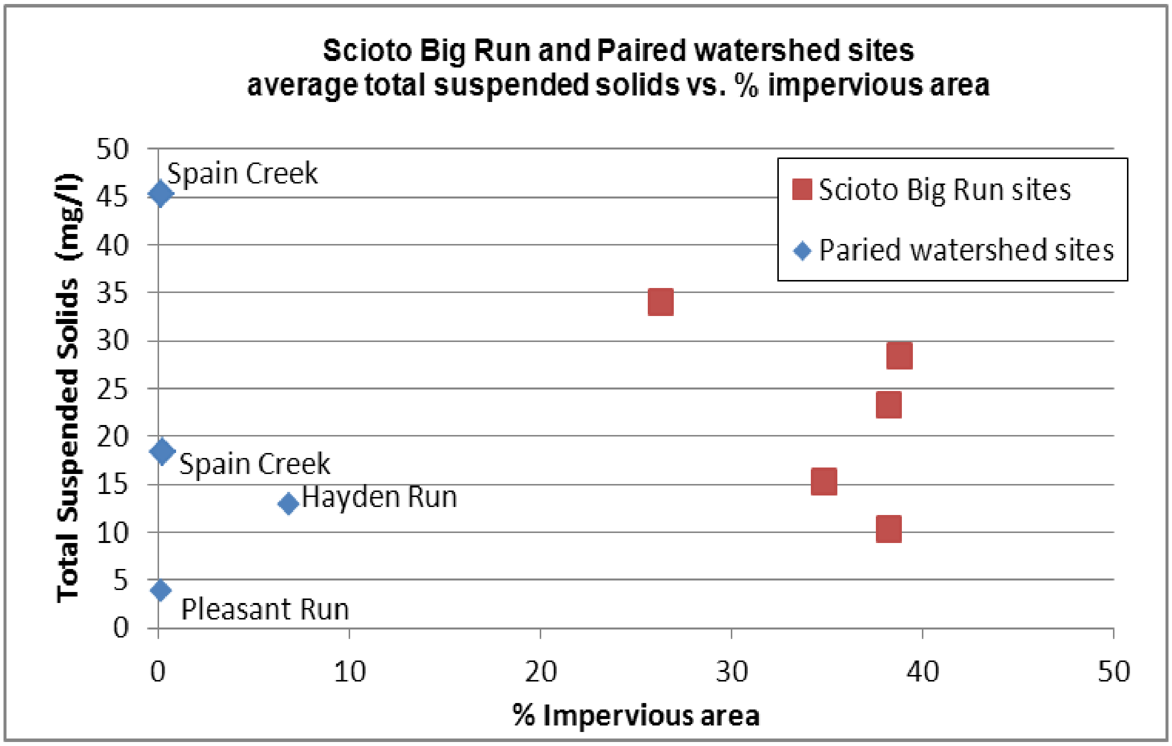

Figure 43

In examining the results from Figures 29 through 43 the majority of the water quality concentrations for the paired sites do not indicate a difference from the Scioto Big Run sites. Nitrate+ nitrite is the parameter with the greatest difference from the Scioto Big Run and paired watershed sites, with the paired sites having a higher concentration. This is expected considering the paired sites drain a much greater portion of agricultural land and nitrate is normally sourced from these areas.

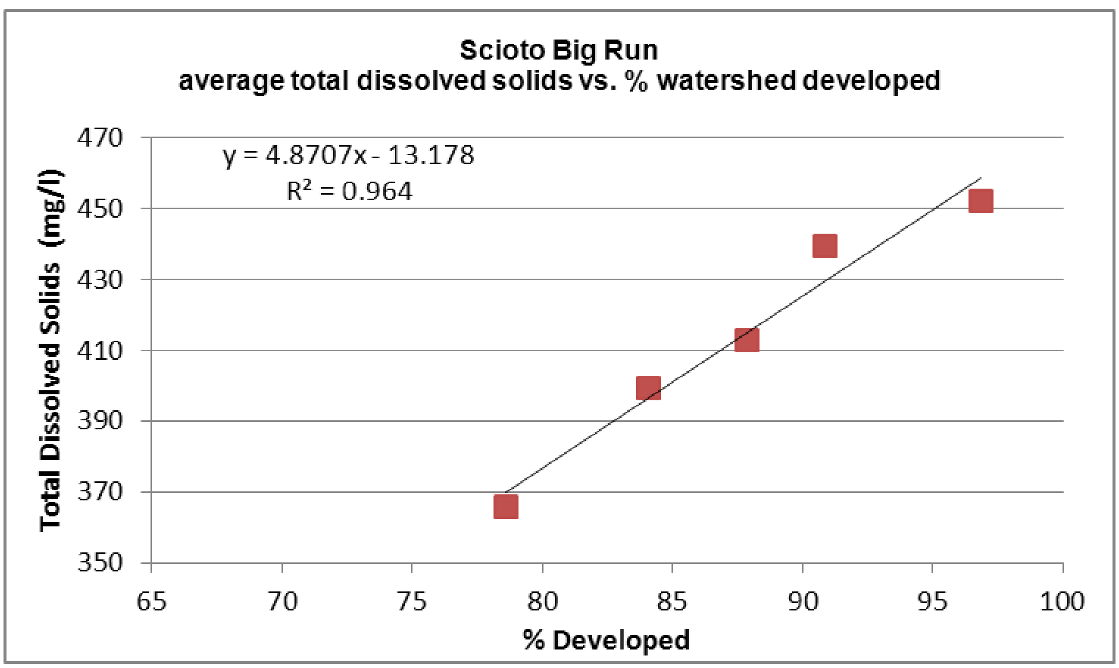

Figure 44

One interesting observation noted from Figure 37 is the relationship between total dissolved solids and the percent of watershed area developed among the Scioto Big Run sites. Figure 44 below shows the same plot, but without the paired watershed sites. A linear regression equation and line is shown in Figure 44. While the relationship between TDS and urbanization is well known (Schoonover, 2005), the strong correlation is striking and possibly worth further evaluation.

Works cited:

Ohio EPA. 1999. Association Between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams. Ohio Environmental Protection Agency Technical Bulletin. MAS/1999-1-1. Columbus, OH. http://epa.ohio.gov/portals/35/guidance/assoc_load.pdf

Ohio EPA, 2012. Surface Water Field Sampling Manual, Draft Version 4.0

Schoonover, J.E.; Lockaby, B.G.; Pan, S. 2005. Changes in chemical and physical properties of stream water across an urban-rural gradient in western Georgia. Urban Ecosystems. 8: 107–124.

Sloto, R.A., and Crouse, M.Y., 1996, HYSEP: A computer program for streamflow hydrograph separation and analysis: U.S. Geological Survey Water-Resources Investigations Report 96-4040, 46 p.

US EPA, 2007. An Approach for Using Load Duration Curves in the Development of TMDLs. EPA 841-B-07-006

USGS. 1984 Discharge Ratings at Gaging Stations. TWRI 3-A10.