The Ozarks Environmental and Water Resources Institute (OEWRI)
Missouri State University (MSU)

FINAL REPORT FOR:

NUTRIENT TRANSPORT AND FATE FROM MUNICIPAL BIOSOLIDS LAND APPLICATION

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SCOPE AND OBJECTIVES

Biosolids are the residual by-product of the municipal treatment of wastewater and are used to fertilize forage crops and pastures in southwest Missouri. Human health risks for land application of biosolids are considered low when the material is properly handled and treated per environmental regulations (USEPA, 1994[a]). Regardless, the public perception is that land applied biosolids release nutrients and trace metals during runoff events and contribute to water quality problems in nearby streams and lakes. Land application rates of biosolids are site specific and are based on soil fertility, crop needs, and production goals to avoid over-fertilization where valuable nutrients can move off of fields and into receiving waters (MDNR, 1985).

Like all organic fertilizers (e.g. manure, chicken litter), biosolids are high in phosphorus (P) per unit nitrogen (N) and over-application of P can occur when applied at a rate based on N needs of the crop (Shober and Sims, 2003). Over-application can cause excess P to wash off the landscape into receiving waters during runoff events and is a leading factor in eutrophication of aquatic ecosystems (Correll, 1999; Dodds, 2006). Trace metal concentrations in runoff from biosolids treated fields are influenced by site specific conditions, such as soil type, moisture conditions, and conservation practices (Al-Wabel et. al., 2002; Richards et al, 2004; and Galdos et al, 2009). However, little is known about metals in runoff from other fertilizer sources since concentrations of many trace metals in biosolids are near or below concentrations of metals in poultry litter and inorganic fertilizers (Spicer, 2002).

In the Ozarks, questions still remain on the release of nutrients and metals from biosolids applications during runoff events and the contamination of downstream receiving water bodies under local soil, slope, and crop conditions. Working with the Missouri Department of Natural Resources (MDNR), Natural Resources Conservation Service (NRCS), and Missouri State University (MSU), the City of Springfield has conducted a 3-year study to compare the runoff rates of nutrients and metals from fields treated with biosolids to fields treated with traditional inorganic fertilizer. The purpose of this study is to determine the effect of biosolids application on runoff quality under field conditions. The specific objectives of the study are:

1. Implement an experimental field plot monitoring program using runoff auto-samplers to measure the concentrations and loads of nutrients and metals released from fields treated with biosolids;

2. Compare the levels of nutrients and metals in runoff, surface soils, and forage measured in biosolids treated fields to fields treated as control (no application) and with traditional fertilizer;
3. Use this information to support the continued approval of biosolids applications by government regulators and provide information to the general public on the safety of using biosolids as a component in an overall nutrient management plan.

The Ozarks Environmental and Water Resources Institute (OEWRI) at Missouri State University is responsible for providing technical support and implementation of water quality monitoring activities and surface soil sampling and testing activities, and reporting for the project (www.oewri.missouristate.edu). The Darr School of Agriculture at Missouri State University is responsible for the soil morphological classification, forage collection and analysis, and weed control of the site. The Natural Resources Conservation Service Southwest Missouri Water Quality Office provided the nutrient management plan. Specific contributions in data collection, reporting and editing for this report came from the following:

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This report organizes and summarizes data collected over the three year sampling period from November 2008 through August 2011 and provides detailed methods and results for water quality monitoring, soil testing, and forage analysis. Maps, figures, tables, and photos corresponding to these sections are at the end of the narrative. Appendices of all field data collected during the study can also be found at the end of this report.

STUDY AREA

The Biosolids Demonstration Site is located in Lawrence County in the Sac River Watershed (hydrologic unit code 10290106). The site is located on a 40 acre tract in the SE ¼ of the SE ¼ of the northern half of Section 3, Township 29N, Range 27W in northern Lawrence County (Figure 1). This tract is bisected by a small tributary valley flowing north into Limestone Creek, a tributary to Turnback Creek and the Sac River Basin. The surface geology of the area is typical of the Springfield Plateau of the Ozarks which is dominated by cherty Mississippian age limestone along with remnants of Pennsylvanian age sandstones. Generally, upland soils are

derived from residuum topped by a thin layer of loess material (Hughes, 1982). On hillslopes, residual soils are capped by a layer of silty and cherty colluvium, which increases in thickness going downslope. Mapped soils for this property are the Viraton silt loam on the top of the uplands, Nixa cherty silt loam on the sideslopes, and Clarksville cherty silt loam in the steeper areas below where the Nixa series is located (Figure 2). The Viraton and Nixa series typically contain a fragipan and are classified as moderately well drained while the Clarksville is somewhat excessively drained. Site specific soil descriptions and deviations from the typical profiles will be discussed later on in this report. Previous management included a combination of haying cool season grass fescue each spring followed by grazing of beef cattle for the duration of the season. Upland cattle grazing and forage management in similar small catchment areas is typical for this region. Land was leased prior to the initiation of the study, cattle were removed off-site and excluded from returning by constructing a fence.

METHODS

Site Selection

This property was chosen based on the uniformity in land cover, landscape position, slope, and soil type as best as could be done under natural conditions. A site assessment was conducted during the initiation phase of planning to determine the feasibility of the experiment and to determine the site suitability for the application of biosolids. Existing conditions were inventoried, populated into the Missouri Phosphorus Index (MUE, 2007) and determined that application of organic material at nitrogen based rates was permissible.

Four separate catchments were selected in a single field on a Wilderness-Viraton Soil Association (Table 1). Catchments designated for the study plots are located off the east and west facing slopes along a ridge running generally south-to-north with slopes ranging from 3.5% to almost 14%. Sites were located near the top of the watershed to eliminate run-on influences. All sites drained to an identifiable pour point at the base of the slope in a small draw where concentrated flow could be captured. The entire site was surveyed and a topographic map created to identify the drainage area of each catchment ranging from 0.38 acres to 3 acres (Figure 3).

Because of the topography of the site, each watershed generally overlaid two of the four soil map units present on the site (Table 1). Goss soils are classified as a clayey-skeletal, mixed, active, mesic Typic Paleudalfs and are typically found on side slopes of ridges. Viraton soils are generally located on more level summit landscape positions and are classified as a fine loamy,

siliceous, active, mesic Oxyaquic Fragiudalfs. The Nixa soils are more generally on ridge tops and are classified as a loamy-skeletal, siliceous, active, mesic Glossic Fragiudults. Clarksville soils are on the steeper slopes of hillsides ranging from 3-20% and are classified as loamy-skeletal, siliceous, semiactive, mesic Typic Paleudults. Forage suitability classifications for each soil were described as a gravelly upland, gravelly pan, or loamy pan suitability group with an estimated yield goal of 2-3 tons of grass per acre. All soils do not meet hydric criteria and each contain properties consistent with the karst geology of the Missouri Ozarks region.

Soil morphological classification was performed to assess the variability in soil properties across the site and to compare soil pit field descriptions to the mapping units in the soil survey. Test pit locations on the landscape were determined by using aerial photo maps of the area and comparing them with observations using clinometers to locate proper slopes on the landform for summit, shoulder, back slope and foot slope positions. Pits were dug to a depth of 60 in. to 80 in. (where permitted) to observe horizons of the soil pedons and recorded using field notes as described in USDA (2002). Taxonomy classifications were determined according to USDA (2006). Locations of soil pits can be found in Figure 2.

The dominant parent materials for this site are colluvium over residuum. On the flat uplands, the upper horizon consists of a thin layer of loess up to 8” deep (Table 2, Photo 1). Along the broad head slope, a well formed fragipan is present between 32”and 45” deep, while a shallower, weak fragipan exists on the narrow interfluve at the crest of the narrow ridge (Photo 2). The presence of redoxamorphic features above the fragipan and within the prismatic seams through the fragipan are indicators of a seasonally high water table (Photo 3). The steeper side slopes are coarser closer to the surface, with sporadic remnants of weathered sandstone present 50” to 60” below the surface (Photos 4 and 5). In the bottom of the colluvial valley there is nearly a 2 foot accumulation of alluvium over colluvium that contains high chert content (Photo 6). Soil morphology descriptions are available at the Missouri Cooperative Soil Survey website at soils.missouri.edu.

The experimental design of this study called for four individual nutrient treatments, each applied to a separate catchment. Details of each catchment are described below:

Site 1 catchment size = 0.38 acres - this site drains the east side of the ridge on the north end of the property. This site drains primarily the backslope and footslope landscape positions and was designated as the control.

Site 2 catchment size = 0.65 acres - this site also drains the east side of the ridge and received a commercial fertilizer application. Only a small portion of this catchment drains the summit landscape position, mostly draining the backslope and footslope.

Site 3 catchment size = 3 acres - this site drains from the southern end of the property on the east side of the ridge. The majority of this catchment drains the summit landscape position. This site received the low rate biosolids application.

Site 4 catchment size = 1.28 acres - this site drains the west side of the ridge running through the property on the summit and backslope landscape positions. This site will received a biosolids application at a rate higher than site 3.

Nutrient Management and Treatment Strategy

In 2008, soil samples were collected at three different landscape positions (summit, back slope, and foot slope) along established transects in each watershed. At each landscape position, in each watershed, individual soil cores were collected at 6-8 inches in depth and combined to comprise a single sample. Samples were used to establish the general fertility of the site and to determine the lime requirement at 400 Effective Neutralizing Material. Global positioning technology was utilized to assist in subsequent re-sampling each summer. Samples were air dried and sent to the University of Missouri Soil Testing Laboratory for soil analysis (Appendix A).

The City of Springfield, Missouri provided biosolids from its Southwest Wastewater Treatment Plant for the study. Initial analysis of biosolids conducted by the Southwest Wastewater Treatment Plant Laboratory was used to estimate Plant Available Nitrogen (PAN). PAN is estimated using the following equation:

$$PAN = f_o(\text{organic N (ppm)}) + f_a(NH_3\text{-N (ppm)}) + NO_3\text{-N (ppm)}$$

f_o (Availability factor (organic)) = 0.2
f_a (Availability factor (ammonia)) = 0.7

Using established mineralization rates for anaerobically digested sewage sludge, it was estimated the plant available nitrogen from a single 3 t/ac (dry) application was roughly equivalent to the annual nitrogen recommendation for a 3 t/ac yield goal of cool season grass (USEPA, 1994[b]; MUE, 2004). At a rate of 6 t/ac (dry) of biosolids, nearly three growing seasons of nitrogen would be delivered. Because the Southwest Wastewater Treatment Plant is located

in a nutrient sensitive watershed, limited phosphorus is allowed in the discharged wastewater. Consequently, large quantities of phosphorus are retained in the biosolids and applied to land with the nitrogen (nearly 600 lbs/ac P_2O_5 at the 6 t/ac rate).

Experimental design was also influenced by the desire to match experimental protocol to local farming practices. Typically, farmers participating in a cooperative program with the City of Springfield receive a single application of biosolids to suitable fields under specified conditions, including appropriate setback distances from surface features (MDNR, 1985). Repeat applications are infrequent within a three year time frame. Thus, biosolid applications were made only in the first year of the experiment. For the commercial fertilizer treatment, equivalent amounts of nutrients were included in the blend to balance the nutrients delivered from the 3 t/ac biosolid application rate. Similar to the biosolids application, all of the added phosphate and potash from the commercial fertilizer were applied in the first year. However, unlike the biosolid application, the total amount of nitrogen was divided into three annual applications to closer represent local practices. This strategy front loads nitrogen application for the biosolids treatments, but represents reality in the field.

A calcic limestone application was made on the entire property by a commercial dealer on September 9, 2008 to adjust soil acidity to near neutral levels. The biosolids applications were made with a commercial Terra-Gator 3104 side discharge spreader on October 23, 2008 and the commercial fertilizer applied by a commercial dealer on October 28, 2008. Biosolids samples were collected on the day of application and analyzed by the laboratory to determine actual nutrient concentrations of the processed material from the treatment plant. This analysis, coupled with actual field application measurements, was utilized to determine the actual nutrient application to each catchment area (Table 3).

Site 1 received no treatment and is designated as the control. Site 2 received a commercial fertilizer application based on a 3 t/ac yield goal of 54+299+13 ($N+P_2O_5+K_2O$) in year 1. In year 2 and 3, a fertilizer application rate of 54+0+0 ($N+P_2O_5+K_2O$) were applied to mimic the slow release of N from the breakdown of biosolids over that time. These subsequent applications occurred August 5, 2009 and August 30, 2010. Site 3 received 3 t/ac biosolid application, which is equivalent to the commercial fertilizer application. Finally, site 4 received 6 t/ac biosolids application rate, which is the maximum rate allowed.

The biosolid analysis revealed the material spread contained more (37 %) plant available nitrogen, nearly the same (+/- 3.5%) phosphorus and less (76%) potash than the analysis used for planning purposes. Adjustments to the commercial fertilizer rates applied in the second year on August 5, 2009 were made to compensate for variability of the application rate and

biosolid concentration applied in the first year. Concerning the comparative treatments, the total nutrient quantities applied over the 3 growing seasons are estimated to be within 1 lbs/ac for nitrogen and phosphorus, but the watershed treated with commercial fertilizer received 10 lbs/ac more K_2O than the watershed treated with biosolids at 3 t/ac.

Hydrology and Water Quality Monitoring

<u>Weir Design and Runoff Measurements</u>

Runoff discharge was measured by weir-calibrated transducer measurements. At each site, a PVC board dam with a one foot tall 90° v-notch weir was constructed to intercept run-off in the individual catchments (Photo 7). The dam and weir allows water to be captured and released at a predictable rate based on standard weir-discharge relationships (French, 1985). Portable auto-samplers (Model # 6712, Teledyne ISCO) equipped with a rain gage and stage recorders were placed at each site to collect rainfall and run-off data. Rain gages measure and record total rainfall in 1/100th inch increments over 5 minute time periods. A pressure transducer level sensor with datalogger was positioned upstream of the v-notch weir that measures and records water levels every 5 minutes at each site.

Stage versus discharge relationships were created for each site based on the position of the pressure transducer to the bottom of the v-notch weir (Table 4 and Photos 7 and 8). Some storm events generated enough runoff to collect behind the dams constructed below each site, but did not fill to a level where it flowed through the weir. In this case, samples were collected and analyzed, and half of the capacity above the weir at the level of the notch was used for the runoff volume estimated by field measurements. Discharge volume was calculated by taking the average of all discharge measurements collected over the storm event and multiplying that discharge by the duration of the event. Yields were then calculated by dividing the discharge volume by the drainage area from each catchment.

<u>Water Quality Sampling</u>

A strainer was positioned next to the pressure transducer upstream of each dam and was connected to the auto-sampler with a 25 ft. suction line. Initially, each auto-sampler contained twenty-four 1 liter bottles and was programmed to collect 1 liter of water every 10 minutes when the stage recorder detected water behind the weir. However, since June 2009, auto-samplers were fitted with a single 10 L Nalgene composite bottle and reprogrammed to collect single event composite samples. During a storm event, the sampler collected 500 ml samples every 15 minutes when rainfall rate and level reach set point (0.10 in/30 min and 0.1 ft., respectively). The new configuration saved time and limited error in the field as well as reduced prep time in the lab.

After a sample was collected, composite bottles were removed, and the sample was split for further analysis. Samples were split among three bottles to be analyzed for: (1) metals, preserved with HNO_3 to a pH < 2; (2) nutrients, preserved with H_2SO_4 to a pH < 2; and (3) total suspended solids (TSS), fecal coliform, and pH, no preservative added. In addition, a field duplicate and a field blank were collected for each sampling event to ensure proper sample collection procedure.

Water Quality Analysis

Samples were analyzed at the City of Springfield's Southwest Wastewater Treatment Plant for metals, nutrients, total suspended solids (TSS), fecal coliform, and pH following Environmental Protection Agency Methods (EPA) and Standard Methods for the Examination of Water and Wastewater (SM4500) protocol (Table 5). Average field blank concentrations were less than detection limits for metals, ammonia and fecal coliform. Average field blank concentrations for other parameters were 1.1 mg/l TSS, 0.25 mg/l total kjeldahl nitrogen (TKN), 0.066 mg/l nitrate, and 0.062 mg/l total phosphorus (TP). Median relative percent difference of the duplicate ranged from 4-29% for all parameters. More details on the analyses can be found at http://www.epa.gov/waterscience/methods/.

Surface Soil Monitoring

Sampling

Surface soils within each watershed were monitored to measure changes in metals and nutrients over the study period. Surface soils were sampled approximately 1 month after lime was applied, but prior to fertilizer and biosolids applications. Soil samples were collected at each of the 4 sites at the footslope, backslope, and summit landscape positions to determine site variability (Table 6, Figure 3, and Photo 9). To compare variability within each landscape position, three soil samples were collected at each of the three landscape positions at each site. The three samples were collected along a transect that cut across the drainage way, one in the center and the other two ≈6-10 ft to each side at each landscape position. Additionally, one randomly selected duplicate was collected to measure sampling variability. A total of twelve samples were collected at each site for each sampling period. Surface soil samples were collected with a trowel by removing vegetation and excavating soil in an area approximately 6 in. long, 6 in. wide, and 2 to 3 in. deep, and placed in a quart Ziploc bag. Data on site and sample variability can be found in Appendix G.

Analysis

Samples were processed at MSU by drying in a 60° C oven for 24 hr. Dried samples were sieved to 2 mm to remove debris, and one cup of sample was placed in a new Ziploc bag and labeled.

Soil analysis was conducted by the University of Massachusetts Soil and Plant Tissue Testing Laboratory to determine pH, buffer pH, and concentrations of extractable nutrients, heavy metals, and aluminum (Appendix B). This study focused on interpretation of soil pH, nitrate (NO_3), phosphorus (P), boron (B), cadmium (Cd), copper (Cu), iron (Fe), Manganese (Mn), lead (Pb), and zinc (Zn).

Soil organic carbon analysis was computed by OEWRI using a procedure that measures total carbon and inorganic carbon using an Elementar vario EL III CHNOS Elemental Analyzer. Total carbon content was determined using a high temperature decomposition procedure with average precision of <4% relative percent difference (RPD) (OEWRI, 2007). Inorganic carbon content was analyzed in a similar manner as total carbon, however sediment samples were pretreated in a 450^{o}C muffle furnace for 6 hours to remove the organic component. Organic carbon was then calculated by subtracting the inorganic carbon from the total carbon.

Forage Analysis

Agronomic response to each of the four treatments was monitored by measuring yield along transects established on different landscape positions in each watershed. Plant and soil nutrient levels were also monitored by collecting annual forage and soil samples. Yield and quality were determined at the same plot locations on each harvest date. Subsamples were collected and sent to a laboratory for analysis of forage characteristics. Forage sampling sites were selected along a line parallel to the soil sampling transects previously established in each watershed. The beginning and end of each transect were marked with a steel rod, flagged and geo-referenced for subsequent surveys. Forage sampling plots were established at three locations within treated areas of each watershed (1) "Low", 25 to 65 feet from the steel rod (distances varied in order to assure the sample was collected well within the treated area); (2) "Summit", 10 to 20 feet downslope from the highest landscape position along the transect (again, distance varied to assure that the samples were collected well within the treated area; and (3) "Mid", near the midpoint between the low and summit positions. Each plot was 7 ft by 20 ft with the long axis perpendicular to the slope. Plots were mowed using a walk-behind sicklebar mower set to a cut height of 4 inches (Photo 16). The sample (excluding tree coppices and plant material and residues from below the cut height) was carefully raked, bagged and fresh biomass was determined using a precision spring scale. Where the crop had lodged (due to wind or rain), two or three iterations of cutting and raking were required to mow the forage to the desired height. Forage quality analysis was conducted by Custom Laboratory in Golden City, Missouri.

RESULTS

Hydrology and Sample Collection

Rainfall

Runoff was generated either during relatively short, high intensity storm events, or relatively long, low intensity storm events. Year 1 rainfall totals generating runoff ranged from 0.56 inches on November 6, 2008 to 1.89 inches June 16, 2009 (Table 7). Year 2 rainfall totals ranged from 0.63 inches on January 25, 2010 to 5.07 inches on October 9, 2009. Year 3 rainfall totals ranged from 0.68 inches on May 28, 2011 to 2.49 inches on April 26, 2011. All storms, with the exception of the 5.07 inches on October 9, 2009, were <2yr rainfall recurrence interval. The 5.07 inches occurred in ≈24 hours and is about the 5-10yr rainfall recurrence interval. Individual storm rainfall totals that produced runoff in year 2 were higher and occurred more frequently than in years 1 and 3.

The sampling period was marked by alternating times when rainfall was higher and lower than normal (Figure 4). There were times when monthly rainfall totals were >6 inches higher than the 30 year average in October 2009 and September 2010. Conversely, there were 6 months during the sampling period when rainfall was 2-4 inches below the 30 year average. Additionally, substantial rainfall totals that did occur during the middle of the growing season when the grass was tall or during the hot summer months did not produce runoff. Rainfall during these periods would either be intercepted by tall vegetation or soak into very dry upper soil layers and would not produce runoff.

Runoff Yields

Runoff yield varied tremendously among catchments over the sampling period due to a complicated set of factors such as rainfall, drainage area, soils, vegetation, and slope. Of all these, soil infiltration rate appears to be the biggest factor in controlling the variability in runoff yield. Sites 2 and 3, with lower slopes, typically generated higher runoff than site 1 and site 4 with higher slopes (Figure 5). Generally, catchments with lower slope do not produce as much runoff as catchments with higher slopes. However, soils with a fragipan can limit infiltration capacity of the soil and can produce higher runoff. For instance, site 3 has the lowest slope, but much of the drainage area is underlain by a fragipan. This is likely a factor in site 3 sometimes having the highest runoff yield and sometimes not. Sites 1 and 4, while having high slopes, lacked a mature fragipan and the large amount of rock fragments in the soil likely allowed rapid permeability at these sites. Slope versus runoff relationships may not be assumed at the field-scale in the Ozarks, as steeper slopes with skeletal soils and rock outcrops can infiltrate more water than lower slope catchments underlain by a fragipan. These hydrological characteristics

become important in water quality studies because ultimately runoff volume determines the impact of a contaminant leaving a site during a storm event.

Sample Events

A total of 88 individual composite samples were collected at all four sites over a 34 month period between November 1, 2008 and August 31, 2011. During year 1, from November 1, 2008 to July 31, 2009, 23 composite samples were collected. Of these, 6 were from site 1, 9 from site 2, 5 from site 3, and 3 from site 4 (Table 7). In year 2, between August 1, 2009 to July 31, 2010, a total of 39 composite samples were collected. Of the year 2 samples, 10 were from site 1, 11 from site 2, 9 from site 3, and 9 from site 4. In year 3, between August 1, 2010 to August 31, 2011, a total of 26 individual composite samples were collected. Of the year 3 samples, 7 were from site 1, 8 from site 2, 7 from site 3, and 4 from site 4. Samples were not collected over the three year sampling period because:

1. Small catchment area generates low discharge volume
2. Equipment malfunctions (dead batteries, clogged lines, etc.)
3. Height of vegetation and dormancy impact interception and water uptake
4. Soil moisture conditions
5. Dam and weirs needed “seasoning” following installation in year 1
6. Very dry conditions in summer of 2011

Water Quality

The following section will describe water quality data collected for each site over the 2.9 year sampling period from November 1, 2008 to August 31, 2011. Water quality trends are reported in four ways: (1) comparison of site average over the entire sample period to look at overall trends and variability; (2) comparison of annual median values for each site to assess yearly changes in water quality parameters; (3) analysis of time-series plots from each site showing individual sample concentrations from the initial biosolids application date of October 23, 2008; and (4) comparison of time-series plots since the initial biosolids application date showing individual storm yield from each site.

Overall Concentrations

Nutrient concentrations tended to be higher for the commercial fertilized site compared to the biosolids treated sites and the control. Average nutrient concentrations were around 2-5 times higher in runoff from the commercial fertilizer site 2 compared to both biosolids treated sites and the control for the entire sampling period (Table 8). Comparing the biosolids treated sites, average concentrations of TKN, Nitrate, and TP are 30-40% higher at the 6 t/ac site 4 compared

to the 3 t/ac site 3. However, average ammonia was nearly 5 times higher in the 6 t/ac site 4 compared to the 3 t/ac site 3. Average ammonia and TKN concentrations in the 3 t/ac site 3 were less than the average concentrations found at the control site 1. Nitrate and TP concentrations at the control site 1 were the lowest among sites. Average TSS concentrations ranged from 14 mg/l at site 1 to 64 mg/l at site 2 over the sample period. Sample pH remained consistent at all sites over the sample period.

Total Phosphorus (TP)

Initial post application release concentrations of TP were much higher at the commercial fertilized site 2 compared to the biosolids treated sites 3 and 4 and the control site 1. In year 2, site 2 median TP concentrations decreased 75% while the median TP concentrations in the biosolids treated watersheds increased slightly from year 1 to year 2 (Figure 6). This increase is probably due to a combination of factors. One, the breakdown of organic phosphorus in the biosolids is more mobile in year 2 and two, significant rain events that occurred in year 2 physically transported biosolids material down slope. Regardless, median TP concentrations for sites 3 and 4 are less-than half of that from the fertilized site 2. Median TP concentrations at site 1 were similar in years 1 and 2. All median TP concentrations dropped in year 3, with the control site 1 having similar concentrations to the biosolids treated sites 3, and 4. Median TP concentrations at the fertilized site 2 were only slightly higher.

Concentrations of TP tend to decrease over time from initial application in year 1 at sites 2 and 4, and are slightly higher in year 2 at site 3. Time-series analysis of TP concentrations shows generally decreasing concentrations over time at sites 2 and 4 to near levels at the control by year 3 (Figure 7). Concentrations immediately after application of fertilizer at site 2 were extremely high for the first sample collected and then concentrations decrease steadily. Concentrations of TP are more variable for the biosolids treated site 3 over time again suggesting physical transport by a storm event is likely causing higher concentrations in year 2. All TP concentrations past day 400 are generally <2 mg/L, which is near the highest TP concentration sampled at control site 1. In this case, TP concentrations are back to pre-treatment levels after the first year.

Time-series yield analysis shows the majority of TP from the study site was transported during a single event on day 352 underscoring the flashiness of nonpoint loads (Figure 8). This event was the highest TP yield for all of the sites. These data show the pollution potential is higher the closer the large rain event is to the date of application. The fertilized site 2 had nearly 50% more runoff, but there was nearly 3 times more TP per acre than the equivalent 3T biosolids site 3. These data suggest that TP in fertilizers can be much more mobile in this situation than

equivalent rates of biosolids treated to fields. Due to far different runoff characteristics, the yield impact from the 6T rate biosolids treated site 4 is inconclusive for this study.

Total Kjeldahl Nitrogen (TKN)

Concentrations of TKN in runoff were highly variable within and between sites. Median TKN concentrations decrease at 3 of the 4 sites from year 1-2 and then increase slightly in year 3 (Figure 9). Meanwhile, TKN concentrations increase from year 1-2 at site 4 and then decrease in site 3. However, median TKN concentrations in samples from the control site 1 are higher in year 1 than at any time at sites 3 and 4. High variability at site 1 suggests high natural variability cannot be distinguished from changes in management.

Time-series analysis show TKN concentrations can be high at all sites regardless of management. High TKN concentrations at site 2 immediately after application dropped sharply and stayed fairly consistent for the rest of the sampling period (Figure 10). Perhaps particulate fertilizer was sampled in the first event giving such high concentrations. Sites 1, 3 and 4 are more variable over time, which shows storm events may be transporting particulate nitrogen down slope. However, the single high concentration at site 1 suggests this may be due to natural variability. Given these results, TKN variability cannot be attributed to fertilizer or biosolids application.

Similar to TP yield, time-series yield analysis shows the majority of TKN from the study site was transported during a single event on day 352 (Figure 11). Again, this single event produced the highest TKN yields for all of the sites and the fertilized site 2 had nearly a 3 times higher yield than the equivalent 3T biosolids site 3. These trends suggest that TKN in fertilizers can be much more mobile in this situation than equivalent rates of biosolids treated to fields.

Ammonia

Ammonia concentrations can be initially high the first year after application at the high biosolids application rate, but are similar to the control thereafter. Median ammonia concentrations remained relatively consistent at sites 1, 2 and 3 between year 1 and 2, while concentrations dropped significantly in year 2 at site 4 (Figure 12). With the exception of year 1 sampling at site 4, median ammonia concentrations are higher at the control site 1 compared to the other sites during the sampling period. By year 3, median ammonia concentrations were similar at all sites. Time-series analysis again shows extremely high ammonia concentrations for the 1st sample collected after fertilizer application at site 2 (Figure 13). Ammonia concentrations at site 2 then decrease to near the levels at the other sites and stays fairly consistent for the remainder of the sampling period. Ammonia concentrations at site 4 are also elevated in the first sampling after application of 6 t/ac biosolids. However, similarly to site 2,

ammonia concentrations decrease after that to near levels at the other sites.   Ammonia yields were similar to TP and TKN (Figure 14).

Nitrate

Nitrate levels varies widely in the fertilized site 2 compared to the biosolids treated sites and the control. Median nitrate concentrations varied slightly between year 1 and 2 for sites 1, 3 and 4 and increased significantly in year 2 at site 2 (Figure 15). For year 3, median nitrate concentrations increased at sites 1, 3 and 4 and decreased at site 2. Changes in nitrate concentrations at sites 3 and 4 are near that of the control site 1, suggesting natural variability is as high as in the biosolids treated sites. However, nitrate concentrations at site 2 nearly double in year 2.   Time-series analysis shows nitrate concentrations at site 2 are highly variable throughout the sample period (Figure 16). Nitrate concentrations at other sites are consistently low and have less variability. These data suggest excess nitrate moves off fertilizer sites at greater rates than biosolids treated fields. Nitrate yield was again highest on day 352 at site 2 (Figure 17). However, unlike the other forms of nitrogen, the other sites produce nearly the yields throughout the sampling period.

Total Suspended Solids (TSS)

Median TSS concentrations varied considerably between years at each site with no apparent trend due to management (Figure 18). Instead, this variability is due to differences between site characteristics and storm events. Concentrations of TSS increased in year 2 at site 1, 2 and 3 and decreased at site 4. Median TSS concentrations decreased at all sites in year 3.   Time-series analysis indicates high median concentrations in year 2 are influenced by single high events samples and the majority of samples are <100 mg/L for most events (Figure 19). The highest TSS yields coincide with high TSS concentrations in year 2 (Figure 20).

pH

Sample pH is consistently within the neutral range at all sites throughout the study and does not appear to influence water quality results. Median pH readings were around 7 for all sites between years 1, 2, and 3 (Figure 21). Time series analysis shows site 2 has the most variability among sites over the sampling period (Figure 22). However, pH varies <1 standard unit over the sampling period. With pH consistently in the neutral range, it has little influence on the solubility of nutrients and metals.

Trace Metals

Concentrations were below method detection limits for most trace metals analyzed for this study, with the exception of copper (Cu) and zinc (Zn). Concentrations of arsenic, cadmium, lead, mercury, molybdenum and silver were all below detection limits for all samples. Nickel

and selenium were found in <2% of samples and chromium was found in <3% of samples. Copper (Cu) was detected in >10% and zinc (Zn) in >25% of samples collected throughout the period.

The site with the higher biosolids application rate had more samples (25%) with detectable Cu than the other 3 sites. For sites 1 and 3, Cu was detected in <10% of samples collected over the sample period (Table 9). Of the samples collected at site 2, <11% of the samples were above detection limits. Cu was detected in 25% of the samples from site 4 (6 t/ac). However, the maximum Cu concentration for the study (27.5 ppb) is from site 2.

Zinc was detected more often in samples collected from the high rate biosolids treated site 4 and had higher concentrations compared to the other 3 sites. At sites 1, 2, 3, Zn was not detected in 75% of the samples collected and concentrations were similar for all 3 sites (Table 10). At Site 4 (6 t/ac) Zn was detected in >50% of the samples collected and maximum concentration was >2 times higher than the maximum concentration at the other 3 sites.

Fecal Coliform

For the majority of the samples collected for this study, fecal coliform concentrations were similar for all sites. Fecal coliform for the interquartile range (25th-75th percentile) were as follows: site 1, 30-790 col/100 mL; site 2, 28-1,073 col/100 mL; site 3, 24-1,330 col/100 mL; and site 4, 10-2,530 col/100 mL (Table 11). Concentrations for the 90^{th} percentile sample were similar at sites 1 and 3 and slightly lower at site 4. The highest concentration did occur at site 4, but high concentrations were also detected at the control site 1. These data show high fecal coliform concentrations can occur on both biosolids treated and non-biosolids treated fields.

Surface Soils

During 4 annual sampling periods over a 3 year span, 196 individual surface soil samples were collected and analyzed for pH, nutrients (P and NO_3), micronutrients (B, Cu, Fe, Mn, Zn), and potentially toxic metals (Pb, Cd). The initial soil sampling occurred prior to the biosolids and fertilizer application and is designated as year 0 samples. Samples designated years 1, 2, and 3 were collected after biosolids and fertilizer application annually for the next three years. Samples were also analyzed for site variability (triplicate analysis) and sample variability (duplicates) to assess the inherent variability in the sampling protocol.

Site and Sample Variability

Variability in soil parameters was assessed at two different scales, variability within a landscape position and variability at a sample site. Variability in samples collected at each landscape

position over the sampling period is assessed to verify that changes in soil parameters are due to changes in management, not variability in the landscape or due to sampling protocol. Site variability was assessed using the coefficient of variation percentage (cv%), which is the percent difference of the standard deviation compared to the average for the three samples collected at each landscape position. Sample site variability was generally <30% for all parameters with the exception of NO_3, which had an overall average cv% of 40% with the highest variability occurring on the backslope (Table 12).

Sample variability was also assessed by collecting a random duplicate at the same location as one of the three samples collected for site variability. The difference is reported as relative percent difference (RPD). Again, the average overall RPD is <30% for all parameters with the exception of NO_3 which has an RPD of ≈50% (Table 13). Determination of site and sample variability is important for verifying interpretation of results and shows in this case changes in soil pH should at least be >4% and changes in P, B, Cu, Fe, Mn, and Zn concentrations should be >30% to be significant. Finally, changes in NO_3 should be >50% to be significant.

Soil pH

Mean soil pH ranged from 5.7 to 7 at individual sites over the entire sampling period, which fall within the normal range for plants (5.5-7.5) (UMA, 2010; Figure 23). At each site, soil pH increased every year with the largest increase occurring at site 2. The annual increase in soil pH is likely due to the breakdown of agriculture lime designed to raise the pH in the soil applied prior to application of fertilizers and biosolids and the changes in pH are significantly higher (>4%) than the site and sample variability. These data suggest variations in soil pH are not contributing to soil geochemical trends. Also, biosolids application does not appear to have changed the soil pH over the sampling period.

Nutrients

Over the sampling period there was very little NO_3 buildup in the soil at all sites. Mean annual soil NO_3 moved from the low range to the medium range of values recommended for plants from year 0-1 at all sites (Figure 24). This is an unexpected result at Site 1 that may indicate either a problem with the analysis or that NO_3 can be that high naturally. Annual changes did exceed the calculated site and sample variability of 50%. Regardless, NO_3 concentrations mostly stayed within the low range for soils at all sites suggesting biosolids applications do not result in substantial NO_3 buildup in the soil.

Soil P increased following fertilizer and biosolids application before decreasing to near pre-treatment levels by the end of year 3. Trends were similar at sites 2, 3, and 4 in response to amendments while site 1 showed a steady decrease in soil P over the sampling period. Mean

soil P concentrations increased from years 0-1 year at sites 2, 3 and 4 after application of biosolids at site 3 and 4 and equivalent amounts of P in fertilizer on site 2 and did exceed the calculated soil and sample variability of 30% (Figure 25). Soil P remained consistent from years 1-2 and then dropped significantly in year 3 suggesting leaching, runoff, or forage harvest depleted the soil P at all sites. Meanwhile soil P decreased from year 0-1 at the control site 1, but was consistent between year 1-2 and decreased from year 2-3. This suggests all of the treatment areas cycled soil P in a similar manner over the sampling period regardless of amendments. Overall mean soil P concentrations at site 2 were very high in years 1 and 2, while soil P concentrations at sites 3 and 4 did not go above the high range for soils (UMA, 2010). By year 3, soil P at all sites was at or below the site 1 concentration at year 0. These results show biosolids application raises soil P, but decline over time and do not exceed those of fertilized sites.

Soil P trends at each landscape position reflect the method fertilizer and biosolids were applied to the different catchments. At site 2, fertilizer was spread evenly over the entire catchment, and soil P increases in year 1 at all landscape positions (Figure 26). However, at sites 3 and 4 there appears to be different soil P patterns on the backslope and footslope landscape positions from the overall trends that are a reflection of how the biosolids was applied compared to the fertilizer. At site 3, soil P increases on the backslope but does not increase significantly at the footslope, which was avoided during biosolids application because it was too close to a drainage way. Soil P concentrations remain consistent for the remainder of the sampling period at the backslope landscape position suggesting biosolids may be physically transported downslope during rain events. Similar results can be seen at site 4.

While soil P concnetrations tended to have similar trends in fields that were amended with biosolids and fertilizer, P concentrations were higher in year 3 at biosolids treated sites compared to year 0. After 3 years, soil P at the fertilized site was about 20 ppm which was the same prior to amendments. At the biosolids treated sites, soil P more than doubled at the summit locations which was the area targeted by the biosolids application. These results suggest P from biosolids application improves soil P over a longer period of time when compared to equivalent amounts of P in traditional fertilizers. It appears the organic based P breaks down slower over time than the more soluble form of P in traditional mineral fertilizer.

Micronutrients

Micronutrients are elements that are important for plant growth in very small amounts (UMA, 2010). For this study, B, Cu, Fe, Mn, and Zn were tested to see how these micronutrients changed due to management over the sampling period. Overall mean concentrations of B, Zn, Cu, and Fe were low or within the normal range found in soils (Figures 27-31; UMA, 2010).

However, the mean soil Mn of 49 ppm did exceed the normal range for soils (Figures 23; UMA, 2010). These high soil Mn concentrations are likely due to the lime application that occurred prior to initial soil sampling in year 0. Soil Mn is high in all sites starting in year 0, which was sampled prior to application of fertilizer at site 2 and biosolids at sites 3 and 4. Also, soil Mn concentrations decrease over the sampling period at all sites to the normal range by year 3 suggesting this micronutrient was cycled through over that time. These data show the application of biosolids did not significantly increase the levels of B, Cu, Fe, Mn, and Zn in the soil.

Potentially Toxic Metals

High levels of soil Pb and Cd can potentially be toxic to people, plants, and animals. A normal range of concentrations for Pb in soil is 15-40 ppm and Cd should be <1 ppm (UMA, 2010). Over this study, all individual samples were ≤1 ppm for Pb and ≤0.1 ppm for Cd (Tables 14 and 15). Data from this study suggests biosolids applications did not cause significant increases in soil Pb and Cd levels and that soils tested during this study were at the low range of normal values expected in soils.

Organic Carbon

Biosolids application may have an impact on organic carbon in the soil, but results were inconclusive because the yearly differences are less than the calculated site and sample variability (≈20%). Mean overall organic carbon levels declined from year 0 to year 3 at the non-biosolids sites 1 and 2 and remained steady at the 3 t/yr site 3, and increased slightly at the 4 t/yr site 4 (Figure 32). While the annual changes in mean overall organic carbon content are less than the sample and site variability, analysis of organic carbon by landscape position shows that site 4 appears to have a measurable increase (Figure 33). At site 4, the summit has a 30% decrease in organic carbon content from years 0-3. However, the backslope and footslope positions have nearly a 30% increase in organic carbon content from year 0-3. These data suggest a couple of things. First, the 6 t/ac application rate appears to have significantly increased the organic matter content at this site while the 3 t/ac rate was too low to make a significant impact in this case. Second, biosolids appear to be fairly mobile, as organic matter content is increasing downslope. This is particularly significant since biosolids were not applied to the backslope and footslope positions at site 4.

Forage Analysis

Total annual forage yields from sites treated with biosolids (sites 3 and 4) were greater than in sites 1 and 2 (mineral fertilizer and untreated control, respectively) for 2009 (Table 16). Annual yields were generally lower in 2010, which was attributed to seasonal differences in

temperature and rainfall. However, despite the effect of weather, forage yields in the treated plots (sites 2-4) in 2010 were still at least 65% higher than the untreated control (site 1) (Table 16). Despite the continued application of nutrient inputs to site 2 in August of each year (see Nutrient Management and Treatment Strategy, pp. 10-11), annual yield of biosolids treated sites (sites 3 and 4) continued to be similar to annual yield of site 2 in 2010. Although small, yield in spring of 2011 from sites 2, 3 and 4 was two- to three-times greater than from site 1 (Figure 34).

Forage quality and mineral concentration was influenced by treatment. Percent nitrogen (a measure of crude protein) in hay from the fertilized sites 2, 3 and 4 were higher in the fall cuttings compared to the spring cuttings. The untreated control (site 1) was more uniform in N level, but lower than what was observed in sites 2, 3 and 4 (Figure 35). Except for the fall 2010 cutting from site 2, fall cuttings from sites 2, 3 and 4 were higher relative to spring cuttings. Fertilizer type, rainfall, timing of harvest, and grass species composition may all factor into the variability in forage nutrient uptake. The amount of copper and zinc in the forage varied unpredictably with respect to treatments among sites and between cuttings. The lack of trend with treatment type for copper concentration (and that values are far below levels thought to be toxic (i.e. 100 ppm) suggests that there is no cause for concern about copper levels in forage harvested from biosolids applied sites compared to conventionally fertilized and control sites. Zinc levels in forage harvested from all sites were always near or lower than levels thought be beneficial for livestock maintenance (i.e. 30 ppm). Supplementation might be desirable, but has not been shown to have consistent benefit.

Available energy and digestibility of forage as measured by percent acid detergent fiber (ADF) and neutral detergent fiber (NDF) analyses predict similar or higher quality forage (particularly in fall harvests) from sites 2, 3 and 4 than from site 1. Note that ADF is inversely correlated to available energy, and that NDF is inversely correlated to digestibility of forage – therefore a smaller value indicates a forage of higher quality. Among treated sites (sites 2, 3 and 4), both ADF and NDF were lower in sites 2, 3 and 4 than site 1 in fall harvests, but similar in spring harvest in 2009 and 2010 (Appendix I).

Relative feed value (RFV) combines ADF and NDF into a single, unit-less statistic that attempts to predict intake with a value of 100 being equivalent to alfalfa at full bloom. A larger number indicates a hay of greater quality. The statistic is often used in marketing of hay and can be used to compare quality of hays of the same species. RFV at site 1 remained fairly consistent (about 80) for four of five cuttings (lower in fall 2010) (Appendix I). The mineral fertilizer and biosolids treated fields had higher RFV in the fall cutting each year relative to the untreated

control (site 1). In four of five harvests (all except fall 2009), RFV demonstrated an increasing trend across sites 2, 3 and 4, with site 4 normally having the highest RFV.

Data described above are averages calculated from sub-samples collected from an unreplicated demonstration project. Consequently, while the data may be informative, the forage yield and quality results should be considered descriptive statistics from a demonstration rather than results of a properly constructed hypothesis test.

PROJECT SUMMARY

This section covers the activities over the entire 2.9 year sampling period of the Biosolids Runoff Monitoring Project from November 2008 through August 2011. Listed below are 20 important statements that summarize this report:

1. The study site was chosen based on uniformity of landscape position and land cover typical of agricultural practices in southwest Missouri. The site was surveyed and four small catchments were delineated, ranging from 0.38 to 3 acres.

2. Soil samples were collected and analyzed for fertilizer and liming recommendations. A nutrient management plan was created that outlined specifications for fertilizer based on soil test reports for biosolids and equivalent commercial fertilizer applications. A fertilizer and equivalent biosolids application rate (3 t/ac) was applied for a 3 t/ac forage yield goal site 2 and 3. On site 4, the maximum allowable biosolids application rate of 6 t/ac was applied. Site 1 was not treated and left as the control.

3. Five individual soil pits were characterized for soil morphology over the study area to determine the variability in soil type over multiple landscape positions that may not be represented in published soil surveys. Pedogenic differences in soil parent material, structure, and thickness can impact infiltration rate and infiltration capacity, as well as soil fertility and growth rates.

4. Weirs were constructed in areas of concentrated flow near the bottom of each catchment to capture runoff and estimate discharge. Automatic samplers were deployed and fitted with rain gages and stage recorders programmed to sample when runoff occurred. A 500 mL sample was collected at the first flush and then a subsequent 500 mL sample was collected every 15 minutes over the duration of the storm.

5. Over the 34 month sampling period (November 1^{st}, 2008 – August 31^{st}, 2011) covered by this report, 88 individual composite storm runoff samples were collected and analyzed.

6. Rainfall events that produced runoff varied from as little as 0.56 inches to 5.1 inches. Higher total rainfall amounts were recorded in the year 2 sample period compared to years 1 and 3.

7. Runoff volume yield varied greatly among catchments suggesting seasons, land cover, and soil at the sites play an important role in the impact on water quality. Runoff yield from sites 2 and 3 were comparable. Site 1 had much lower yields, while site 4 runoff yields were so low it was difficult to compare to the other sites.

8. The fertilizer treated site typically had overall runoff nutrient concentrations 2-5 times higher than sites treated with biosolids and the control.

9. Nutrient concentrations in runoff were highest post-application in year 1 and then decreased over time. By year 3, nutrient concentrations were similar at all sites.

10. Metal concentrations in most samples were below detection limits. However, concentrations of Cu and Zn in runoff were detectable more often in the 6 t/ac biosolids treated site 4 and at higher concentrations compared to the other 3 sites.

11. The highest fecal coliform concentration over the sampling period came from the biosolids treated site 4, but the next highest concentration came from the control. These data suggest fecal coliform can be high in storm water runoff in agricultural land uses regardless of nutrient management decisions.

12. A total of 196 individual surface soil samples were collected annually starting prior to application of fertilizer and biosolids in year 0. Triplicate samples and random duplicates were selected to assess sample and site variability.

13. Surface soil sample variability is <30% for most parameters and can be as high as 40% for NO_3. This suggests that changes in soil chemistry must in general be >40% to be significant.

14. Surface soil data shows an increase in soil P after fertilizer and biosolids application, but did not exceed the normal range for soils at sites 3 and 4. Meanwhile, soil pH remained very consistent over the three sampling periods.

15. Concentrations of most micronutrients (B, Cu, Fe, Zn) in the surface samples remained within the normal range for soils. The exception is Mn, which was high prior to fertilizer and biosolids application in year 0 and is likely due to liming that occurred on the site prior to sampling.

16. Concentrations of potentially toxic metals (Cd, Pb) were low in surface soils samples at all sites.

17. Organic carbon was analyzed in the surface soil samples for 3 of the 4 sampling periods. There was a slight increase in soil organic carbon in the biosolids treated sites, but these changes were within the site and sample variability assessed for this site.

18. A total of 60 forage plots were harvested and analyzed over the sampling period to assess the quality and quantity of forage at each site.

19. Means of subplots (i.e. three different landscape positions) within treatments suggest that forage crop quality and yields of biosolids treated sites tended to be equivalent to (or greater than) the mineral fertilizer treated site. Yield was typically lower, but forage quality was typically higher, in the fall cuttings. Cu and Zn levels in forage harvested from the biosolids treated sites were comparable to forage harvested from the fertilized or untreated control sites.

20. Overall, this study suggests that biosolids are a safe alternative to traditional fertilizers when applied at rates that are recommended for specific site conditions and yield goals. Sediment, nutrient, metals, and fecal coliform yields were similar or lower in runoff from biosoilds treated field than from fields treated with equivalent rates of traditional fertilizers and with no fertilizer.

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TABLES

Table 1. Watershed and Nutrient Management Treatment Details at the Study Site

Site	Nutrient Treatment	Soil Map Units Present (Hughes, 1982)	Forage Suitability Group
1	Control	Goss very cobbly silt loam, 15-35% slopes Nixa very gravelly silt loam, 3-8% slopes	Gravelly Upland Gravelly Pan
2	Commercial Fertilizer	Nixa very gravelly silt loam, 3-8% slopes Viraton silt loam, 2-5% slopes	Gravelly Pan Loamy Pan
3	Biosolids at Commercial Fertilizer Equivalent	Nixa-Clarksville complex, 3-20% slopes Viraton silt loam, 2-5% slopes	Gravelly Upland Loamy Pan
4	Biosolids at Double Commercial Fertilizer Equivalent	Viraton silt loam, 2-5% slopes Nixa very gravelly silt loam, 3-8% slopes	Loamy Pan Gravelly Pan

Table 2. Summary of Soil Morphology Analysis

Pit #	Landscape Position	Parent Material	Elevation (feet)	Slope	% Coarse Rock Frag.	Notes
1	Head Slope	Loess/Colluvium/Residuum	1,215	1%	0-25	8” Loess (10 YR4/3) Fragipan (32”- 45”) Redox features
2	Interfluve	Colluvium/Residuum	1,199	2%	10-60	Weak fragipan (20”-35”) Redox features
3	Side Slope	Colluvium/Residuum	1,195	4%	5-50	Weathered sandstone present (50”-60”)
4	Side Slope	Colluvium/Residuum	1,176	12%	5-60	
5	Colluvial Valley	Alluvium/Colluvium	1,166	6%	40-50	Alluvium (0”-23”)

Table 3. Watershed and Nutrient Management Details at the Study Site

Site	Treatment Name	Experimental Year	Planned Nutrient Application (lbs/ac) $N + P_2O_5 + K_2O$	Actual Nutrient Application (lbs/ac) $N + P_2O_5 + K_2O$
1	Control	1	0 + 0 + 0	0 + 0 + 0
		2	0 + 0 + 0	0 + 0 + 0
		3	0 + 0 + 0	0 + 0 + 0
2	Commercial Fertilizer	1	54 + 299 + 13	54 + 299 + 13
		2	54 + 0 + 0	82 + 20 + 0
		3	54 + 0 + 0	82 + 0 + 0 *
3	Commercial Fertilizer Equivalent Biosolids @ 3 dry tons/a	1	111 + 299 + 13	160 + 319 + 3
		2	34 + 0 + 0	38 + 0 + 0
		3	17 + 0 + 0	19 + 0 + 0
4	Double Commercial Fertilizer Equivalent Biosolids @ 6 dry tons/a	1	222 + 598 + 26	303 + 558 + 6
		2	68 + 0 + 0	64 + 0 + 0
		3	34 + 0 + 0	32 + 0 + 0

Table 4. Drainage Area, Weir Geometry, and Discharge Equations

Site	Ad (acres)	Weir			Rating Curve Equation
		Top Width (ft)	Height (ft)	Height of Notch ab. Ground Level (ft)	
1	0.38	1.23	0.61	0.22	$Q = 1.8965(d_w)^3 - 0.4023(d_w)^2 - 0.1085(d_w) + 0.0224$
2	0.65	1.18	0.6	0.22	$Q = 1.4936(d_w)^3 + 0.2247(d_w)^2 - 0.4025(d_w) + 0.0642$
3	3	1.18	0.6	0.26	$Q = 1.4936(d_w)^3 - 0.3577(d_w)^2 - 0.3852(d_w) + 0.117$
4	1.28	1.19	0.64	0.23	$Q = 1.3331(d_w)^3 + 0.4238(d_w)^2 - 0.5228(d_w) + 0.0855$

Ad = drainage area

Q = Discharge in cubic feet per second (cfs)

d_w = depth of water (feet)

Table 5. Test Parameters, Methods, Method Detection Limits, Method Accuracy and Precision, and Project Accuracy and Precision

Nutrient	Method	Method Detection Limit (mg/L)	Method Accuracy (mg/L)	Method Precision (mg/L)	Project Accuracy (mg/L)	Project Precision (mg/L)
Total Kjheldal Nitrogen	EPA 351.2	0.03	±10	±10	±15	±10
Total Phosphorus	EPA 365.4	0.01	±10	±5	±15	±7
Nitrate	EPA 300.0	0.01	±10	±5	±15	±10
Ammonia	SM4500-NH3-D	0.1	±20	±10	±20	±10
Metal		**Method Detection Limit (µg/L)**	**Method Accuracy (µg/L)**	**Method Precision (µg/L)**	**Project Accuracy (µg/L)**	**Project Precision (µg/L)**
Arsenic	EPA 200.7	15	±10	±5	±10	±5
Cadmium	EPA 200.7	5	±10	±5	±10	±5
Chromium	EPA 200.7	10	±10	±5	±10	±5
Copper	EPA 200.7	5	±10	±5	±10	±5
Lead	EPA 200.7	15	±10	±5	±10	±5
Nickel	EPA 200.7	10	±10	±5	±10	±5
Molybdenum	EPA 200.7	20	±10	±5	±10	±5
Potassium	EPA 200.7	50	±10	±5	±10	±5
Selenium	EPA 200.7	20	±10	±5	±10	±5
Silver	EPA 200.7	5	±10	±5	±10	±5
Zinc	EPA 200.7	5	±10	±5	±10	±5
Mercury	EPA 245.1	0.2	±10	±5	±10	±5
Other		**Method Detection Limit**	**Method Accuracy**	**Method Precision**	**Project Accuracy**	**Project Precision**
Total Suspended Solids	SM2540 D	1 mg/L	±10 mg/L	±5 mg/L	±10 mg/L	±4 mg/L
pH	SM4500-H+B	0.1 std units	±20 std units	±20 std units	±10 std units	±5 std units
Fecal Coliform/100mL	SM 9222 D	1 coli/100mL	±10 coli/100mL	±10 coli/100mL	±20 coli/100mL	±14 coli/100mL

Table 6. Landscape Position and Surface Soil Sample Locations Upstream of Weir

Site	Landscape Position	Distance of Slope Break Upstream of Weir (ft)	Distance Upstream of Weir (ft)
	Footslope	0 – 98	26
Site 1	Backslope	98 - 180	131
	Summit	> 180	295
	Footslope	0 – 131	53
Site 2	Backslope	131 - 213	131
	Summit	> 213	279
	Footslope	0 – 131	66
Site 3	Backslope	131 - 253	197
	Summit	> 253	459
	Footslope	0 – 98	69
Site 4	Backslope	98 - 246	164
	Summit	> 246	328

Table 7. Rainfall Totals, Duration, and Sites Collected for Storm Events

Date	Total Rainfall (in)	Rainfall Duration (hrs)	Peak Intensity (in/5 min)	Avg. Intensity (in/hr)	Rainfall Recurrence Interval (yrs) **	Sites Collected
			Year 1			
11/6/2008	0.56	0.63	0.13	0.88	<2yr	1,2
2/11/2009	1.74	15.2	0.24	0.11	<2yr	1,2
4/12/2009	1.25	14.4	0.05	0.09	<2yr	1,2,3
4/20/2009	1.27	21.5	0.09	0.06	<2yr	2,3
5/1/2009	1.68	11.9	0.25	0.14	<2yr	1,2,3,4
5/13/2009	0.94	0.79	0.20	1.19	<2yr	1,2,3,4
6/16/2009	1.77	9.0	0.16	0.20	<2yr	1,2,3,4
6/30/2009	1.10	6.6	0.03	0.17	<2yr	2
7/20/2009	1.83	23.4	0.18	0.08	<2yr	2
			Year 2			
8/11/2009	1.38	6.0	0.16	0.23	<2yr	4
8/19/2009	1.44	14.6	0.17	0.10	<2yr	4
9/10/2009	1.21	13.3	0.11	0.09	<2yr	4
9/20/2009	1.27	17.1	0.03	0.07	<2yr	4
9/22/2009	2.80	16.4	0.22	0.18	<2yr	1,2,3,4
10/9/2009	5.07	26.5	0.12	0.20	5-10yr	1,2,3,4
10/30/2009	0.98	14.9	0.09	0.07	<2yr	1,2,3,4
1/22/2009	0.54	22.4	0.04	0.02	<2yr	2
1/25/2010	0.63	20.3	0.06	0.03	<2yr	1,2,3
2/22/2010	0.83	23.4	0.04	0.04	<2yr	1,2,3
3/22/2010	0.82	44.9	0.15	0.02	<2yr	1,2
3/25/2010	1.37	19.8	0.06	0.07	<2yr	1,2,3,4
5/14/2010	1.95	12.3	0.11	0.16	<2yr	1,2,3,4
*5/20/2010**	*1.74**	-	-	-	-	1,2,3
7/12/2010	2.24	7.5	0.22	0.33	<2yr	1,2,3
			Year 3			
9/16/2010	0.95	1.3	0.24	0.70	<2yr	1,2,3
11/26/2010	2.08	7.9	0.28	0.26	<2yr	1,2,3
2/25/2011	1.24	6.5	0.07	0.19	<2yr	1,2,3,4
3/9/2011	0.74	7.3	0.08	0.10	<2yr	2
3/14/2011	1.05	11.2	0.09	0.09	<2yr	1,2,3,4
4/23/2011	1.29	16.1	0.13	0.08	<2yr	1,2,3,4
4/26/2011	2.49	33.3	0.07	0.08	<2yr	1,2,3,4
5/28/2011	0.68	1.4	0.29	0.50	<2yr	1,2,3

* Rainfall data from the site was lost. Rainfall total from the National Weather Service in Springfield was used.

** Based on Greene County Storm Water Design Standards (Greene County, 1999).

Table 8. Water Quality Summary Statistics

		TSS (mg/l)	TKN (mg/l)	NH3-N (mg/l)	NO3-N (mg/l)	TP (mg/l)	pH (Std Units)
Site 1 (control)	n	21	23	23	23	23	22
	mean	14	2.43	0.215	0.163	0.376	7.1
	sd	*13*	*2.05*	*0.225*	*0.158*	*0.397*	*0.1*
Site 2 (fertilizer)	n	28	29	29	29	29	28
	mean	64	5.46	1.45	1.12	3.03	7.2
	sd	*119*	*11.9*	*6.92*	*2.28*	*6.35*	*0.2*
Site 3 (3T Bio)	n	20	21	21	21	21	20
	mean	43	2.30	0.150	0.164	0.528	7.2
	sd	*136*	*1.54*	*0.099*	*0.109*	*0.546*	*0.1*
Site 4 (6T Bio)	n	15	16	15	14	16	15
	mean	28	3.12	0.717	0.220	0.738	7.2
	sd	*44*	*3.54*	*2.02*	*0.097*	*1.76*	*0.1*

Table 9. Frequency Distribution for Cu in Water Samples

Cu (ppb)	min	10%	25%	50%	75%	90%	max
Site 1 (n=22)	<DL	<DL	<DL	<DL	<DL	<DL	7.5
Site 2 (n=28)	<DL	<DL	<DL	<DL	<DL	3.4	27.5
Site 3 (n=21)	<DL	<DL	<DL	<DL	<DL	<DL	8.2
Site 4 (n=16)	<DL	<DL	<DL	<DL	3.7	11.1	19.6

Table 10. Frequency Distribution for Zn in Water Samples

Zn (ppb)	min	10%	25%	50%	75%	90%	max
Site 1 (n=22)	<DL	<DL	<DL	<DL	<DL	6.3	25.2
Site 2 (n=28)	<DL	<DL	<DL	<DL	<DL	7.7	17.4
Site 3 (n=21)	<DL	<DL	<DL	<DL	<DL	7.0	26.1
Site 4 (n=16)	<DL	<DL	<DL	4.1	7.3	21.8	69.1

Table 11. Frequency Distribution for Fecal Coliform in Water Samples

Fecal (col/100 ml)	min	10%	25%	50%	75%	90%	max
Site 1 (n=21)	<DL	10.0	30	82	790	5,600	29,000
Site 2 (n=28)	<DL	5.0	28	190	1,073	2,764	8,000
Site 3 (n=20)	<DL	4.6	24	641	1,330	5,850	16,640
Site 4 (n=15)	<DL	1.5	10	60	2,530	4,900	190,000

Table 12. Overall Soil Sample Site Variability at each Landscape Position.

Variable	Footslope (cv%)	Backslope (cv%)	Summit (cv%)	Overall Mean cv%
pH	2.8	3.4	2.6	2.9
NO_3	35.4	51.0	34.2	40.2
P	29.8	19.8	27.4	25.7
B	20.9	16.9	13.4	17.0
Cu	8.5	24.5	23.3	18.8
Fe	21.9	21.6	18.7	20.7
Mn	22.0	18.4	26.5	22.3
Zn	16.5	29.3	24.1	23.3
OC%	17.1	10.3	25.6	17.7

Table 13. Annual Average Soil Sample Variability.

Site	Year	pH RPD	NO_3 RPD	P RPD	B RPD	Cu RPD	Fe RPD	Mn RPD	Zn RPD	OC% RPD
1	0	2.3	0.0	22.9	19.0	0.0	13.2	22.6	18.1	17.3
	1	3.0	10.6	24.6	22.2	0.0	27.8	23.9	12.9	-
	2	1.0	0.0	18.6	0.0	200	68.0	13.9	18.5	15.5
	3	2.7	66.7	8.9	7.4	3.9	7.1	37.3	12.1	8.8
2	0	1.2	0.0	27.1	9.5	0.0	12.5	20.5	22.2	21.5
	1	2.7	30.4	40.2	0.0	0.0	9.4	7.9	1.6	-
	2	2.5	104	19.1	0.0	66.7	16.2	14.4	13.1	31.9
	3	1.5	41.0	21.4	0.0	3.9	8.1	24.5	14.5	14.3
3	0	1.6	0.0	27.4	13.3	0.0	16.3	8.7	12.1	14.3
	1	4.2	42.9	25.2	35.6	26.7	9.5	8.4	5.1	-
	2	1.0	127	21.1	0.0	22.2	15.4	21.8	13.0	8.4
	3	1.5	90.8	8.8	0.0	7.8	5.5	32.5	17.0	4.9
4	0	1.5	63.0	16.1	9.5	0.0	9.0	15.3	19.4	18.2
	1	3.6	33.0	16.2	13.3	7.4	10.0	18.1	4.9	-
	2	5.6	87.0	65.5	0.0	133	106	48.1	83.8	5.6
	3	2.0	122	7.5	0.0	3.9	0.0	37.5	19.8	12.2
	mean	2.4	51.1	23.2	8.1	29.7	20.9	22.2	18.0	14.4
	min	1.0	0.0	7.5	0.0	0.0	0.0	7.9	1.6	4.9
	max	5.6	127	65.5	35.6	200	106	48.1	83.8	31.9

Table 14. Frequency Distribution for Soil Pb (n=49)

Pb (ppm)	Min	10%	25%	50%	75%	90%	Max
Site 1	<DL	<DL	<DL	1	1	1	1
Site 2	<DL	<DL	<DL	1	1	1	1
Site 3	<DL	<DL	<DL	<DL	<DL	0.2	1
Site 4	<DL	<DL	<DL	<DL	1	1	1

Table 15. Frequency Distribution for Soil Cd (n=49)

Cd (ppm)	Min	10%	25%	50%	75%	90%	Max
Site 1	<DL	<DL	<DL	0.1	0.1	0.1	0.1
Site 2	<DL	<DL	<DL	0.1	0.1	0.1	0.1
Site 3	<DL	<DL	<DL	0.1	0.1	0.1	0.1
Site 4	<DL	<DL	<DL	0.1	0.1	0.1	0.1

Table 16. Estimated Annual Forage Yield (spring and fall harvests combined)

Year	-----estimated dry tons/A -------			
	Site 1 (Control)	Site 2 (Fert.)	Site 3 (3T Bio)	Site 4 (6T Bio)
2009	2.0	3.2	3.8	4.4
2010	1.7	2.9	2.8	3.2
2011 (spring only)	0.2	0.4	0.5	0.6

Table 17. Forage Relative Feed Value (RFV)

Cutting	Site 1 (Control)	Site 2 (Fert)	Site 3 (3T Bio)	Site 4 (6T Bio)
Spring 2009	79	73	76	78
Fall 2009	82	97	90	90
Spring 2010	79	77	78	80
Fall 2010	66	76	89	96
Spring 2011	84	86	89	91

FIGURES

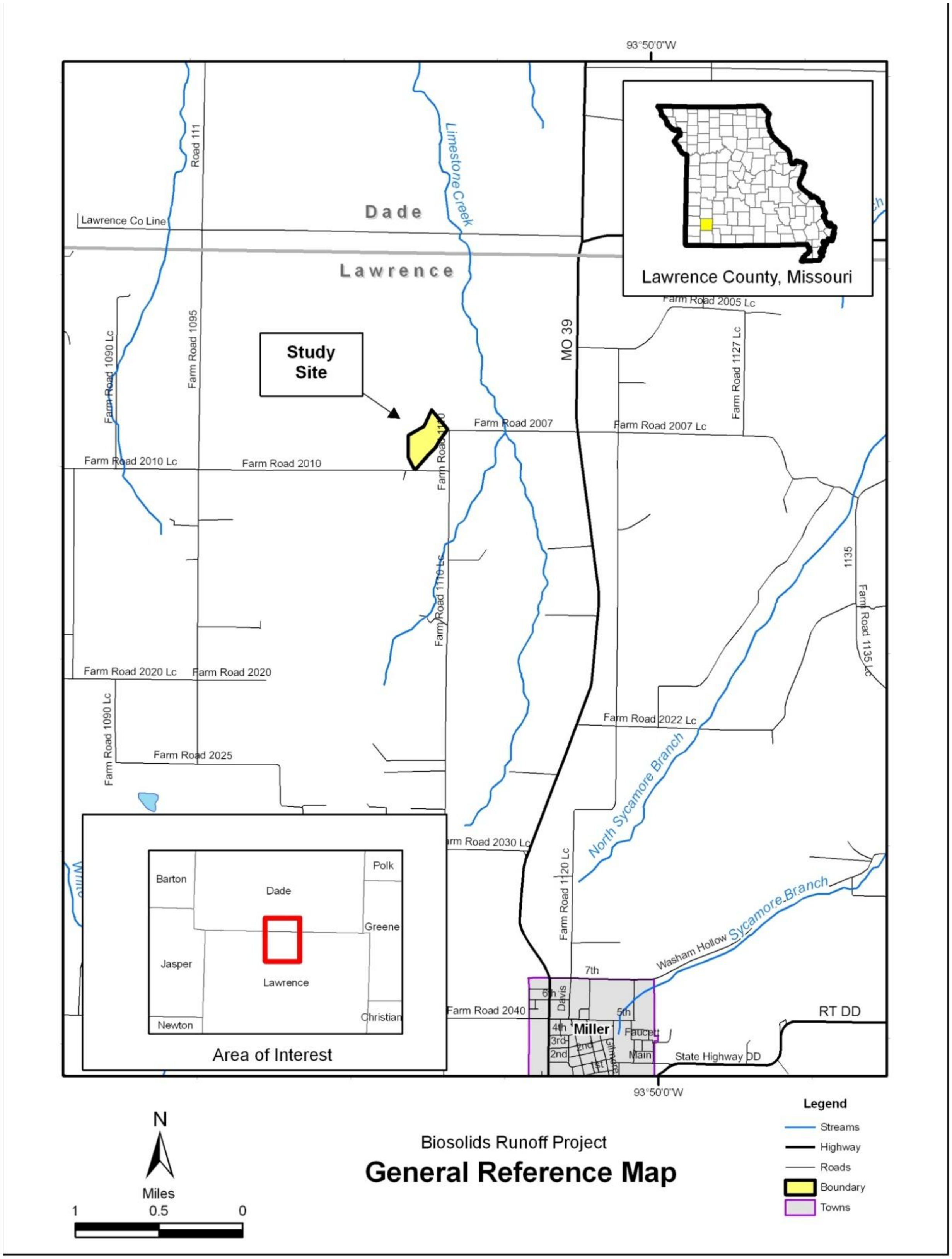

Figure 1. Study site location

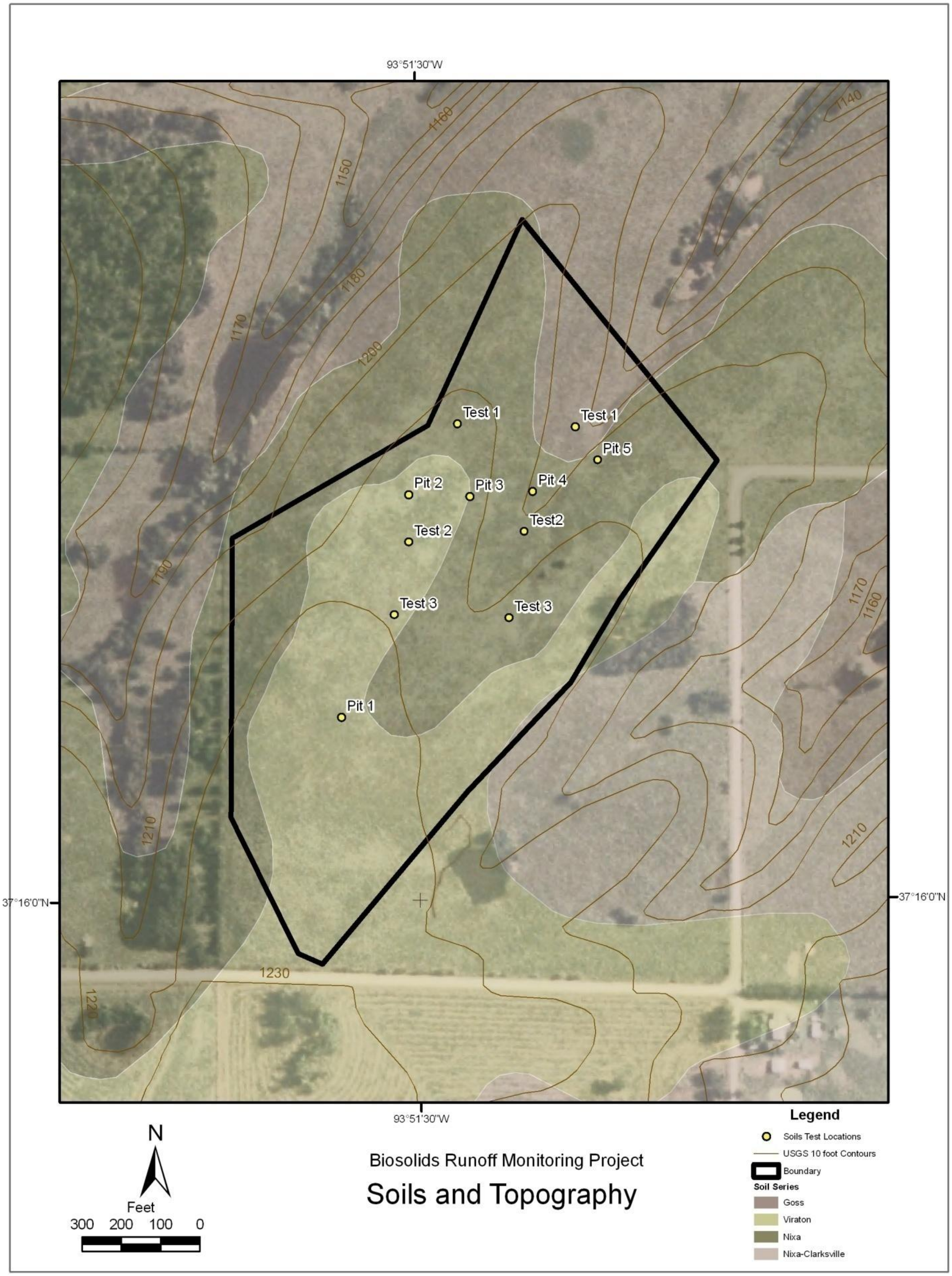

Figure 2. Mapped soils with soil test and soil morphology soil pit locations

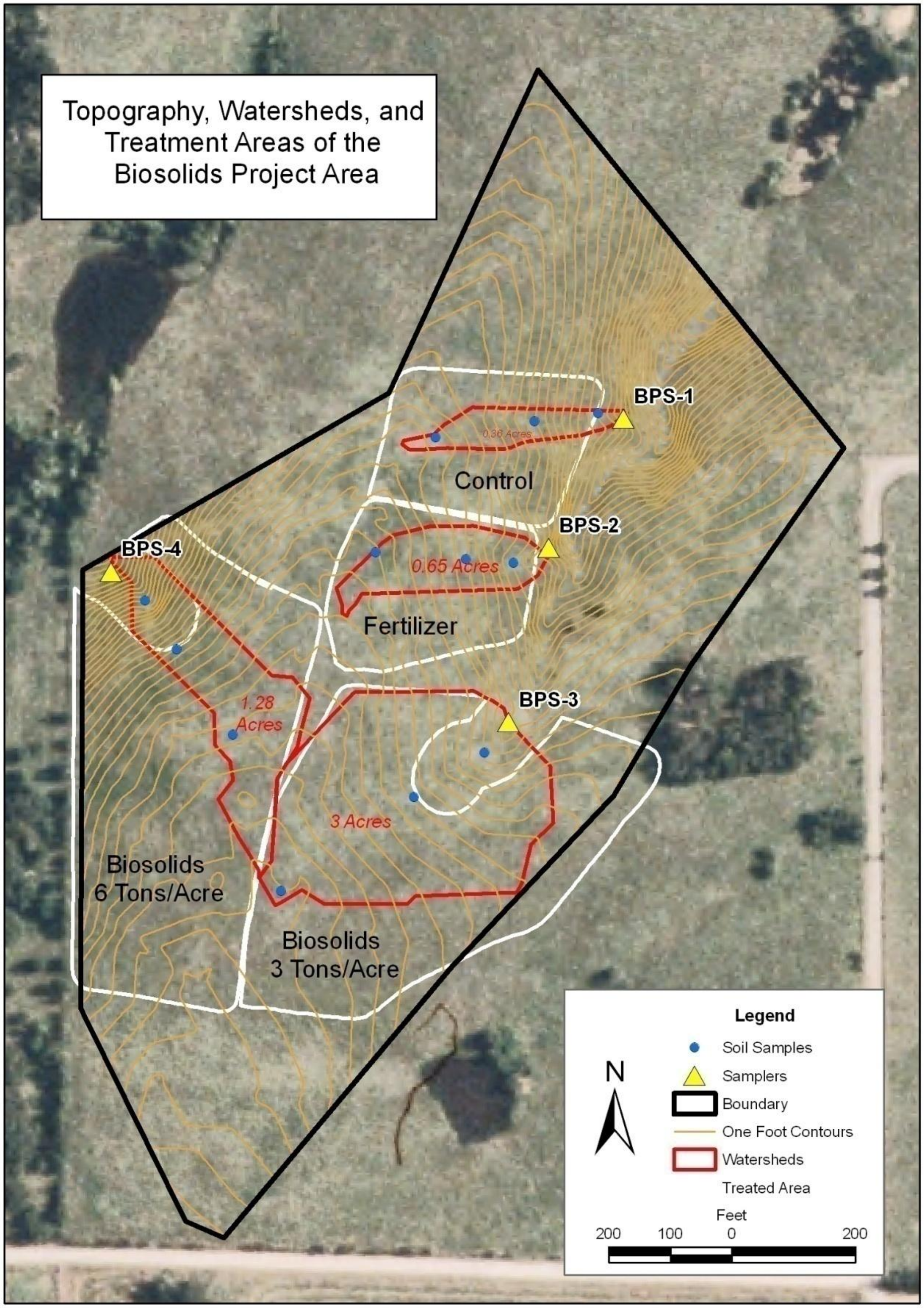

Figure 3. Site topography, watershed areas, surface soil sample locations, and treatment zones

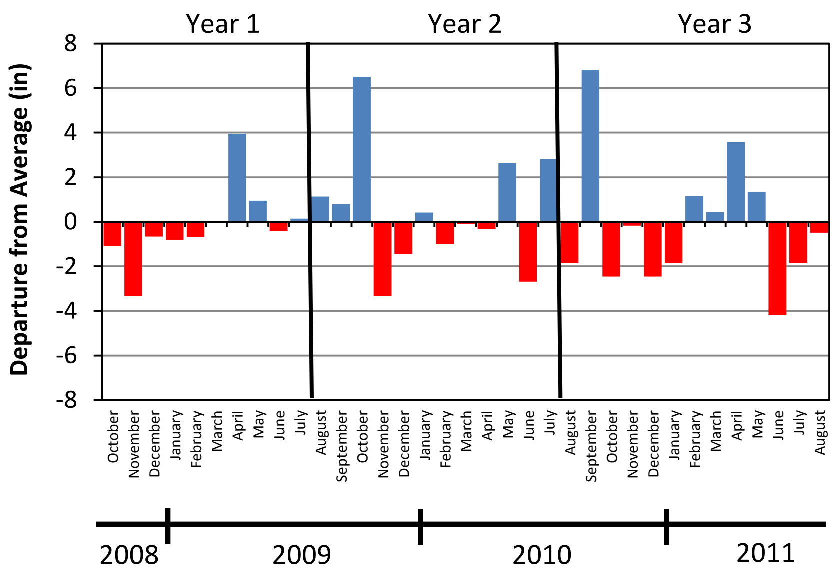

Figure 4. Departure from the average monthly rainfall totals over the sampling period

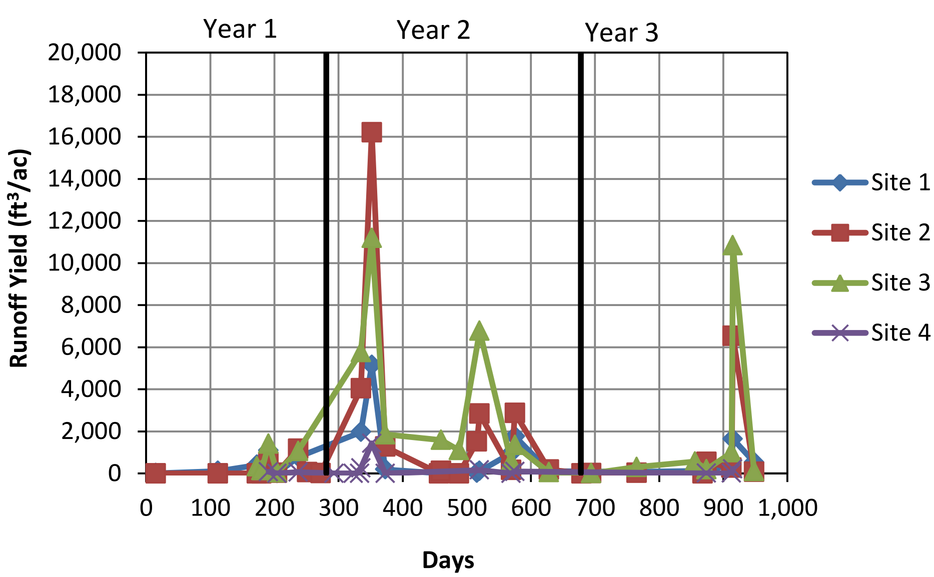

Figure 5. Time-series plot of runoff yield by site

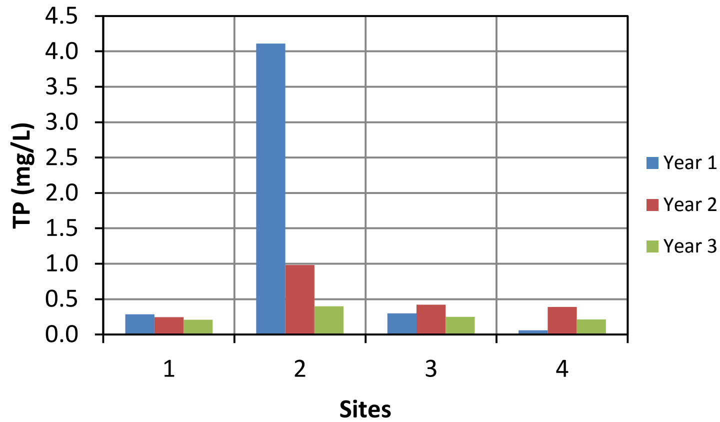

Figure 6. Annual median TP by site

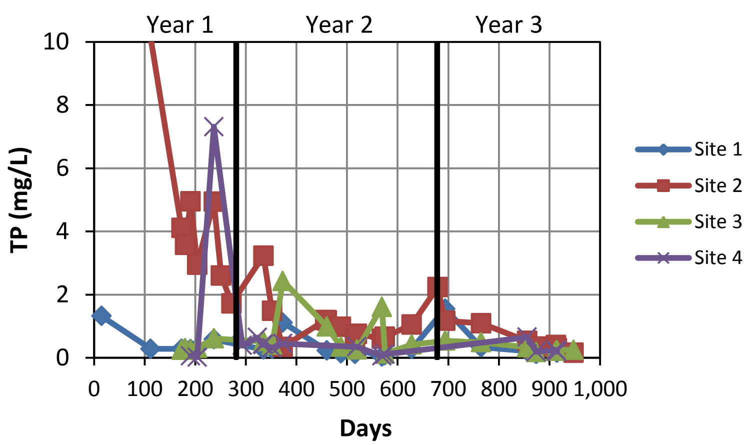

Figure 7. Time-series plot of TP over the sample period

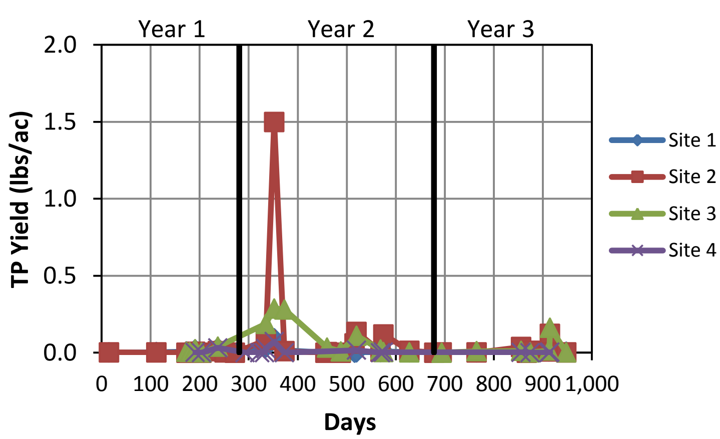

Figure 8. Time-series plot of TP yield over the sample period

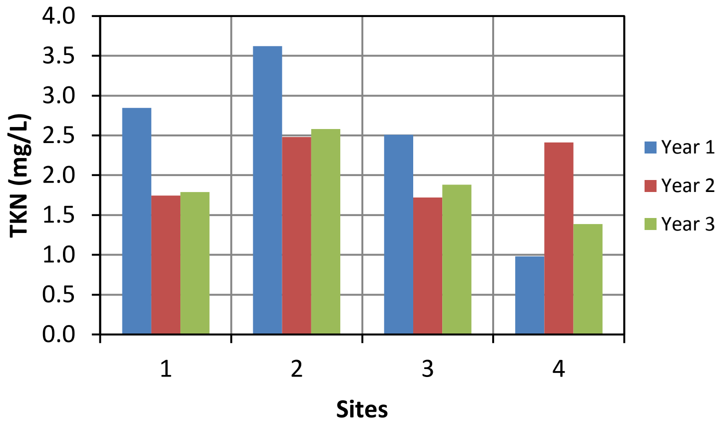

Figure 9. Annual median TKN by site

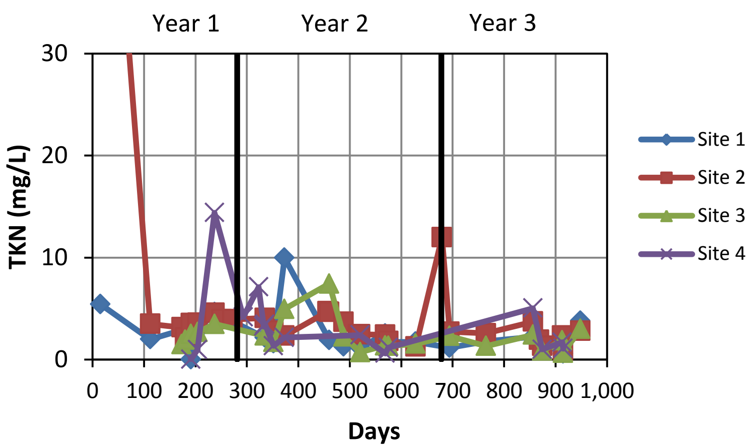

Figure 10. Time-series plot of TKN over the sample period

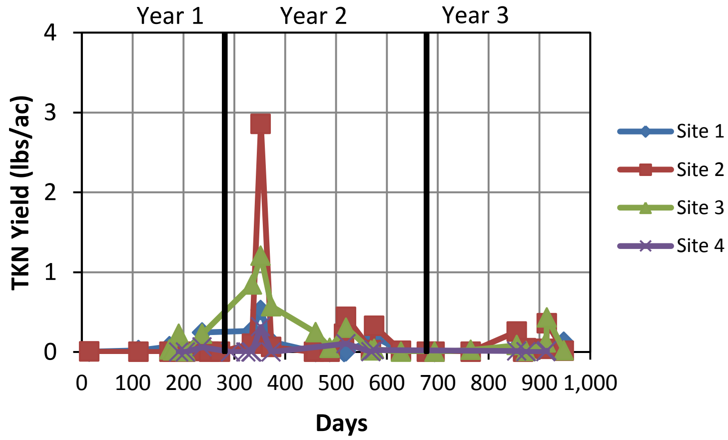

Figure 11. Time-series plot of TKN yield over the sample period

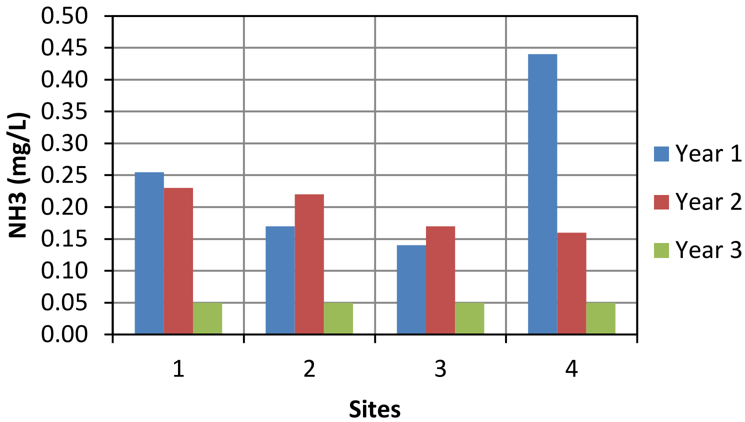

Figure 12. Annual median ammonia by site

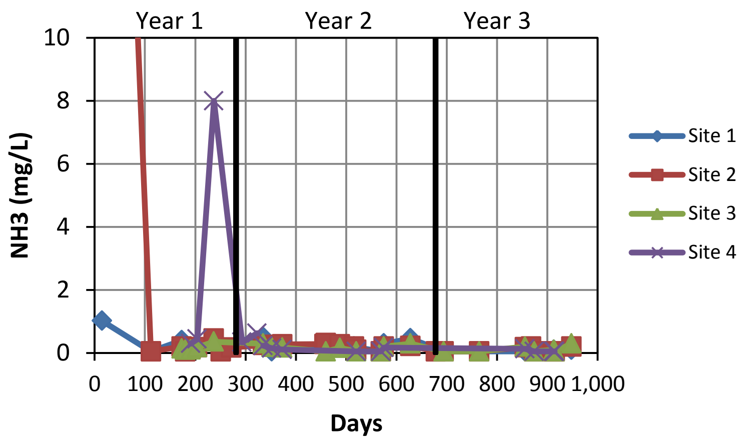

Figure 13. Time-series plot of ammonia over the sample period

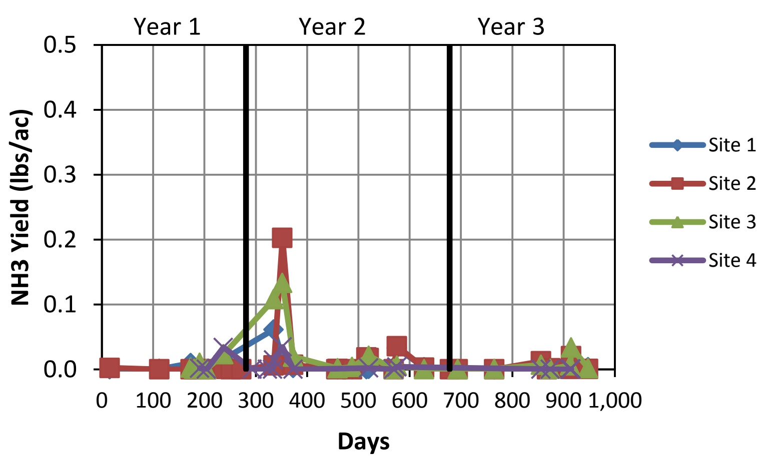

Figure 14. Time-series plot ammonia yield over the sampling period

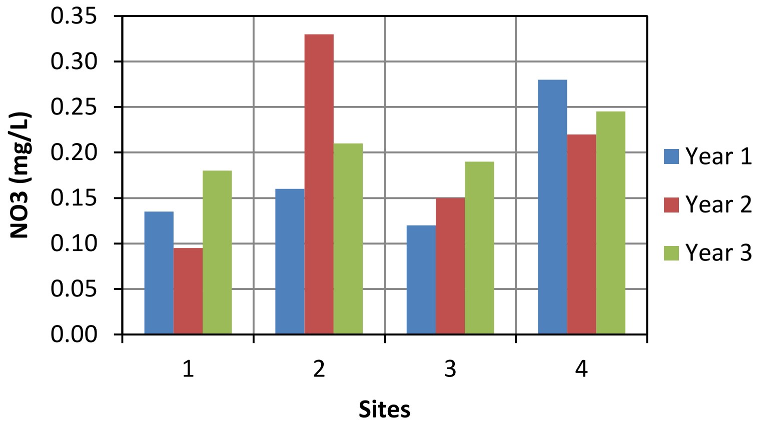

Figure 15. Annual median nitrate over time

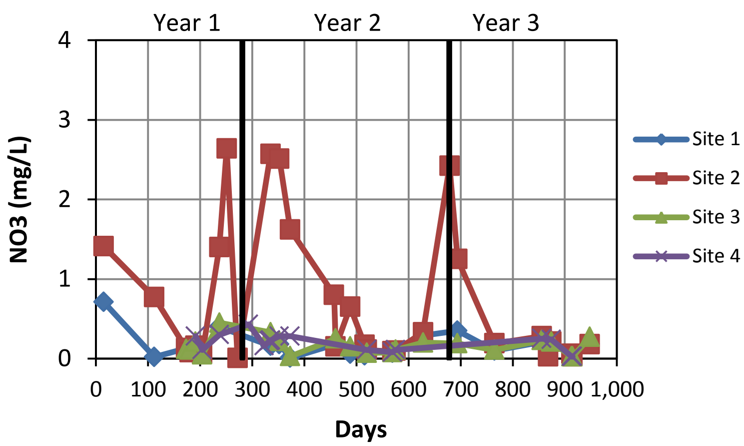

Figure 16. Time-series plot of nitrate over the sample period

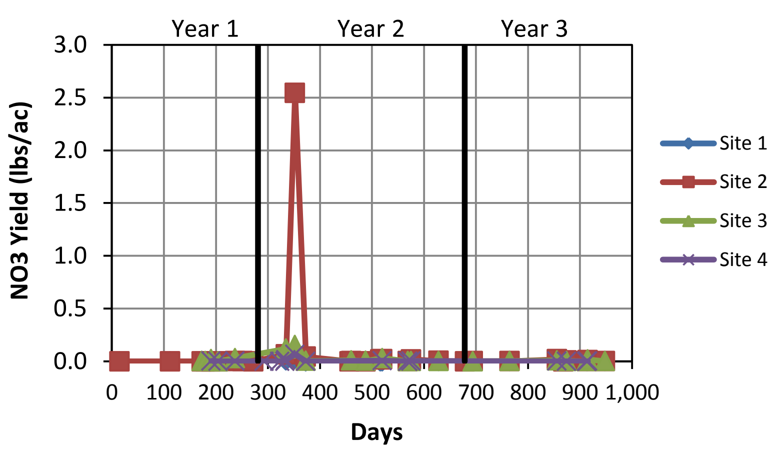

Figure 17. Time-series plot nitrate yield over the sample period

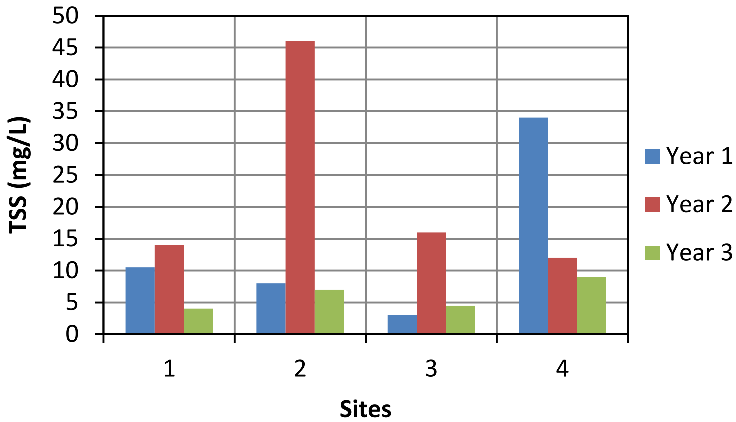

Figure 18. Annual median TSS by site

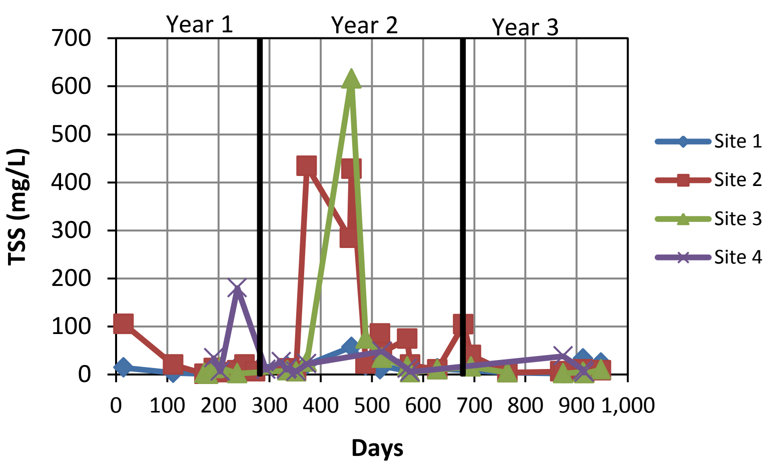

Figure 19. Time-series plot of TSS over the sample period

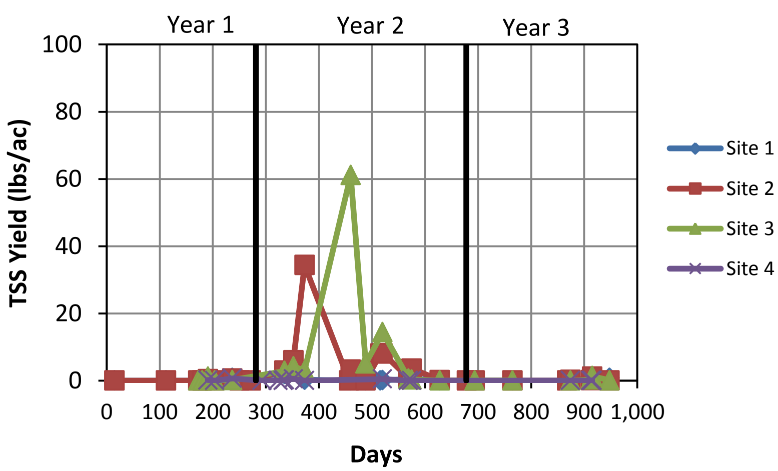

Figure 20. Time-series plot of TSS yield over the sample period

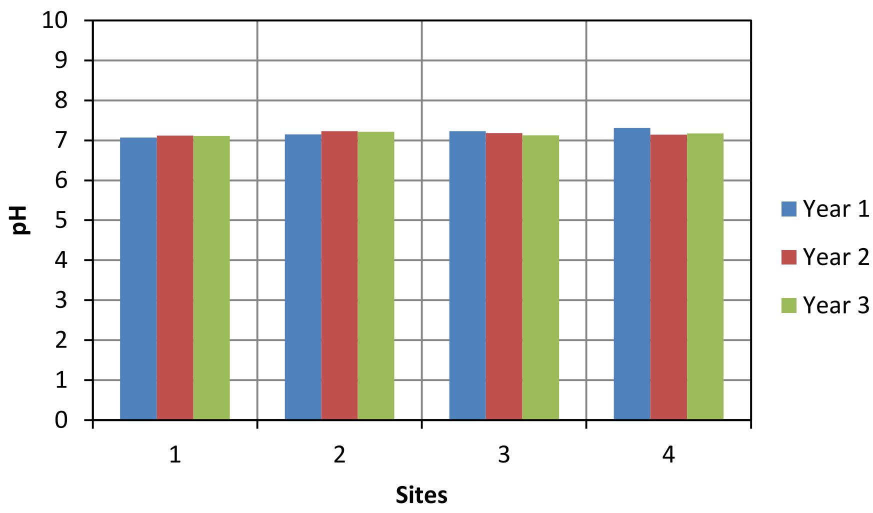

Figure 21. Annual median pH by site

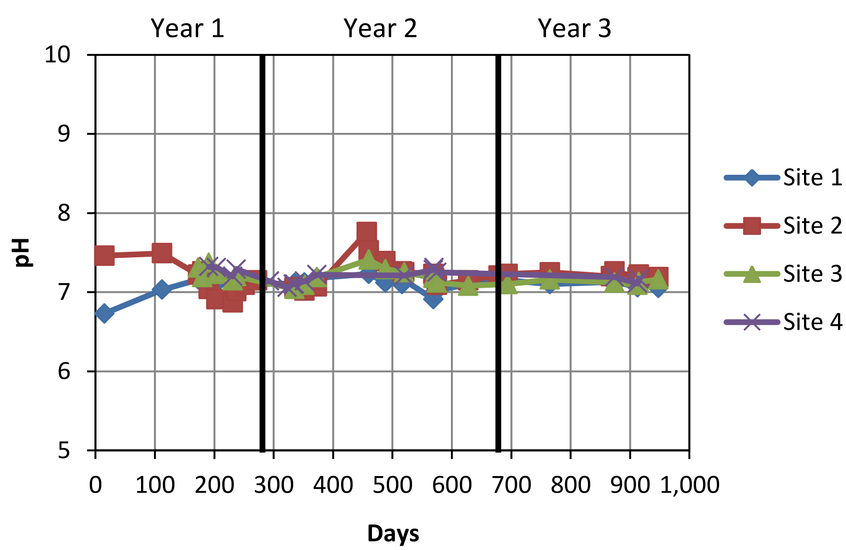

Figure 22. Time-series plot of pH over the sample period

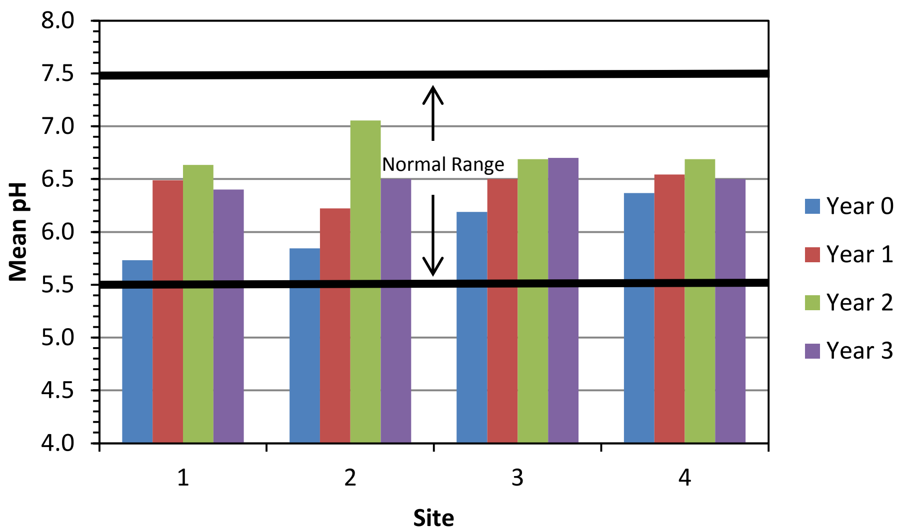

Figure 23. Annual mean soil pH by site

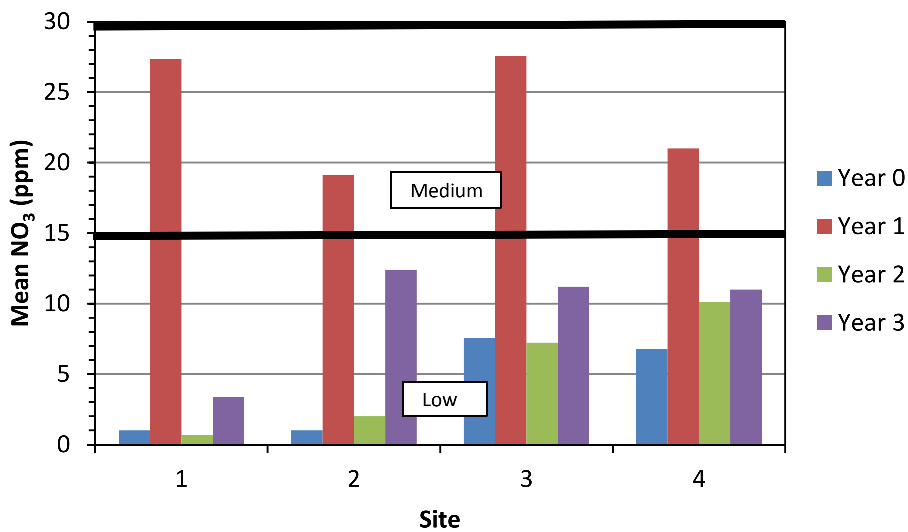

Figure 24. Annual mean soil NO_3 by site

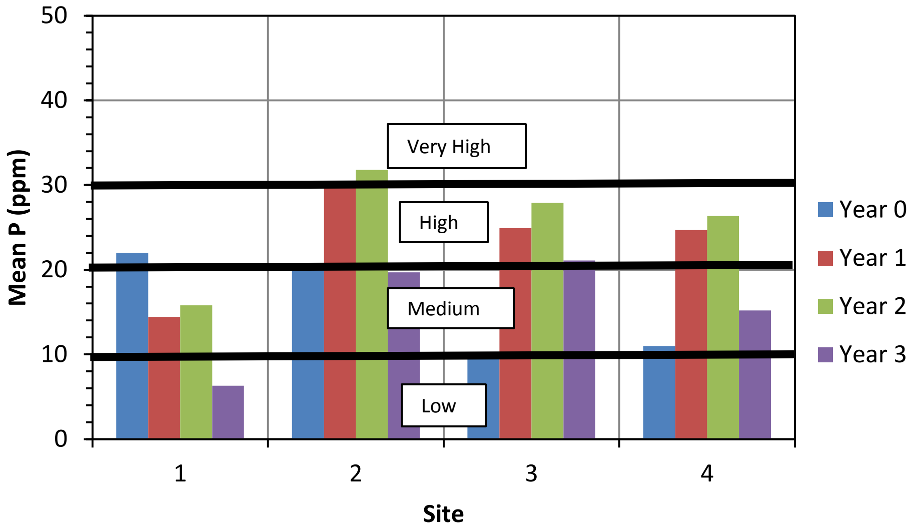

Figure 25. Annual mean soil P by site

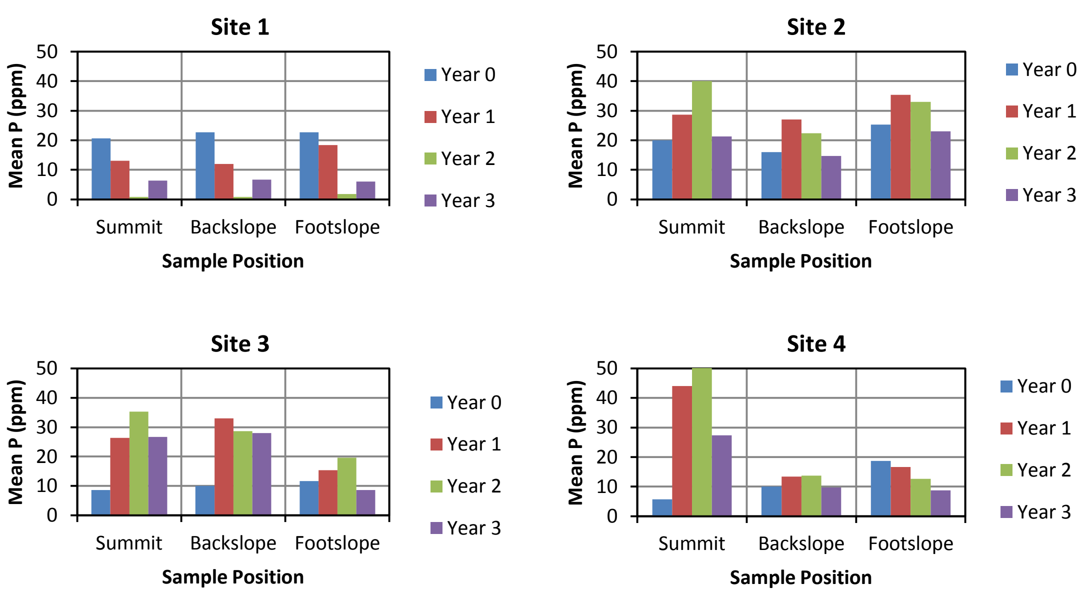

Figure 26. Annual mean soil P by landscape position

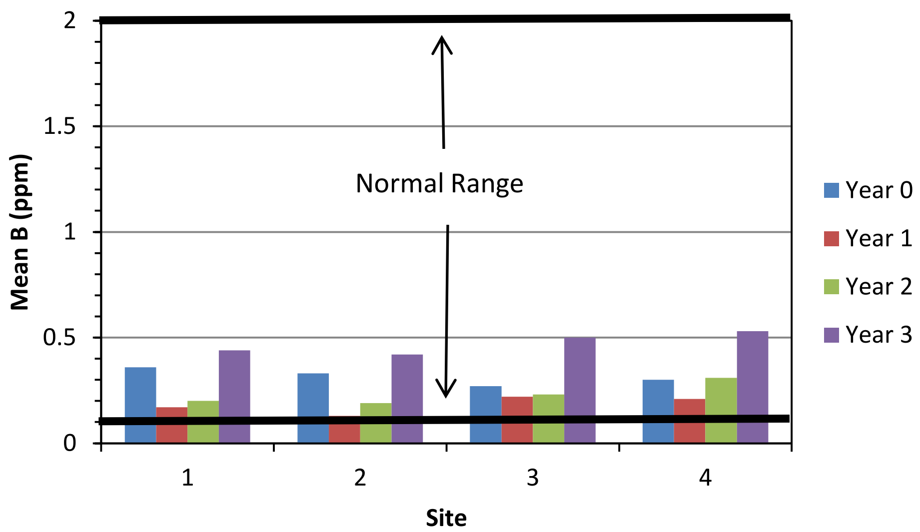

Figure 27. Annual mean B by site

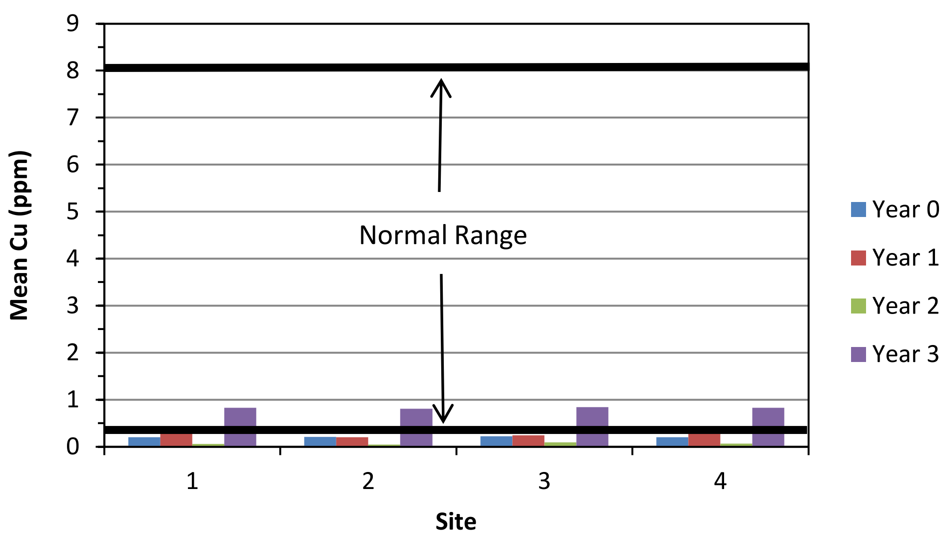

Figure 28. Annual mean Cu by site

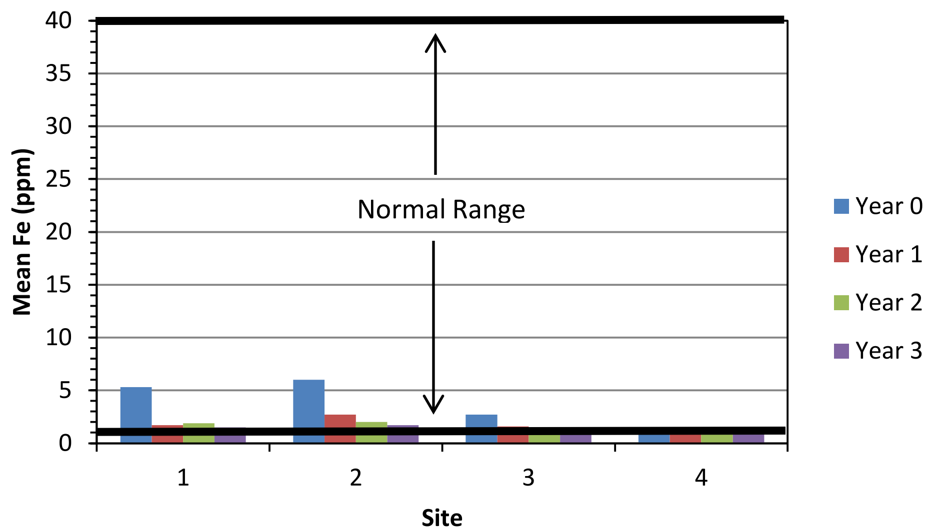

Figure 29. Annual mean Fe by site

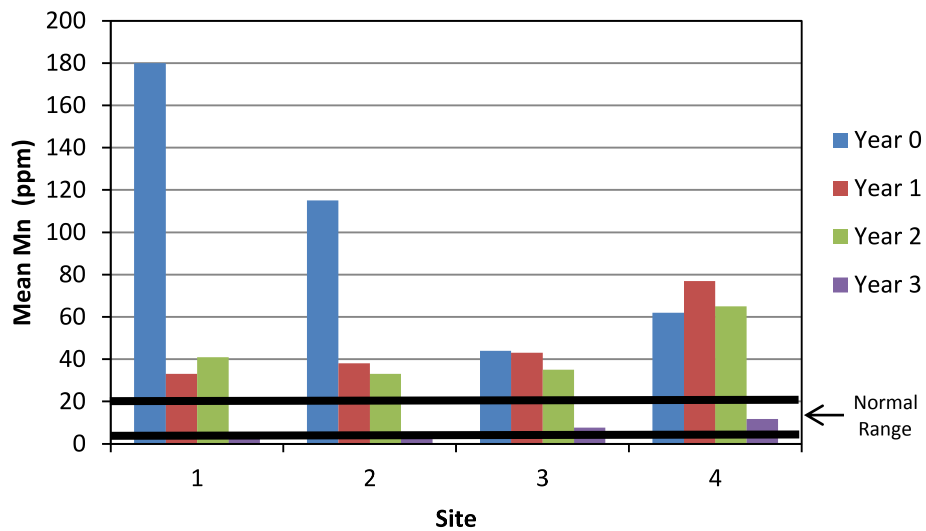

Figure 30. Annual mean Mn by site

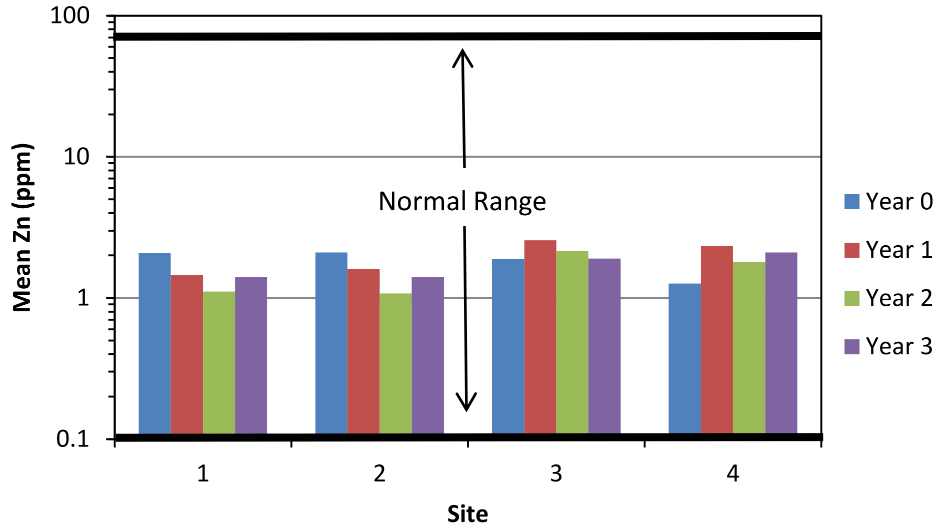

Figure 31. Annual mean soil Zn by site

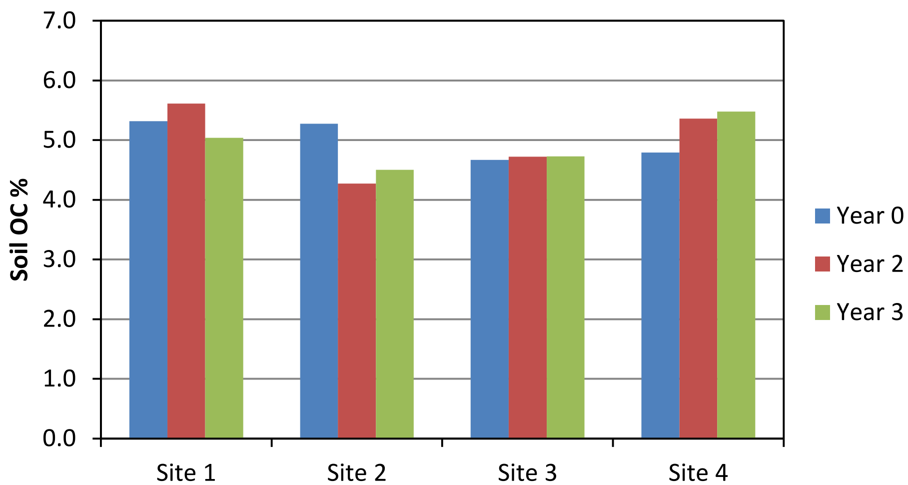

Figure 32. Mean soil organic carbon content by site for years 0, 2, and 3

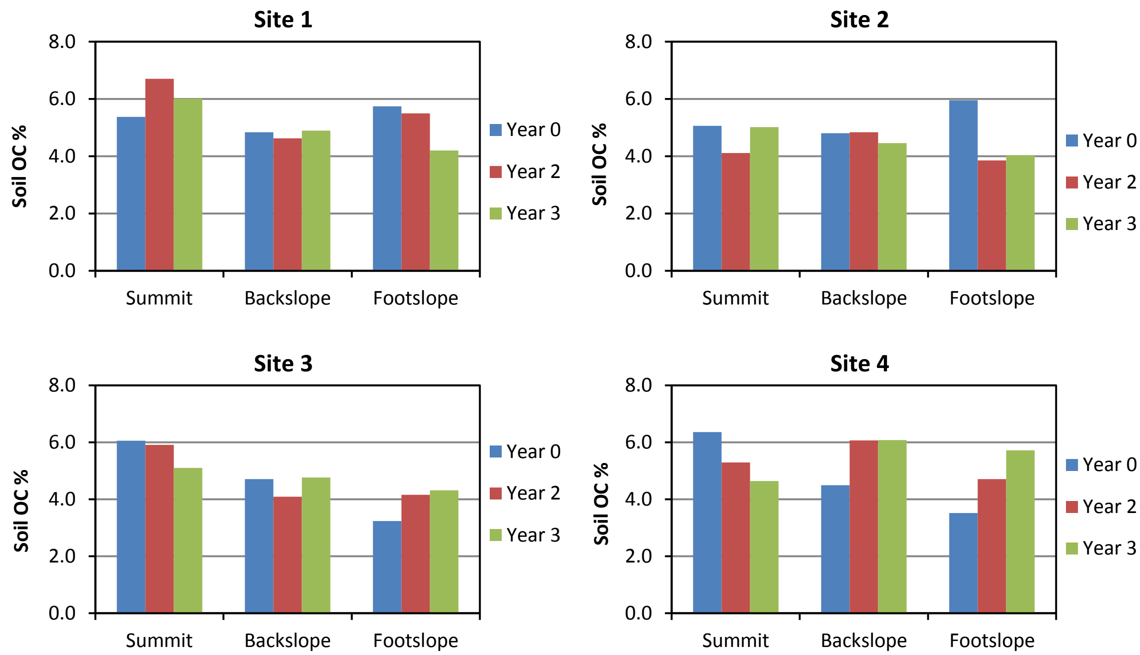

Figure 33. Mean soil organic carbon content by landscape position for years 0, 2, and 3

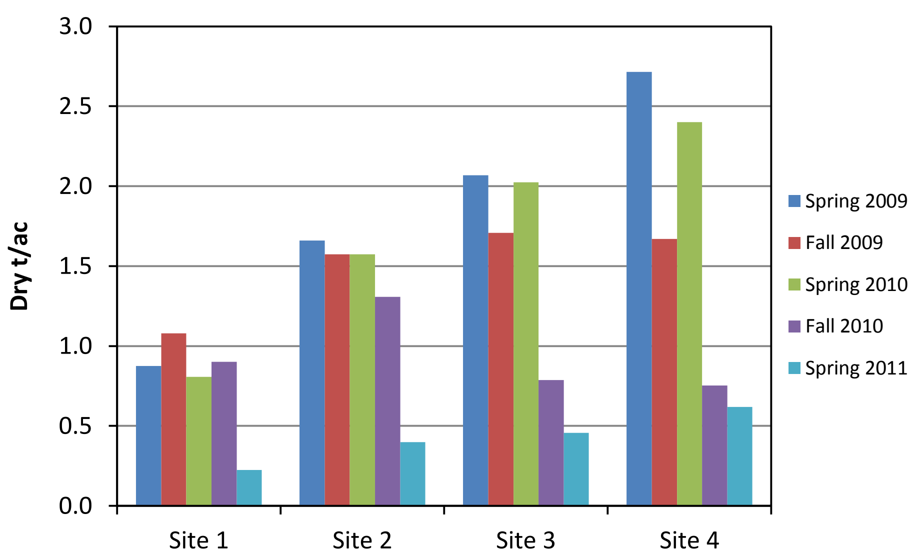

Figure 34. Seasonal forage yield by site

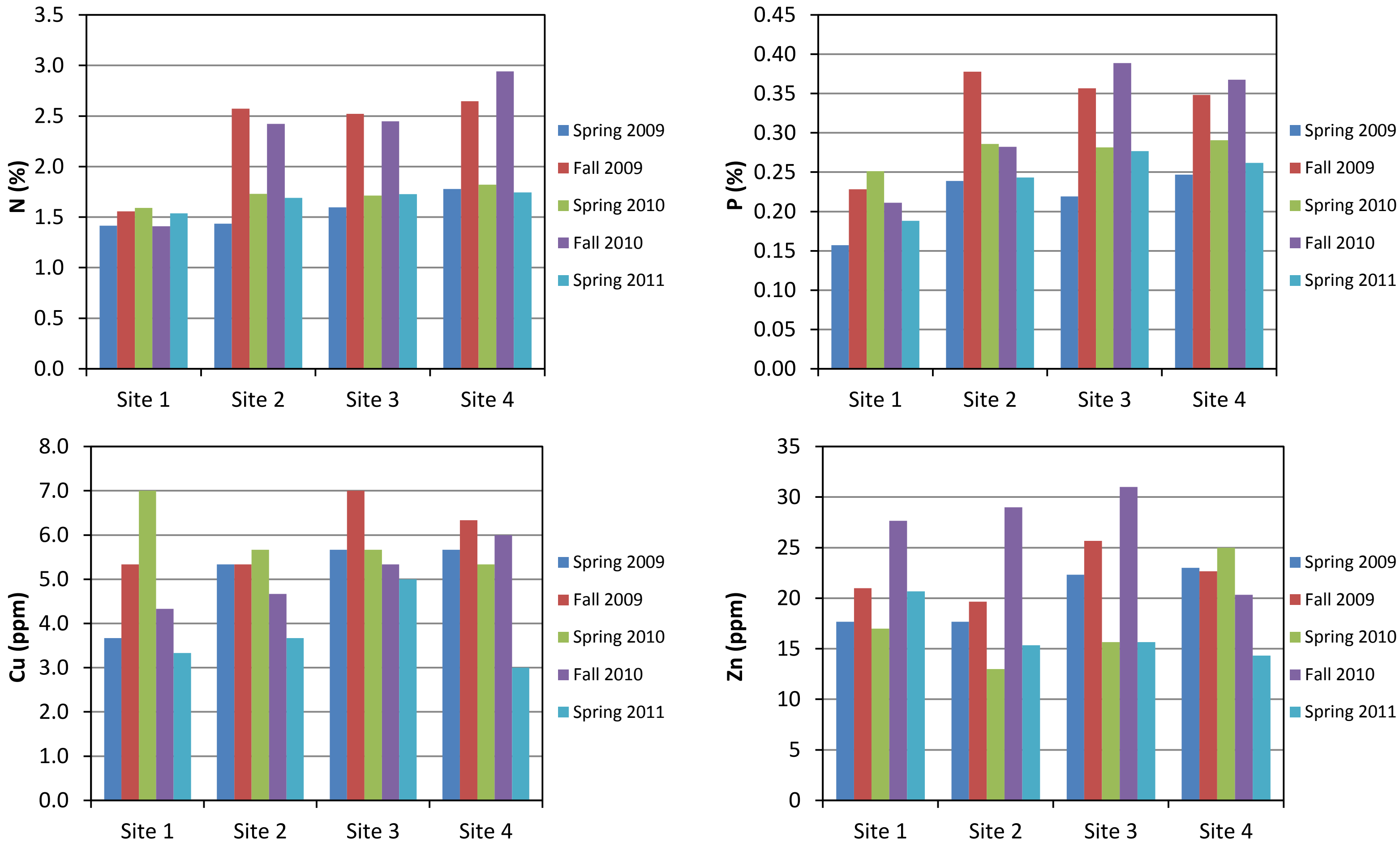

Figure 35. Annual Nitrogen, Phosphorus, Copper and Zn in forage harvest

PHOTOS

Photo 1. Soil pit #1 from the head slope landscape position showing silty texture from loess parent material over older reworked loess sitting on top of a fragipan.

Photo 2. Soil pit #2 from the narrow interfluve between sites 1 and 4 showing colluvial material over a weak fragipan over red residuum below.

Photo 3. Prismatic structure and gray seams indicative of fragipan pedology in SW Missouri.

Photo 4. Soil pit #3 from the slightly steeper shoulder side slope with rocky colluvium over cherty red clay residiuum.

Photo 5. Top 15 inches of pit #4 similar to pit #3 above.

Photo 6. Soil pit from the valley bottom landscape position with unconsolidated rocky colluvial parent material that may be result of past land clearing.

Photo 7. V-notch weir, pressure transducer, and strainer location

Photo 8. Pressure transducer and strainer location

Photo 9. Surface soil sample transect

Photo 10. Sampler housing along main draw on the project site (October 2008)

Photo 11. Auto-sampler and rain gage installation (October 2008)

Photo 12. Tom Dewitt soil coring along the ridge with class (October 2008)

Photo 13. Example of a soil profile at the project site (loess over colluvium over residuum) (October 2008)

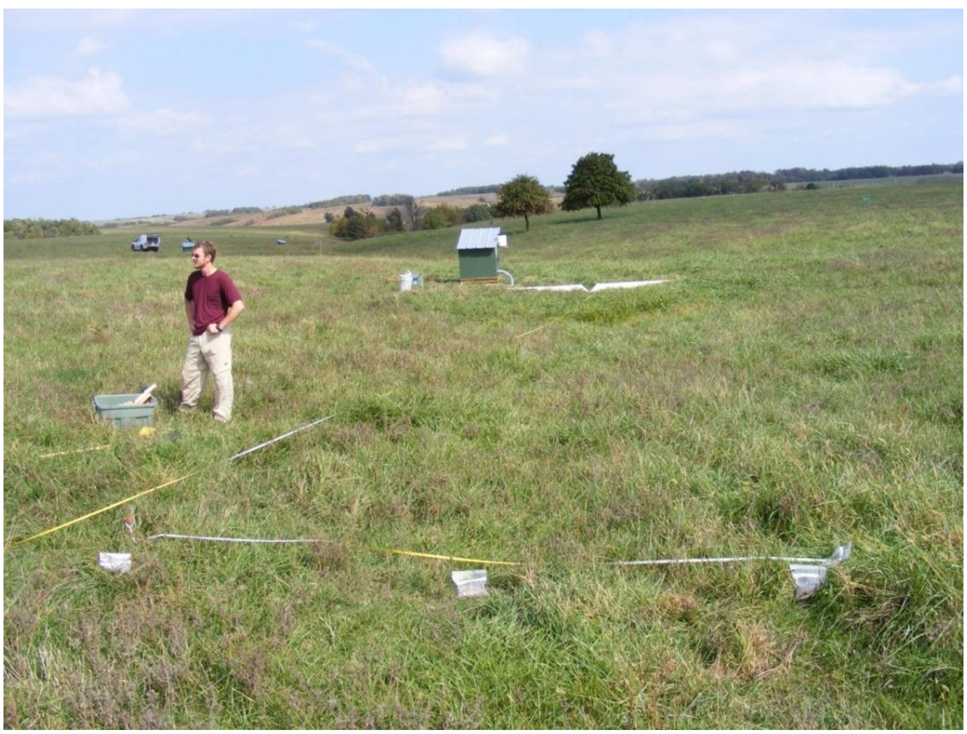

Photo 14. Surface soil sampling (October 2008)

Photo 15. Watershed divide between the 6 t/ac biosolids treated site 4 (right) and control site 1 (left).

Photo 16. Harvesting forage with a walk-behind sicklebar mower.

APPENDIX A: Soil Test Results

University Extension
University of Missouri-Columbia

Soil Test Report

Soil Testing Laboratory
23 Mumford Hall, MU
Columbia, MO 65211
Phone: (573) 882-0623

or

Soil Testing Laboratory
P.O. Box 160
Portageville, MO 63873
Phone: (573)379-5431

http://www.soiltest.psu.missouri.edu/

Serial no. S41722-1	**Lab no. C0810745**
County Greene	Region 6
Submitted 8/1/2008	Processed 8/6/2008

Soil sample submitted by: Firm Number: Outlet:

FIELD INFORMATION			
Field ID BIO 1		Sample no 1	
Acres	Last Limed unknown	Irrigated No	
Last crop 18 COOL SEASON GRASS HAY			FSA Copy N

This report is for:
MSU-GGP
901 NATIONAL
SPRINGFIELD MO 65802

SOIL TEST INFORMATION				RATING
				Very Low / Low / Medium / High / Very High / Excess
pH_s	(salt pH)	5.7		************************
Phosphorus	(P)	29	lbs/A	*************************
Potassium	(K)	173	lbs/A	***************************
Calcium	(Ca)	1987	lbs/A	**********************************
Magnesium	(Mg)	131	lbs/A	************
Sulfur	(SO_4-S)		ppm	
Zinc	(Zn)		ppm	
Manganese	(Mn)		ppm	
Iron	(Fe)		ppm	
Copper	(Cu)		ppm	

Organic matter 3.7 %	Neutralizable acidity 3.0 meq/100g	Cation Exch. Capacity 8.7 meq/100g
PH in water	Electrical Conductivity Mmho/cm	Sodium (Na) lbs/A
Nitrate (NO_3-N) Topsoil ppm	Subsoil ppm	Sampling Depth Top Inches Subsoil Inches

NUTRIENT REQUIREMENTS

Cropping options	Yield goal	N	P_2O_5	K_2O	Zn	S
18 COOL SEASON GRASS HAY	3 T/A	120	40	115		
18 COOL SEASON GRASS HAY	5 T/A	200	60	180		

(Pounds per acre: N, P_2O_5, K_2O, Zn, S)

LIMESTONE SUGGESTIONS	
Effective Neutralizing Material (ENM)	0
Effective magnesium (EMg)	***

Comments
---For hay production apply nitrogen just before spring growth begins (typically March). Consider splitting nitrogen applications if the rate exceeds 90 lbs N/acre, applying 60% in March and the balance in mid August.
---Some herbicide labels list restrictions based on soil pH in water. This sample has an estimated pH in water of 6.2 . Use this estimated pH in water as a guide. If you wish to have soil pH in water analyzed, contact your dealer or Extension specialist listed below.
***Limestone is not currently recommended. For a future limestone application, suggest using dolomitic limestone if readily available, but yield response to magnesium is not likely.

I normally suggest no more than 120 lbs nitrogen per year on cool season grass hay fields. I suggest split applications of this amount with 60-80 lbs in the early spring and the balance in the early fall.

Regional Agronomy Specialist Tim Schnakenberg Phone 417-357-6812 *Tim Schnakenberg*
Signature

White-Farmer, Yellow-FSA, Blue-Firm, Pink-Extension MP 189 Revised 1/96
University of Missouri, Lincoln University, U.S. Department of Agriculture & Local University Extension Councils Cooperating Columbia
Equal opportunity institutions

University Extension
University of Missouri-Columbia

Soil Test Report

Soil Testing Laboratory
23 Mumford Hall, MU
Columbia, MO 65211
Phone: (573) 882-0623

or

Soil Testing Laboratory
P.O. Box 160
Portageville, MO 63873
Phone: (573)379-5431

http://www.soiltest.psu.missouri.edu/

Serial no. S41722-3	**Lab no. C0810747**
County Greene	Region 6
Submitted 8/1/2008	Processed 8/6/2008

Soil sample submitted by: Firm Number: Outlet:

FIELD INFORMATION			
Field ID BIO 3		Sample no 3	
Acres	Last Limed unknown	Irrigated No	
Last crop 18 COOL SEASON GRASS HAY		FSA Copy N	

This report is for:
MSU-GGP
901 NATIONAL
SPRINGFIELD MO 65802

SOIL TEST INFORMATION				RATING (Very Low / Low / Medium / High / Very High / Excess)
pH_s	(salt pH)	5.5		**********************
Phosphorus	(P)	18	lbs/A	****************
Potassium	(K)	171	lbs/A	**************************
Calcium	(Ca)	2156	lbs/A	**********************************
Magnesium	(Mg)	106	lbs/A	********
Sulfur	(SO_4-S)		ppm	
Zinc	(Zn)		ppm	
Manganese	(Mn)		ppm	
Iron	(Fe)		ppm	
Copper	(Cu)		ppm	

Organic matter 5.1 %	Neutralizable acidity 4.0 meq/100g	Cation Exch. Capacity 10.1 meq/100g
PH in water	Electrical Conductivity Mmho/cm	Sodium (Na) lbs/A
Nitrate (NO_3-N) Topsoil ppm	Subsoil ppm	Sampling Depth Top Inches, Subsoil Inches

NUTRIENT REQUIREMENTS

Cropping options	Yield goal	N	P_2O_5	K_2O	Zn	S
18 COOL SEASON GRASS HAY	3 T/A	120	55	115		
18 COOL SEASON GRASS HAY	5 T/A	200	75	185		

(Pounds per acre: N, P_2O_5, K_2O, Zn, S)

LIMESTONE SUGGESTIONS

Effective Neutralizing Material (ENM)	650
Effective magnesium (EMg)	65

Comments
---For hay production apply nitrogen just before spring growth begins (typically March). Consider splitting nitrogen applications if the rate exceeds 90 lbs N/acre, applying 60% in March and the balance in mid August.
---Some herbicide labels list restrictions based on soil pH in water. This sample has an estimated pH in water of 6.0 . Use this estimated pH in water as a guide. If you wish to have soil pH in water analyzed, contact your dealer or Extension specialist listed below.
---To determine limestone needed in tons/acre, divide your ENM requirement by the guarantee of your limestone dealer.
***<u>Suggest using dolomitic limestone to increase magnesium in your soil. If dolomitic limestone is not available, under high management use a soluble source of magnesium fertilizer at a rate of 30 to 40 pounds Mg per acre.</u>

Our lime recommendations are for a one-time application and N-P-K are annual applications. Retest in 3-4 years.

Regional Agronomy Specialist Tim Schnakenberg Phone 417-357-6812 *Tim Schnakenberg*
Signature

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Portageville, MO 63873
Phone: (573)379-5431

http://www.soiltest.psu.missouri.edu/

Serial no. S41722-5	**Lab no. C0810749**
County Greene	Region 6
Submitted 8/1/2008	Processed 8/6/2008

Soil sample submitted by: Firm Number: Outlet:

FIELD INFORMATION		
Field ID BIO 5	Sample no 5	
Acres	Last Limed unknown	Irrigated No
Last crop 18 COOL SEASON GRASS HAY		FSA Copy N

This report is for:
MSU-GGP
901 NATIONAL
SPRINGFIELD MO 65802

SOIL TEST INFORMATION				RATING (Very Low / Low / Medium / High / Very High / Excess)
pH_s	(salt pH)	5.4		**********************
Phosphorus	(P)	10	lbs/A	********
Potassium	(K)	155	lbs/A	**************************
Calcium	(Ca)	2080	lbs/A	***********************************
Magnesium	(Mg)	125	lbs/A	************
Sulfur	(SO_4-S)		ppm	
Zinc	(Zn)		ppm	
Manganese	(Mn)		ppm	
Iron	(Fe)		ppm	
Copper	(Cu)		ppm	

Organic matter 2.7 %	Neutralizable acidity 3.5 meq/100g	Cation Exch. Capacity 9.4 meq/100g
PH in water	Electrical Conductivity Mmho/cm	Sodium (Na) lbs/A
Nitrate (NO_3-N) Topsoil ppm / Subsoil ppm	Sampling Depth Top Inches	Subsoil Inches

NUTRIENT REQUIREMENTS

Cropping options	Yield goal	N	P_2O_5	K_2O	Zn	S
18 COOL SEASON GRASS HAY	3 T/A	120	70	120		
18 COOL SEASON GRASS HAY	5 T/A	200	90	190		

(Pounds per acre)

LIMESTONE SUGGESTIONS

Effective Neutralizing Material (ENM)	640
Effective magnesium (EMg)	***

Comments
---For hay production apply nitrogen just before spring growth begins (typically March). Consider splitting nitrogen applications if the rate exceeds 90 lbs N/acre, applying 60% in March and the balance in mid August.
---Some herbicide labels list restrictions based on soil pH in water. This sample has an estimated pH in water of 5.9 . Use this estimated pH in water as a guide. If you wish to have soil pH in water analyzed, contact your dealer or Extension specialist listed below.
---To determine limestone needed in tons/acre, divide your ENM requirement by the guarantee of your limestone dealer.
***Suggest using dolomitic limestone if readily available, but yield response to magnesium is not likely.

Regional Agronomy Specialist Tim Schnakenberg Phone 417-357-6812 *Tim Schnakenberg*
Signature

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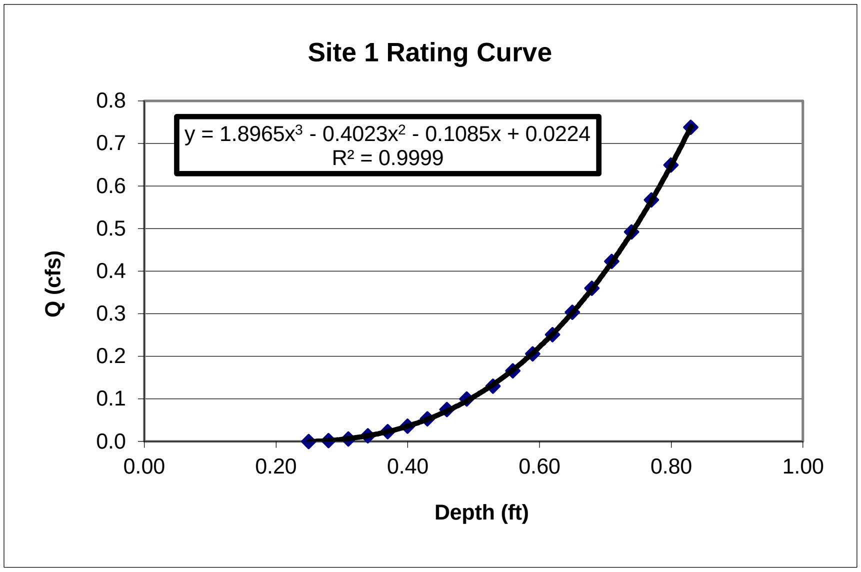
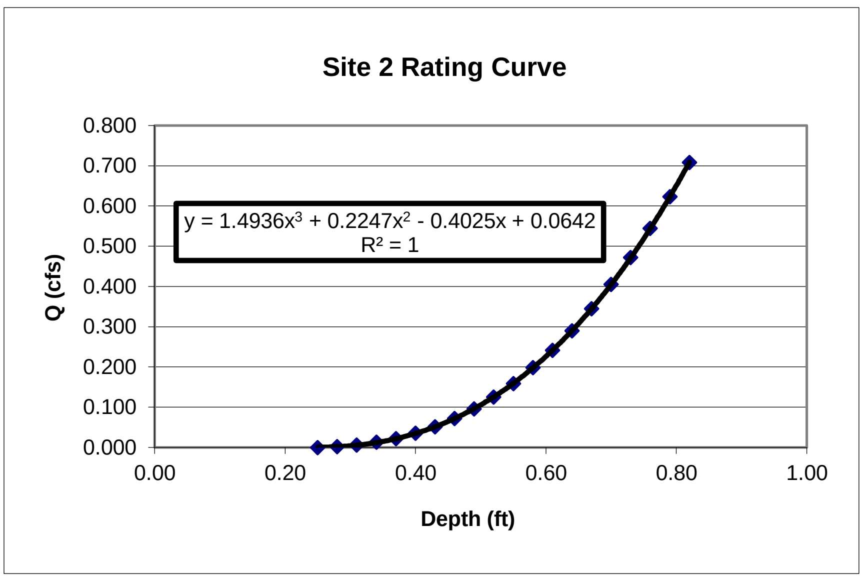
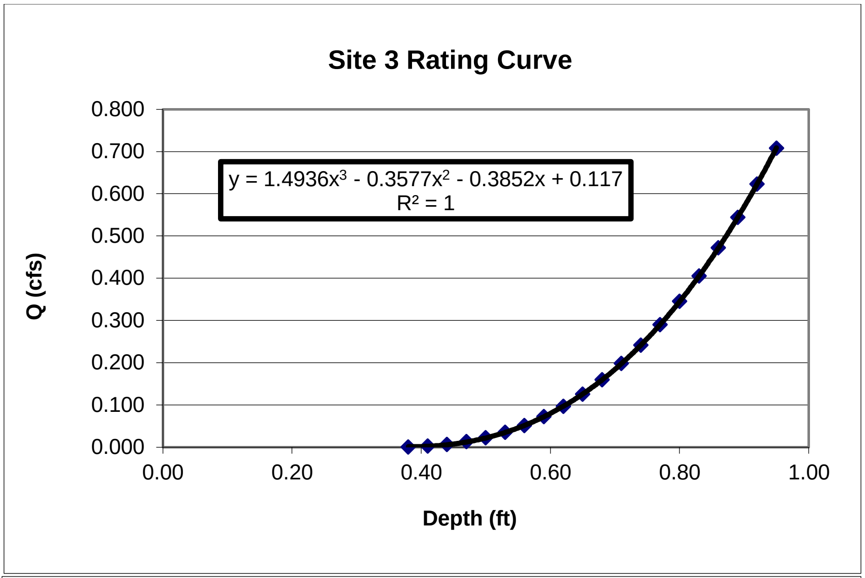
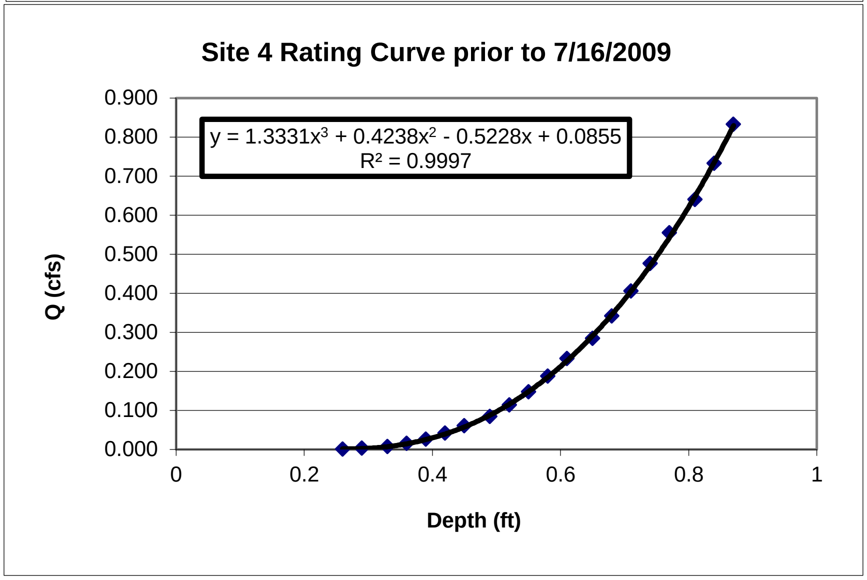
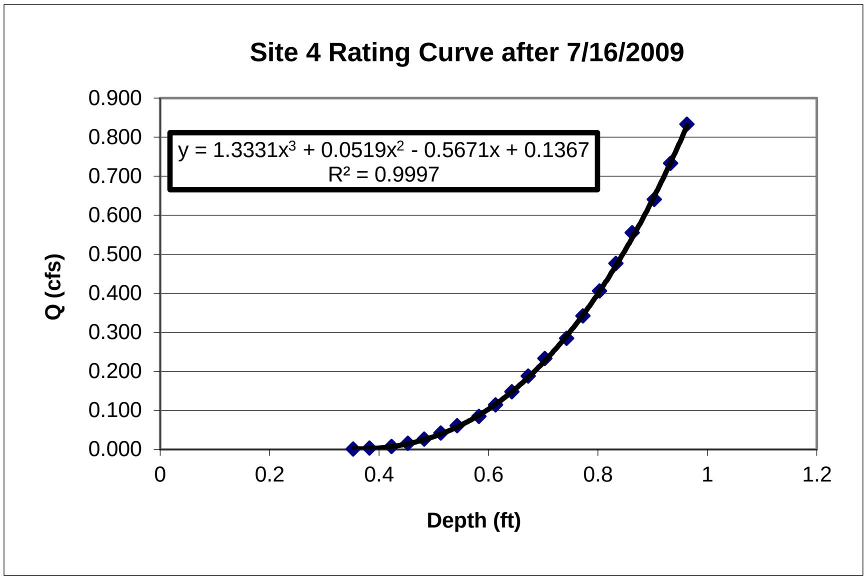
APPENDIX B: Discharge Rating Curves






Site 3 Rating Curve
y = 1.4936x³ - 0.3577x² - 0.3852x + 0.117
R² = 1
Q (cfs)
0.800
0.700
0.600
0.500
0.400
0.300
0.200
0.100
0.000
0.00
0.20
0.40
0.60
0.80
1.00
Depth (ft)


Site 4 Rating Curve prior to 7/16/2009
y = 1.3331x³ + 0.4238x² - 0.5228x + 0.0855
R² = 0.9997
Q (cfs)
0.900
0.800
0.700
0.600
0.500
0.400
0.300
0.200
0.100
0.000
0
0.2
0.4
0.6
0.8
1
Depth (ft)


Site 4 Rating Curve after 7/16/2009
y = 1.3331x³ + 0.0519x² - 0.5671x + 0.1367
R² = 0.9997
Q (cfs)
0.900
0.800
0.700
0.600
0.500
0.400
0.300
0.200
0.100
0.000
0
0.2
0.4
0.6
0.8
1
1.2
Depth (ft)

APPENDIX C: Rainfall and Runoff Volume Data

Date	Total Rainfall Vol. (ft^3)	Total Runoff Vol.(ft^3)	Est. Runoff%	Est. Infiltration %
		Site 1		
Year 1				
11/6/2008	772	1.8	<1	>99
2/11/2009	2,400	41	1.7	98.3
4/12/2009	1,724	152	8.8	91.2
5/1/2009	2,317	413	17.8	82.2
5/13/2009	1,297	1.7	<1	>99
6/16/2009	2,442	298	12.2	87.8
Year 2				
9/22/2009	3,862	749	19.4	80.6
10/9/2009	6,994	1,955	28.0	72.0
10/30/2009	1,352	72	5.3	94.7
1/25/2010	869	0.37	<1	>99
2/22/2010	1,145	0.37	<1	>99
3/22/2010	1,131	9.6	<1	>99
3/25/2010	1,890	41	2.2	97.8
5/14/2010	2,690	363	13.5	86.5
5/20/2010	2,400	669	27.9	72.1
7/12/2010	3,090	40	1.3	98.7
Year 3				
9/16/2010	1,310	0.37	<1	>99
11/26/2010	2,869	32	1.1	98.9
2/25/2011	1,710	150	8.8	91.2
3/14/2011	1,448	44	3.0	97.0
4/23/2011	1,779	161	9.0	91.0
4/25/2011	3,435	623	18.1	81.9
5/28/2011	938	200	21.3	78.7
		Site 2		
Year 1				
11/6/2009	1,321	0.66	<1	>99
2/10/2009	4,106	0.66	<1	>99
4/12/2009	2,949	0.66	<1	>99
4/20/2009	2,997	0.66	<1	>99
5/1/2009	3,964	350	8.8	91.2
5/13/2009	2,218	17	<1	>99
6/16/2009	4,176	756	18.1	81.9
6/30/2009	2,595	39	1.5	98.5
7/20/2009	4,318	1.20	<1	>99
Year 2				
9/22/2009	6,607	2,624	39.7	60.3
10/9/2009	11,963	10,539	88.1	11.9
10/30/2009	2,312	824	35.6	64.4
1/22/2010	1,274	0.66	0.1	99.9
1/25/2010	1,486	79.8	5.4	94.6
2/22/2010	1,958	0.66	0.0	100.0
3/22/2010	1,935	986	51.0	49.0
3/25/2010	3,233	1,841	56.9	43.1
5/14/2010	4,601	101	2.2	97.8
5/20/2010	4,106	1,866	45.5	54.5
7/12/2010	5,285	119	2.3	97.7
Year 3				
9/16/2010	2,242	8.6	0.4	99.62
11/26/2010	4,908	11	0.2	99.8
2/25/2011	2,926	712	24.3	75.7
3/9/2011	1,746	0.66	<1	>99
3/14/2011	2,477	352	14.2	85.8

4/23/2011	3,044	171	5.6	94.4
4/25/2011	5,875	4245	72.3	27.7
5/28/2011	1,604	48	3.0	97.0
		Site 3		
Year 1				
4/12/2009	13,613	1,001	7.4	92.6
4/20/2009	13,830	427	3.1	96.9
5/1/2009	18,295	4,209	23.0	77.0
5/13/2009	10,237	106	1.0	99.0
6/16/2009	19,275	3,180	16.5	83.5
Year 2				
9/22/2009	30,492	17,280	56.7	43.3
10/9/2009	55,212	33,573	60.8	39.2
10/30/2009	10,672	5,554	52.0	48.0
1/25/2010	6,861	4,766	69.5	30.5
2/22/2010	9,039	3,299	36.5	63.5
*3/25/2010**	*14,919**	*20,322**	-	-
5/14/2010	21,236	1,729	8.1	91.9
5/20/2010	18,949	4,027	21.3	78.7
7/12/2010	24,394	154	0.6	99.4
Year 3				
9/16/2010	10,346	22	0.2	99.8
11/26/2010	22,651	911	4.0	96.0
2/25/2011	13,504	1,679	12.4	87.6
3/14/2011	11,435	577	5.0	95.0
*4/23/2011***	*41,164***	*35,485***	*86.2***	*13.8***
5/28/2011	7,405	299	4.0	96.0
		Site 4		
Year 1				
5/1/2009	7,806	99	1.3	98.7
5/13/2009	4,368	0.27	<1	>99
6/16/2009	8,224	78	<1	>99
Year 2				
8/11/2009	6,412	0.27	<1	>99
8/19/2010	6,691	0.27	<1	>99
9/10/2009	5,901	0.27	<1	>99
9/20/2009	13,010	324	2.5	97.5
9/22/2009	23,557	1,824	7.7	92.3
10/9/2009	4,553	1.3	<1	>99
10/30/2009	6,366	201	3.2	96.8
3/25/2010	9,060	0.27	<1	>99
5/14/2010	8,085	118	1.5	98.5
Year 3				
2/25/2011	5,762	47	<1	>99
3/14/2011	4,879	3.7	<1	>99
4/23/2011	5,994	2.7	<1	>99
4/25/2011	11,570	271	2.3	97.7

* Estimated runoff volume due to freezing of ponded water behind the weir

** Combination of two events

APPENDIX D: Raw Fertilizer and Biosolids Nutrient and Metals Analysis

Location	Nutrients (mg/kg)				% Total Solids	Fecal coliform (coli/100 mL)	pH (std units)	Metals (mg/kg)											
	TKN	NH3-N	NO3-N	TP				As	Cd	Cr	Cu	Pb	Hg	Mo	Ni	K	Se	Ag	Zn
Commercial Fertilizer	83,979	19,800	14,364	36,166	-	NS	NS	<15	5.8	125	8.2	<15	<0.2	<20	15.4	25,300	<20	<5	230
Biosolids - 3 Dry Tons	78,400	18,430	136	21,860	22.3	100,500	NS	<15	<5	10.7	61.5	<15	0.24	<20	<10	408	<20	<5	101
Biosolids - 6 Dry Tons	76,340	21,410	195	20,990	22.9	99,200	NS	<15	<5	10.6	59.7	<15	0.23	<20	<10	417	<20	<5	99

APPENDIX E: Surface Soil Sample Data

Year 0 Soil Data collected October 13, 2008

Sample Name	Site	Distance from Weir (ft)	Cross Section Distance (ft)	Weight (g/5cc)	Soil pH	Buffer pH	Al	P	K	Ca	NO_3-N	Mg	B	Mn	Zn	Cu	Fe	S	Pb*	Total Pb**	Cd	Ni	Cr
BIO 1	1	26.2	0	4.35	5.6	6.7	12	24	125	2,290	0	169	0.3	110	2.2	0.2	3.5	49.3	1	37	0.1	0.1	0
BIO 2	1	26.2	0-D	4.19	5.7	6.7	11	24	125	2,474	0	151	0.4	127	2	0.2	3.6	54.2	0	33	0.1	0.1	0.1
BIO 3	1	26.2	6.6	4.95	5.4	6.7	19	11	66	1,467	0	104	0.3	123	2.3	0.2	6.3	39.4	1	33	0.1	0.1	0
BIO 4	1	26.2	13.1	4.18	5.6	6.7	12	33	187	2,465	0	166	0.4	190	2.7	0.2	3.1	59.7	0	32	0.1	0.1	0.1
BIO 5	1	131.2	0	4.26	5.8	6.8	11	25	129	3,935	0	207	0.3	114	1.8	0.2	3.3	70.9	0	32	0.1	0.1	0.1
BIO 6	1	131.2	6.6	4.22	5.9	6.9	14	23	152	3,548	0	165	0.4	174	1.4	0.2	4.1	68	1	33	0.1	0.1	0.1
BIO 7	1	131.2	13.1	4.69	5.6	6.8	19	20	141	3,003	0	147	0.3	96.6	1.7	0.2	7.6	63.6	1	33	0.1	0.1	0.1
BIO 8	1	131.2	13.1-D	4.39	5.7	6.8	20	17	383	3,712	0	122	0.3	123	1.5	0.2	7.5	73	1	33	0.1	0.1	0.1
BIO 9	1	295.3	0	4.8	5.8	6.9	13	14	79	3,127	0	110	0.3	128	1.3	0.2	8.3	58.4	0	31	0.1	0.1	0.1
BIO 10	1	295.3	0-D	4.49	6	7	13	24	75	3,161	0	131	0.4	172	1.8	0.2	5.8	63.1	0	30	0.1	0.1	0.1
BIO 11	1	295.3	6.6	4.36	6	6.8	14	23	198	5,024	0	131	0.4	308	3.3	0.2	6.3	90.2	0	30	0.1	0.2	0.1
BIO 12	1	295.3	13.1	4.54	5.9	6.9	13	25	87	2,671	0	117	0.5	378	2	0.2	4.8	59.6	0	28	0.1	0.1	0.1
BIO 13	2	52.5	0	4.46	5.5	6.6	19	24	169	2,867	0	131	0.3	131	3	0.2	8	63	1	38	0.1	0.1	0.1
BIO 14	2	52.5	0-D	4.56	5.3	6.7	25	18	138	2,054	0	108	0.3	170	2.4	0.2	8.4	53.3	1	41	0.1	0.2	0.1
BIO 15	2	52.5	6.6	4.54	5.5	6.7	21	19	109	2,903	0	112	0.3	183	2.5	0.3	10.5	65.2	1	37	0.1	0.2	0.1
BIO 16	2	52.5	13.1	4.03	5.4	6.6	14	33	317	2,127	0	188	0.3	153	3.3	0.2	5	55.5	1	37	0.1	0.1	0.1
BIO 17	2	131.2	0	4.73	6.2	7	8	17	213	4,104	0	123	0.4	97.9	1.1	0.2	4.5	70.1	0	29	0.1	0.1	0.1
BIO 18	2	131.2	6.6	4.52	5.9	6.8	10	18	106	4,478	0	144	0.3	78.4	1.7	0.2	4.1	73.2	0	32	0.1	0.1	0.1
BIO 19	2	131.2	6.6-D	4.59	5.9	6.9	14	17	97	4,427	0	148	0.3	96.9	1.9	0.2	5.1	73.9	0	33	0.1	0.1	0.1
BIO 20	2	131.2	13.1	4.66	5.8	6.7	27	13	214	3,233	0	133	0.3	83.3	1.6	0.2	8.5	60.2	1	35	0.1	0.2	0.1
BIO 21	2	278.9	0	4.4	6.1	6.9	13	24	137	3,737	0	197	0.4	102	2.2	0.2	3.7	65.5	0	31	0.1	0.1	0.1
BIO 22	2	278.9	6.6	4.41	6	6.8	13	21	160	4,264	0	153	0.4	134	2.1	0.2	4.9	73.6	0	31	0.1	0.1	0.1
BIO 23	2	278.9	6.6-D	4.45	6	6.9	14	13	156	3,419	0	138	0.3	116	1.5	0.2	4.4	58.9	0	32	0.1	0.1	0.1
BIO 24	2	278.9	13.1	4.58	6.2	6.9	19	15	120	5,339	0	136	0.3	75.4	1.4	0.2	4.8	82.6	1	35	0.1	0.2	0.1
BIO 25	3	65.6	0	4.55	6.1	6.7	10	15	208	3,901	9	205	0.3	53.2	3.4	0.2	1.5	57.6	0	30	0.1	0.1	0.1

Sample Name	Site	Distance from Weir (ft)	Cross Section Distance (ft)	Weight (g/5cc)	Soil pH	Buffer pH	Al	P	K	Ca	NO_3-N	Mg	B	Mn	Zn	Cu	Fe	S	Pb*	Total Pb**	Cd	Ni	Cr
BIO 26	3	65.6	6.6	4.69	5.8	6.6	19	8	74	2,435	9	78	0.2	53.9	2.6	0.2	2.6	39.3	0	32	0.1	0.1	0
BIO 27	3	65.6	13.1	4.2	5.9	6.7	15	12	180	2,939	9	139	0.3	65.2	3.1	0.2	3.5	49.1	0	31	0.1	0.2	0.1
BIO 28	3	65.6	13.1-D	4.51	5.8	6.6	17	8	141	2,048	8	111	0.2	57.1	2.8	0.2	3.3	36.1	0	31	0.1	0.1	0
BIO 29	3	196.9	0	4.1	6.5	7	6	11	193	2,443	15	178	0.3	22.3	1.5	0.2	0.9	39.6	0	29	0.1	0.1	0
BIO 30	3	196.9	0-D	4.69	6.4	7	7	9	128	2,695	10	148	0.3	24.3	1.4	0.2	1	40.8	0	28	0	0.1	0
BIO 31	3	196.9	6.6	4.54	6.2	6.9	10	8	350	1,988	13	144	0.3	33.2	1.4	0.3	1.8	34	0	29	0	0.1	0
BIO 32	3	196.9	13.1	4.37	6.5	7	6	11	153	2,798	11	161	0.3	34.8	0.9	0.2	1	42.8	0	28	0.1	0.1	0
BIO 33	3	459.3	0	4.63	6	6.8	12	10	88	2,462	0	141	0.2	40.5	1.4	0.2	3.1	40.7	0	30	0.1	0.1	0
BIO 34	3	459.3	0-D	4.57	5.9	6.8	15	8	117	1,685	0	123	0.2	42.3	1.7	0.2	4.3	31.2	0	32	0.1	0.1	0
BIO 35	3	459.3	6.6	4.24	6.5	7	8	12	196	4,578	1	193	0.3	49.9	1.6	0.2	2.7	69.2	0	28	0.1	0.1	0.1
BIO 36	3	459.3	13.1	5.11	6.2	7	16	4	88	2,172	1	103	0.2	38.6	1	0.3	6.8	33.4	0	28	0	0.1	0
BIO 37	4	68.9	0	4.16	6.5	7	5	15	110	3,280	12	86	0.4	78.6	1.9	0.2	0.7	49.7	0	27	0.1	0.1	0
BIO 38	4	68.9	6.6	4.3	6.2	6.8	8	17	108	2,680	10	108	0.3	103	2.4	0.2	0.9	44.2	0	27	0.1	0.1	0
BIO 39	4	68.9	6.6-D	4.17	6.2	6.8	8	17	108	2,477	10	117	0.3	93.1	2.1	0.2	0.9	42	0	30	0.1	0.1	0
BIO 40	4	68.9	13.1	4.31	6.4	6.9	5	24	103	2,714	11	136	0.4	77.1	2.2	0.2	0.7	44.2	0	27	0.1	0.1	0
BIO 41	4	164.0	0	4.21	6.5	7	11	11	137	4,513	1	114	0.3	56.7	0.5	0.2	1.3	64.4	0	30	0.1	0.1	0.1
BIO 42	4	164.0	6.6	4.42	6.6	7	7	8	91	3,319	10	86	0.3	56.5	0.6	0.2	1	49.4	0	29	0.1	0.1	0.1
BIO 43	4	164.0	13.1	4.28	6.5	7	9	11	145	2,624	5	133	0.3	65.9	0.7	0.2	1	43.8	0	28	0.1	0.1	0
BIO 44	4	164.0	13.1-D	4.26	6.7	7.1	6	18	217	4,907	7	161	0.4	63.7	0.9	0.2	1	70.1	0	28	0.1	0.1	0.1
BIO 45	4	328.1	0	4.33	6.3	7	12	7	186	1,814	8	135	0.3	38.2	0.9	0.2	1.6	33	0	28	0	0.1	0
BIO 46	4	328.1	0-D	4.45	6.2	6.9	14	7	118	2,332	1	130	0.3	53	1.1	0.2	2.1	36.5	0	27	0.1	0.1	0
BIO 47	4	328.1	6.6	4.78	6.1	6.9	19	4	84	1,913	1	73	0.2	47.5	0.8	0.2	1.9	32	0	29	0	0.1	0
BIO 48	4	328.1	13.1	4.57	6.2	6.8	11	6	81	1,821	3	88	0.2	33.3	1.4	0.2	1.7	31.4	0	31	0.1	0.1	0

Notes: D refers to duplicate sample.
All elements are in parts per million (ppm).
* Extracted Pb
**Estimated total Pb

Year 1 Soil Data Collected July 16, 2009

Sample Name	Site	Distance from Weir (ft)	Cross Section Distance (ft)	Weight (g/5cc)	Soil pH	Buffer pH	Al	P	K	Ca	NO_3-N	Mg	B	Mn	Zn	Cu	Fe	Pb*	Total Pb**	Cd	Ni	Cr
BIO 49	1	26.2	0	3.34	6.8	7.1	9	28	262	3,758	29	197	0.2	40.8	1.8	0.3	1.2	1	33	0.1	0.1	0.1
BIO 50	1	26.2	0D	3.51	6.6	7.1	8	19	202	3,300	31	172	0.2	28.3	1.6	0.3	1	1	34	0.1	0.1	0.1
BIO 51	1	26.2	6.6	3.82	6.3	6.9	9	15	258	2,251	35	182	0.2	27.9	2	0.4	2.2	0	33	0.1	0.1	0.1
BIO 52	1	26.2	13.1	4.03	5.9	6.6	12	12	196	2,027	36	149	0.1	40.3	2.9	0.4	2.1	1	34	0.1	0.1	0.1
BIO 53	1	131.2	0	4.31	6.3	6.9	9	11	202	1,949	22	126	0.1	26.4	1	0.4	1.1	0	32	0.1	0.1	0
BIO 54	1	131.2	6.6	4.11	6.3	6.9	9	12	125	2,505	13	107	0.2	25.5	1.1	0.3	2	0	32	0.1	0.1	0
BIO 55	1	131.2	6.6D	4.23	6.4	7.0	9	11	126	2,158	14	96	0.1	20.4	0.9	0.3	1.6	0	32	0.1	0.1	0
BIO 56	1	131.2	13.1	4.19	6.6	6.9	9	13	154	3,355	30	162	0.2	28	1	0.2	1.7	1	35	0.1	0.1	0.1
BIO 57	1	295.2	0	4.49	6.4	6.9	9	7	103	1,975	11	104	0.1	29	1.1	0.2	1.8	0	32	0.1	0.1	0
BIO 58	1	295.2	6.6	4.38	7.0	7.1	8	15	118	4,082	27	124	0.2	37.2	0.8	0.2	1.2	0	31	0.1	0.1	0.1
BIO 59	1	295.2	13.1	4.08	6.8	7.0	8	17	279	3,101	43	164	0.2	37.3	1.4	0.2	1.7	0	31	0.1	0.1	0.1
BIO 60	1	295.2	13.1D	4.22	6.5	7.0	7	13	273	2,650	36	157	0.2	42.6	1.5	0.2	1.1	0	31	0.1	0.1	0
BIO 61	2	52.5	0	3.9	6.3	6.9	11	22	187	4,098	30	172	0.2	38.2	2	0.2	2.4	1	34	0.1	0.1	0.1
BIO 62	2	52.5	6.6	4.43	5.9	6.7	15	21	95	2,150	32	102	0.1	43.7	2	0.2	3.4	1	36	0.1	0.1	0.1
BIO 63	2	52.5	13.1	3.6	6.3	6.9	10	63	166	2,555	38	172	0.2	27.8	2.1	0.2	2.8	0	32	0.1	0.1	0.1
BIO 64	2	52.5	13.1D	3.96	6.0	6.8	11	46	126	2,178	22	151	0.2	28.1	2.2	0.2	2.9	0	33	0.1	0.1	0.1
BIO 65	2	131.2	0	4.06	6.4	6.9	11	38	156	3,094	21	172	0.2	25.4	1.4	0.2	2.2	0	32	0.1	0.1	0.1
BIO 66	2	131.2	6.6	4.21	6.2	6.9	13	21	155	2,417	8	115	0.1	32.1	1.1	0.2	2.5	1	35	0.1	0.1	0
BIO 67	2	131.2	6.6D	4.34	6.3	6.9	14	16	133	2,430	9	113	0.1	29.6	1.1	0.2	2.7	1	35	0.1	0.1	0.1
BIO 68	2	131.2	13.1	4.12	6.1	6.8	16	22	126	2,643	10	102	0.1	29	1.7	0.2	2.8	1	35	0.1	0.1	0.1
BIO 69	2	278.8	0	4.54	6.1	6.9	13	22	76	2,001	10	101	0.1	41.3	1.3	0.2	2.7	0	32	0.1	0.1	0
BIO 70	2	278.8	6.6	4.33	6.1	6.9	12	36	95	2,432	11	119	0.1	48.8	1.7	0.2	3.1	0	33	0.1	0.1	0.1
BIO 71	2	278.8	0D	4.65	6.2	6.9	12	42	93	2,472	13	107	0.1	47.7	1.3	0.2	3.2	0	31	0.1	0.1	0.1
BIO 72	2	278.8	13.1	4.49	6.6	7.0	10	28	246	2,766	12	116	0.1	59.1	1.1	0.2	2	0	30	0.1	0.1	0.1
BIO 73	3	65.6	0	4.18	6.7	7.0	10	13	127	3,064	11	112	0.1	40.6	1.4	0.2	1.3	0	33	0.1	0.1	0.1
BIO 74	3	65.6	6.6	3.98	6.7	7.0	8	19	165	2,254	12	135	0.2	48.8	1.6	0.2	1.2	0	31	0.1	0.1	0.1
BIO 75	3	65.6	6.6D	4.3	6.2	6.9	10	13	131	2,178	13	126	0.1	46.9	1.7	0.2	1.6	0	32	0.1	0.1	0.1
BIO 76	3	65.6	13.1	4.31	6.9	7.1	8	14	130	2,782	7	108	0.2	30.9	0.9	0.2	1.2	0	32	0.1	0.1	0
BIO 77	3	196.8	0	4.18	6.4	6.9	13	26	160	3,417	45	183	0.3	51.5	3.8	0.3	2	0	31	0.1	0.1	0.1
BIO 78	3	196.8	6.6	4.1	6.5	7.0	8	47	297	2,327	38	239	0.3	66.5	3.1	0.3	1.3	0	31	0.1	0.1	0.1
BIO 79	3	196.8	6.6D	4.39	6.3	6.9	9	32	278	2,009	56	198	0.2	80.3	3	0.2	1.3	0	30	0.1	0.1	0.1

Sample Name	Site	Distance from Weir (ft)	Cross Section Distance (ft)	Weight (g/5cc)	Soil pH	Buffer pH	Al	P	K	Ca	NO_3-N	Mg	B	Mn	Zn	Cu	Fe	Pb*	Total Pb**	Cd	Ni	Cr
BIO 80	3	196.8	13.1	4.25	6.4	7.0	9	26	176	2,104	38	199	0.2	42.9	5	0.3	1.4	0	30	0.1	0.1	0.1
BIO 81	3	459.2	0	4.17	6.2	6.9	10	35	128	2,581	45	178	0.3	47.5	3.6	0.3	2.2	0	31	0.1	0.1	0.1
BIO 82	3	459.2	6.6	4.31	6.2	6.9	10	19	104	2,221	36	141	0.2	31.5	1.7	0.2	1.6	0	31	0.1	0.1	0
BIO 83	3	459.2	6.6D	4.34	6.3	7.0	10	19	113	1,965	15	145	0.2	32.3	1.6	0.3	1.6	0	31	0.1	0.1	0
BIO 84	3	459.2	13.1	4.17	6.5	7.0	10	25	159	2,594	16	144	0.2	31	1.8	0.2	2.3	0	30	0.1	0.1	0.1
BIO 85	4	68.9	0	3.82	6.5	6.9	8	18	124	2,670	14	95	0.2	137	2.2	0.2	0.9	0	30	0.1	0.1	0.1
BIO 86	4	68.9	6.6	3.96	6.4	6.9	8	16	107	2,470	15	113	0.2	108	2.1	0.2	0.8	0	31	0.1	0.1	0.1
BIO 87	4	68.9	13.1	4.09	6.1	6.9	10	16	106	1,786	11	112	0.1	98.6	1.4	0.2	1.2	0	32	0.1	0.1	0.1
BIO 88	4	68.9	0D	3.81	6.7	7.0	9	18	141	2,802	14	111	0.2	169	1.9	0.2	0.9	0	30	0.1	0.1	0.1
BIO 89	4	164.0	0	4.03	7.2	7.1	9	16	180	4,023	16	94	0.2	35.7	0.5	0.2	0.9	0	31	0.1	0.1	0.1
BIO 90	4	164.0	6.6	4.17	7.0	7.1	11	14	214	3,430	6	106	0.2	78.7	0.7	0.2	0.9	0	31	0.1	0.1	0.1
BIO 91	4	164.0	13.1	4.28	6.4	6.9	12	10	147	2,472	10	107	0.1	97.4	1	0.2	1.3	0	32	0.1	0.1	0.1
BIO 92	4	164.0	0D	4.14	7.1	7.2	9	15	170	3,746	36	89	0.2	39.5	0.5	0.2	1	0	31	0.1	0.1	0.1
BIO 93	4	328.0	0	4.1	6.3	6.9	9	45	177	2,680	38	183	0.3	50.2	4.9	0.5	2.1	0	30	0.1	0.1	0.1
BIO 94	4	328.0	6.6	4.08	6.5	7.0	9	41	140	2,553	34	171	0.3	41.6	3.4	0.3	1.9	0	30	0.1	0.1	0.1
BIO 95	4	328.0	13.1	4.14	6.5	6.9	10	46	166	2,812	45	194	0.3	47.2	4.8	0.5	2.3	0	30	0.1	0.1	0.1
BIO 96	4	328.0	13.1D	4.44	6.1	6.8	12	30	131	2,427	36	161	0.2	59.6	4.8	0.4	2.8	0	31	0.1	0.1	0.1

Notes: D refers to duplicate sample.
All elements are in parts per million (ppm).
* Extracted Pb
**Estimated total Pb

Year 2 Soil Data Collected June 18, 2010

Sample Name	Site	Distance from Weir (ft)	Cross Section Distance (ft)	Weight (g/5cc)	Soil pH	Buffer pH	Al	P	K	Ca	NO_3	Mg	B	Mn	Zn	Cu	Fe	Pb*	Total Pb**	Cd	Ni	Cr
BIO 97	1	26.2	0.0	4.01	6.0	6.7	7	11	130	1,812	2.0	134	0.2	56.3	2.4	0.10	1.6	1	41	0.1	0	0
BIO 98	1	26.2	6.6	3.51	6.2	6.8	5	13	133	1,818	2.0	125	0.2	52.7	1.6	0.10	2.4	1	40	0	0	0.1
BIO 99	1	26.2	13.1	3.49	7.0	7.1	3	36	201	4,026	2.0	178	0.5	59.8	1.4	0.10	1.3	1	42	0	0	0.1
BIO 100	1	26.2	6.6D	3.85	6.3	6.8	5	13	142	2,087	2.0	135	0.2	50	1.6	0.00	2.2	1	36	0	0	0
BIO 101	1	131.2	0.0	3.67	6.0	6.9	6	10	146	1,497	0.0	94	0.2	46.7	0.8	0.00	1.7	1	35	0	0	0
BIO 102	1	131.2	6.6	3.73	6.9	7.1	3	13	136	2,716	0.0	113	0.3	39.9	0.8	0.10	1.2	1	35	0	0	0
BIO 103	1	131.2	13.1	3.78	6.6	7.1	4	14	138	2,591	0.0	101	0.2	33.7	0.7	0.00	1.6	1	35	0	0	0
BIO 104	1	131.2	6.6D	3.78	7.0	7.1	3	21	194	3,442	0.0	128	0.3	50.2	1.2	0.00	1.2	1	37	0	0	0.1
BIO 105	1	295.2	0.0	3.75	7.1	7.2	3	17	182	3,306	0.0	135	0.3	10.3	0.6	0.00	2.7	0	33	0	0	0
BIO 106	1	295.2	6.6	3.76	6.9	7.1	3	16	137	3,675	0.0	124	0.3	30.8	1	0.10	2.9	1	35	0	0	0
BIO 107	1	295.2	13.1	3.67	7.0	7.2	2	12	292	3,274	0.0	104	0.3	39.5	0.7	0.00	104	1	35	0	0	0
BIO 108	1	295.2	13.1D	3.82	7.0	7.2	2	11	350	2,973	0.0	95	0.3	45.3	0.6	0.10	1.2	1	34	0	0	0
BiIO 109	2	52.5	0.0	3.59	6.6	7.0	5	34	122	2,405	7.0	119	0.2	20.5	1.4	0.00	2.6	1	35	0	0	0
BIO 110	2	52.5	6.6	3.79	6.5	7.0	7	32	124	2,191	5.0	103	0.2	42.9	1.4	0.10	2	1	37	0.1	0	0.1
BIO 111	2	52.5	13.1	3.36	6.5	7.0	6	33	94	2,714	0.0	79	0.1	23.9	1.2	0.10	2.2	1	39	0	0	0
BIO 112	2	52.5	0.0D	3.96	6.5	7.0	5	36	130	2,334	2.0	117	0.2	26.9	1.3	0.00	2.8	1	35	0	0	0
BIO 113	2	131.2	0.0	3.83	6.7	7.1	4	27	106	2,576	0.0	104	0.2	29.9	1.1	0.10	1.9	1	33	0	0	0
BIO 114	2	131.2	6.6	4.02	6.7	7.1	6	18	99	2,803	2.0	94	0.2	33.7	0.8	0.10	1.6	1	33	0	0	0
BIO 115	2	131.2	13.1	3.65	6.4	7.0	9	22	158	2,599	2.0	111	0.2	35.1	1.2	0.00	2.5	1	34	0	0	0
BIO 116	2	131.2	6.6D	4.02	6.4	7.0	8	19	122	2,393	0.0	100	0.2	32.1	0.9	0.00	2.2	1	33	0	0	0
BIO 117	2	278.8	0.0	3.98	7.2	7.2	3	52	103	3,629	1.0	101	0.2	40.2	0.9	0.00	1.8	0	31	0	0	0
BIO 118	2	278.8	6.6	4.07	6.9	7.0	4	38	92	2,416	1.0	93	0.2	32.3	0.8	0.00	1.6	0	31	0	0	0
BIO 119	2	278.8	13.1	3.78	6.7	7.1	5	30	110	2,659	0.0	94	0.2	36.7	0.9	0.00	2.2	0	32	0	0	0
BIO 120	2	278.8	13.1D	3.83	6.6	7.0	6	48	115	3,019	0.0	120	0.2	41.1	1.1	0.00	2	1	33	0	0	0
BIO 121	3	65.6	0.0	3.69	7.1	7.2	3	26	142	3,181	10.0	116	0.2	24.9	0.9	0.00	1.2	1	33	0	0	0
BIO 122	3	65.6	6.6	3.7	7.0	7.1	2	14	147	2,603	4.0	129	0.2	21.7	0.8	0.00	0.9	0	31	0	0	0
BIO 123	3	65.6	13.1	3.66	7.0	7.1	2	19	166	2,471	2.0	143	0.2	22.2	1	0.00	1.1	0	32	0	0	0
BIO 124	3	65.6	0.0D	3.53	7.1	7.1	2	25	152	3,217	7.0	131	0.2	22.8	1.1	0.00	1.5	1	33	0	0	0
BIO 125	3	196.8	0.0	4.1	6.3	7.0	5	30	87	2,059	10.0	114	0.2	37.5	2.8	0.10	2	0	31	0	0	0
BIO 126	3	196.8	6.6	4.15	6.5	7.0	5	27	117	2,143	3.0	107	0.2	27.9	2.4	0.10	1.8	0	31	0	0	0
BIO 127	3	196.8	13.1	4.08	6.5	7.0	5	29	119	2,255	9.0	111	0.3	33.2	3	0.20	1.8	0	30	0	0	0

Sample Name	Site	Distance from Weir (ft)	Cross Section Distance (ft)	Weight (g/5cc)	Soil pH	Buffer pH	Al	P	K	Ca	NO_3	Mg	B	Mn	Zn	Cu	Fe	Pb*	Total Pb**	Cd	Ni	Cr
BIO 128	3	196.8	6.6D	4.22	6.3	6.9	8	20	157	1,999	0.0	98	0.2	38.9	2.4	0.10	2	0	31	0	0	0
BIO 129	3	459.2	0.0	3.77	6.5	7.0	6	46	110	2,447	13.0	122	0.3	60.3	3.6	0.20	1.6	0	30	0	0	0
BIO 130	3	459.2	6.6	3.76	6.7	7.0	5	37	94	2,256	12.0	109	0.3	54	2.9	0.10	1.3	0	30	0	0	0
BIO 131	3	459.2	13.1	4.45	6.6	7.0	8	23	67	1,729	2.0	35	0.2	35.6	1.9	0.10	1.4	0	29	0	0	0
BIO 132	3	459.2	13.1D	4.17	6.6	7.0	7	31	75	2,228	13.0	82	0.2	45.2	2.3	0.20	1.6	0	30	0	0	0
BIO 133	4	68.9	0.0	4.17	6.7	7.0	3	12	89	2,272	0.0	93	0.2	148	1.2	0.00	0.4	1	37	0.1	0	0.1
BIO 134	4	68.9	6.6	3.8	6.8	7.1	2	15	91	2,771	12.0	69	0.3	84.1	1.6	0.00	0.6	1	35	0.1	0	0
BIO 135	4	68.9	13.1	4.39	6.6	6.9	3	11	111	2,587	3.0	88	0.3	83.3	1.6	0.00	0.5	0	32	0.1	0	0
BIO 136	4	68.9	13.1D	4.03	6.7	6.9	3	13	110	2,569	3.0	85	0.3	111	1.8	0.00	33	0	33	0.1	0	0
BIO 137	4	164.0	0.0	3.88	7.7	7.1	4	19	165	4,211	1.0	101	0.3	66.4	0.6	0.00	0.9	1	35	0	0	0
BIO 138	4	164.0	6.6	4.19	6.9	7.0	6	9	144	3,141	12.0	102	0.3	55.8	0.7	0.00	0.6	1	35	0	0	0
BIO 139	4	164.0	13.1	4.06	7.1	7.1	4	13	153	4,029	11.0	73	0.3	53.4	0.6	0.00	0.9	1	35	0	0	0
BIO 140	4	164.0	0.0D	3.94	6.8	7.1	4	41	119	3,527	17.0	119	0.3	47.5	2.7	0.10	1.3	1	33	0	0	0
BIO 141	4	328.0	0.0	3.21	6.9	7.1	4	62	229	3,799	18.0	133	0.4	29.3	3	0.20	1.8	1	34	0	0	0
BIO 142	4	328.0	6.6	4.46	6.7	7.0	5	36	126	2,536	17.0	128	0.3	28.5	2.5	0.10	1.3	0	31	0	0	0
BIO 143	4	328.0	13.1	4.36	6.6	7.0	5	60	172	3,324	17.0	143	0.4	36.4	4.4	0.30	1.7	0	32	0	0	0
BIO 144	4	328.0	6.6D	4.14	6.9	7.0	6	11	143	3,394	7.0	108	0.3	68.7	0.7	0.00	0.5	1	33	0	0	0

Notes: D refers to duplicate sample.
All elements are in parts per million (ppm).
* Extracted Pb
**Estimated total Pb

Year 3 Soil Data Collected September 1, 2011

Sample Name	Site	Distance from Weir (ft)	Cross Section Distance (ft)	Weight (g/5cc)	Soil pH	Buffer pH	Al	P	K	Ca	NO_3	Mg	B	Mn	Zn	Cu	Fe	Pb*	Total Pb**	Cd	Ni	Cr
Bio 145	4	328.0	0.0	4.26	6.0	6.4	12	16	76	1,636	11	110	0.6	10.0	3.3	0.9	1.7	1.0	39	0.1	0.1	0.1
Bio 146	4	328.0	6.6	4.45	6.2	6.7	9	26	93	2,043	15	123	0.6	8.7	2.8	0.9	1.5	1.0	33	0.1	0.1	0.0
Bio 147	4	328.0	13.1	4.26	6.4	6.7	8	40	88	2,635	18	133	0.6	14.9	3.9	0.9	1.5	1.0	33	0.1	0.1	0.0
Bio 148	4	328.0	13.1D	4.13	6.6	6.8	8	39	433	2,129	2	144	0.6	7.6	2.9	0.8	1.5	0.0	33	0.1	0.0	0.0
Bio 149	4	164.0	0.0	3.94	6.6	6.8	8	9	163	2,617	2	89	0.5	8.9	1.1	0.8	1.1	1.0	34	0.1	0.0	0.0
Bio 150	4	164.0	6.6	4.29	7.2	7.1	6	10	169	3,929	5	110	0.5	16.6	0.8	0.8	1.2	0.0	33	0.0	0.0	0.0
Bio 151	4	164.0	13.1	3.91	7.2	7.1	6	10	199	4,124	5	97	0.6	9	0.9	0.8	1.2	1.0	34	0.0	0.0	0.0
Bio 152	4	164.0	6.6D	4.22	7.1	7.1	6	11	183	3,402	0	121	0.5	11.4	0.9	0.8	1.2	1.0	34	0.0	0.0	0.0
Bio 153	4	68.9	0.0	4.21	6.5	6.8	6	7	101	2,574	11	100	0.5	9.2	1.6	0.8	0.8	1.0	34	0.1	0.0	0.0
Bio 154	4	68.9	6.6	4.12	6.3	6.7	7	10	136	2,412	15	94	0.5	8.6	1.9	0.8	1.0	0.0	33	0.1	0.0	0.0
Bio 155	4	68.9	13.1	4.13	6.0	6.7	8	9	105	2,100	17	110	0.4	23.3	2.4	0.8	1.0	1.0	34	0.1	0.1	0.0
Bio 156	4	68.9	13.1D	4.29	6.1	6.6	7	10	101	2,132	18	128	0.4	21.0	2.0	0.8	1.0	1.0	33	0.1	0.0	0.0
Bio 157	4	6.6	6.6	4.20	6.7	6.9	6	15	235	2,580	0.0	117	0.5	5.1	1.6	0.8	0.9	1.0	33	0.1	0.0	0.0
Bio 158	3	6.6	6.6	3.87	6.5	6.9	7	16	235	3,201	13	81	0.5	9.0	2.3	0.8	1.9	1.0	34	0.1	0.0	0.0
Bio 159	3	65.6	0.0	4.35	6.8	7.0	6	11	150	2,810	2	133	0.5	9.1	1.4	0.8	1.1	0.0	32	0.0	0.0	0.0
Bio 160	3	65.6	6.6	4.25	6.6	7.0	6	6	105	2,433	17	131	0.5	10.3	1.2	0.8	1.0	0.0	33	0.1	0.0	0.0
Bio 161	3	65.6	13.1	3.93	6.7	7.0	7	9	92	2,469	15	114	0.5	9.9	1.2	0.8	1.3	1.0	35	0.1	0.0	0.0
Bio 162	3	65.6	6.6D	4.13	6.6	7.0	6	6	101	2,280	18	123	0.5	8.2	1.2	0.8	1.1	1.0	33	0.1	0.0	0.0
Bio 163	3	196.8	0.0	4.15	6.9	7.1	7	28	130	3,828	2	128	0.5	6.8	1.9	0.8	1.4	0.0	32	0.1	0.0	0.0
Bio 164	3	196.8	6.6	4.58	6.9	7.1	7	26	133	2,850	0	125	0.5	3.7	1.7	0.8	1.2	0.0	32	0.0	0.0	0.0
Bio 165	3	196.8	13.1	4.38	6.4	7.0	9	30	191	2,519	18	155	0.5	5.8	2.9	0.9	1.5	0.0	33	0.0	0.0	0.0
Bio 166	3	196.8	0.0D	4.31	6.8	7.1	8	28	109	3,063	0	126	0.5	6.9	2.2	0.9	1.5	0.0	32	0.0	0.0	0.0
Bio 167	3	459.2	0.0	4.42	6.6	7.0	8	30	83	2,395	18	112	0.5	11.0	2.6	0.9	1.5	0.0	32	0.1	0.0	0.0
Bio 168	3	459.2	6.6	4.33	6.5	7.0	8	26	78	2,286	18	119	0.5	7.1	2.2	0.9	1.4	0.0	32	0.1	0.0	0.0
Bio 169	3	459.2	13.1	4.33	6.5	6.9	7	24	98	2,195	11	123	0.5	6.0	2.1	0.9	1.2	0.0	31	0.0	0.0	0.0
Bio 170	3	459.2	0.0D	4.44	6.8	7.1	7	23	79	2,764	9	104	0.5	5.1	1.8	0.8	1.5	0.0	32	0.0	0.0	0.0
Bio 171	2	6.6	6.6	4.47	6.5	6.9	6	23	219	2,786	18	150	0.5	4.1	1.9	0.8	1.2	0.0	32	0.1	0.0	0.0
Bio 172	2	52.5	0.0	3.93	6.7	7.1	7	33	121	3,499	17	124	0.5	7.6	1.5	0.8	1.7	1.0	34	0.1	0.0	0.1
Bio 173	2	52.5	6.6	4.19	6.3	6.9	10	16	175	1,777	0	94	0.4	2.8	1.4	0.8	1.6	1.0	35	0.1	0.1	0.0
Bio 174	2	52.5	13.1	4.19	6.2	7.0	8	20	126	2,029	17	110	0.4	5	1.7	0.8	2.4	1.0	33	0.1	0.0	0.0

Sample Name	Site	Distance from Weir (ft)	Cross Section Distance (ft)	Weight (g/5cc)	Soil pH	Buffer pH	Al	P	K	Ca	NO_3	Mg	B	Mn	Zn	Cu	Fe	Pb*	Total Pb**	Cd	Ni	Cr
Bio 175	2	52.5	0.0D	4.15	6.6	7.0	7	25	90	2,880	17	93	0.5	7.5	1.8	0.8	1.7	1.0	34	0.1	0.0	0.0
Bio 176	2	131.2	0.0	4.19	6.8	7.1	6	15	145	2,871	0	114	0.5	6.3	1.3	0.8	1.4	1.0	34	0.0	0.0	0.0
Bio 177	2	131.2	6.6	4.30	6.7	7.1	8	22	154	2,641	7	115	0.4	5.8	1.1	0.8	1.6	1.0	34	0.0	0.0	0.0
Bio 178	2	131.2	13.1	4.44	6.3	7.0	9	7	65	2,069	18	90	0.4	5.3	1.2	0.8	1.4	1.0	34	0.1	0.0	0.0
Bio 179	2	131.2	6.6D	4.15	6.5	7.0	8	17	118	2,404	3	113	0.4	5	1.2	0.8	1.8	1.0	33	0.0	0.0	0.0
Bio 180	2	278.8	0.0	4.45	6.8	7.1	7	26	52	2,345	18	92	0.4	5.4	1.1	0.8	1.6	0.0	31	0.1	0.0	0.0
Bio 181	2	278.8	6.6	4.39	6.3	7.0	8	19	73	2,026	18	97	0.4	8	1.8	0.9	1.7	1.0	35	0.1	0.0	0.0
Bio 182	2	278.8	13.1	4.17	6.6	7.0	8	19	70	2,394	17	92	0.4	5.6	1.3	0.8	1.7	1.0	33	0.1	0.0	0.0
Bio 183	2	278.8	0.0D	4.45	6.6	7.2	7	17	47	2,139	11	86	0.4	3.1	1.1	0.9	1.5	0.0	33	0.1	0.0	0.0
Bio 184	1	6.6	6.6	3.56	6.6	7.1	5	14	167	3,056	7	157	0.6	2.9	1.8	0.8	1.4	1.0	33	0.1	0.0	0.0
Bio 185	1	26.2	0.0	3.90	5.9	6.8	7	7	113	23,174	18	105	0.4	3.5	1.8	0.8	1.5	1.0	35	0.1	0.0	0.0
Bio 186	1	26.2	6.6	4.12	5.8	6.9	11	5	104	1,677	0	110	0.4	5.5	2.2	0.9	2.0	1.0	35	0.1	0.1	0.0
Bio 187	1	26.2	13.1	3.88	5.8	6.7	8	6	113	2,166	5	104	0.4	4.8	2.4	0.9	1.5	1.0	36	0.1	0.1	0
Bio 188	1	26.2	0.0D	3.96	6.3	7.0	6	8	116	2,223	0	148	0.5	5.2	1.5	0.8	1.4	1.0	34	0.1	0.0	0.0
Bio 189	1	131.2	0.0	4.22	6.6	7.1	6	7	143	2,223	0	126	0.5	5.2	1.1	0.9	1.3	1.0	33	0.0	0.0	0.0
Bio 190	1	131.2	6.6	4.14	6.7	7.1	6	6	114	2,251	0	117	0.4	4.3	1.0	0.8	1.4	1.0	34	0.0	0.0	0.0
Bio 191	1	131.2	13.1	4.21	6.8	7.1	6	7	174	2,383	5	116	0.5	4.5	1.0	0.8	1.4	0.0	33	0.0	0.0	0.0
Bio 192	1	131.2	13.1D	4.09	6.8	7.1	6	7	114	2,372	5	113	0.5	3.4	1.1	0.8	1.4	0.0	33	0.0	0.0	0.0
Bio 193	1	295.2	0.0	3.95	6.9	7.2	6	7	96	2,604	0	95	0.5	4.9	1.2	0.8	1.5	1.0	33	0.0	0.0	0.0
Bio 194	1	295.2	6.6	4.11	6.8	7.2	6	6	107	1,848	0	79	0.4	4.9	0.9	0.8	1.5	0.0	32	0.0	0.0	0.0
Bio 195	1	295.2	13.1	4.12	6.6	7.2	6	6	118	2,014	3	86	0.5	3.8	1.0	0.8	1.3	0.0	33	0.0	0.0	0.0
Bio 196	1	295.2	0.0D	4.04	6.8	7.2	5	8	130	2,549	0	95	0.5	3.1	1.1	0.9	1.3	0.0	33	0.0	0.0	0.0

Notes: D refers to duplicate sample.
All elements are in parts per million (ppm).
* Extracted Pb
**Estimated total Pb

APPENDIX F: Water Quality Analysis Results

Location	Date	TKN	NH3-N	NO3-N	TP	TSS (mg/L)	Fecal coliform (coli/100 mL)	pH (std units)	As	Cd	Cr	Cu	Pb	Hg	Mo	Ni	K	Se	Ag	Zn
		Nutrients (mg/L)							Metals (µg/L)											
								Site 1												
	11/6/2008	5.44	1.0	0.71	1.32	14	790	6.7	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	2/11/2009	1.99	<0.1	0.02	0.28	3	30	7.0	<15	<5	<10	<5	<15	<0.2	<20	<10	6,250	<20	<5	<5
	4/13/2009	2.89	0.4	0.13	0.28	1	10	7.2	<15	<5	<10	<5	<15	<0.2	<20	<10	1,600	<20	<5	<5
Site 1	4/13/2009*	1.86	0.14	0.11	0.19	2	30	7.2	<15	<5	<10	<5	<15	<0.2	<20	<10	1,540	<20	<5	<5
Year 1	5/1/2009	<0.03	<0.1	0.14	0.27	11	-	7.0	<15	<5	<10	<5	<15	<0.2	<20	<10	2,690	<20	<5	<5
	5/14/2009	2.80	0.2	0.07	0.29	10	-	7.1	<15	<5	<10	<5	<15	<0.2	<20	<10	1,850	<20	<5	<5
	6/16/2009	4.65	0.3	0.40	0.58	16	29,000	7.1	<15	<5	14.2	<5	<15	<0.2	<20	10.8	8,700	<20	<5	<5
	6/16/2009*	5.72	0.3	0.46	0.57	14	29,000	7.1	<15	<5	15	<5	<15	<0.2	<20	10.9	8,860	<20	<5	<5
	9/22/2009	2.16	0.5	0.16	0.26	16	2,300	7.1	<15	<5	<10	<5	<15	<0.2	<20	<10	9,000	<20	<5	6.4
	10/9/2009	1.59	<0.1	0.18	0.28	10	520	7.1	<15	<5	<10	<5	<15	<0.2	<20	<10	5,180	<20	<5	<5
	10/30/2009	9.97	0.2	0.01	1.11	20	200	7.2	<15	<5	<10	<5	<15	<0.2	<20	<10	7,680	<20	<5	<5
Site 1	1/25/2010	1.91	0.3	0.18	0.23	57	50	7.2	<15	<5	<10	<5	<15	<0.2	<20	<10	3,400	<20	<5	<5
Year 2	2/22/2010	1.29	0.3	0.06	0.14	18	20	7.1	<15	<5	<10	<5	<15	<0.2	<20	<10	3,610	<20	<5	<5
	3/22/2010	1.38	0.2	0.04	0.12	10	30	7.1	<15	<5	<10	<5	<15	<0.2	<20	<10	1,460	20.2	<5	<5
	3/26/2010	1.18	0.2	0.09	0.26	17	82	7.2	<15	<5	<10	<5	<15	<0.2	<20	<10	1,750	<20	<5	<5
	5/14/2010	2.54	<0.1	0.07	0.04	8	227	6.9	<15	<5	<10	<5	<15	<0.2	<20	<10	1,440	<20	<5	<5
	5/20/2010	1.75	0.3	0.10	0.08	5	964	7.0	<15	<5	<10	<5	<15	<0.2	<20	<10	810	<20	<5	<5
	7/12/2010	1.74	0.5	0.29	0.28	12	9,000	7.1	<15	<5	<10	<5	<15	<0.2	<20	<10	5,080	<20	<5	<5
	9/16/2010	1.17	<0.1	0.35	1.55	-	-	7.2	<15	<5	<10	5.2	<15	<0.2	<20	<10	12,240	<20	<5	25.2
	11/26/2010	1.79	<0.1	0.10	0.33	4	350	7.1	<15	<5	<10	<5	<15	<0.2	<20	<10	2,520	<20	<5	<5
Site 1	2/25/2011	2.23	<0.1	0.21	0.21	-	30	-	<15	<5	<10	7.5	<15	<0.2	<20	<10	2,830	<20	<5	13
Year 3	3/14/2011	1.08	<0.1	0.22	0.12	2	16	7.1	<15	<5	<10	<5	<15	<0.2	<20	<10	2,220	<20	<5	5.7

		Nutrients (mg/L)							Metals (µg/L)											
Location	Date	TKN	NH3-N	NO3-N	TP	TSS (mg/L)	Fecal coliform (coli/100 mL)	pH (std units)	As	Cd	Cr	Cu	Pb	Hg	Mo	Ni	K	Se	Ag	Zn
	4/23/2011	1.91	0.1	<0.05	0.29	33	-	7.1	<15	<5	<10	<5	<15	<0.2	<20	<10	1,110	<20	<5	<5
	4/25/2011	0.59	<0.1	<0.05	0.16	4	30	7.1	<15	<5	<10	<5	<15	<0.2	<20	<10	500	<20	<5	<5
	5/28/2011	3.80	0.1	0.18	0.16	24	5,600	7.1	<15	<5	<10	<5	<15	<0.2	<20	<10	1,200	<20	<5	<5
								Site 2												
	11/6/2008	66.70	37.4	1.41	34.20	105	250	7.5	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	2/11/2009	3.50	<0.1	0.77	10.10	20	30	7.5	<15	<5	<10	<5	<15	<0.2	<20	<10	12,600	<20	<5	<5
	4/13/2009	3.15	0.2	0.13	4.11	1	70	7.2	<15	<5	<10	<5	<15	<0.2	<20	<10	2,580	<20	<5	<5
	4/20/2009	2.15	<0.1	0.08	3.57	<2	20	7.3	<15	<5	<10	<5	<15	<0.2	<20	<10	2,120	<20	<5	<5
Site 2	4/20/2009*	2.02	<0.1	0.08	3.73	2	<1	7.3	<15	<5	<10	<5	<15	<0.2	<20	<10	1,970	<20	<5	<5
Year 1	5/1/2009	3.57	0.1	0.16	4.95	13	NR	7.0	<15	<5	<10	<5	<15	<0.2	<20	<10	3,280	<20	<5	<5
	5/14/2009	3.62	0.2	0.06	2.94	4	NR	6.9	<15	<5	<10	<5	<15	<0.2	<20	<10	2,740	<20	<5	<5
	6/16/2009	4.58	0.5	1.40	4.94	8	8,000	7.0	<15	<5	<10	<5	<15	<0.2	<20	<10	12,200	<20	<5	<5
	6/30/2009	3.96	<0.1	2.64	2.60	20	1,545	7.1	<15	<5	<10	<5	<15	<0.2	<20	<10	10,600	<20	<5	<5
	7/21/2009	3.95	0.2	<0.01	1.72	6	1,000	7.2	<15	<5	<10	<5	<15	<0.2	<20	<10	10,700	<20	<5	6.4
	9/22/2009	4.09	0.3	2.57	3.23	12	2,000	7.1	<15	<5	<10	<5	<15	<0.2	<20	<10	12,600	<20	<5	<5
	10/9/2009	2.82	0.2	2.51	1.48	6	890	7.0	<15	<5	<10	<5	<15	<0.2	<20	<10	10,800	<20	<5	<5
	10/30/2009	2.34	0.3	1.62	0.34	434	190	7.1	<15	<5	<10	5.5	<15	<0.2	<20	<10	11,050	<20	<5	17.4
	1/22/2010	4.73	0.3	0.80	1.19	284	40	7.8	<15	<5	<10	<5	<15	<0.2	<20	<10	7,080	<20	<5	6.9
Site 2	1/25/2010	4.66	0.3	0.15	1.18	428	50	7.5	<15	<5	<10	<5	<15	<0.2	<20	<10	3,600	<20	<5	10.9
Year 2	2/22/2010	3.71	0.3	0.65	0.98	22	5	7.4	<15	<5	<10	<5	<15	<0.2	<20	<10	5,570	<20	<5	<5
	3/22/2010	2.46	0.2	0.17	0.65	85	5	7.3	<15	<5	<10	<5	<15	<0.2	<20	<10	2250	<20	<5	<5
	3/26/2010	2.48	0.1	0.11	0.76	46	173	7.3	<15	<5	<10	<5	<15	<0.2	<20	<10	1,050	<20	<5	<5
	5/14/2010	2.44	0.1	0.09	0.60	74	1,129	7.2	<15	<5	<10	<5	<15	<0.2	<20	<10	2,240	<20	<5	<5
	5/20/2010	1.82	0.2	0.10	0.66	20	1,054	7.1	<15	<5	<10	<5	<15	<0.2	<20	<10	1,170	<20	<5	<5
	7/12/2010	1.28	0.2	0.33	1.05	10	624	7.2	<15	<5	<10	<5	<15	<0.2	<20	<10	5,600	<20	<5	<5

			Nutrients (mg/L)											Metals (µg/L)						
Location	Date	TKN	NH3-N	NO3-N	TP	TSS (mg/L)	Fecal coliform (coli/100 mL)	pH (std units)	As	Cd	Cr	Cu	Pb	Hg	Mo	Ni	K	Se	Ag	Zn
	9/1/2010	12.00	<0.1	2.42	2.23	104	1,730	7.2	<15	<5	<10	6.1	<15	<0.2	<20	<10	14,100	<20	<5	18.5
	9/16/2010	2.73	<0.1	1.25	1.17	40	4,545	7.2	<15	<5	<10	<5	<15	<0.2	<20	<10	7,030	<20	<5	7
	11/26/2010	2.58	<0.1	0.19	1.09	4	189	7.3	<15	<5	<10	<5	<15	<0.2	<20	<10	3,670	<20	<5	<5
Site 2	2/25/2011	3.73	0.18	0.28	0.53	-	<10	-	<15	<5	<10	27.5	<15	<0.2	<20	<10	4,050	<20	<5	20.1
Year 3	3/9/2011	1.95	0.20	<0.05	0.31	6	<10	7.2	<15	<5	<10	<5	<15	<0.2	<20	<10	3,770	<20	<5	13.4
	3/14/2011	1.35	<0.1	0.21	0.35	6	634	7.3	<15	<5	<10	<5	<15	<0.2	<20	<10	1,200	<20	<5	<5
	4/23/2011	2.34	<0.1	0.06	0.40	10	NR	7.2	<15	<5	<10	<5	<15	<0.2	<20	<10	777	<20	<5	<5
	4/25/2011	0.88	<0.1	<0.05	0.30	3	120	7.2	<15	<5	<10	<5	<15	<0.2	<20	<10	<50	<20	<5	<5
	5/28/2011	2.82	0.2	0.18	0.16	8	4700	7.2	<15	<5	<10	<5	<15	<0.2	<20	<10	1,280	<20	<5	<5
								Site 3												
	4/13/2009	1.49	0.1	0.12	0.25	3	370	7.3	<15	<5	<10	<5	<15	<0.2	<20	<10	839	<20	<5	<5
	4/20/2009	1.94	0.1	0.11	0.30	<2	30	7.2	<15	<5	<10	<5	<15	<0.2	<20	<10	1,050	<20	<5	<5
Site 3	5/1/2009	2.51	0.1	0.21	0.25	13	NR	7.4	<15	<5	<10	<5	<15	<0.2	<20	<10	1,890	<20	<5	<5
Year 1	5/1/2009*	5.23	<0.1	0.2	0.18	12	NR	7.4	<15	<5	<10	<5	<15	<0.2	<20	<10	1,840	<20	<5	<5
	5/14/2009	2.69	0.2	0.05	0.31	14	NR	7.2	<15	<5	<10	8.2	<15	<0.2	<20	<10	2,440	<20	<5	<5
	6/16/2009	3.48	0.4	0.45	0.61	2	9,000	7.2	<15	<5	<10	<5	<15	<0.2	<20	<10	10,100	<20	<5	<5
	9/22/2009	2.34	0.3	0.33	0.52	8	4,700	7.0	<15	<5	<10	<5	<15	<0.2	<20	<10	7,500	<20	<5	<5
	10/9/2009	1.72	0.2	0.22	0.41	6	760	7.1	<15	<5	<10	<5	<15	<0.2	<20	<10	5,500	<20	<5	<5
	10/30/2009	4.97	0.2	0.03	2.43	26	609	7.2	<15	<5	<10	<5	<15	<0.2	<20	<10	6,290	<20	<5	<5
Site 3	1/25/2010	7.44	<0.1	0.25	0.99	616	50	7.4	<15	<5	<10	<5	<15	<0.2	<20	<10	5,800	<20	<5	26.1
Year 2	2/22/2010	2.26	0.2	0.15	0.35	74	270	7.3	<15	<5	<10	<5	<15	<0.2	<20	<10	4,410	<20	<5	<5
	3/26/2010	0.72	<0.1	0.07	0.26	34	1,173	7.3	<15	<5	<10	<5	<15	<0.2	<20	<10	1,200	<20	<5	<5
	5/14/2010	1.39	<0.1	0.08	1.61	16	730	7.2	<15	<5	<10	<5	<15	<0.2	<20	<10	3,200	<20	<5	<5
	5/20/2010	1.34	0.2	0.11	0.13	4	5,500	7.1	<15	<5	<10	<5	<15	<0.2	<20	<10	902	<20	<5	<5
	7/12/2010	1.55	0.3	0.20	0.42	10	673	7.1	<15	<5	<10	<5	<15	<0.2	<20	<10	4,170	<20	<5	<5

Location	Date	TKN	NH3-N	NO3-N	TP	TSS (mg/L)	Fecal coliform (coli/100 mL)	pH (std units)	As	Cd	Cr	Cu	Pb	Hg	Mo	Ni	K	Se	Ag	Zn
		Nutrients (mg/L)							Metals (µg/L)											
	9/16/2010	2.31	<0.1	0.19	0.54	16	16,640	7.1	<15	<5	<10	<5	<15	<0.2	<20	<10	4,050	<20	<5	8.3
	11/26/2010	1.33	<0.1	0.11	0.49	4	1,081	7.2	<15	<5	<10	<5	<15	<0.2	<20	<10	1,970	<20	<5	<5
Site 3	2/25/2011	2.44	0.2	0.23	0.33	-	<10	-	<15	<5	<10	5.8	<15	<0.2	<20	<10	4,900	<20	<5	7
Year 3	3/14/2011	0.87	<0.1	0.21	0.18	2	<10	7.1	<15	<5	<10	<5	<15	<0.2	<20	<10	1,070	<20	<5	<5
	4/23/2011	1.88	0.1	<0.05	0.22	5	-	7.1	<15	<5	<10	<5	<15	<0.2	<20	<10	957	<20	<5	<5
	4/25/2011	0.64	<0.1	<0.05	0.24	2	<10	7.1	<15	<5	<10	<5	<15	<0.2	<20	<10	<50	<20	<5	<5
	5/28/2011	3.01	0.3	0.27	0.25	10	1,800	7.2	<15	<5	<10	<5	<15	<0.2	<20	<10	970	<20	<5	<5
								Site 4												
	5/1/2009	<0.03	0.3	0.28	0.06	34	-	7.3	<15	<5	<10	<5	<15	<0.2	<20	<10	1,330	<20	<5	6.3
Site 4	5/14/2009	0.98	0.4	0.11	0.02	6	-	7.3	<15	<5	<10	<5	<15	<0.2	<20	<10	807	<20	<5	<5
Year 1	5/14/2009*	1.08	0.45	0.82	0.08	4	-	7.4	<15	<5	<10	<5	<15	<0.2	<20	<10	638	<20	<5	<5
	6/16/2009	14.40	8.0	0.30	7.31	180	190,000	7.3	<15	<5	<10	19.6	<15	<0.2	<20	13.7	190,000	<20	<5	69.1
	8/11/2009	4.18	0.3	0.43	0.390	10	2,000	7.1	<15	<5	<10	7.3	<15	<0.2	<20	<10	5,410	<20	<5	9.4
	9/10/2009	7.12	0.6	0.16	0.640	26	20	7.1	<15	<5	12.7	11.7	<15	<0.2	<20	<10	12,600	<20	<5	16
	9/20/2009	3.25	-	0.22	0.420	10	3,060	7.1	<15	<5	<10	<5	<15	<0.2	<20	<10	10,000	<20	<5	6.6
Site 4	9/22/2009	3.45	0.2	0.23	0.420	13	6,100	7.1	<15	<5	<10	<5	<15	<0.2	<20	<10	<500	<20	<5	6.2
Year 2	10/9/2009	1.36	0.2	0.28	0.310	6	940	7.1	<15	<5	<10	<5	<15	<0.2	<20	<10	4,330	<20	<5	<5
	10/30/2009	2.17	0.1	0.28	0.450	22	3,100	7.2	<15	<5	<10	<5	<15	<0.2	<20	<10	7,400	<20	<5	<5
	3/26/2010	2.41	<0.1	0.11	0.350	48	60	7.2	<15	<5	<10	<5	<15	<0.2	<20	<10	1,810	<20	<5	<5
	5/14/2010	0.61	<0.1	0.08	0.060	12	10	7.3	<15	<5	<10	<5	<15	<0.2	<20	<10	1,620	<20	<5	<5
	5/20/2010	1.18	0.2	0.11	0.110	5	400	7.3	<15	<5	<10	<5	<15	<0.2	<20	<10	1,070	<20	<5	<5
	2/25/2011	5.04	0.1	0.25	0.65	-	10	-	<15	<5	<10	10.4	<15	<0.2	<20	<10	8,090	<20	<5	27.5
Site 4	3/14/2011	1.01	<0.1	0.24	0.19	38	3	7.2	<15	<5	<10	<5	<15	<0.2	<20	<10	3,510	<20	<5	5.7
Year 3	4/23/2011	1.69	<0.1	<0.025	0.24	9	-	7.1	<15	<5	<10	<5	<15	<0.2	<20	<10	3,230	<20	<5	<5

Location	Date	TKN	NH3-N	NO3-N	TP	TSS (mg/L)	Fecal coliform (coli/100 mL)	pH (std units)	As	Cd	Cr	Cu	Pb	Hg	Mo	Ni	K	Se	Ag	Zn
		Nutrients (mg/L)							Metals (µg/L)											
	4/25/2011	1.08	<0.1	<0.025	0.19	4	20	7.2	<15	<5	<10	<5	<15	<0.2	<20	<10	850	<20	<5	<5
								Field Blanks												
	11/6/2008	0.14	<0.1	<0.05	<0.01	<1	<1	6.5	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	2/11/2009	0.36	<0.1	0.02	0.01	<1	<1	6.6	<15	<5	<10	<5	<15	<0.2	<20	<10	<50	<20	<5	<5
	4/13/2009	0.45	<0.1	0.12	0.15	<1	<1	6.5	<15	<5	<10	<5	<15	<0.2	<20	<10	<50	<20	<5	<5
Field	4/20/2009	<0.03	<0.1	0.07	0.22	<2	<1	6.2	<15	<5	<10	<5	<15	<0.2	<20	<10	<50	<20	<5	<5
Blanks	5/1/2009	0.17	<0.1	0.14	0.02	<1	-	6.3	<15	<5	<10	<5	<15	<0.2	<20	<10	<50	<20	<5	<5
Year 1	5/14/2009	0.19	<0.1	<0.01	<0.01	<1	-	6.8	<15	<5	<10	<5	<15	<0.2	<20	<10	<50	<20	<5	<5
	6/16/2009	0.62	<0.1	0.38	0.08	<1	<1	6.8	<15	<5	<10	<5	<15	<0.2	<20	<10	<50	<20	<5	<5
	6/30/2009	0.36	<0.1	<0.01	0.11	<1	<1	6.8	<15	<5	<10	<5	<15	<0.2	<20	<10	<50	<20	<5	<5
	7/21/2009	0.40	<0.1	<0.01	<0.01	<1	<50	6.7	<15	<5	<10	<5	<15	<0.2	<20	<10	<50	<20	<5	<5
	8/11/2009	<0.03	<0.1	0.14	0.14	<1	<1	6.9	<15	<5	<10	<5	<15	<0.2	<20	<10	<50	<20	<5	<5
	9/10/2009	<0.03	<0.1	0.12	0.08	<1	<1	6.9	<15	<5	<10	<5	<15	<0.2	<20	<10	<50	<20	<5	<5
	9/20/2009	0.08	ns	0.17	0.04	<1	-	6.9	<15	<5	<10	<5	<15	<0.2	<20	<10	<50	<20	<5	<5
	9/22/2009	0.09	<0.1	<0.05	0.03	<1	<1	6.9	<15	<5	<10	<5	<15	<0.2	<20	<10	<50	<20	<5	<5
	10/9/2009	0.29	<0.1	<0.05	0.21	<1	<1	7.0	<15	<5	<10	<5	<15	<0.2	<20	<10	<50	<20	<5	<5
Field	10/30/2009	-	<0.1	<0.01	-	<1	<1	7.0	<15	<5	<10	<5	<15	<0.2	<20	<10	<50	<20	<5	<5
Blanks	1/22/2010	<0.03	<0.1	<0.01	0.12	<1	<2	6.9	<15	<5	<10	<5	<15	<0.2	<20	<10	<50	<20	<5	<5
Year 2	1/25/2010	<0.03	<0.1	<0.01	0.10	<1	<1	7.0	<15	<5	<10	<5	<15	<0.2	<20	<10	<50	<20	<5	<5
	2/22/2010	<0.03	<0.1	<0.01	<0.01	<1	<1	6.8	<15	<5	<10	<5	<15	<0.2	<20	<10	<50	<20	<5	<5
	3/22/2010	0.32	<0.1	<0.01	0.04	<1	<1	6.5	<15	<5	<10	<5	<15	<0.2	<20	<10	<50	<20	<5	<5
	3/26/2010	0.36	<0.1	0.06	0.10	<1	<1	6.5	<15	<5	<10	<5	<15	<0.2	<20	<10	<50	<20	<5	<5
	5/14/2010	<0.03	<0.1	0.07	<0.01	4	<1	6.6	<15	<5	<10	<5	<15	<0.2	<20	<10	<50	<20	<5	<5
	5/15/2010	<0.03	<0.1	0.12	<0.01	<1	<1	6.6	<15	<5	<10	<5	<15	<0.2	<20	<10	88.6	<20	<5	<5
	5/20/2010	0.45	<0.1	0.10	<0.01	<1	<1	6.6	<15	<5	<10	<5	<15	<0.2	<20	<10	87.8	<20	<5	<5

Location	Date	Nutrients (mg/L)							Metals (µg/L)												
		TKN	NH3-N	NO3-N	TP	TSS (mg/L)	Fecal coliform (coli/100 mL)	pH (std units)	As	Cd	Cr	Cu	Pb	Hg	Mo	Ni	K	Se	Ag	Zn
Field Blanks Year 3	7/12/2010	0.41	<0.1	0.01	<0.01	<1	<1	6.8	<15	<5	<10	<5	<15	<0.2	<20	<10	<50	<20	<5	<5
	9/1/2010	1.67	<0.1	0.11	0.06	<1	<1	6.8	-	-	-	-	-	<0.2	-	-	-	-	-	-
	9/16/2010	0.10	<0.1	<0.05	0.06	<1	<10	6.9	-	-	-	-	-	<0.2	-	-	-	-	-	-
	11/26/2010	<0.03	<0.1	0.08	0.04	<1	<10	6.8	<15	<5	<10	<5	<15	<0.2	<20	<10	<50	<20	<5	<5
	2/25/2011	0.46	<0.1	0.19	0.14	-	<1	-	-	-	-	-	-	<0.2	-	-	-	-	-	-
	3/9/2011	0.17	<0.1	<0.01	<0.01	<1	<10	6.8	-	-	-	-	-	-	-	-	-	-	-	-
	3/14/2011	<0.03	-	0.22	0.06	<1	<1	6.9	-	-	-	-	-	-	-	-	-	-	-	-
	4/23/2011	0.38	<0.1	<0.01	0.04	<1	-	6.8	<15	<5	<10	<5	<15	<0.2	<20	<10	<50	<20	<5	<5
	4/25/2011	<0.03	<0.1	<0.01	0.11	<1	<1	6.9	<15	<5	<10	<5	<15	<0.2	<20	<10	<50	<20	<5	<5
	5/28/2011	0.25	<0.1	0.06	0.03	<1	<1	6.7	<15	<5	<10	<5	<15	<0.2	<20	<10	<50	<20	<5	<5

APPENDIX G: Water Quality Sampling Duplicate Variability

Date	TKN RPD	NH3-N RPD	NO3-N RPD	TP RPD	TSS RPD	Fecal RPD	pH RPD
			Year 1				
4/13/2009	43	96	17	38	67	100	0.1
6/16/2009	6.2	0.0	0.0	4.4	67	0.0	0.8
4/20/2009	70	75	4.9	33	8.0	190	0.3
5/1/2009	9.7	2.2	153	120	40	-	0.7
6/10/2009	196	0.0	11	3.3	120	0.0	0.4
5/14/2009	21	0.0	14	1.7	13	-	0.3
			Year 2				
8/11/2009	21	3.0	4.8	0.0	18	133	0.7
9/10/2009	5.5	4.7	55	1.6	18	0.0	0.9
9/22/2009	6.6	67	6.3	1.9	22	65	0.1
10/9/2009	3.4	17	0.0	2.4	0.0	9.7	0.1
10/30/2009		43	0.0		89	42	0.1
2/22/2010	0.0	36	18	0.0	77	0.0	0.3
3/22/2010	21	29	0.0	8.0	22	50	0.3
3/26/2010	99	32	12	21	124	0.0	0.4
5/14/2010	40	0.0	0.0	0.0	13	126	0.0
5/15/2010	11	115	8.7	156	67	111	2.7
5/15/2010	29	32	8.7	67	100	3.2	0.3
5/20/2010	58	67	120	13	22	17	0.3
7/12/2010	1.9	31	4.9	2.4	33	13	0.3
			Year 3				
9/16/2010	4.9	0	147	77	22.2	144	1.4
11/26/2010	12	0	0	2	0	16	0.6
2/25/2011	77	25	4	77	-	120	-
3/14/2011	64	0	5	0	40	-	0.3
4/23/2011	6	89	0	70	114	-	-
5/28/2011	7	33	6	106	67	130	0

APPENDIX H: Soil Morphology Data

Owner: Biosolid Project Depth to Bedrock: GPS Location: 37° 16.073' N: 93° 51.542' W +/-12ft	County: Lawrence, MO Pit #: 1 Described By: Recorded By: Doug Gisselbeck Tom DeWitt	Soil Drainage Class: Up Slope: Convex, Across Slope: Convex Excavation Depth: 60'	Landscape Position: Summit	Date: 11/19/2008 Geomorphic: Head Slope Aspect: N Elevation: 1215' % Slope: 1
Vegetation: Grass (Pasture- fescue)	Parent Material: Loess / Colluvium / Residuum		Geology: Mo	

Horizon		Munsell Color (moist)	P/V Surface Features (2)	Texture		% Coarse Fragment By Volume		Consistence (4)	Structure (5)	Roots/ Pores (6)	RMF /or Notes
Designation	Depth/ Boundary (1)			USDA (3)	% Clay	< 3"	> 3"				
Ap	0 – 5" (13cm) AS	10YR 4/3		SIL	12	0	0	VFR	1 F GR 1 F SBK	M F/M M F/M	1% F/FMM
BE	5 – 8" (20cm) CS	10YR 5/4		SIL	14	0	0	FR	2 F SBK	MF CF	1% F/FMM
Bt1	8 – 18" (45cm) CW	7.5YR 5/4	5% 10YR 5/4 CLF/APF	SIL	25	1	0	FR	2 M SBK	MF CF	2% F/FMM
Bt2	18 – 25" (64cm) CW	7.5YR 4/4	10YR 4/3 CLF/HPF	SICL	36	2	0	FI	2 M PR → 2 M SBK	FF FF	5% F/FMM
Bt3	25 – 32" (89cm) CW	7.5YR 4/4	10YR 4/2 CLF/VPF	SICL	30	5	0	FI	2 M PR → 2 M SBK	FF FF	5% D/FMM
2Btx1	32 – 38" (97cm) CW	7.5YR 4/6	10YR 4/2 CLF/VPF	GR SICL	32	20	0	FI	1 M PR → 3 M SBK	VFF VFF	10YR 5/2 FED 2% D/FMN Clay films on vertical prism faces. Vert. seams <3" apart
2Btx2	38 – 45" (114cm) CW	5YR 4/6	↓	GR SICL	38	25	0	VFI	1 M PR → 3 M SBK	VFF VFF	↓
3Bt	45 – 60" (152cm) ----	2.5YR 4/6	↓	GR SICL	36	20	0	FI	1 M PR → 2 F SBK	VFF VFF	↓

Owner: BioSolid Project Depth to Bedrock:	County: Lawrence, MO Pit #: 2	Soil Drainage Class: Up Slope: Convex Across Slope: Convex	Date: 11/19/2008 Geomorphic: Interfluve
GPS Location: 37° 16.173' N: 93° 51.507' W +/-12ft	Described By: Recorded By: Doug Gisselbeck Tom DeWitt	Excavation Depth: 60" Landscape Position: Summit	Aspect: N Elevation: 1199' % Slope: 2
Vegetation: Grass (Pasture-fescue)	Parent Material: Colluvium / Residuum		Geology: Mo

Horizon		Munsell Color (moist)	P/V Surface Features (2)	Texture		% Coarse Fragment By Volume		Consistence (4)	Structure (5)	Roots/ Pores (6)	RMF /or Notes
Designation	Depth/ Boundary (1)			USDA (3)	% Clay	< 3"	> 3"				
Ap	0 – 4" (10cm) CS	10YR 3/3		SIL	14	10		VFR	2 M GR	M F/M M VF/F	
BE or Ap2	4 – 7" (18cm) CS	10YR 5/3		SIL	12	10		VFR	2 F SBK → 1 F GR	M F/M M VF/F	(SLF?)
Bt1	7 – 11" (28cm) CW	7.5YR 5/3		GR SIL	18	20		FR	2 M SBK	M VF/F M VF/F	F/F CLF
Bt2	11 - 20" (51cm) CW	5YR 4/4		GRV SICL	36	25	15	FR	2 M SBK	CF CF	
2Btx1	20 - 29" (74cm) CW	2.5YR 4/6	10YR 5/2 CLF/VPF 10YR 5/3 SLF F/F	GRX SICL	32	40	20	BR	1 M PR → 2 M SBK	CF CF	Weak fragipan; 7.5YR 6/2 FED in gray seams. Gray seams 2 – 3" apart
2Btx2	29 - 38" (97cm) CW	2.5YR 4/6	10YR 5/2 CKF/VPF 2.5YR 3/6 CLF	GRX SICL	36	40	20	BR	1 M PR → 3 M SBK	FF FF	↓
3Bt	38 - 60" (152cm) ----	10R 3/6	10YR 5/2 CLF/VPF	GRV C	60	15	15	EF	2 M PR → 2 M SBK	FF FF	↓

Owner: BioSolid Project
County: Lawrence, MO
Soil Drainage Class:
Date: 11/19/2008
Depth to Bedrock:
Pit #: 3
Up Slope: Convex
Across Slope: Convex
Geomorphic: Side Slope
GPS Location: 37° 16.173‘ N: 93° 51.471‘ W +/-12ft
Described By: Recorded By: Doug Gisselbeck Tom DeWitt
Excavation Depth: 60”
Landscape Position: Shoulder
Aspect: E
Elevation: 1195’
% Slope: 4
Vegetation: Grass (Pasture=fescue)
Parent Material: Colluvium / Residuum
Geology: Mo

Horizon		Munsell Color (moist)	P/V Surface Features (2)	Texture		% Coarse Fragment By Volume		Consistence (4)	Structure (5)	Roots/ Pores (6)	RMF /or Notes
Designation	Depth/ Boundary (1)			USDA (3)	% Clay	< 3”	> 3”				
Ap	0 – 3” (8cm) CS	10YR 3/3		SIL	12	5		VFR	2 F GR	M F/M M F/M	
Ap2	3 – 7” (18cm) CS	10YR 4/3		SIL	12	10		VFR	2 M SBK → 1 F GR	M F/M M F/M	
Bt1	7 – 16” (41cm) CS	7.5YR 5/4	10YR 6/3 SLF 10YR 4/2 CLF/APF	SICL	28	15		FR	2 M SBK	CF CF	F/F FMM
Bt2	16 - 28” (71cm) CW	5YR 4/4	10YR 6/3 SLF 10YR 4/2 CLF/APF	GR SICL	36	25	5	FR	2 M SBK	CF FF	F/F FMM
2Bt3	28 - 36” (91cm) CW	2.5YR 4/4	10YR 6/3 SLF 10YR 4/2 CLF/APF	GR SICL	39	20/5 G/PG	5	FI	1 M PL → 2 M SBK	FF FF	Vertical Seams Para-rock frag. 1 M sandstone channers
2Bt4	36 - 43” (109cm) CW	2.5YR 4/6	40% 10YR 4/2 CLF/VPF	GR C	55	20/5 G/PG	5	EF	2 M PL → 2 M SBK	FF FF	20% 2.5Y 7/2 FED
3Bt5	43 - 50” (127cm) GW	2.5YR 4/6	30% 10YR 4/2 CLF/VPF 20% 10YR 6/2	GR SIC	45	15	10	VFI	1 M PR → 1M PL	---- ----	20% 2.5Y 7/2 FED
3Bt	50 – 60” (152cm) ----	2.5YR 4/6		CNV SICL	38	25 PGR	25 PCN	FI	1 M PL	---- ----	30% 2.5Y 7/2 FED Masses of Weathered sandstone

Owner: BioSolid Project County: Lawrence, MO Soil Drainage Class: Date: 11/19/2008

Depth to Bedrock: Pit #: 4 Up Slope: Convex Across Slope: Geomorphic: Side Slope

Convex

GPS Location: Described By: Excavation Depth: Landscape Position: Aspect: % Slope:

37° 16.173‘ N: 93° 51.443‘ W +/-12ft Recorded By: 80” Back Slope Elevation: 12

Doug Gisselbeck Tom DeWitt E 1176’

Vegetation: Grass (Pasture-fescue) Parent Material: Colluvium / Residuum Geology: Mo

Horizon Designation	Horizon Depth/ Boundary (1)	Munsell Color (moist)	P/V Surface Features (2)	Texture USDA (3)	Texture % Clay	% Coarse Fragment By Volume < 3”	% Coarse Fragment By Volume > 3”	Consistence (4)	Structure (5)	Roots/ Pores (6)	RMF /or Notes
Ap	0 – 4” (10cm) CS	10YR 3/2		SIL	12	5		VFR	2 F GR	M F/M M F/M	
Ap2	4 – 8” (20cm) CS	10YR 4/3		SIL	12	10		VFR	1 F SBK → 1 F GR	M F/M M F/M	
Bt1	8 – 18” (46cm) CS	7.5YR 4/4	10YR 4/2 CLF/APF	SICL	28	15		FR	2 M SBK	CF CF	
Bt2	18 - 25” (64cm) CW	7.5YR 5/3 15% 5YR 4/4	(CRK or RPO?) ↕	GR SICL	38	20		FI	2 M SBK	CF CF	(SLF?)
Bt3	25 - 32” (81cm) CW	2.5YR 3/6	↓	GR SIC	42	30		VFI	2 M PR → 3 M SBK	FF FF	10YR 5/2 FED Roots in vertical seams
2Bt4	32 – 62” (157cm) CW	2.5YR 3/6	↓	GRV SIC	48	45	15	VFI	2 M PR → 3 M SBK	FF FF	↓
2Bt5	62 – 80” (203cm) ----	2.5YR 3/6	↓	GRV C	55	20	20	EF	2 M PR → 3 M SBK	FF FF	↓

Owner: BioSolid Project		County: Lawrence, MO			Soil Drainage Class:				Date: 11/19/2008			
Depth to Bedrock:		Pit #: 5			Up Slope: Concave		Across Slope: Concave		Geomorphic: Head Slope			
GPS Location: 37° 16.184‘ N: 93° 51.406‘ W +/-12ft		Described By: Recorded By: Doug Gisselbeck Tom DeWitt			Excavation Depth: 60”		Landscape Position: Footslope		Aspect: Elevation: NE 1166’	% Slope: 6		
Vegetation: Grass (Pasture-fescue)		Parent Material: Local Alluvium / Colluvium					Geology: Mo					

Horizon		Munsell Color (moist)	P/V Surface Features (2)	Texture		% Coarse Fragment By Volume		Consistence (4)	Structure (5)	Roots/ Pores (6)	RMF /or Notes
Designation	Depth/ Boundary (1)			USDA (3)	% Clay	< 3”	> 3”				
Ap	0 – 12” (30cm) CS	10YR 3/2		GRV SIL	14	35	5	VFR	3 F GR	M F/M M F/M	
Ap2	12 - 23” (58cm) CW	10YR 3/3		GRV SIL	16	40	20	VFR	1 F SBK → 2 F GR	M F/M M F/M	
2Bt1	23 – 47” (119cm) AW	5YR 4/4	10YR 4/3 CLF/VPF	GRV SICL	38	35	5	FI	2 M SBK	FF C F/M	5% FMM Vertical Gray Seams
2Bt2	47 – 60” (152cm) ----	2.5YR 3/6	10YR 4/2 CLF/VPF	GRV SIC	45	45	5	VFI	1 M PR → 2 M SBK	FF FF	8% FMM Irregular shaped 20% 10yr 5/2 FED

Comments: Alluvial / Colluvial mix, pit is in a narrow drainage way.

Taxonomy/Series: **Clayey-Skeletal Pachic Paleudolls**

Notations used to describe soil profile descriptions.

(1) Boundary: (A = abrupt, C = clear, G = gradual, D = diffuse) (S = smooth, W = wavy, I = irregular)

(2) NASIS Code: [(RMF and P & V Surface Features: (Amount class = %) (Distinctness class, F = faint, D = distinct, P = prominent) (Continuity class, D = discontinuous) (Kind, SAF = clean sand or silt over clay, CLF = clay films) (Location code, APF = on faces of peds, LPO = lining pores, RPO = on surfaces along root channels, SPO = on surfaces along pores)]

(3) Texture: (texture modifier, fragment content % by volume, GR = 15 to < 35 %, GRV = 35 to < 60 %, GRX = 60 to < 90 %) (SIL = silt loam, SICL = silty clay loam, C = clay, SIC = silty clay, L= loam, CL = clay loam)

(4) Consistence, moist conditions (VFR = very friable, FR = friable, FI = firm, VFI = very firm, EFI = extremely firm)

(5) Structure [(grade, 1 = weak, 2 = moderate, 3 =strong)(size, VF = very fine, F = fine, M = medium, C = coarse) (shape, GR = granular, SBK = subangular blocky, ABK = angular blocky, PR = prismatic, M = massive)

(6) Roots/Pores (abundance, F = few, C = common, M = many) (size, VF = very fine, F = fine, M = medium, C = coarse)

APPENDIX I: Forage Data

Spring 2009

Parameter	Site 1		Site 2		Site 3		Site 4	
	AVG	SEM	AVG	SEM	AVG	SEM	AVG	SEM
Dry Matter %	29.61	1.02	27.60	0.77	28.68	0.35	27.33	1.94
Protein .... %	8.84	0.67	8.97	0.50	9.98	0.40	11.11	0.72
A D Fiber .... %	43.40	1.14	45.93	0.83	44.53	0.28	43.63	1.56
N D Fiber(a) ..... %	64.72	1.19	68.08	1.27	66.37	0.31	65.62	2.07
Crude Fiber ...... %								
Lignin .... %								
T D N .... %	52.15	0.94	50.06	0.68	51.21	0.23	51.96	1.29
NE Lactation MCAL/LB	0.513	0.011	0.489	0.008	0.502	0.003	0.511	0.015
NE Gain .... MCAL/LB	0.222	0.014	0.192	0.010	0.209	0.003	0.220	0.019
NE Maint ... MCAL/LB	0.473	0.015	0.440	0.011	0.458	0.004	0.470	0.020
Digst Energy MCAL/LB	0.473	0.015	0.440	0.011	0.458	0.004	0.470	0.020
Nitrogen .... %	1.415	0.108	1.435	0.080	1.596	0.065	1.777	0.116
Calcium .... %	0.340	0.069	0.317	0.040	0.280	0.035	0.330	0.061
Phosphorus .... %	0.157	0.015	0.239	0.010	0.219	0.006	0.247	0.018
Ca:P 1.5 to 2.0	*2.2*		*1.3*		*1.3*		*1.3*	
Magnesium .... %	0.123	0.012	0.123	0.006	0.143	0.015	0.143	0.021
Potassium .... %	1.647	0.061	1.980	0.125	1.787	0.055	1.807	0.191
Sodium .... %	0.006	0.002	0.008	0.003	0.009	0.006	0.015	0.010
Iron .... PPM	80.00	17.32	70.00	0.00	100.00	43.59	103.33	5.77
Copper .... PPM	3.67	0.58	5.33	1.53	5.67	1.15	5.67	0.58
Manganese ...... PPM	40.00	14.18	63.67	6.66	44.33	8.50	46.00	7.21
Zinc .... PPM	17.67	2.89	17.67	2.08	22.33	1.15	23.00	2.65
RFV [Quality Standard]	79 [4]		73 [5]		76 [4]		78 [4]	
Nitrate (NO3)	Negative		Negative		Negative		Negative	
Yield								
fresh lbs/plot (140sqft)	19.0		38.7		46.3		63.8	
dry lbs/plot	5.6		10.7		13.3		17.4	
dry tons/A (extrapolated)	0.9		1.7		2.1		2.7	

Fall 2009

Parameter	Site 1		Site 2		Site 3		Site 4	
	AVG	SEM	AVG	SEM	AVG	SEM	AVG	SEM
Moist / Dry Matter %	40.11	1.16	29.61	0.71	32.29	0.76	29.36	2.08
Protein .... %	9.73	0.98	16.08	0.88	15.76	1.06	16.54	1.79
A D Fiber .... %	42.63	0.93	37.72	0.35	40.12	0.63	40.29	2.03
N D Fiber(a) ..... %	63.17	0.54	57.15	0.65	59.11	0.45	58.50	2.37
Crude Fiber ...... %								
Lignin .... %								
T D N .... %	52.78	0.77	56.84	0.28	54.86	0.52	54.71	1.68
NE Lactation MCAL/LB	0.52	0.01	0.57	0.00	0.54	0.01	0.54	0.02
NE Gain .... MCAL/LB	0.23	0.01	0.29	0.00	0.26	0.01	0.26	0.02
NE Maint ... MCAL/LB	0.48	0.01	0.55	0.00	0.52	0.01	0.51	0.03
Digst Energy MCAL/LB	0.48	0.01	0.55	0.00	0.52	0.01	0.51	0.03
Nitrogen .... %	1.56	0.16	2.57	0.14	2.52	0.17	2.65	0.29
Calcium .... %	0.44	0.04	0.52	0.03	0.53	0.04	0.50	0.09
Phosphorus .... %	0.23	0.01	0.38	0.03	0.36	0.02	0.35	0.03
Ca:P 1.5 to 2.0	*1.94*		*1.38*		*1.49*		*1.44*	
Magnesium .... %	0.14	0.03	0.23	0.02	0.27	0.03	0.24	0.02
Potassium .... %	1.91	0.11	3.10	0.16	2.88	0.19	3.22	0.33
Sodium .... %	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.00
Iron .... PPM	80.00	17.32	90.00	17.32	236.67	228.11	106.67	5.77
Copper .... PPM	5.33	1.15	5.33	0.58	7.00	1.73	6.33	0.58
Manganese ...... PPM	36.67	13.61	62.00	8.00	47.33	3.21	43.67	7.51
Zinc .... PPM	21.00	4.00	19.67	4.16	25.67	2.52	22.67	3.06
RFV [Quality Standard]	82 [4]		97 [3]		90 [3]		90 [3]	
Nitrate (NO3)	Negative		Negative		Negative		Negative	
Yield								
fresh lbs/plot (140sqft)	17.3		34.2		34.0		36.5	
dry lbs/plot	7.0		10.1		11.0		10.7	
dry tons/A (extrapolated)	1.1		1.6		1.7		1.7	

Spring 2010

Parameter	Site 1		Site 2		Site 3		Site 4	
	AVG	SEM	AVG	SEM	AVG	SEM	AVG	SEM
Dry Matter %	27.14	1.01	26.53	1.73	27.20	0.15	26.33	0.96
Protein .... %	9.94	0.97	10.81	1.08	10.70	0.42	11.37	1.08
A D Fiber .... %	41.03	0.90	41.49	1.20	41.47	0.21	40.31	0.42
N D Fiber(a) ..... %	66.92	1.79	68.08	1.49	67.69	0.59	66.49	0.30
Crude Fiber ...... %								
Lignin .... %								
T D N .... %	54.10	0.74	53.73	0.99	53.74	0.18	54.70	0.34
NE Lactation MCAL/LB	0.536	0.009	0.532	0.012	0.532	0.002	0.543	0.004
NE Gain .... MCAL/LB	0.251	0.011	0.245	0.014	0.246	0.003	0.259	0.005
NE Maint ... MCAL/LB	0.504	0.012	0.498	0.016	0.498	0.003	0.513	0.005
Digst Energy MCAL/LB	0.504	0.012	0.498	0.016	0.498	0.003	0.513	0.005
Nitrogen .... %	1.590	0.155	1.729	0.174	1.713	0.067	1.820	0.172
Calcium .... %	0.423	0.023	0.360	0.036	0.373	0.031	0.357	0.015
Phosphorus .... %	0.251	0.008	0.286	0.031	0.282	0.006	0.291	0.012
Ca:P 1.5 to 2.0	*1.7*		*1.3*		*1.3*		*1.2*	
Magnesium .... %	0.157	0.006	0.153	0.015	0.163	0.015	0.150	0.010
Potassium .... %	1.573	0.152	1.640	0.207	1.540	0.052	1.707	0.137
Sodium .... %	0.005	0.000	0.005	0.000	0.012	0.013	0.005	0.000
Iron .... PPM	160.00	30.00	110.00	10.00	103.33	5.77	106.67	11.55
Copper .... PPM	7.00	2.65	5.67	0.58	5.67	0.58	5.33	0.58
Manganese ...... PPM	37.00	3.00	41.33	4.73	27.67	5.86	31.33	0.58
Zinc .... PPM	17.00	1.00	13.00	6.93	15.67	1.53	25.00	3.46
RFV [Quality Standard]	79 [4]		77 [4]		78 [4]		80 [4]	
Nitrate (NO3)	Negative		Negative		Negative		Negative	
Yield								
fresh lbs/plot (140sqft)	19.2		38.2		47.8		58.7	
dry lbs/plot	5.2		10.1		13.0		15.5	
dry tons/A (extrapolated)	0.8		1.6		2.0		2.4	

Fall 2010

Parameters	Site 1		Site 2		Site 3		Site 4	
	AVG	SEM	AVG	SEM	AVG	SEM	AVG	SEM
Dry Matter %	37.78	1.89	32.11	1.17	28.91	1.67	29.81	1.58
Protein .... %	8.81	0.37	15.15	3.13	15.30	1.30	18.38	1.98
A D Fiber .... %	46.57	1.36	42.70	2.31	38.28	0.96	35.98	1.48
N D Fiber(a) ..... %	73.88	2.26	68.22	3.32	61.74	0.21	59.43	1.82
Crude Fiber ...... %								
Lignin .... %								
T D N .... %	49.53	1.12	52.73	1.91	56.38	0.79	58.27	1.22
NE Lactation MCAL/LB	0.483	0.013	0.520	0.022	0.563	0.009	0.585	0.014
NE Gain .... MCAL/LB	0.184	0.017	0.231	0.028	0.283	0.011	0.310	0.017
NE Maint ... MCAL/LB	0.431	0.018	0.482	0.030	0.539	0.012	0.568	0.019
Digst Energy MCAL/LB	0.431	0.018	0.482	0.030	0.539	0.012	0.568	0.019
Nitrogen .... %	1.410	0.059	2.423	0.501	2.447	0.208	2.940	0.317
Calcium .... %	0.463	0.065	0.440	0.020	0.537	0.032	0.623	0.071
Phosphorus .... %	0.211	0.021	0.282	0.027	0.389	0.018	0.368	0.029
Ca:P 1.5 to 2.0	*2.2*		*1.6*		*1.4*		*1.7*	
Magnesium .... %	0.103	0.015	0.137	0.006	0.200	0.030	0.207	0.012
Potassium .... %	1.043	0.172	1.537	0.210	1.713	0.358	1.797	0.111
Sodium .... %	0.005	0.000	0.005	0.000	0.005	0.000	0.005	0.000
Iron .... PPM	113.33	23.09	93.33	11.55	100.00	0.00	46.67	40.41
Copper .... PPM	4.33	0.58	4.67	0.58	5.33	0.58	6.00	0.00
Manganese ...... PPM	38.00	14.73	45.00	20.07	52.33	10.26	40.00	11.79
Zinc .... PPM	27.67	4.04	29.00	11.36	31.00	6.56	20.33	0.58
RFV [Quality Standard]	66 [5]		76 [4]		89 [3]		96 [3]	
Nitrate (NO3)	Trace		Negative		Negative		0.90%	
<u>Yield</u>								
fresh lbs/plot (140sqft)	15.3		26.2		17.5		16.25	
dry lbs/plot	5.8		8.4		5.1		4.8	
dry tons/A (extrapolated)	0.9		1.3		0.8		0.8	

Spring 2011

Parameters	Site 1		Site 2		Site 3		Site 4	
	AVG	SEM	AVG	SEM	AVG	SEM	AVG	SEM
Dry Matter %	30.98	0.47	30.08	1.64	27.97	0.60	27.10	1.03
Protein .... %	9.60	0.32	10.56	0.43	10.80	0.62	10.91	0.19
A D Fiber .... %	40.5	0.38	40.2	0.540	39.0	0.673	38.7	0.77
N D Fiber(a) ..... %	64.2	0.459	62.6	1.154	61.5	0.79	60.5	1.41
Crude Fiber ...... %								
Lignin .... %								
T D N .... %	54.51	0.31	54.83	0.45	55.8	0.56	56.07	0.64
NE Lactation MCAL/LB	0.541	0.004	0.54	0.01	0.556	0.006	0.56	0.01
NE Gain .... MCAL/LB	0.257	0.005	0.26	0.01	0.275	0.008	0.28	0.01
NE Maint ... MCAL/LB	0.510	0.005	0.51	0.01	0.530	0.009	0.53	0.01
Digst Energy MCAL/LB	1.090	0.006	1.1	0.01	1.115	0.011	1.12	0.01
Nitrogen .... %	1.54	0.05	1.69	0.07	1.73	0.10	1.75	0.03
Calcium .... %	0.45	0.06	0.42	0.026	0.46	0.02	0.46	0.05
Phosphorus .... %	0.19	0.01	0.243	0.006	0.277	0.021	0.262	0.011
Ca:P 1.5 to 2.0	*2.4*		*1.7*		*1.7*		*1.8*	
Magnesium .... %	0.12	0.01	0.13	0	0.147	0.006	0.13	0.01
Potassium .... %	1.50	0.12	1.65	0.132	1.707	0.046	1.85	0.13
Sodium .... %	0.005	0.001	0.006	0.001	0.008	0.005	0.006	0.002
Iron .... PPM	83.33	15.28	80	17.32	100	0	116.67	55.08
Copper .... PPM	3.33	0.58	3.67	1.15	5	1.73	3	0
Manganese ...... PPM	39.33	12.06	49.33	3.79	51	3.61	49	9.17
Zinc .... PPM	20.67	2.89	15.33	2.08	15.67	2.89	14.33	2.08
RFV [Quality Standard]	84 [4]		86 [4]		89 [3]		91 [3]	
Nitrate (NO3)	Negative		Negative		Negative		Negative	
<u>Yield</u>								
fresh lbs/plot (140sqft)	4.7		8.5		10.5		14.7	
dry lbs/plot	1.4		2.6		2.9		4.0	
dry tons/A (extrapolated)	0.2		0.4		0.5		0.6	

APPENDIX J: Biosolids Workshop: Agenda and Abstracts

Missouri Natural Resources Conference
February 2-4, 2011
Tan-Tar-A Resort
Osage Beach, Missouri

Conference Theme:
The Human Element: People, Politics, and Conservation

Workshop Title and Abstract:

Friday, February 4
8:00-10:00 am

Environmental Stewardship of Biosolids Land Application: Implications regarding soil health, nutrient cycling, storm water runoff, and agricultural production

Biosolids are the residual by-product of the municipal treatment of wastewater used as an alternative organic fertilizer. When applied to agricultural fields at appropriate rates, biosolids can be a safe and effective part of a nutrient management plan. The City of Springfield's Southwest Wastewater Treatment Plant (SWTP) produces approximately 6,000 dry tons of biosolids per year providing local farmers a much needed source of nutrients and organic matter that otherwise would be sent to the landfill. Questions still remain about the impacts on water quality runoff from treated fields under local soil, slope, and crop conditions found in southwest Missouri. A multi-disciplinary team from the City of Springfield, Missouri State University, and the Natural Resources Conservation Service is conducting a 3-year study to compare the runoff rates of nutrients and metals from fields treated with biosolids to fields treated with traditional inorganic fertilizer. The purpose of this study is to determine the effect of biosolids application on runoff quality under field conditions. The objectives of this study are: 1) implement an experimental field plot monitoring program using runoff auto-samplers to measure the concentrations and loads of nutrients and metals released from fields treated with biosolids; 2) compare the levels of nutrients and metals in runoff and forage measured in biosolids applied fields to fields treated as control (no application) and with traditional fertilizer; and 3) use this information to support the continued approval of biosolids applications by government regulators and provide information to the general public on the safety of using biosolids as a component in an overall nutrient management plan.

Workshop Organizing Committee: Bob Pavlowsky and Marc Owen (contact Marc Owen at mowen@missouristate.edu or 417-836-3197)
Moderator: Bob Pavlowsky, Ph.D., Director of the Ozarks Environmental and Water Resources Institute (OEWRI), Missouri State University, Springfield, MO

List of Topics and Presenters:

1) 8:00 am - *Overview of the City of Springfield's Biosolids Program*
   Scott Foley, City of Springfield's Biosolids Program Coordinator, Springfield, MO
2) 8:20 am - *Site and Soil Characterization of the Biosolids Project Area, Lawrence County, Missouri*
   Tom DeWitt, Soil Scientist and Per Course Faculty, Darr School of Agriculture, Missouri State University, Springfield, MO
3) 8:40 am - *A Nutrient Strategy that Includes Biosolids: Implications on Soil Health and Water Quality*
   Steve Hefner, Team Leader, South Missouri Water Quality Office, Natural Resources Conservation Service, Ozark, MO
4) 9:00 am - *Water Quality and Runoff Characteristics from Agricultural Fields Applied with Biosolids and Mineral Fertilizers, Lawrence County, Missouri*
   Marc Owen, Research Specialist II, OEWRI, Missouri State University, Springfield, MO
5) 9:20 am - *Biosolids and nutrient runoff under simulated rainfall*
   Cody Wallace and Michael Burton, Ph.D., Darr School of Agriculture, Missouri State University, Springfield, MO
6) 9:40 am - *Forage productivity and quality in the bio-solids project*
   Michael Burton, Ph.D. and Cody Wallace, Darr School of Agriculture, Missouri State University, Springfield, MO

List of Abstracts:

Overview of the City of Springfield's Biosolids Program

Scott Foley, City of Springfield Public Work-Sanitary Services, Springfield, MO 65802, (417) 864-1923, Sfoley@springfieldmo.gov

Abstract:
Biosolids is the residual by-product of the municipal treatment of wastewater that can be disposed by proper land application. The City of Springfield Missouri's Southwest Wastewater Treatment Plant produces nearly 6,000 dry tons of biosolids per year. Springfield's Biosolids Program distributes this material to local farmers and is a free source of nutrients and organic matter that otherwise would be sent to the landfill. Human health risks for land application of biosolids are considered low when the material is properly handled and treated per environmental regulations. However, public perception is that land applied biosolids release nutrients and traces metals during runoff events and contribute to water quality problems in nearby streams and lakes. The City of Springfield has initiated a three year study to evaluate runoff water quality from land applied biosolids compared to commercial fertilizer on agricultural fields with typical soil and slope conditions found in southwest Missouri.

Site and Soil Characterization of the Biosolids Project Area, Lawrence County, Missouri

Tom DeWitt and Doug Gisselbeck, William H. Darr School of Agriculture, Missouri State University, Springfield, MO 65897, (417) 848-8404, TomDeWitt@missouristate.edu

The Biosolids Project site is located in northern Lawrence County in the Sac River Watershed. The surface geology of the area is typical of the Springfield Plateau of the Ozarks which is dominated by cherty Mississippian age limestone along with remnants of Pennsylvanian age sandstones. Soil pits were dug for site specific soil descriptions and characterization data at five landscape positions at the site. The dominant parent materials for this site are colluvium over cherty limestone residuum. Soil characteristics range from a well-formed fragipan on the flat uplands to nearly 2 feet of alluvium in the colluvial valley. These data are compared to the published soil survey data and are available on the http://soilsurvey.org site on the CARES website. The Springfield MLRA Soil Survey Office provided major assistance for gathering this documentation in Lawrence County, Missouri.

A Nutrient Strategy that Includes Biosolids: Implications on Soil Health and Water Quality

Steve G. Hefner[1], Bob Pavlowsky[2], Marc Owen[2], Michael Burton[3], Cody Wallace[3], Ed Malter[4], Scott Foley[4], Tom DeWitt[3], and Doug Gisselbeck[3]

[1] Natural Resources Conservation Service, USDA Service Center, Ozark, MO 65721, (417) 581-2719, steven.hefner@mo.usda.gov

[2] Missouri State University, Ozarks Environmental and Water Resources Institute, Springfield, MO

[3] Missouri State University, William H. Darr School of Agriculture, Springfield, MO

[4] City of Springfield Missouri, Public Works, Sanitary Services, Springfield, MO

ABSTRACT

An algal bloom in Table Rock Lake near Branson, Missouri over a decade ago caused discontent among area residents and produced an enhanced awareness of water quality issues. The establishment of more stringent wastewater discharge regulations for the region has required plant operators to remove more phosphorus from discharge effluent. Surface water systems have responded favorably but consequently, more phosphorus remains in the by-product of the waste treatment (biosolids). Instead of alternate disposal methods, the City of Springfield land applies biosolids to grasslands. Many farmers experience the benefits of biosolids application, especially when applied to soils deficient in nutrients and organic matter.

Given the need to obtain local data, the City of Springfield, the Ozarks Environmental and Water Resources Institute at Missouri State University, the Agriculture Department at Missouri State University, the Greene County Soil and Water Conservation District, and the USDA Natural Resources Conservation Service partnered to establish the case study. The purpose of the case study was to quantify any benefits and ease any misconceptions of area residents regarding the threat to water resources. Procedures involved the use of small watershed catchments and various monitoring techniques on a cool season grassland in Lawrence County, Missouri.

This paper will serve to introduce the regional water quality concerns, a discussion on the biosolids and soil health, and the methodology approach behind the case study. Other papers in the workshop provide details regarding the City of Springfield's Biosolids Program, on-site hydrology and nutrient loading dynamics, forage and soil monitoring, and nutrient runoff comparisons through rainfall simulations.

Water Quality and Runoff Characteristics from Agricultural Fields Applied with Biosolids and Mineral Fertilizers, Lawrence County Missouri

Marc Owen, Bob Pavlowsky, and Jennifer Duzan, Ozarks Environmental and Water Resources Institute, Missouri State University, Springfield, MO 65897, (417) 836-3197, mowen@missouristate.edu

ABSTRACT

Biosolids are known to be a safe organic fertilizer for agricultural fields when applied at the proper rate and within specified setbacks limits. However, questions still remain about the impacts on water quality runoff from treated fields under local soil, slope, and crop conditions found in southwest Missouri. This study is designed to evaluate the contamination potential of biosolids compared to traditional mineral fertilizers at the field scale. Four small plots were monitored using runoff auto-samplers that measure the concentrations and loads of nutrients released from fields treated with biosolids and mineral fertilizers over a three year period. Initial results show nutrients from fields treated with commercial fertilizers are more mobile and can deliver higher amounts of nutrients compared to the equivalent low rate biosolids applied site with similar nutrient inputs. Results indicate water quality from the high rate biosolids application is similar to that of the commercial fertilizer. Samples from the low rate biosolids application had concentrations near that of the control site, suggesting properly applied biosolids can have little impact on runoff water quality. More data needs to be gathered and analyzed to verify this trend. Metals and bacteria were only detected in a few samples, so no clear trend could be identified at this time.

Biosolids and nutrient runoff under simulated rainfall.

Cody Wallace and Michael Burton, William H. Darr School of Agriculture, Missouri State University, Springfield, MO 65897, (417) 836-5638, wallace15@live.missouristate.edu

ABSTRACT

Rainfall simulators were used on small plots (1.5m x 2m) during the summer of 2010 to examine the effects of sequential small rainfall events in reducing the potential for nutrient runoff from a large rainfall event. The study was conducted at the State Fruit Experiment Station (Mtn. Grove, MO) on the same soil series (Viraton) as is present at the biosolids project site (near Miller, MO).

Forage productivity and quality in the bio-solids project

Michael Burton and Cody Wallace, William H. Darr School of Agriculture, Missouri State University, Springfield, MO 65897, (417) 836-5085, mikeburton@missouristate.edu

ABSTRACT
Forage was harvested from three plots within each treatment of the biosolids demonstration project. Manner and timing of harvest were selected to simulate a twice-per-year haying system common in south Missouri. Fresh weights were collected at the time of harvest and subsamples were analyzed for moisture and nutrient concentration. The 3- and 6-ton (nominal dry wt/A) biosolids treatments produced more or similar quantities of forage as the mineral fertilizer treatment in both years despite an annual addition of N fertilizer to the mineral fertilizer treatment. Biosolids and mineral fertilizer treatments produced 1.5- to 2-times as much forage on a dry weight basis when compared to an untreated control. Digestible energy (%) and crude protein (%) in the 3- and 6-ton (nominal dry wt/A) biosolids treatments was similar to or greater than levels observed in the fertilized and untreated control treatments on all harvest dates.