The Ozarks Environmental and Water Resources Institute (OEWRI)
Missouri State University (MSU)
City of Springfield, Missouri

YEAR ONE ANNUAL REPORT FOR:

NUTRIENT TRANSPORT AND FATE FROM MUNICIPAL BIOSOLIDS LAND APPLICATION

Prepared by:
Marc R. Owen, M.S., Research Specialist II, OEWRI
Jennifer Duzan, M.S., Research Specialist I, OEWRI
Robert T. Pavlowsky, Ph.D., Director, OEWRI
Michael Burton, Ph.D., Department of Agriculture, MSU
Tom Dewitt, Department of Agriculture, MSU
Cody Wallace, Graduate Assistant, Department of Agriculture, MSU
Doug Gisselbeck, Graduate Assistant, Department of Agriculture, MSU
Steve Hefner, Natural Resources Conservation Service (NRCS)
Scott Foley, Biosolids Coordinator, Springfield

December 9, 2009

OEWRI EDR-09-003

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PHOTOS

SCOPE AND OBJECTIVES

Biosolids is the residual by-product of the municipal treatment of wastewater used to fertilize agricultural fields in southwestern 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[1]). 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 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 P to move off of 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 applied 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, NRCS, and MSU, the City of Springfield 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 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 applied 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 for the project (www.oewri.missouristate.edu). This report organizes and summarizes data collected for the first year of sampling from November 2008 through July 2009 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 data collected 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 the 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. 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, 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 0.5 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.

The experimental design called for four individual nutrient treatments, each applied to a separate catchment. Details of each catchment are given here:

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. This site 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 is designated to receive biosolids application.

Site 4 – (Catchment size = 1.28 acres) this site drains the west side of the ridge running through the property. This site drains the summit and backslope landscape positions. This site will also receive a biosolids application at a rate higher than site 3.

Nutrient Management

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 bulked 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 dry tons/acre application was roughly equivalent to the annual nitrogen recommendation for a 3 tons/acre yield goal of cool season grass (USEPA, 1994[2], UM, 2004). At a rate of 6 dry tons/acre 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 dry ton/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 dry tons/acre 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 calcidic limestone application was made by a commercial dealer on 9-9-2008 to adjust soil acidity to near neutral levels. The biosolids applications were made with a commercial Terra-Gator 3104 side discharge spreader on 10-23-2008 and the fertilizer applied by a commercial dealer on 10-28-2008. 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 2).

Site 1 would receive 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 ($N+P_2O_5+K_2O$) will be applied to mimic the slow release of N from the breakdown of biosolids over that time. Site 3 received 3 dryT/ac biosolid application, which is equivalent to the commercial fertilizer application. Finally, site 4 received 6 dryT/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 8-5-2009 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 dry tons/ac .

Hydrology and Water Quality Sampling

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 1). 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 $1/100^{th}$ inch increments over 5 minutes time periods. A pressure transducer level sensor with datalogger is 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 2 and Photos 1 and 2).

A strainer was positioned next to the pressure transducer upstream of each dam and connected to the auto-sampler with a 25 ft. suction line. Weirs at sites 3 and 4 had to be continually modified until samples began collecting. 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. Upon collection, bottles were removed from the sampler and composited and thoroughly homogenized in a one gallon container.

For logistical reasons, the auto-samplers were set to collect an event composite. They were fitted with 10 L Nalgene composite bottles and reprogrammed to both save time and limit error in the field as well as reduced prep time in the lab. Since June 2009, auto-samplers collect 500 ml samples every fifteen minutes when rainfall rate and level reach set point (0.10 in/30 min and 0.1 ft., respectively). After a sample has collected, composite bottles are removed, and the sample is split for further analysis. The composite sample was split among four 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, (3) total suspended solids (TSS), fecal coliforms, and pH – no preservative, and (4) specific conductivity – no preservative. 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, TSS, fecal coliforms, and pH following Environmental Protection Agency Methods (EPA) and Standard Methods for the Examination of Water and Wastewater (SM4500) protocol (Table 4). Samples were analyzed at Ozarks Environmental and Water Resources Institute for specific conductivity by a Horiba U22 multi-probe meter. More details on the analyses can be found at http://www.epa.gov/waterscience/methods/.

Surface Soil Monitoring

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 (Figure 3, Table 5 and Photo 3). To compare variability within each landscape position, four soil samples were collected along a transect at each landscape position; three on a 14 ft. cross-section. One randomly selected duplicate was collected to measure sampling variability. A total of twelve samples were collected at each site. 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. A total of 48 samples were collected in year one. Data on site and sample variability can be found in Appendix G.

Surface Soil Analysis

Samples were processed at Missouri State University 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).

Soil Morphology Characterization

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.

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 was measured by harvesting a known area of land, taking fresh forage weights, and drying subsamples to determine moisture content. Samples were also collected and sent to a laboratory for analysis of other 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 X 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. 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, MO.

YEAR 1 - PRELIMINARY RESULTS

Sample Collection and Hydrology

A total of 23 composite samples were collected at all four sites over a 9 month period between November 1, 2008 and August 1, 2009. Of the 23 composite samples collected, 6 were from site 1, 9 from site 2, 5 from site 3, and 3 from site 4 (Table 6). Samples were not collected over that period because:

1. Small catchments area
2. Equipment malfunctions (dead batteries, clogged lines, etc.)
3. Height of vegetation and dormancy
4. Pre-storm soil moisture conditions

5. Dam and weirs needed “seasoning” following installation

Runoff was generated either during relatively short, high intensity storm events, or relatively long, low intensity storm events. Rainfall totals generating runoff ranged from 0.56 inches on November 6, 2008 to 1.89 inches June 16, 2009 (Table 6). Individual storm rainfall intensities over the same period ranged from 0.06 in/hr (1.29 inches in 21.5 hrs) on April 19-20, 2009, to 1.18 in/hr (0.93 inches in 0.8 hrs) on May 13, 2009. Rainfall depth was converted to volume that ranged from 772 ft^3 at site 1 on November 6, 2008 to 18,731 ft^3 at site 3 on June 16, 2009. In general, > 1 inch of rain is needed to generate runoff if the event duration is greater than 1 hour. Runoff is generated even over long, slow rainfall events >1 inch when field capacity is reached and rainfall is greater than infiltration capacity. For rainfall durations < 1 hour, rainfall intensities of 1 in/hr are needed to generate runoff as rainfall exceeds infiltration rate. Again, these estimates vary by season.

Runoff discharge also varied among catchments over the sampling period due to variability in rainfall, drainage area, soils, vegetation, and slope. Some rainfall intensities were able to generate 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, but no runoff data could be generated. For the storm events where runoff data was generated, peak instantaneous discharge measurements ranged from as low as 0.009 cfs on Feb. 10, 2009 for site 2 to as high as 0.58 cfs on June 16, 2009 at site 3 (Table 7). The maximum capacity of a 1 foot, 90 degree weir is 1 cfs.

Storms generating enough runoff to activate the stage recorder varied from as low as 1.5 ft^3 at site 1 on May 13, 2009 to as high as 4,358 ft^3 at site 3 on May 1, 2009. Runoff volume as a percentage of total rainfall volume also ranged from 0.1% runoff at site 1 on May 13, 2009 to 24.1% runoff at site 3 on May 1, 2009. These data suggest that under the current conditions of the site, nearly 25% of the total rainfall volume can leave the site as runoff at certain rainfall intensities. 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. The continued hydrological monitoring in the next year will help better understand the rainfall-runoff dynamics of this site.

Another observation worth mentioning is that the catchment draining site 4 has proven to behave differently than the other sites. Site 4 is located on the western slope of the ridge that runs south-to-north across the property, while the other 3 sites are located on the eastern side of the slope. Data collected over the study period indicates the western facing slope receives slightly more rainfall than the other sites, anywhere from 2%-17% higher rainfall amounts.

Most storms in this area come from the west, and whether the winds force more rain into the rain gage, or the sites on the eastern slope are a little more sheltered, there is a disparity in the total rainfall each side of the slope receives during some storms. Furthermore, runoff volumes at site 4 are also low compared to the same storms at the other sites. This most likely is due to the rockiness of site 4, where less water stays on the surface due to higher permeability soils on that side of the ridge.

Water Quality

Median TP concentrations for all samples vary from 0.06 mg/L at site 4 to 4.11 mg/L at site 2 (Figure 4). Sites 1 and 3 have similar median TP concentrations around 0.3 mg/L. Site 2, with commercial fertilizer, had the highest concentration of TP in the samples collected at over 34 mg/L during the November 6, 2008 storm event. This event was the first collected after commercial fertilizer was applied to site 2. Over the first year of this study it appears site 2 has produced the highest TP values among sites, with site 4 (6 dryT/ac) having the highest variability. Sites 1 and 3 seem to have similar TP concentrations so far in the study.

Median TKN concentrations ranged from 0.98 mg/L at site 4 to 3.62 mg/L at site 2 (Figure 5). Sites 1 and 3 had similar median TKN concentrations of 2.51 and 2.85 mg/L. Similar to TP concentrations, sites 2 and 4 have the highest variability among sites, and site 2 also has the highest concentration of TKN detected in this study at 66.7 mg/L in the November 6, 2008 storm event. Again sites 1 and 3 have similar variability over the sampling period.

Median total ammonia concentrations ranged from 0.14 mg/L at site 3 to 0.44 mg/L at site 4 (Figure 6). Sites 1 and 2 had similar median total ammonia concentrations of 0.26 and 0.19 mg/L. Again, site 2 has the highest overall total ammonia concentration of 37.4 mg/L during the November 6, 2008 storm. However, site 4 has the highest overall total ammonia concentration among sites. If the November 6, 2008 sample from site 2 is removed, site 4 has almost double the total ammonia concentration compared to the other three sites.

Median nitrate concentrations ranged from 0.12 mg/L at site 3 to 0.28 mg/L at site 4 (Figure 7). Sites 1 and 2 were slightly higher median nitrate concentrations than site 3 at 0.14 and 0.16 mg/L, respectively. Site 2 has the highest nitrate concentration among sites at 2.64 mg/L for the November 6, 2008 storm sample. Site 2 also has the highest variability in nitrate concentrations, but site 1, the control, has the second highest variability among sites. These data suggest that there is a natural variability of nitrate during storm events.

Median TSS concentrations ranged from 3 mg/L at site 3 to 34 mg/L at site 4. Sites 1 and 2 have similar TSS concentrations of 11 and 8 mg/L (Figure 8). Site 4, the 6 dryT/ac of biosolids, had the highest TSS concentration among sites at 180 mg/L. Sites 2 and 4 had the highest variability in TSS concentrations, but if the November 6, 2008 storm sample is removed site 4 clearly has the highest TSS concentrations among sites. Sites 2 and 3 had similar TSS concentrations with all samples containing < 20 mg/L TSS.

Median pH were very similar ranging from 7.1 to 7.3 for all 4 sites (Figure 9). Site 2, however, had the highest variability in pH readings ranging from 6.9 to 7.5.

Metals were detected in 4 of the 23 samples collected over the study period. At site 4, 6.3 ug/L Zn was detected in the water sample from the May 21, 2009 storm event (Table 8). Also at site 4, 69.1 ug/L Zn and 19.6 ug/L Cu were detected in the June 16, 2009 storm sample. At site 1, which is the control, 14.2 ug/L Cr and 10.8 ug/L Ni were detected in the May 21, 2009 storm sample. At site 2, 6.4 ug/L Zn was detected in the July 21, 2009 storm sample. All metals were non-detect for the remaining 19 samples collected.

Due to extremely high variability in Fecal Coliform concentrations, the geometric mean is used to describe variability among sites. The geometric means range from 30.2 coli/100 mL at site 3 to 68.3 coli/100 mL at site 2 (Table 9). All sites were below detect for the May 1, 2009 and May 14, 2009 storm samples, and these values were used to calculate the geometric mean using half the detection limit value. The highest Fecal Coliform concentration was 190,000 coli/100 mL at site 4 for the June 16, 2009 storm sample.

The field blanks and duplicates were high for nutrients during some events. These issues are being addressed with moving to the composites bottle sampling method.

Surface Soils

Soil pH and nutrients followed similar patterns with sites 1 and 2 sharing similar characteristics and sites 3 and 4 having similar characteristics (Figure 10). Median soil pH ranged from 5.8 to 5.9 at sites 1 and 2 while sites 3 and 4 had a soil pH range from 6.2 to 6.4. Minimum pH values were near 5.4 at sites 1 and 2. Soil P was nearly twice as high in sites 1 and 2 as in site 3 and 4 (Figure 11). Median soil P ranged from 11 ppm at site 3 and 4, to 23 ppm at site 1. Sites 1 and 4 had the highest within site variability of > 20 ppm. Soil N was just the opposite with sites 1 and 2 having no N measured, but sites 3 and 4 had median N values of 8 and 9 ppm (Figure 12).

With the exception of Zn and Pb, metals in the surface soils were fairly consistent among sites. Median soil Zn ranged from 0.9 ppm at site 4 to 2.1 ppm at site 2. The highest variability of Zn concentrations was at site 3 ranging from 0.9 to 3.4 ppm (Figure 13). Median total Pb in the soil ranged from 28 ppm at site 4 to 35 ppm at site 2 (Figure 14). The highest variability in soil Pb was at sites 1 and 2 with concentrations ranging 9 ppm from the minimum to maximum values. Median concentrations of Cu, Cd, and Ni did not vary among sites, and median Cr concentrations were 0.1 ppm for sites 1 and 2 and 0 at sites 3 and 4 (Figure 15-18).

Site and sample variability was high for some samples, but another year and further analysis is needed to verify.

Soil Morphology

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 14). 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. The presence of redoxamorphic features above the fragipan and within the prismatic seams through the fragipan are indicators of a seasonally high water table. The steeper sides slopes are coarser closer to the surface, with sporadic remnants of weathered sandstone present 50" to 60" below the surface. In the bottom of the colluvial valley there is nearly a 2 foot accumulation of alluvium over colluvium that contains high chert content.

Forage Analysis

Testing the forage harvested from each of the 4 sites showed improvement in the quantity of forage but not the quality of the forage at the sites where biosolids are applied compared to the control. Nitrogen content in the forage was higher at sites 3 and 4, with site 4 having the highest percentage (1.78%) (Figure 17). Phosphorus content was at least 30% higher in the fields that were treated with fertilizer or biosolids compared to the control. Copper content was relatively uniform among sites 2, 3, and 4, and lower at site 1. Zinc content was highest for forage collected at sites applied with biosolids (22.3 ppm at site 3 and 23 ppm at site 4) compared to sites 1 and 2 (17.67 ppm at each). Sites 3 and 4 had the highest forage yields with 2.1 and 2.7 dryT/ac being collected, with site 2 having 1.7 dryT/ac, and site 1 having 0.9 dryT/ac (Table 5). Overall forage quality was poor with Relative Feed Values (RFV) of <80 at all sites. Forage quality was ranked as poor for sites 1, 3, and 4, and site 2 had a reject forage grade. The plots lacked true replication, the results were averaged across landscape positions within each

treatment. The results should therefore be considered descriptive statistics rather than results of a properly constructed hypothesis test.

CONCLUSIONS

This report covers the activities over the first year of the Biosolids Runoff Monitoring Project from May 2008 through July 2009. There are 9 main conclusions of this report:

1. Samples sites were 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 dryT/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 dryT/ac was applied. Site 1 was not treated and left as the control.
3. 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.
4. Over the 9 month sampling period (November 1st, 2008 – July 31st, 2009) covered by this report, 23 individual composite samples were collected and analyzed. Rainfall intensities capable of producing runoff ranged from quick, high intensity rain events lasting < 1 hour to long, slow rain events that last several hours.
5. The amount of runoff volume generated from different storm events varied with rainfall intensity and duration. Maximum runoff volume measured over the sampling period was as high as 25% of the recorded rainfall measured as runoff for the larger storm events.
6. Concentrations of nutrients, metals and TSS were higher and more variable at site 2 and site 4 than at sites 3 and 1. Site 2 has treated with commercial fertilizer and site 4 was treated at the 6 dryT/ac biosolids application rate. No pattern could be seen in the total coliform concentrations over the sampling period.
7. Surface soil samples were collected and analyzed for nutrient and metals prior to application of fertilizer and biosolids to establish baseline soil geochemisrty. Three samples and one duplicate were collected at each of three landscape positions in each catchment for a total of 48 samples in year one.

8. Five individual soil pits were characterized for soil morphology over the study area to access 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.
9. Forage was cut, collected and analyzed to measure differences in metal uptake and forage quality and quaintly among treated catchment areas. Metal content was similar for forage collected among sites with Zn being slightly higher in forage from the biosolids applied plots. Generally, forage quality is poor off of all plots, with the commercial fertilizer catchment having the lowest quality forage. Forage collected from site 4 produced the highest yield (2.7 T/ac), then site three (2.1 T/ac), site 2 (1.7 T/ac) and site 1 (0.9 T/ac).

Over the next year, a second round of soil testing and another year of water sampling will provide a larger dataset to which comparisons may be drawn.

REFERENCES

Al-Wabel, M.A., D.M. Heil, D.G. Westfall, and K.A. Barbarick, 2002. Solution Chemistry Influence on Metal Mobility in Biosolids-Amended Soils. Journal of Environmental Quality 31:1,157-1,165.

Correll, D.L., 1999. Phosphorus: A Rate Limiting Nutrient in Surface Waters. Poultry Science 78:674-682.

Dodds, W.K., 2006. Eutrophication and Tropic State in Rivers and Streams. Limnol. Oceanogr., 51(1, part 2):671-680.

Duncomb, D.R., W.E. Larson, C.E. Clapp, R.H. Dowdy, D.R. Linden, and W.K. Johnson, 1982. Effect of Liquid Wastewater Sludge Application on Crop Yield and Water Quality. Water Pollution Control Federation, Vol. 54, No 8, Conference Preview Issue, (August 1982) pp. 1,185-1,193.

French, R.H., 1985. Open-Channel Hydraulics. McGraw-Hill, New York.

Galdos, M.V., I.C. De Maria, O.A. de Camargo, and S.C Falci Dechen, 2009. Sewage Sludge Application on Cultivated Soils: Effect on Runoff and Trace Metal Load. Sci. Agric. (Piracicaba, Braz.), 66(3):368-376.

Hughes, H.E., 1982. Soil Survey of Greene and Lawrence Counties, Missouri. United States Department of Agriculture, Soil Conservation Service.

Missouri Department of Natural Resources (MDNR), 1985. Agricultural Use of Municipal Wastewater Sludge - A Planning Guide. Division of Environmental Quality, Water Pollution Control Program, Second Addition.

Richards, B.K., B.M. Schulte, A. Heileg, T.S. Steenhuis, M.B. McBride, E.Z. Harrison, and P. Dickson, 2004. Environmental Impacts of Applying Manure, Fertilizer, and Sewage Biosolids on a Dairy Farm. Journal of the American Water Resources Association, 40(4):1,025-1,042.

Shober, A.L. and J.T. Sims, 2003. Phosphorus Restrictions for Land Application of Biosolids: Current Status and Future Trends. Journal of Environmental Quality, 32:1,955-1,964.

Spicer, S., 2002. Fertilizers, Manure, or Biosolids? Researchers Compare the Benefits and Risks of Fertilizers and Soil Amendments. Water Environment and Technology Publication, 14(7) p.32.

United States Environmental Protection Agency, 1994[1]. A Plain English Guide to the EPA Part 503 Biosolids Rule. Office of Wastewater Management, Washington D.C., EPA/832/R-93/003.

United States Environmental Protection Agency, 1994[2]. Land Application of Sewage Sludge: A Guide for Land Appliers on the Requirements of Federal Standards for the Use or Disposal of Sewage Sludge 40-CFR Part 503, p. E-7, Exhibit E-3. Example Mineralization Rates. Washington D.C., EPA/831/B-93/002b.

University of Missouri, 2004. Soil Test Interpretations and Recommendations Handbook. College of Agriculture, Division of Plant Sciences.

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. Watershed and Nutrient Management Details at the Study Site

Site	Treatment Name	Experimental Year	Planned Nutrient Application (lbs/a) $N + P_2O_5 + K_2O$	Actual Nutrient Application (lbs/a) $N + P_2O_5 + K_2O$
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 3. 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	$Q = 1.9069(d_w)^3 - 0.4207(d_w)^2 - 0.0981(d_w) + 0.0206$
2	0.65	1.18	0.6	0.22	$Q = 1.4413(d_w)^3 + 0.3164(d_w)^2 - 0.4538(d_w) + 0.0733$
3	3	1.18	0.6	0.26	$Q = 1.626(d_w)^3 - 0.5969(d_w)^2 - 0.2461(d_w) + 0.091$
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 4. 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 5. 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)
Site 1	Footslope	0 – 98	26
	Backslope	98 - 180	131
	Summit	> 180	295
Site 2	Footslope	0 – 131	53
	Backslope	131 - 213	131
	Summit	> 213	279
Site 3	Footslope	0 – 131	66
	Backslope	131 - 253	197
	Summit	> 253	459
Site 4	Footslope	0 – 98	69
	Backslope	98 - 246	164
	Summit	> 246	328

Table 6. Rainfall Totals, Duration, and Sites Collected for Storm Events

Date	Total Rainfall (in)	Rainfall Duration (hrs)	Sites Collected
11/6/09	0.56	0.63	1 & 2
2/11/09	1.72	15.1	1 & 2
4/12/09	1.2	12.4	1, 2, & 3
4/20/09	1.27	21.5	2 & 3
5/1/09	1.68	12	1, 2, 3, & 4
5/13/09	0.93	0.80	1, 2, 3, & 4
6/16/09	1.72	8.50	1, 2, 3, & 4
6/30/09	1.1	6.6	2
7/20/09	1.83	23.4	2

Table 7. Rainfall and Discharge Data

Date	Site	Total Rainfall	Duration	Peak Rainfall Intensity	Avg. Rainfall Intensity	Total Rainfall Volume	Peak Q	Total Runoff Vol.	Est. Runoff	Est. Infiltration
		(in)	(hr)	(in/5min)	(in/hr)	(ft3)	(cfs)	(ft3)	%	%
11/6/2008	1	0.56	0.63	0.13	0.88	772	0.01	3	0.3	99.7
2/11/2009	1	1.72	15.1	0.18	0.11	2,373	0.009	66	2.8	97.2
4/12/2009	1	1.29	12.4	0.05	0.1	1,779	0.02	145	8.2	91.8
5/1/2009	1	1.59	11.5	0.25	0.14	2,193	0.11	466	21.2	78.8
5/13/2009	1	0.93	0.8	0.22	1.16	1,283	0.003	1.5	0.1	99.9
6/16/2009	1	1.74	8.4	0.27	0.21	2,400	0.18	318	13.3	86.8
11/6/2009	2	0.56	0.63	0.13	0.88	1,321	nd	nd	nd	nd
2/10/2009	2	1.76	15.3	0.3	0.12	4,153	0	0	0	100
4/12/2009	2	1.2	15.3	0.05	0.08	2,831	0	0	0	100
4/20/2009	2	1.29	21.5	0.1	0.06	3,044	0	0	0	100
5/1/2009	2	1.67	11.8	0.26	0.14	3,940	0.06	396	10.1	89.9
5/13/2009	2	0.94	0.8	0.22	1.18	2,218	0.019	17	0.8	99.2
6/16/2009	2	1.72	8.5	0.1	0.20	4,058	0.29	757	18.7	81.3
6/30/2009	2	1.1	6.6	0.03	0.17	2,595	0.08	39	1.5	98.5
7/20/2009	2	1.83	23.4	0.18	0.08	4,318	0	0	0	100
4/12/2009	3	1.27	15.5	0.05	0.08	13,830	0.09	984	7.1	92.9
4/20/2009	3	1.24	21.5	0.07	0.06	13,504	0.04	406	3	97
5/1/2009	3	1.66	12.1	0.25	0.14	18,077	0.41	4,358	24.1	75.9
5/13/2009	3	0.93	0.8	0.2	1.16	10,128	0.02	90	0.9	99.1
6/16/2009	3	1.72	8.5	0.1	0.20	18,731	0.58	3,112	16.6	83.4
5/1/2009	4	1.78	12.2	0.23	0.15	8,271	0.02	128.5	1.6	98.4
5/13/2009	4	0.95	0.75	0.17	1.27	4,414	0	0	0	100
6/16/2009	4	1.89	10.4	0.16	0.18	8,782	0.02	86.5	1	99

Table 8. Metals Detected in Water Samples

Site	Date	Metal Detected (ppb)			
		Cr	Ni	Zn	Cu
1	6/16/2009	14.2	10.8	-	-
2	7/21/2009	-	-	6.4	-
4	5/21/2009	-	-	6.3	-
4	6/16/2009	-	-	69.1	19.6

Table 9. Fecal Coliform in Water Samples

Site	Minimum (coli/100mL)	Geometric Mean (coli/100mL)	Maximum (coli/100mL)
1	<MDL	288	29,000
2	<MDL	278	8,000
3	<MDL	464	9,000
4	<MDL	190,000	190,000

Table 10. 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 11. Forage Analysis Data

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 Standrd	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 (extrap)	0.9		1.7		2.1		2.7	

FIGURES

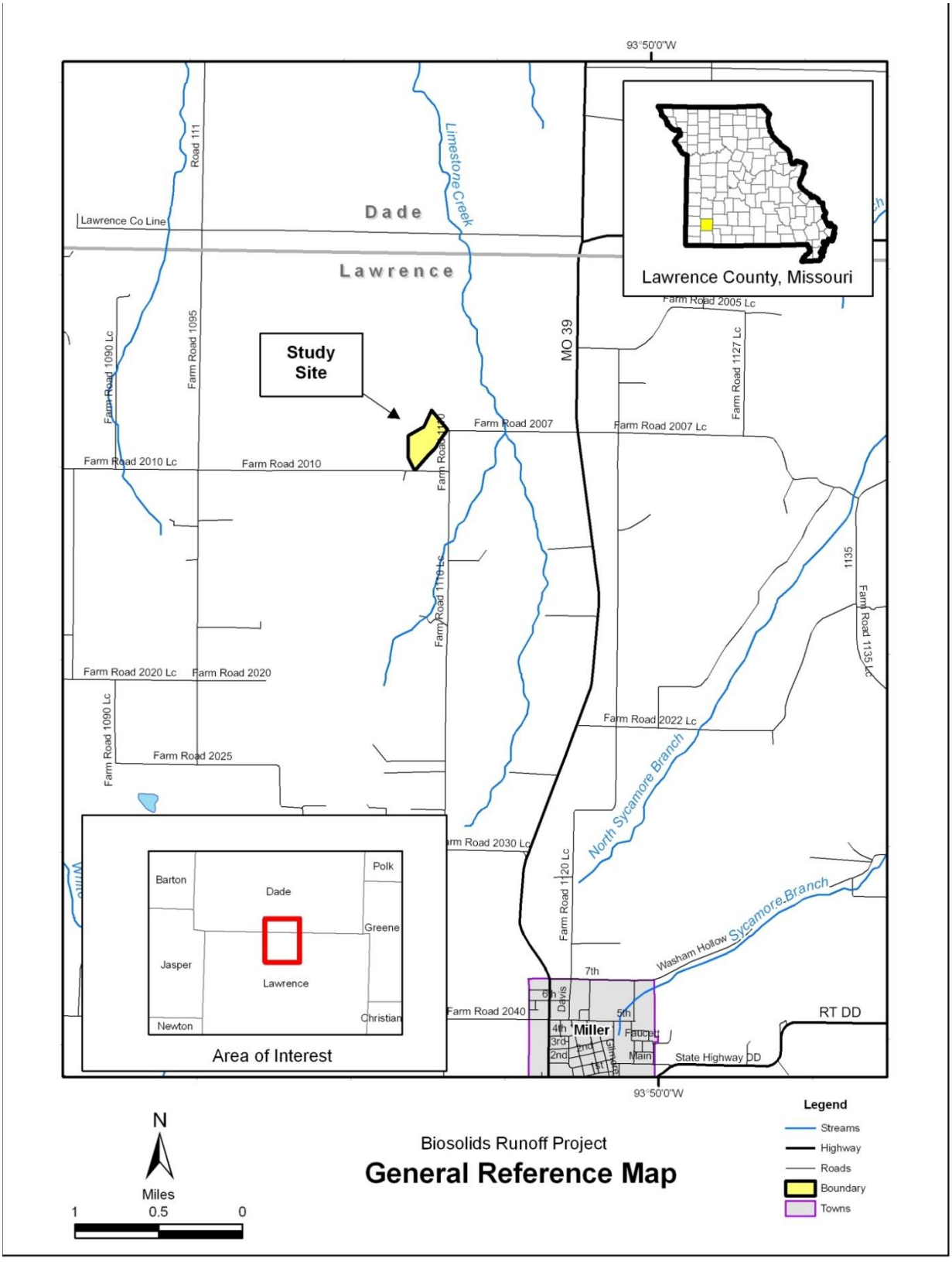


Figure 1. Study site location

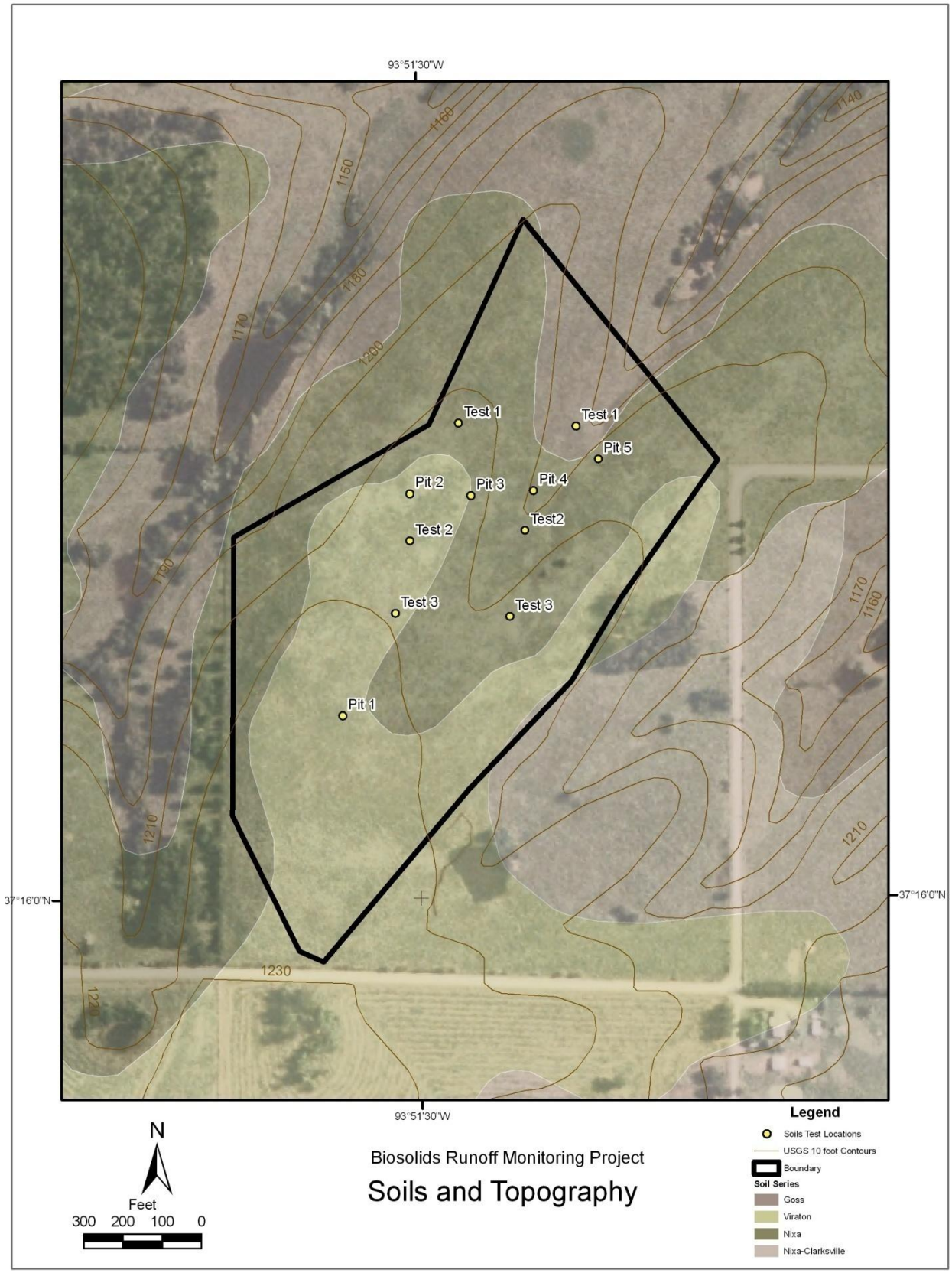


Figure 2. Mapped soils with soil test and soil morphology soil pit locations

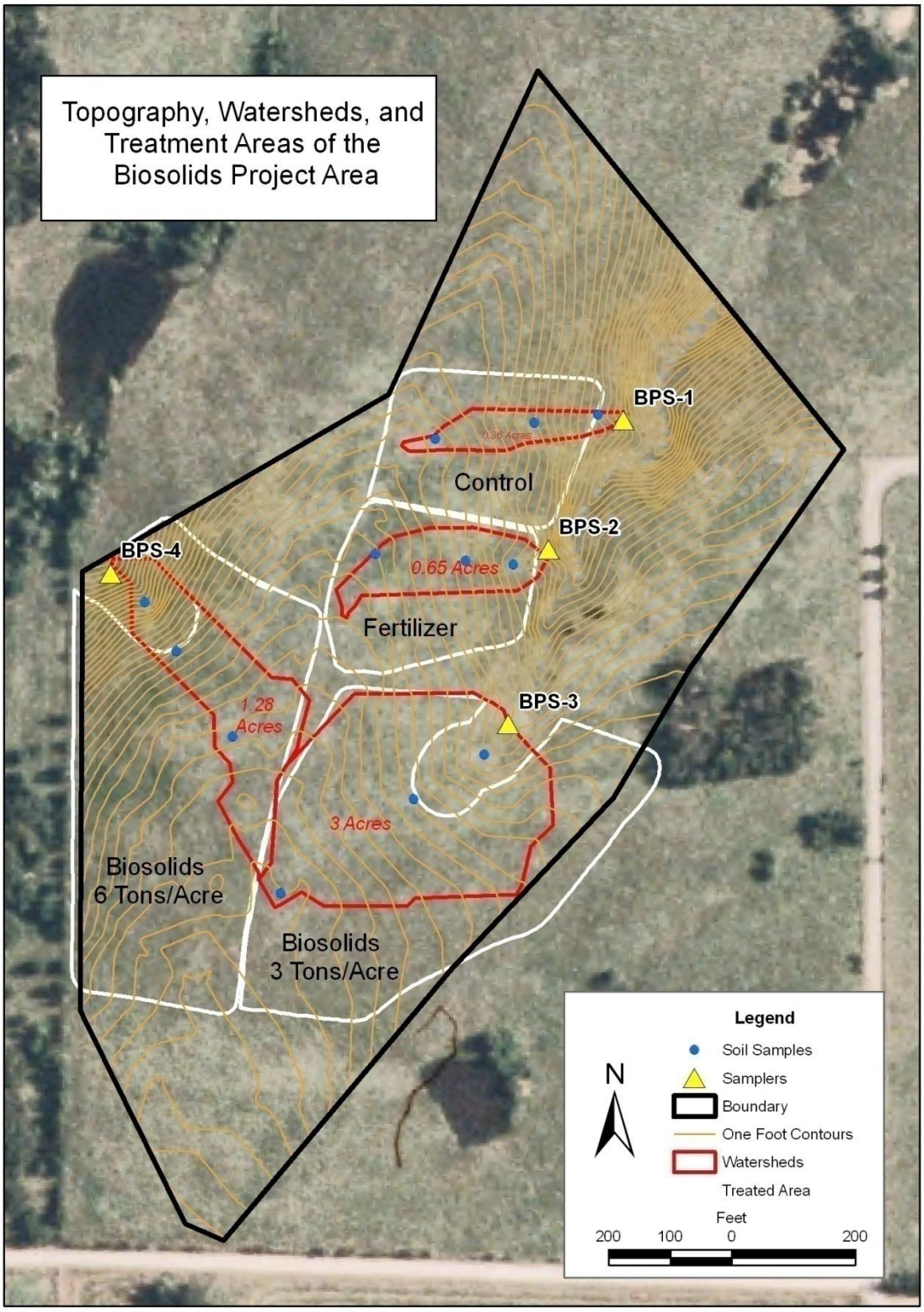


Figure 3. Site topography, watershed areas, surface soil sample locations, and treatment zones

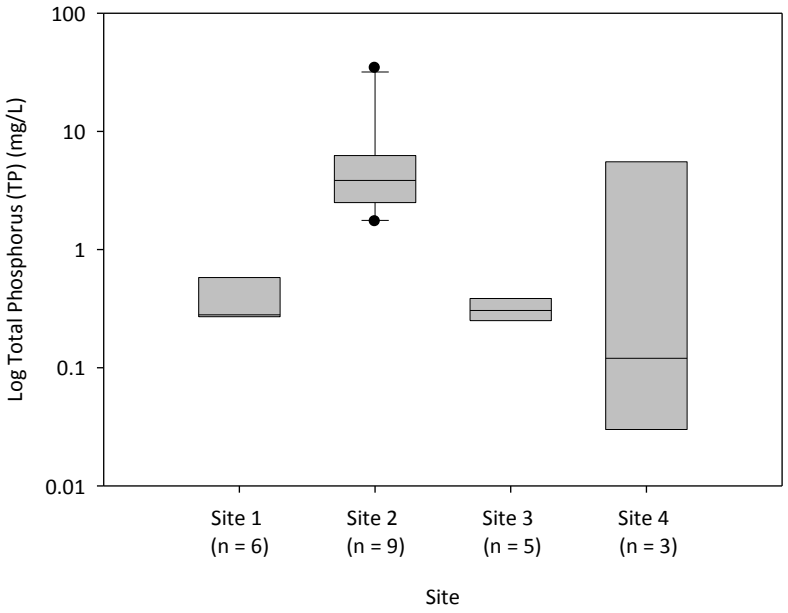


Figure 4. Total Phosphorus

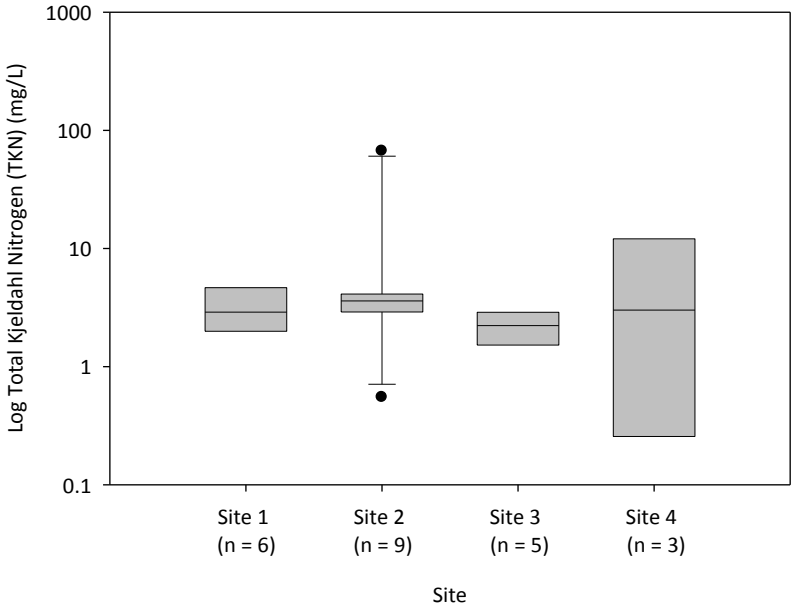


Figure 5. Total Kjeldahl Nitrogen

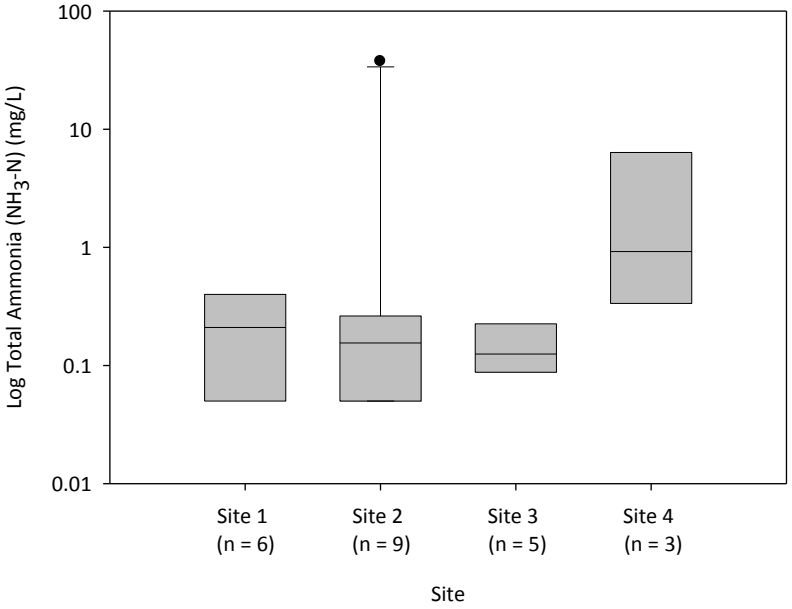


Figure 6. Total Ammonia

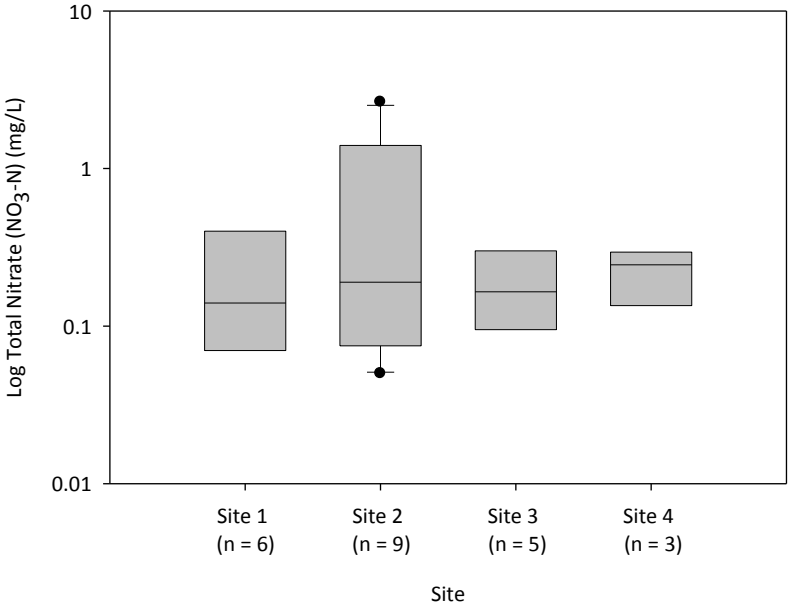


Figure 7. Total Nitrate

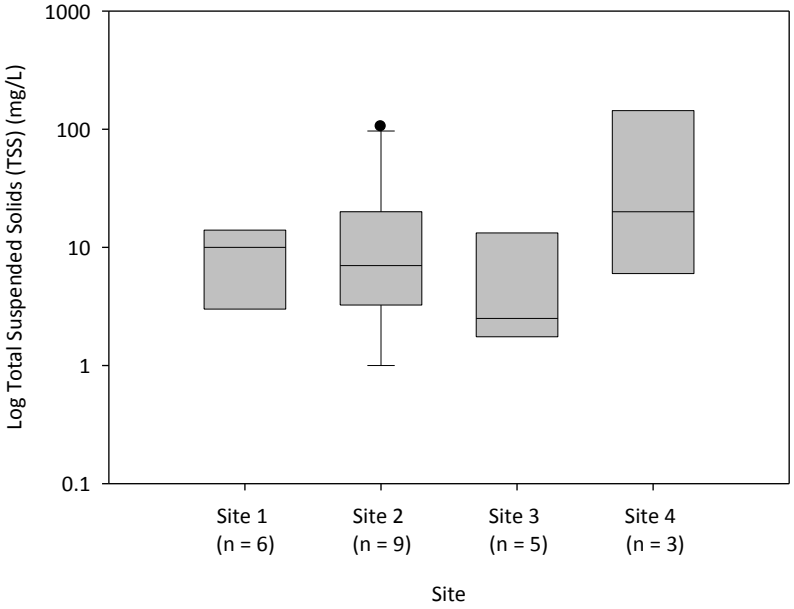


Figure 8. Total Suspended Solids

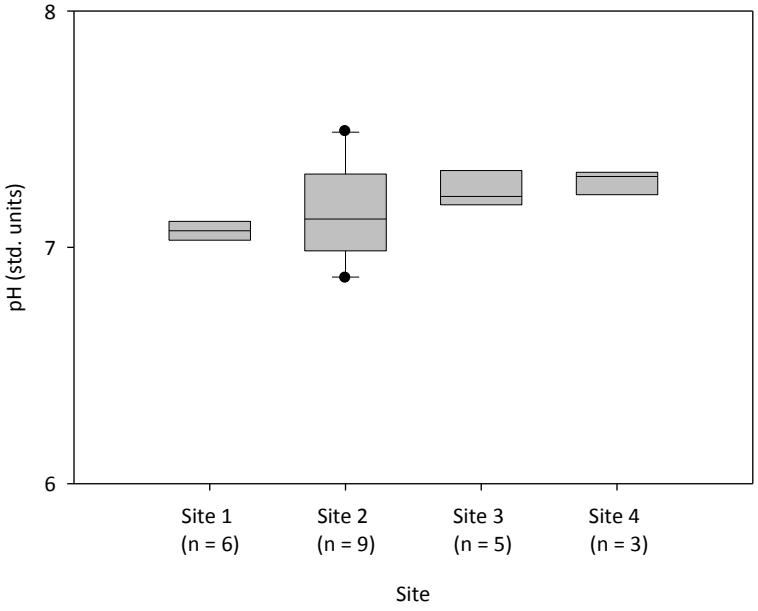


Figure 9. Water Sample pH

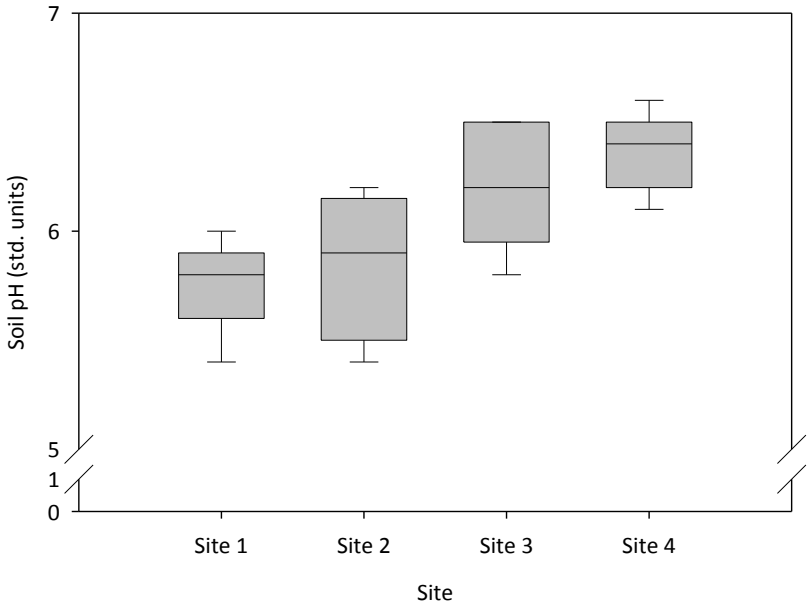


Figure 10. Soil pH (n=9 each site)

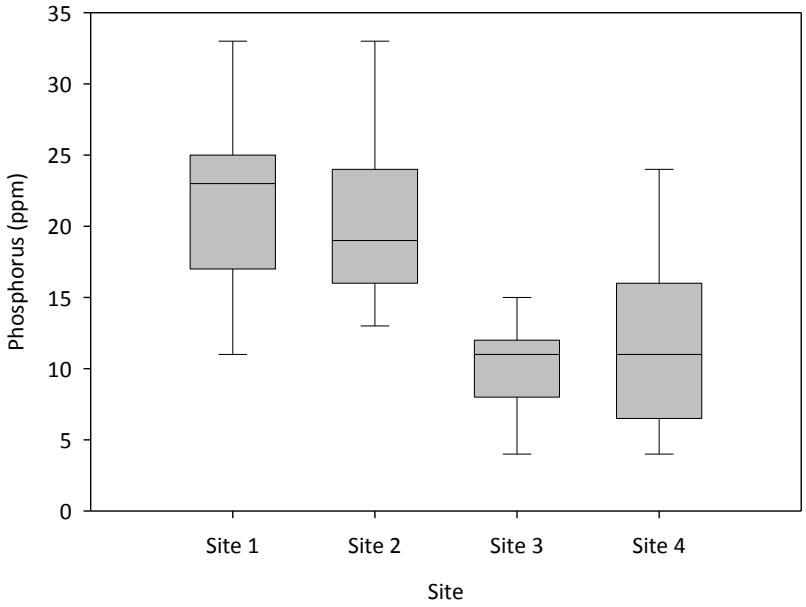


Figure 11. Soil Phosphorus (n=9 each site)

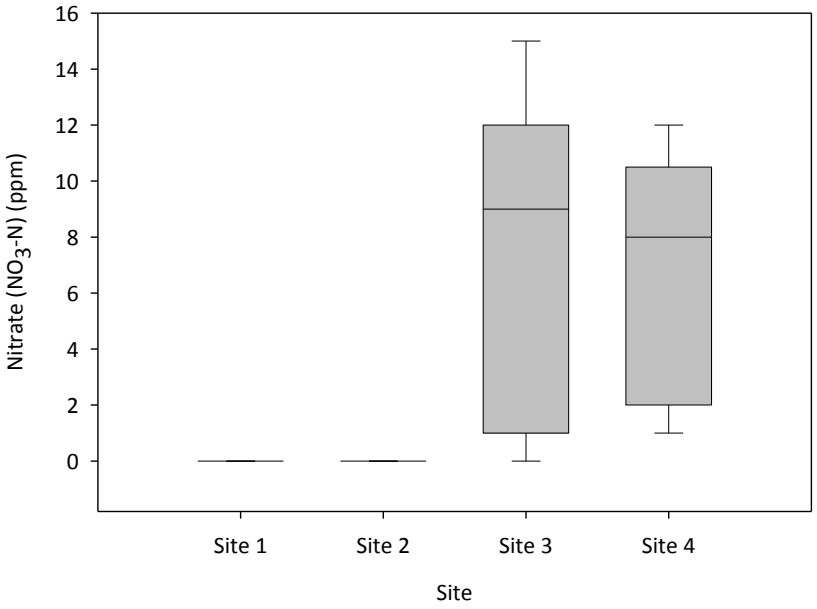


Figure 12. Nitrate in Soil (n=9 each site)

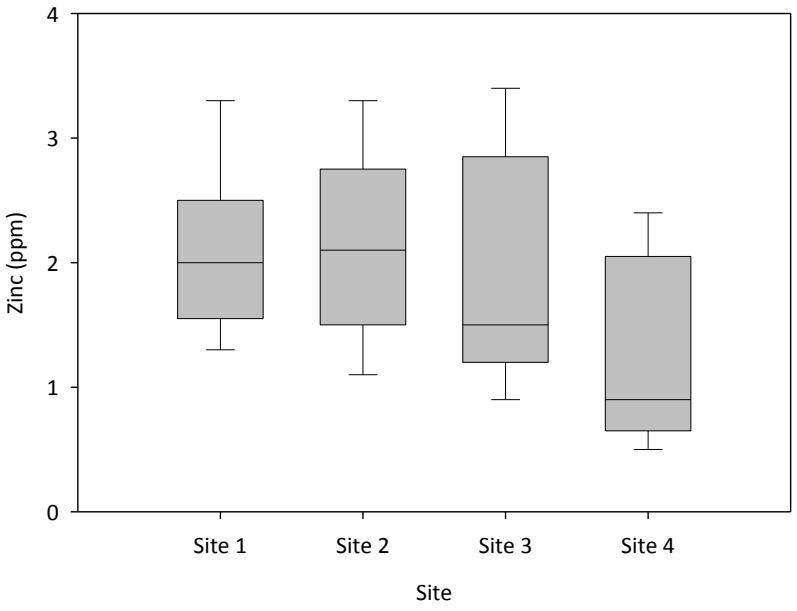


Figure 13. Soil Zinc (n=9 each site)

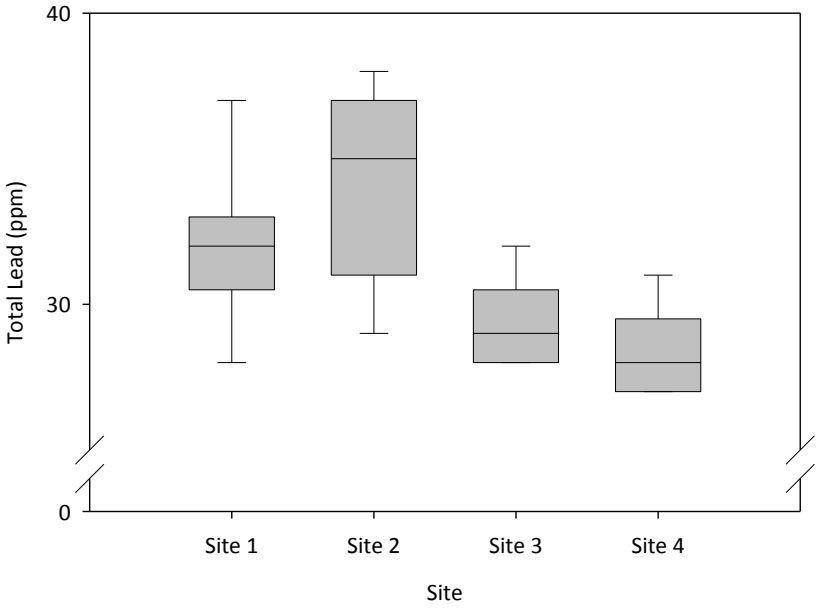


Figure 14. Total Lead in Soil (n=9 each site)

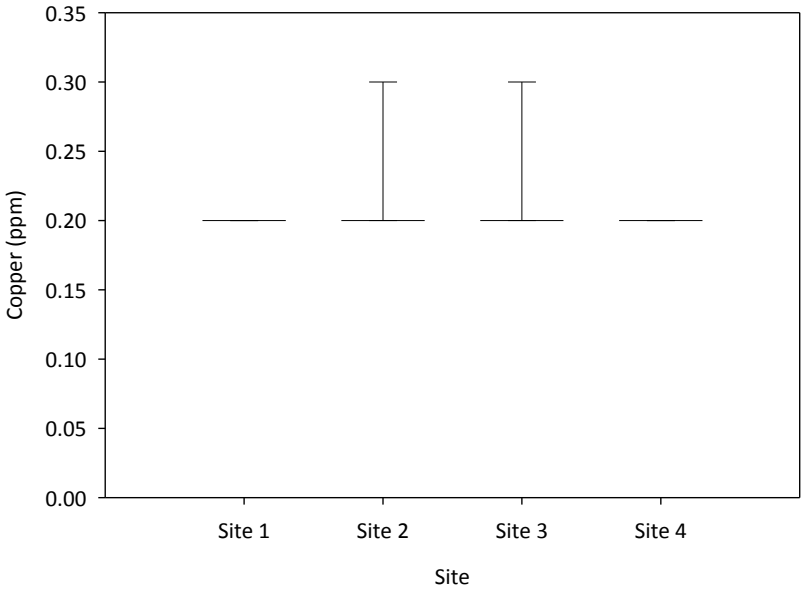


Figure 15. Soil Copper (n=9 each site)

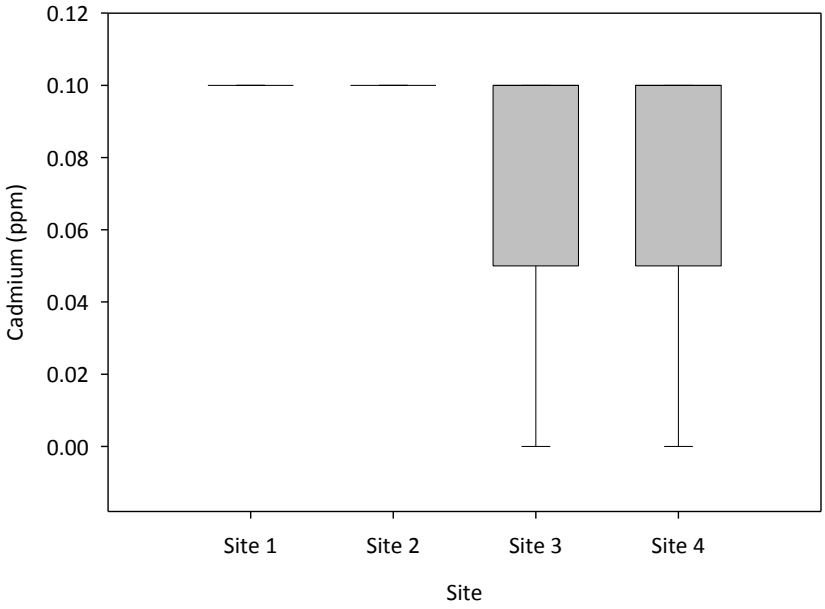


Figure 16. Cadmium in Soil (n=9 each site)

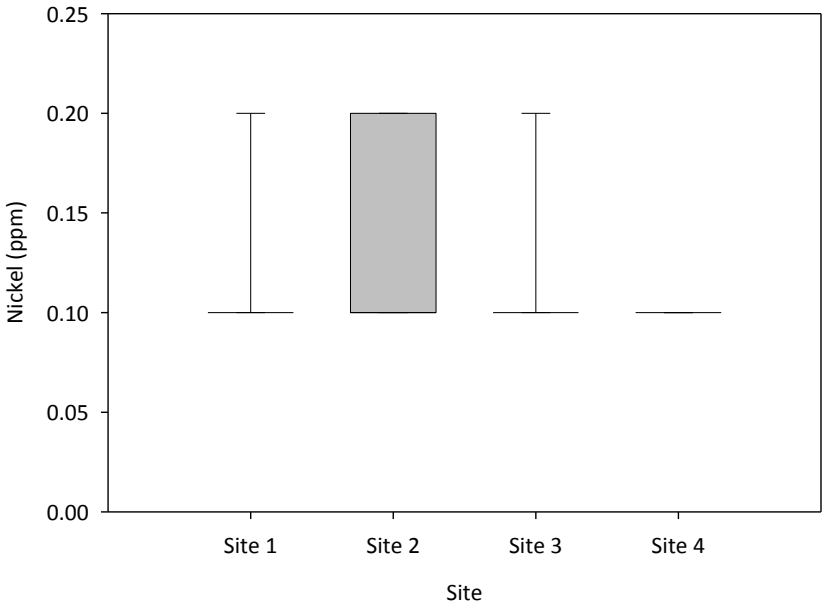


Figure 17. Nickel in Soil (n=9 each site)

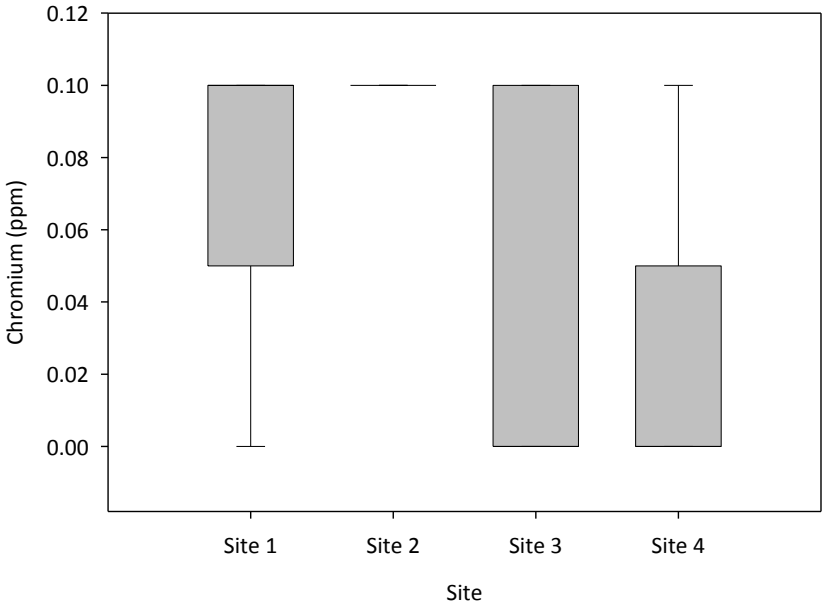


Figure 18. Chromium in Soil (n=9 each site)

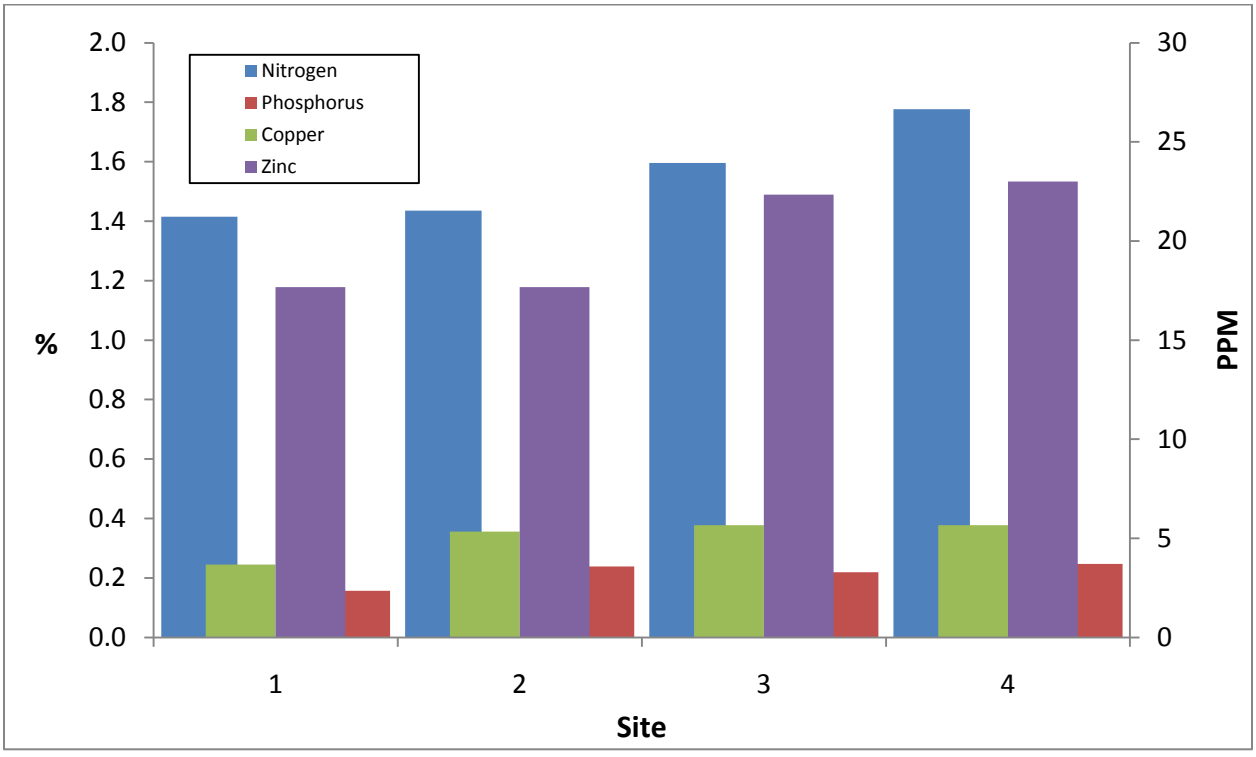


Figure 19. % Nitrogen, % Phosphorus, Copper (ppm) and Zinc (ppm) in Forage

PHOTOS

Photo 1. V-Notch Weir, Pressure Transducer, and Strainer Location

Photo 2. Presssure Transducer and Strainer Location

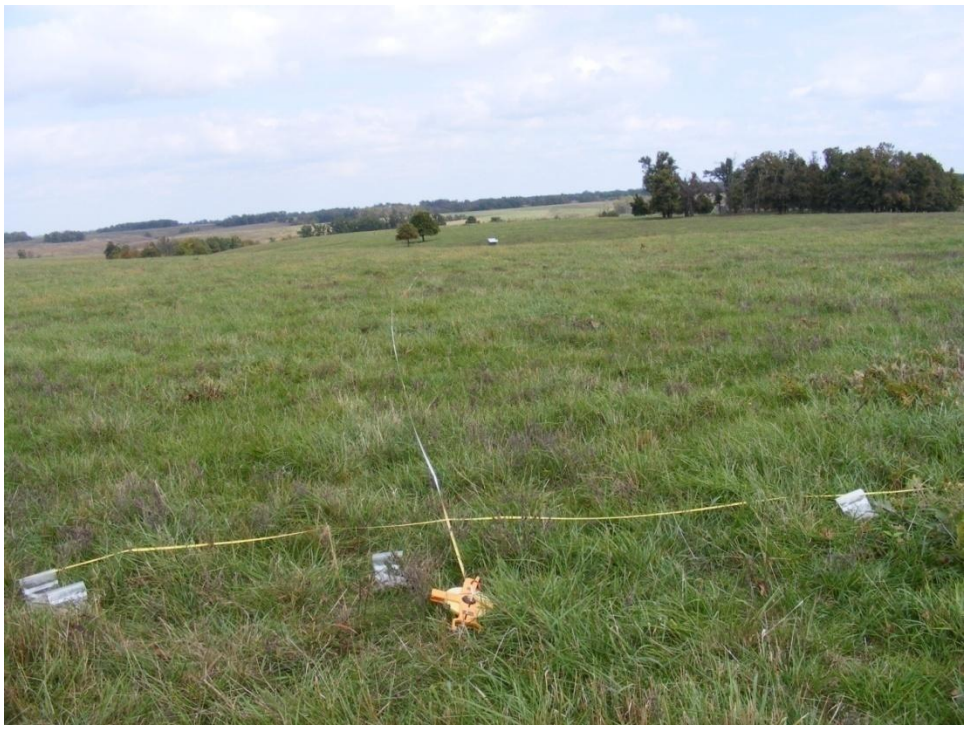


Photo 3. Surface Soil Sample Transect

Photo 4. Sampler housing along main draw on the project site (October 2008)

Photo 5. Auto-sampler and Rain Gage Installation (October 2008)

Photo 6. Tom Dewitt Soil Coring Along the Ridge with Class (October 2008)

Photo 7. Example of a Soil Profile at the Project Site (Loess over Colluvium over Residuum) (October 2008)

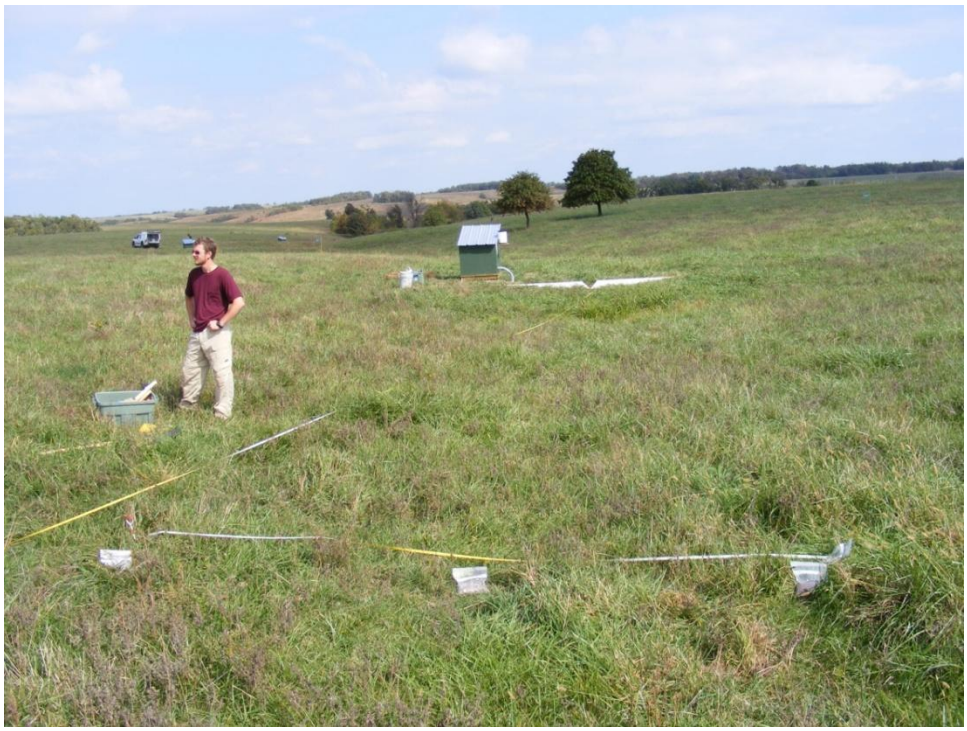


Photo 8. Surface Soil Sampling (October 2008)

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	Pounds per acre 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		

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*

White-Farmer, Yellow-FSA, Blue-Firm, Pink-Extension MP 189 Revised 1/96 Signature

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	Pounds per acre 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		

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.
***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.

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*

White-Farmer, Yellow-FSA, Blue-Firm, Pink-Extension MP 189 Revised 1/96 Signature

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. S41722-5	**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	Pounds per acre 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		

LIMESTONE SUGGESTIONS

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

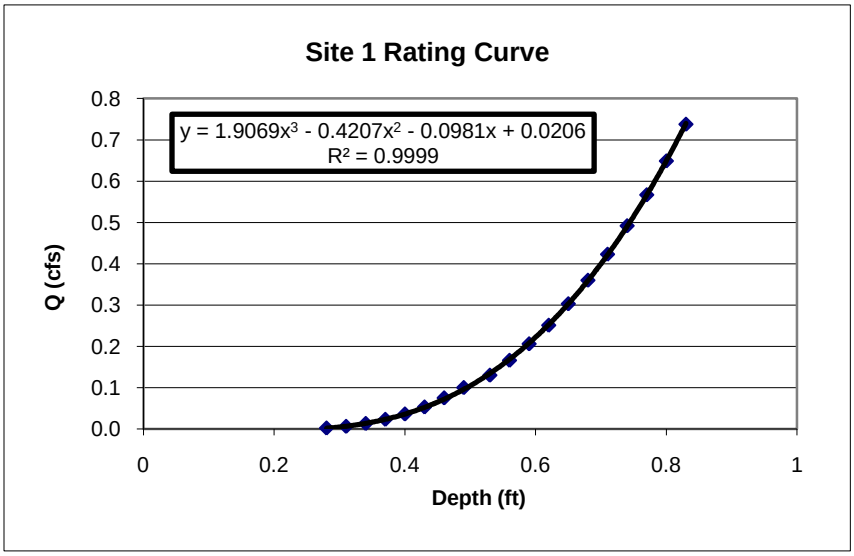
Comments

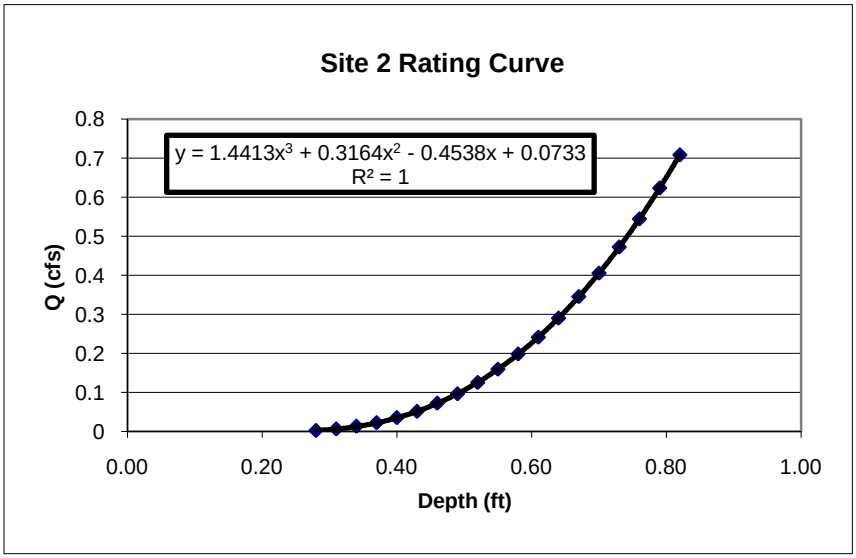
---For hay production apply nitrogen just before spring growth begins (typically March). Consider splitting nitrogen applications if the rate exceeds 90 lbs N/acre, applying 60% in March and the balance in mid August.
---Some herbicide labels list restrictions based on soil pH in water. This sample has 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.

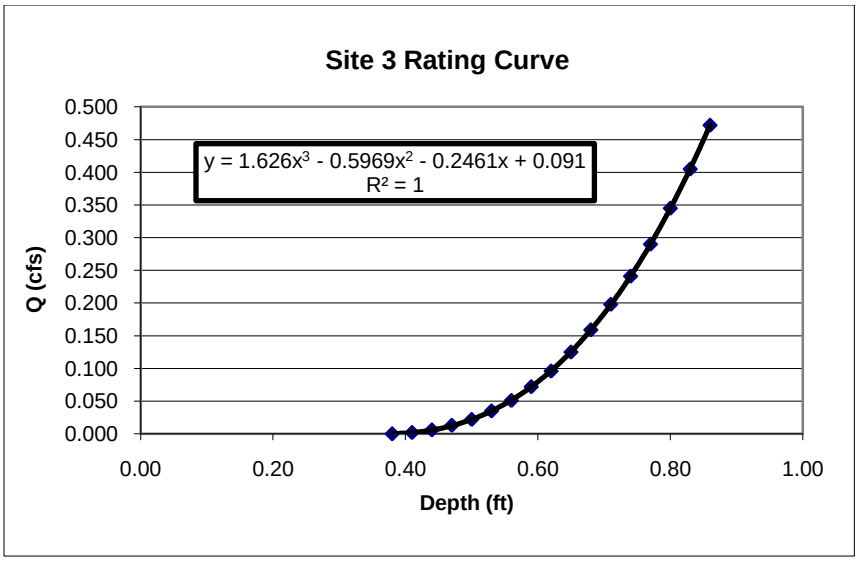
Regional Agronomy Specialist Tim Schnakenberg Phone 417-357-6812 *Tim Schnakenberg*

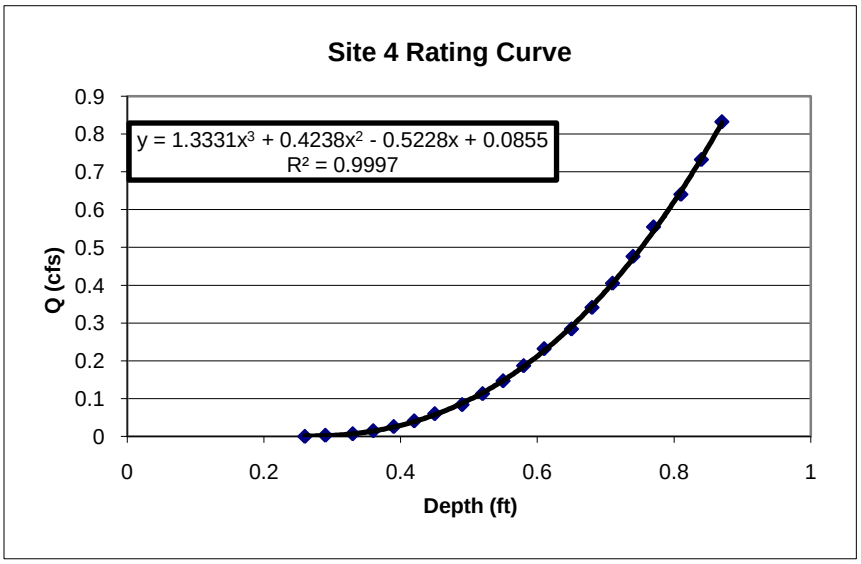
White-Farmer, Yellow-FSA, Blue-Firm, Pink-Extension MP 189 Revised 1/96 Signature

APPENDIX B: Discharge Rating Curves






Site 3 Rating Curve
y = 1.626x³ - 0.5969x² - 0.2461x + 0.091
R² = 1
Q (cfs)
0.500
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.00
0.20
0.40
0.60
0.80
1.00
Depth (ft)


Site 4 Rating Curve
y = 1.3331x³ + 0.4238x² - 0.5228x + 0.0855
R² = 0.9997
Q (cfs)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.2
0.4
0.6
0.8
1
Depth (ft)

APPENDIX C: Raw Fertilizer and Biosolids Nutrient and Metals Analysis

Location	Nutrients (mg/L)							Metals (µg/L)											
	TKN	NH3-N	NO3-N	TP	% Total Solids	Fecal coliform (coli/100 mL)	pH (std units)	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 D: Surface Soil Sample Data

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	2290	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	2474	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	1467	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	2465	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	3935	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	3548	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	3003	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	3712	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	3127	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	3161	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	5024	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	2671	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	2867	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	2054	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	2903	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	2127	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	4104	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	4478	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	4427	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	3233	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	3737	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	4264	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	3419	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	5339	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	3901	9	205	0.3	53.2	3.4	0.2	1.5	57.6	0	30	0.1	0.1	0.1

BIO 26	3	65.6	6.6	4.69	5.8	6.6	19	8	74	2435	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	2939	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	2048	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	2443	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	2695	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	1988	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	2798	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	2462	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	1685	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	4578	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	2172	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	3280	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	2680	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	2477	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	2714	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	4513	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	3319	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	2624	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	4907	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	1814	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	2332	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	1913	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	1821	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

APPENDIX E: Water Quality Analysis Results

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
Site 1	11/6/2008	5.44	1.0	0.71	1.32	14	790	6.73	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	7.03	<15	<5	<10	<5	<15	<0.2	<20	<10	6250	<20	<5	<5
	4/13/2009	2.89	0.4	0.13	0.28	1	10	7.16	<15	<5	<10	<5	<15	<0.2	<20	<10	1600	<20	<5	<5
	4/13/2009*	1.86	0.14	0.11	0.19	2	30	7.17	<15	<5	<10	<5	<15	<0.2	<20	<10	1540	<20	<5	<5
	5/1/2009	<0.03	<0.1	0.14	0.27	11	NR	7.03	<15	<5	<10	<5	<15	<0.2	<20	<10	2690	<20	<5	<5
	5/14/2009	2.80	0.2	0.07	0.29	10	NR	7.11	<15	<5	<10	<5	<15	<0.2	<20	<10	1850	<20	<5	<5
	6/16/2009	4.65	0.3	0.40	0.58	16	29000	7.10	<15	<5	14.2	<5	<15	<0.2	<20	10.8	8700	<20	<5	<5
	6/16/2009*	5.72	0.3	0.46	0.57	14	29000	7.08	<15	<5	15	<5	<15	<0.2	<20	10.9	8860	<20	<5	<5
Site 2	11/6/2008	66.70	37.4	1.41	34.20	105	250	7.46	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	7.49	<15	<5	<10	<5	<15	<0.2	<20	<10	12600	<20	<5	<5
	4/13/2009	3.15	0.2	0.13	4.11	1	70	7.22	<15	<5	<10	<5	<15	<0.2	<20	<10	2580	<20	<5	<5
	4/20/2009	2.15	<0.1	0.08	3.57	<2	20	7.26	<15	<5	<10	<5	<15	<0.2	<20	<10	2120	<20	<5	<5
	4/20/2009*	2.02	<0.1	0.08	3.73	2	<1	7.32	<15	<5	<10	<5	<15	<0.2	<20	<10	1970	<20	<5	<5
	5/1/2009	3.57	0.1	0.16	4.95	13	NR	7.04	<15	<5	<10	<5	<15	<0.2	<20	<10	3280	<20	<5	<5
	5/14/2009	3.62	0.2	0.06	2.94	4	NR	6.91	<15	<5	<10	<5	<15	<0.2	<20	<10	2740	<20	<5	<5
	6/16/2009	4.58	0.5	1.40	4.94	8	8000	7.01	<15	<5	<10	<5	<15	<0.2	<20	<10	12200	<20	<5	<5
	6/30/2009	3.96	<0.1	2.64	2.60	20	1545	7.09	<15	<5	<10	<5	<15	<0.2	<20	<10	10600	<20	<5	<5
	7/21/2009	3.95	0.2	<0.01	1.72	6	1000	7.15	<15	<5	<10	<5	<15	<0.2	<20	<10	10700	<20	<5	6.4
Site 3	4/13/2009	1.49	0.1	0.12	0.25	3	370	7.31	<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	7.19	<15	<5	<10	<5	<15	<0.2	<20	<10	1050	<20	<5	<5
	5/1/2009	2.51	0.1	0.21	0.25	13	NR	7.37	<15	<5	<10	<5	<15	<0.2	<20	<10	1890	<20	<5	<5
	5/1/2009*	5.23	<0.1	0.2	0.18	12	NR	7.35	<15	<5	<10	<5	<15	<0.2	<20	<10	1840	<20	<5	<5
	5/14/2009	2.69	0.2	0.05	0.31	14	NR	7.23	<15	<5	<10	8.2	<15	<0.2	<20	<10	2440	<20	<5	<5
	6/16/2009	3.48	0.4	0.45	0.61	2	9000	7.20	<15	<5	<10	<5	<15	<0.2	<20	<10	10100	<20	<5	<5
Site 4	5/1/2009	<0.03	0.3	0.28	0.06	34	NR	7.32	<15	<5	<10	<5	<15	<0.2	<20	<10	1330	<20	<5	6.3

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 Blank	5/14/2009	0.98	0.4	0.11	0.02	6	NR	7.31	<15	<5	<10	<5	<15	<0.2	<20	<10	807	<20	<5	<5
	5/14/2009*	1.08	0.45	0.82	0.08	4	NR	7.36	<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	190000	7.29	<15	<5	<10	19.6	<15	<0.2	<20	13.7	190000	<20	<5	69.1
	11/6/2008	0.14	<0.1	<0.05	<0.01	<1	<1	6.51	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	6.55	<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	6.50	<15	<5	<10	<5	<15	<0.2	<20	<10	<50	<20	<5	<5
	4/20/2009	<0.03	<0.1	0.07	0.22	<2	<1	6.24	<15	<5	<10	<5	<15	<0.2	<20	<10	<50	<20	<5	<5
	5/1/2009	0.17	<0.1	0.14	0.02	<1	NR	6.28	<15	<5	<10	<5	<15	<0.2	<20	<10	<50	<20	<5	<5
	5/14/2009	0.19	<0.1	<0.01	<0.01	<1	NR	6.75	<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	6.79	<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	6.79	<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	6.71	<15	<5	<10	<5	<15	<0.2	<20	<10	<50	<20	<5	<5

Notes: *field duplicate

APPENDIX F: Water Quality Sampling Field Duplicate and Field Blank Data

Location	Date	TKN RPD	NH3-N RPD	NO3-N RPD	TP RPD	TSS RPD	Fecal RPD
Site 1	4/13/2009	43.37	96.30	16.67	38.30	-66.67	100.0
	6/16/2009	-20.64	0.00	-13.95	1.74	13.33	0.0
Site 2	4/20/2009	6.24	0.00	0.00	-4.38	-66.67	190.24
Site 3	5/1/2009	-70.28	75.0	4.88	32.56	8.0	Below Detect
	6/10/2009	196.12	0.00	-11.32	3.28	120.0	0.0
Site 4	5/14/2009	-9.71	-2.25	-152.69	-120	40.0	Below Detect

Location	Date	TKN RPD	NH_3-N RPD	NO_3-N RPD	TP RPD	TSS RPD	Fecal RPD
Field Blank	11/16/2008	3	FBD	FBD	FBD	FBD	FBD
	2/11/2009	18	FBD	100	4	FBD	FBD
	4/13/2009	30	FBD	100	75	FBD	FBD
	4/20/2009	FBD	FBD	88	73	FBD	FBD
	5/1/2009	850	FBD	100	33	FBD	FBD
	5/14/2009	19	FBD	FBD	FBD	FBD	FBD
	6/16/2009	18	FBD	127	14	FBD	FBD
	6/30/2009	9	FBD	FBD	4	FBD	FBD
	7/21/2009	10	FBD	FBD	FBD	FBD	FBD

FBD = Field blank below detection limit

APPENDIX G: Surface Soil Sampling Site and Sampling Variability Data

Site	Soil pH	P	NO_3-N	Zn	Total Pb
Site 1					
Footslope	2.1	48.8	0.0	11.0	7.8
Backslope	2.6	11.1	0.0	12.7	1.8
Summit	1.7	28.4	0.0	46.1	5.1
Site 2					
Footslope	1.1	28.0	0.0	13.8	1.5
Backslope	3.5	16.5	0.0	21.9	9.4
Summit	1.6	22.9	0.0	22.9	7.1
Site 3					
Footslope	2.6	30.1	0.0	13.3	3.2
Backslope	2.7	17.3	15.4	25.4	2.0
Summit	4.0	48.0	86.6	22.9	4.0
Site 4					
Footslope	2.4	25.3	9.1	11.6	0.0
Backslope	0.9	17.3	84.5	16.7	3.4
Summit	1.6	27.0	90.1	31.1	5.2

Site	Position	Soil pH	P	NO_3-N	Zn	Cu	Total Pb	Cd	Ni	Cr
1	Footslope	5.6	24.0	0.0	2.2	0.2	37.0	0.1	0.1	0.0
1-D	Footslope	5.7	24.0	0.0	2.0	0.2	33.0	0.1	0.1	0.1
Difference		0.1	0.0	0.0	0.2	0.0	4.0	0.0	0.0	0.1
RPD			0.0	0.0	9.5	0.0	11.4	0.0	0.0	200.0
1	Backslope	5.6	20.0	0.0	1.7	0.2	33.0	0.1	0.1	0.1
1-D	Backslope	5.7	17.0	0.0	1.5	0.2	33.0	0.1	0.1	0.1
Difference		0.1	3.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0
RPD			16.2	0.0	12.5	0.0	0.0	0.0	0.0	0.0
1	Summit	5.8	14.0	0.0	1.3	0.2	31.0	0.1	0.1	0.1
1-D	Summit	6.0	24.0	0.0	1.8	0.2	30.0	0.1	0.1	0.1
Difference		0.2	10.0	0.0	0.5	0.0	1.0	0.0	0.0	0.0
RPD			52.6	0.0	32.3	0.0	3.3	0.0	0.0	0.0
2	Footslope	5.5	24.0	0.0	3.0	0.2	38.0	0.1	0.1	0.1
2-D	Footslope	5.3	18.0	0.0	2.4	0.2	41.0	0.1	0.2	0.1
Difference		0.2	6.0	0.0	0.6	0.0	3.0	0.0	0.1	0.0
RPD			28.6	0.0	22.2	0.0	7.6	0.0	66.7	0.0
2	Backslope	5.9	18.0	0.0	1.7	0.2	32.0	0.1	0.1	0.1
2-D	Backslope	5.9	17.0	0.0	1.9	0.2	33.0	0.1	0.1	0.1
Difference		0.0	1.0	0.0	0.2	0.0	1.0	0.0	0.0	0.0
RPD			5.7	0.0	11.1	0.0	3.1	0.0	0.0	0.0
2	Summit	6.0	21.0	0.0	2.1	0.2	31.0	0.1	0.1	0.1
2-D	Summit	6.0	13.0	0.0	1.5	0.2	32.0	0.1	0.1	0.1
Difference		0.0	8.0	0.0	0.6	0.0	1.0	0.0	0.0	0.0

RPD			47.1	0.0	33.3	0.0	3.2	0.0	0.0	0.0
3	Footslope	5.9	12.0	9.0	3.1	0.2	31.0	0.1	0.2	0.1
3-D	Footslope	5.8	8.0	8.0	2.8	0.2	31.0	0.1	0.1	0.0
Difference		0.1	4.0	1.0	0.3	0.0	0.0	0.0	0.1	0.1
RPD			40.0	11.8	10.2	0.0	0.0	0.0	66.7	200.0
3	Backslope	6.5	11.0	15.0	1.5	0.2	29.0	0.1	0.1	0.0
3-D	Backslope	6.4	9.0	10.0	1.4	0.2	28.0	0.0	0.1	0.0
Difference		0.1	2.0	5.0	0.1	0.0	1.0	0.1	0.0	0.0
RPD			20.0	40.0	6.9	0.0	3.5	0.0	0.0	0.0
3	Summit	6.0	10.0	0.0	1.4	0.2	30.0	0.1	0.1	0.0
3-D	Summit	5.9	8.0	0.0	1.7	0.2	32.0	0.1	0.1	0.0
Difference		0.1	2.0	0.0	0.3	0.0	2.0	0.0	0.0	0.0
RPD			22.2	0.0	19.4	0.0	6.5	0.0	0.0	0.0
4	Footslope	6.2	17.0	10.0	2.4	0.2	27.0	0.1	0.1	0.0
4-D	Footslope	6.2	17.0	10.0	2.1	0.2	30.0	0.1	0.1	0.0
Difference		0.0	0.0	0.0	0.3	0.0	3.0	0.0	0.0	0.0
RPD			0.0	0.0	13.3	0.0	10.5	0.0	0.0	0.0
4	Backslope	6.5	11.0	5.0	0.7	0.2	28.0	0.1	0.1	0.0
4-D	Backslope	6.7	18.0	7.0	0.9	0.2	28.0	0.1	0.1	0.1
Difference		0.2	7.0	2.0	0.2	0.0	0.0	0.0	0.0	0.1
RPD			48.3	33.3	25.0	0.0	0.0	0.0	0.0	200.0
4	Summit	6.3	7.0	8.0	0.9	0.2	28.0	0.0	0.1	0.0
4-D	Summit	6.2	7.0	1.0	1.1	0.2	27.0	0.1	0.1	0.0
Difference		0.1	0.0	7.0	0.2	0.0	1.0	0.1	0.0	0.0
RPD			0.0	155.6	20.0	0.0	3.6	0.0	0.0	0.0

APPENDIX H: Soil Morphology Data

Owner: Biosolid Project	County: Lawrence, MO	Soil Drainage Class:		Date: 11/19/2008	
Depth to Bedrock:	Pit #: 1	Up Slope: Convex, Across Slope: Convex		Geomorphic: Head Slope	
GPS Location: 37° 16.073' N: 93° 51.542' W +/-12ft	Described By: Recorded By: Doug Gisselbeck Tom DeWitt	Excavation Depth: 60'	Landscape Position: Summit	Aspect: Elevation: N 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)	10YR 4/3		SIL	12	0	0	VFR	1 F GR 1 F SBK	M F/M	1% F/FMM
	AS									M F/M	
BE	5 – 8" (20cm)	10YR 5/4		SIL	14	0	0	FR	2 F SBK	MF	1% F/FMM
	CS									CF	
Bt1	8 – 18" (45cm)	7.5YR 5/4	5% 10YR 5/4 CLF/APF	SIL	25	1	0	FR	2 M SBK	MF	2% F/FMM
	CW									CF	
Bt2	18 – 25" (64cm)	7.5YR 4/4	10YR 4/3 CLF/HPF	SICL	36	2	0	FI	2 M PR → 2 M SBK	FF	5% F/FMM
	CW									FF	
Bt3	25 – 32" (89cm)	7.5YR 4/4	10YR 4/2 CLF/VPF	SICL	30	5	0	FI	2 M PR → 2 M SBK	FF	5% D/FMM
	CW									FF	
2Btx1	32 – 38" (97cm)	7.5YR 4/6	10YR 4/2 CLF/VPF	GR SICL	32	20	0	FI	1 M PR → 3 M SBK	VFF	10YR 5/2 FED 2% D/FMN Clay films on vertical prism faces. Vert. seams <3" apart
	CW									VFF	
2Btx2	38 – 45" (114cm)	5YR 4/6	↓	GR SICL	38	25	0	VFI	1 M PR → 3 M SBK	VFF	↓
	CW									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	County: Lawrence, MO	Soil Drainage Class:	Date: 11/19/2008
Depth to Bedrock:	Pit #: 2	Up Slope: Convex Across Slope: Convex	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: Elevation: N 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)	10YR 3/3		SIL	14	10		VFR	2 M GR	M F/M	
	CS									M VF/F	
BE or Ap2	4 – 7” (18cm)	10YR 5/3		SIL	12	10		VFR	2 F SBK → 1 F GR	M F/M	(SLF?)
	CS									M VF/F	
Bt1	7 – 11” (28cm)	7.5YR 5/3		GR SIL	18	20		FR	2 M SBK	M VF/F	F/F CLF
	CW									M VF/F	
Bt2	11 - 20” (51cm)	5YR 4/4		GRV SICL	36	25	15	FR	2 M SBK	CF	
	CW									CF	
2Btx1	20 - 29” (74cm)	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	Weak fragipan; 7.5YR 6/2 FED in gray seams. Gray seams 2 – 3” apart
	CW									CF	
2Btx2	29 - 38” (97cm)	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	↓
	CW									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: Elevation: E 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)	10YR 3/3		SIL	12	5		VFR	2 F GR	M F/M	
	CS									M F/M	
Ap2	3 – 7” (18cm)	10YR 4/3		SIL	12	10		VFR	2 M SBK → 1 F GR	M F/M	
	CS									M F/M	
Bt1	7 – 16” (41cm)	7.5YR 5/4	10YR 6/3 SLF 10YR 4/2 CLF/APF	SICL	28	15		FR	2 M SBK	CF	F/F FMM
	CS									CF	
Bt2	16 - 28” (71cm)	5YR 4/4	10YR 6/3 SLF 10YR 4/2 CLF/APF	GR SICL	36	25	5	FR	2 M SBK	CF	F/F FMM
	CW									FF	
2Bt3	28 - 36” (91cm)	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	Vertical Seams Para-rock frag. 1 M sandstone channers
	CW									FF	
2Bt4	36 - 43” (109cm)	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	20% 2.5Y 7/2 FED
	CW									FF	
3Bt5	43 - 50” (127cm)	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
	GW									----	
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: Convex	Geomorphic: Side Slope
GPS Location: 37° 16.173‘ N: 93° 51.443‘ W +/-12ft	Described By: Recorded By: Doug Gisselbeck Tom DeWitt	Excavation Depth: 80”	Landscape Position: Back Slope / Aspect: E / Elevation: 1176’ / % Slope: 12
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)	10YR 3/2		SIL	12	5		VFR	2 F GR	M F/M	
	CS									M F/M	
Ap2	4 – 8” (20cm)	10YR 4/3		SIL	12	10		VFR	1 F SBK → 1 F GR	M F/M	
	CS									M F/M	
Bt1	8 – 18” (46cm)	7.5YR 4/4	10YR 4/2 CLF/APF	SICL	28	15		FR	2 M SBK	CF	
	CS									CF	
Bt2	18 - 25” (64cm)	7.5YR 5/3 15% 5YR 4/4	(CRK or RPO?) ↕	GR SICL	38	20		FI	2 M SBK	CF	(SLF?)
	CW									CF	
Bt3	25 - 32” (81cm)	2.5YR 3/6	↓	GR SIC	42	30		VFI	2 M PR → 3 M SBK	FF	10YR 5/2 FED Roots in vertical seams
	CW									FF	
2Bt4	32 – 62” (157cm)	2.5YR 3/6	↓	GRV SIC	48	45	15	VFI	2 M PR → 3 M SBK	FF	↓
	CW									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: NE / Elevation: 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)	10YR 3/2		GRV SIL	14	35	5	VFR	3 F GR	M F/M	
	CS									M F/M	
Ap2	12 - 23” (58cm)	10YR 3/3		GRV SIL	16	40	20	VFR	1 F SBK → 2 F GR	M F/M	
	CW									M F/M	
2Bt1	23 – 47” (119cm)	5YR 4/4	10YR 4/3 CLF/VPF	GRV SICL	38	35	5	FI	2 M SBK	FF	5% FMM Vertical Gray Seams
	AW									C F/M	
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	8% FMM Irregular shaped 20% 10yr 5/2 FED
	----									FF	

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

Parameter	Site 1 Toe		Site 1 Mid		Site 1 Summit		Site 1 Average and SEM			
	WET	DRY	WET	DRY	WET	DRY	WET		DRY	
Moist / Dry Matter %	71.46488	28.53513	69.43573	30.56428	70.25546	29.74454	70.39	1.02	29.61	1.02
Protein ..... %	2.35056	8.237425	2.667428	8.727271	2.845663	9.56701	2.62	0.25	8.84	0.67
Adj Cr Protein ... %	0	0	0	0	0	0				
Avail Protein .... %	0	0	0	0	0	0				
A.D.F. - N ..... %	0	0	0	0	0	0				
Urea ..... %	0	0	0	0	0	0				
A D Fiber ..... %	12.56972	44.05	13.46968	44.07	12.51948	42.09	12.85	0.53	43.40	1.14
N D Fiber(a) ..... %	18.66483	65.41001	19.98904	65.4	18.84317	63.35	19.17	0.72	64.72	1.19
Crude Fiber ..... %	0	0	0	0	0	0				
Lignin ..... %	0	0	0	0	0	0				
T D N ..... %	14.72764	51.61232	15.76989	51.59581	15.83316	53.23049	15.44	0.62	52.15	0.94
NE Lactation MCAL/LB	0.1447073	0.50712	0.1549389	0.506928	0.1564372	0.525936	0.152	0.006	0.513	0.011
NE Gain .... MCAL/LB	6.12E-02	0.2145625	6.55E-02	0.2143193	0.0708596	0.2382273	0.066	0.005	0.222	0.014
NE Maint ... MCAL/LB	0.1325316	0.4644508	0.1418762	0.4641896	0.1457255	0.4899234	0.140	0.007	0.473	0.015
Digst Energy MCAL/LB	0.1325316	0.4644508	0.1418762	0.4641896	0.1457255	0.4899234	0.140	0.007	0.473	0.015
Crude Fat (EE) ... %	0	0	0	0	0	0				
pH	0		0		0					
Ash ..... %	0	0	0	0	0	0				
Salt ..... %	0	0	0	0	0	0				
Nitrogen ..... %	0.3760895	1.317988	0.4267884	1.396363	0.4553061	1.530722	0.419	0.040	1.415	0.108
Calcium ..... %	8.56E-02	0.3	9.17E-02	0.3	0.1249271	0.42	0.101	0.021	0.340	0.069
Phosphorus ..... %	0.0456562	0.16	5.20E-02	0.17	4.16E-02	0.14	0.046	0.005	0.157	0.015
Magnesium ..... %	3.71E-02	0.13	3.36E-02	0.11	0.0386679	0.13	0.036	0.003	0.123	0.012
Potassium ..... %	0.450855	1.58	0.507367	1.66	0.5056572	1.7	0.488	0.032	1.647	0.061
Sodium ..... %	1.43E-03	0.005	1.53E-03	0.005	2.38E-03	0.008	0.002	0.001	0.006	0.002
Iron ..... PPM	19.97459	70	21.395	70	29.74454	100	23.70	5.28	80.00	17.32
Copper ..... PPM	1.141405	4	1.222571	4	0.8923361	3	1.09	0.17	3.67	0.58
Manganese ..... PPM	12.84081	45	7.335427	24	15.16972	51	11.78	4.02	40.00	14.18
Zinc ..... PPM	5.992377	21	4.890285	16	4.759126	16	5.21	0.68	17.67	2.89
RFV/Quality Standrd	78 [4]		78 [4]		82 [4]		79	[4]		
Nitrate (NO3)	Negative		Negative		Negative		Negative			

Parameter	Site 2 Toe		Site 2 Mid		Site 2 Summit		Site 2 Average and SEM			
	WET	DRY	WET	DRY	WET	DRY	WET		DRY	
Moist / Dry Matter %	72.70585	27.29416	71.52039	28.47962	72.96292	27.03708	27.89	0.84	72.40	0.77
Protein ..... %	2.556663	9.367071	2.394387	8.407371	2.470417	9.137144	8.89	0.68	2.47	0.08
Adj Cr Protein ... %	0	0	0	0	0	0				
Avail Protein .... %	0	0	0	0	0	0				
A.D.F. - N ..... %	0	0	0	0	0	0				
Urea ..... %	0	0	0	0	0	0				
A D Fiber ..... %	12.34242	45.22	13.33985	46.84	12.36406	45.73	46.03	1.15	12.68	0.57
N D Fiber(a) ..... %	18.25979	66.9	19.77055	69.42	18.36088	67.91001	68.16	1.78	18.80	0.84
Crude Fiber ..... %	0	0	0	0	0	0				
Lignin ..... %	0	0	0	0	0	0				
T D N ..... %	13.8235	50.64636	14.04298	49.30889	13.57946	50.22531	49.98	0.95	13.82	0.23
NE Lactation MCAL/LB	0.1353484	0.495888	0.1367978	0.480336	0.1327499	0.490992	0.488	0.011	0.135	0.002
NE Gain .... MCAL/LB	5.47E-02	0.20028	0.0513512	0.1803086	5.25E-02	0.1940173	0.190	0.014	0.053	0.002
NE Maint ... MCAL/LB	0.1225858	0.4491283	0.121826	0.4277656	0.1196179	0.4424216	0.438	0.015	0.121	0.002
Digst Energy MCAL/LB	0.1225858	0.4491283	0.121826	0.4277656	0.1196179	0.4424216	0.438	0.015	0.121	0.002
Crude Fat (EE) ... %	0	0	0	0	0	0				
pH	0		0		0					
Ash ..... %	0	0	0	0	0	0				
Salt ..... %	0	0	0	0	0	0				
Nitrogen ..... %	0.4090661	1.498731	0.3831019	1.34518	0.3952667	1.461943	1.422	0.109	0.396	0.013
Calcium ..... %	9.28E-02	0.34	7.69E-02	0.27	9.19E-02	0.34	0.305	0.049	0.087	0.009
Phosphorus ..... %	0.0682354	0.25	6.72E-02	0.236	6.22E-02	0.23	0.243	0.010	0.066	0.003
Magnesium ..... %	3.55E-02	0.13	3.42E-02	0.12	3.24E-02	0.12	0.125	0.007	0.034	0.002
Potassium ..... %	0.5431537	1.99	0.5980719	2.1	0.5001859	1.85	2.045	0.078	0.547	0.049
Sodium ..... %	1.36E-03	0.005	2.28E-03	0.008	2.70E-03	0.01	0.007	0.002	0.002	0.001
Iron ..... PPM	19.10591	70	19.93573	70	18.92596	70	70.00	0.00	19.32	0.54
Copper ..... PPM	1.910591	7	1.139185	4	1.351854	5	5.50	2.12	1.47	0.40
Manganese ..... PPM	19.37885	71	17.65736	62	15.68151	58	66.50	6.36	17.57	1.85
Zinc ..... PPM	5.458832	20	4.556739	16	4.596304	17	18.00	2.83	4.87	0.51
RFV/Quality Standrd	75 [5]		70 [5]		73 [5]		73	[5]		
Nitrate (NO3)	Negative		Negative		Negative		Negative			

Parameter	Site 3 Toe		Site 3 Mid		Site 3 Summit		Site 3 Average and SEM			
	WET	DRY	WET	DRY	WET	DRY	WET		DRY	
Moist / Dry Matter %	71.131	28.869	71.11187	28.88813	71.71913	28.28088	28.88	0.01	71.32	0.35
Protein ..... %	2.750356	9.527021	2.977435	10.30678	2.855476	10.09684	9.92	0.55	2.86	0.11
Adj Cr Protein ... %	0	0	0	0	0	0				
Avail Protein .... %	0	0	0	0	0	0				
A.D.F. - N ..... %	0	0	0	0	0	0				
Urea ..... %	0	0	0	0	0	0				
A D Fiber ..... %	12.78897	44.3	12.95633	44.85	12.57085	44.45	44.58	0.39	12.77	0.19
N D Fiber(a) ..... %	19.25563	66.7	19.09505	66.1	18.75022	66.3	66.40	0.42	19.03	0.26
Crude Fiber ..... %	0	0	0	0	0	0				
Lignin ..... %	0	0	0	0	0	0				
T D N ..... %	14.84038	51.40592	14.71903	50.95184	14.50302	51.28208	51.18	0.32	14.69	0.17
NE Lactation MCAL/LB	0.1457076	0.50472	0.1442789	0.49944	0.142332	0.50328	0.502	0.004	0.144	0.002
NE Gain .... MCAL/LB	6.11E-02	0.2115206	5.92E-02	0.2048094	5.93E-02	0.2096928	0.208	0.005	0.060	0.001
NE Maint ... MCAL/LB	0.1331393	0.4611842	0.1311473	0.4539834	0.1298721	0.4592223	0.458	0.005	0.131	0.002
Digst Energy MCAL/LB	0.1331393	0.4611842	0.1311473	0.4539834	0.1298721	0.4592223	0.458	0.005	0.131	0.002
Crude Fat (EE) ... %	0	0	0	0	0	0				
pH	0		0		0					
Ash ..... %	0	0	0	0	0	0				
Salt ..... %	0	0	0	0	0	0				
Nitrogen ..... %	0.440057	1.524324	0.4763897	1.649085	0.4568761	1.615495	1.587	0.088	0.458	0.018
Calcium ..... %	0.0692856	0.24	8.67E-02	0.3	8.48E-02	0.3	0.270	0.042	0.080	0.010
Phosphorus ..... %	6.21E-02	0.215	6.24E-02	0.216	6.39E-02	0.226	0.216	0.001	0.063	0.001
Magnesium ..... %	0.0375297	0.13	4.04E-02	0.14	0.0452494	0.16	0.135	0.007	0.041	0.004
Potassium ..... %	0.5340765	1.85	0.5055423	1.75	0.4977434	1.76	1.800	0.071	0.512	0.019
Sodium ..... %	1.44E-03	0.005	4.62E-03	0.016	1.70E-03	0.006	0.011	0.008	0.003	0.002
Iron ..... PPM	23.0952	80	20.22169	70	42.42131	150	75.00	7.07	28.58	12.07
Copper ..... PPM	1.44345	5	1.444407	5	1.979661	7	5.00	0.00	1.62	0.31
Manganese ..... PPM	10.97022	38	11.84413	41	15.27167	54	39.50	2.12	12.70	2.27
Zinc ..... PPM	6.062491	21	6.64427	23	6.504602	23	22.00	1.41	6.40	0.30
RFV/Quality Standrd	76 [4]		76 [4]		76 [4]		76	[4]		
Nitrate (NO3)	Negative		Negative		Negative		Negative			

Parameter	Site 4 Toe		Site 4 Mid		Site 4 Summit		Site 4 Average and SEM			
	WET	DRY	WET	DRY	WET	DRY	WET		DRY	
Moist / Dry Matter %	70.42554	29.57446	73.75879	26.24121	73.82553	26.17448	27.91	2.36	72.67	1.94
Protein ..... %	3.039305	10.27679	3.001056	11.43642	3.037907	11.60637	10.86	0.82	3.03	0.02
Adj Cr Protein ... %	0	0	0	0	0	0				
Avail Protein .... %	0	0	0	0	0	0				
A.D.F. - N ..... %	0	0	0	0	0	0				
Urea ..... %	0	0	0	0	0	0				
A D Fiber ..... %	12.99502	43.94	11.81379	45.02	10.97758	41.94	44.48	0.76	11.93	1.01
N D Fiber(a) ..... %	19.66998	66.51	17.60785	67.1	16.55536	63.25	66.81	0.42	17.94	1.58
Crude Fiber ..... %	0	0	0	0	0	0				
Lignin ..... %	0	0	0	0	0	0				
T D N ..... %	15.29092	51.70314	13.33355	50.81149	13.96522	53.35433	51.26	0.63	14.20	1.00
NE Lactation MCAL/LB	0.1502903	0.508176	0.1306308	0.497808	0.1380379	0.527376	0.503	0.007	0.140	0.010
NE Gain .... MCAL/LB	6.39E-02	0.2158992	5.32E-02	0.2027298	6.28E-02	0.240025	0.209	0.009	0.060	0.006
NE Maint ... MCAL/LB	0.1377835	0.4658868	0.1185457	0.4517538	0.1287425	0.4918629	0.459	0.010	0.128	0.010
Digst Energy MCAL/LB	0.1377835	0.4658868	0.1185457	0.4517538	0.1287425	0.4918629	0.459	0.010	0.128	0.010
Crude Fat (EE) ... %	0	0	0	0	0	0				
pH	0		0		0					
Ash ..... %	0	0	0	0	0	0				
Salt ..... %	0	0	0	0	0	0				
Nitrogen ..... %	0.4862888	1.644286	0.480169	1.829828	0.4860652	1.85702	1.737	0.131	0.484	0.003
Calcium ..... %	0.1064681	0.36	9.71E-02	0.37	6.81E-02	0.26	0.365	0.007	0.091	0.020
Phosphorus ..... %	6.80E-02	0.23	6.95E-02	0.265	6.44E-02	0.246	0.248	0.025	0.067	0.003
Magnesium ..... %	3.55E-02	0.12	3.94E-02	0.15	4.19E-02	0.16	0.135	0.021	0.039	0.003
Potassium ..... %	0.5175531	1.75	0.5300725	2.02	0.4318789	1.65	1.885	0.191	0.493	0.053
Sodium ..... %	4.44E-03	0.015	1.31E-03	0.005	6.28E-03	0.024	0.010	0.007	0.004	0.003
Iron ..... PPM	29.57446	100	28.86533	110	26.17448	100	105.00	7.07	28.20	1.79
Copper ..... PPM	1.478723	5	1.574473	6	1.570469	6	5.50	0.71	1.54	0.05
Manganese ..... PPM	11.82979	40	11.54613	44	14.13422	54	42.00	2.83	12.50	1.42
Zinc ..... PPM	5.914893	20	6.560303	25	6.281875	24	22.50	3.54	6.25	0.32
RFV/Quality Standrd	76 [4]		75 [5]		83 [4]		78	[4]		
Nitrate (NO3)	Negative		Negative		Negative		Negative			