Evaluation of Nutrient and Pathogen Losses From Various Poultry Litter Storage Methods

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Thesis submitted to the faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

In

BIOLOGICAL SYSTEMS ENGINEERING

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July 23, 2002

Blacksburg, Virginia

Keywords: Poultry Litter, Storage, Nutrient Loss, Bacteria, and Water Quality

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ABSTRACT

Considerable concern has developed over the possible pollution from poultry litter storage methods. This study was conducted to evaluate three different storage scenarios; covered stockpiles, uncovered stockpiles, and litter sheds. The stockpiles were monitored over two rainfall simulation events, in both the Ridge and Valley and the Piedmont physiographic provinces, with both surface and subsurface flows analyzed. An observational study, where subsurface water was sampled for a nine-month period was conducted using six litter sheds, three in each of the above provinces. Samples were analyzed for nutrients, fecal coliforms, and solids.

Concentrations of NH_x, TKN, OP, TP, VSS, and FC in surface runoff from uncovered litter piles were all statistically higher (α=0.05) than that from covered piles, with NO_3 being the exception. However, increased runoff volumes originating from the covered litter piles caused mass loadings from both covered and uncovered piles to be similar enough that statistical significance was not obtained, except in the case of FC.

Soil water samples from litter stockpiles did not show a statistically significant treatment effect for concentration data, but uncovered piles did exhibit higher nitrogen concentration estimates than the covered piles. Sample collection frequency showed a statistically significant increase in the number of samples that could be obtained from the edge lysimeter under uncovered litter piles from the Piedmont experimental site. This result indicates uncovered piles are releasing the precipitation absorbed during the rainfall simulation into the sub-surface environment.

In the storage shed study, a greater number of samples were collected per attempt at the Piedmont sheds compared to those at the Ridge and Valley site. While both areas were undergoing a significant drought, Piedmont porous-cup lysimeters yielded samples 63% of the time, compared to 10% for Ridge and Valley lysimeters. Lysimeters located near the edge of the shed were also more likely to yield a sample than those in the center or a background location. Unknown interferences within the litter shed samples prevented three laboratories from obtaining valid nutrient concentrations.

ACKNOWLEDGEMENTS

I would like to express my sincere appreciation to Dr. Lori Marsh and Dr. Eldridge Collins who served as my committee co-chairs. Their support and guidance have been invaluable through this entire project. My thanks also go out to the rest of my committee, Dr. Blake Ross and Dr. David Vaughan for their assistance and hard work, especially during the rainfall simulation events.

I would like to express my gratitude to Julie Jordan and Benjamin Vaughan for their efforts in the Water Quality Laboratory, Leon Alley for hauling poultry litter and simulator assistance, and Charles Karpa and Jan Carr for their help in obtaining and interpreting event hydrographs. I would also like to acknowledge the assistance provided by the 2000 and 2001 NSF Summer Internship Students, and Amanda Masters, for their help with fieldwork and laboratory analysis.

Much appreciation is also extended to Dr. Eric Smith of the Statistical Consulting Center who assisted with statistical analysis issues.

I would like to thank my parents, and my girlfriend, for their continued support and patience during my studies.

Finally, since this study was part of a larger project, I would like to thank Dr. Gary Felton at the University of Maryland who served as the principal coordinator, and the U.S. Environmental Protection Agency for project funding.

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1 Introduction

1.1 Poultry Production

In 1999, the value of broilers produced in the United States was 15.1 billion dollars (USDA, 2000). Virginia, Maryland, and Delaware are each among the top ten poultry-producing states. Based on manure production and nutrient values reported by the Virginia Department of Recreation and Conservation (DCR, 1995), the 815 million broilers produced in these states result in an estimated 28 900 000 and 28 700 000 kg of nitrogen and phosphorus, respectively, most of which is located in the Chesapeake Bay watershed. As a result, considerable concern over pollutant loadings to the Chesapeake Bay has arisen. Due to this concern, the Nutrient Subcommittee of the Chesapeake Bay Program requested poultry litter stockpiles be evaluated in both Maryland and Virginia. The University of Maryland and Virginia Polytechnic Institute and State University embarked on a joint project to examine nutrient loss from litter storage methods on soils typical of those found in poultry producing regions within their respective states.

The concern of the Chesapeake Bay Program is well founded considering that approximately 43% of estuarine square miles within the nation have been identified as impaired, mainly due to agricultural practices (Weitman, 1995). More relevant to Virginia, agriculture has been found to be a major source of nutrients entering the Chesapeake Bay (Jaworski et al., 1992; Vaithiyanathhan and Correll, 1992; and Jordan et al., 1997).

1.2 Litter Handling

A great deal of the concern focused upon poultry producers relates to litter storage and handling practices. Typically, the standard disposal method for poultry litter is land application, either directly from the poultry house, or from storage locations. While land application directly from poultry houses has many benefits, environmental conditions and labor constraints often prevent this from properly occurring. In such cases, some form of litter storage must be utilized. Typically, storage occurs in a roofed shed, covered stockpile, or uncovered stockpile. While roofed sheds are generally considered to provide the greatest environmental protection, the capital investment for shed construction deters some producers. To further complicate issues, some producers claim that properly formed uncovered stockpiles will shed precipitation and not cause significant pollution concerns.

1.3 Environmental Impacts

Two nutrients, nitrogen and phosphorous, are generally considered to be potential major poultry litter pollution problems. Virginia annually produces 18 786 000 kg of nitrogen, and 11 561 000 kg of P_2O_5, from poultry production (James W. Pease, unpublished data, 2002). Both pollutants have been linked to accelerated eutrophication, which can cause many environmental problems, including algal blooms, odor problems, increased turbidity, increases in undesirable fish populations, and fish kills due to decreased oxygen. In fresh water systems, addition of phosphorous typically causes eutrophication to occur. In fact, concentrations of inorganic P above only 0.01 mg/liter in surface water typically cause accelerated eutrophication (Sawyer, 1947; Vollenweider, 1968). However, nitrogen is typically responsible for eutrophication in saline waters.

In response, many states are starting to develop regulations intended to address the public's concern with poultry operations and their potential contribution to environmental pollution. In Virginia, HB 1207 was adopted in 1999 to establish a poultry waste management program designed to address these concerns. The goal of this research is to collect and present data that will aid in development and future revisions of regulations intended to prevent nutrient and bacterial pollution from the storage of poultry litter.

1.4 Objectives

The goal of this study was to examine the effectiveness, with respect to water quality protection, of three typical poultry litter storage methods based on the following objectives:

1. Evaluate surface runoff and soil water originating from covered and uncovered stockpiles in two poultry producing physiographic provinces, and under two antecedent soil moisture conditions.

2. Determine and compare soil nutrient levels under covered and uncovered stockpiles before and after experimental rainfall events.

3. Compare soil water quality beneath storage sheds in two poultry production physiographic provinces.

2 Literature Review

2.1 Litter Composition

Poultry broiler houses generally have some form of bedding material placed in them such as wood shavings, sawdust, or peanut hulls on which the animals are directly raised. Once this material becomes mixed with poultry manure, it is termed poultry litter (Sauer et al, 1999; Williams et al., 1999). Laying houses on the other hand typically have a pit-style storage system where the manure is not mixed with any form of bedding. Both poultry manure and litter contain high quantities of nitrogen and phosphorus, making them a valuable fertilizer resource. However, this high level of nutrients also makes poultry wastes potentially hazardous to the environment.

The nitrogen within poultry waste is typically in the form of organic and ammonical (ammonium and ammonia) nitrogen. Total Kjeldahl Nitrogen (TKN) is the sum of organic and ammonical nitrogen. Since TKN does not include nitrate, typically it is not referred to as total nitrogen (TN). However, since nitrate is absent from poultry waste (Sims and Wolf, 1994), or a minimal percentage of the TN (near 1% or less) (NC State University, Animal and Poultry Manure Production and Characterization, 1994), TKN and TN values are often used interchangeably when dealing with poultry litter. Values range widely, with TKN measurements of 0.3 to 6.7% being reported (Table 2-1). Other TN and TKN values including 2.3% (Parker et al., 1959), 3.0% (Kovar et al., 1999), 3.9% (Sharpley and Moyer, 2000; Rasnake et al., 1991), 4.0% (Stephenson et al., 1990), 4.1% (Sims and Wolf, 1994), and 4.8% (Mozaffari and Sims, 1996) have been reported for broilers. The exact level of nitrogen in the waste varies greatly due to diet composition, poultry species, and management practices.

Unlike most manures, the amount of phosphorous contained within poultry litter is comparable to that of nitrogen. Since many crops need twice as much nitrogen as they do phosphorous, this often leads to over, or under, application of a nutrient. As with nitrogen, phosphorous content varies greatly, ranging from 0.3 to 8.7% P_2O_5 (Table 2-1). Typical total phosphorus values found in the literature include 1.1% (Parker et al., 1959), 1.5% (Sims and Wolf, 1994), 1.6%

(Stephenson et al., 1990; Sharpley and Moyer, 2000), 2.8% (Mozaffari and Sims, 1996; Kovar et al., 1999), and 3.7% (Rasnake et al., 1991).

Table 2-1: Nutrient Content of Poultry Wastes

			Avg	Min	Max				Avg	Min	Max
Broilers	Nutrient	Samples	Values in %				Nutrient	Samples	Values in %		
Fresh Manure	TKN	16	1.3	1	1.7	Cake	TKN	177	2.3	1.1	4.1
	P_2O_5	15	0.8	0.6	1.1		P_2O_5	178	2.7	0.7	5
	K_2O	16	0.6	0.4	0.8		K_2O	174	1.8	0.6	3
Whole House	TKN	1004	3.6	0.8	6.7	Stockpiled	TKN	227	1.7	0.4	3.9
	P_2O_5	997	3.5	0.9	6.8		P_2O_5	222	3.9	0.9	8.7
	K_2O	995	2.4	0.6	3.9		K_2O	222	1.6	0.1	4.4
Breeder	TKN	98	1.9	0.4	4.4						
(Whole House)	P_2O_5	97	2.9	0.8	5.6						
	K_2O	98	1.8	0.6	3.2						

Layers

Fresh Manure	TKN	77	1.4	0.5	2.2	Deep Pit	TKN	33	1.7	0.3	3.5
	P_2O_5	74	1.1	0.3	1.8		P_2O_5	32	2.6	0.8	5.3
	K_2O	69	0.6	0.3	0.9		K_2O	29	1.3	0.5	2.8

Turkeys

Fresh Manure	TKN	20	1.4	1	1.8	Cake	TKN	111	2.3	0.9	3.6
	P_2O_5	23	1.2	0.5	2.3		P_2O_5	109	2.4	0.9	4.3
	K_2O	22	0.6	0.3	1		K_2O	109	1.5	0.5	2.9
Whole House	TKN	541	2.8	0.7	4.6	Stockpiled	TKN	158	1.6	0.4	3.6
	P_2O_5	537	-	1.2	5.9		P_2O_5	156	3.5	0.8	8.4
	K_2O	548	2	0.5	3.6		K_2O	157	1.5	0.2	3.6

*** Source: NC State University, Animal and Poultry Manure Production and Characterization, 1994.**

2.2 Poultry Diet

To explain the high nutrient levels in poultry litter, which can potentially cause negative environmental impacts, you must look at the poultry diet. Diet composition, or what the bird consumes, significantly influences the content of excreted manure that must then be dealt with for disposal. Excess levels of Crude Protein (CP) and phosphorus (P) pass through the birds' digestive tract with no growth benefit, elevating nitrogen and phosphorus levels in the manure. Historically, poultry feed contained excess nutrients to insure that optimum levels of growth were obtained. New research is focusing on determining how much protein and phosphorus is actually needed by poultry to achieve optimum performance while reducing levels of nutrients in the manure.

2.2.1 Crude Protein

Protein is supplied in poultry diets to provide amino acids. Since poultry often require amino acids in proportions differing from that found in their feed, the protein levels of the feed must be raised to supply the highest amino acid demand. This typically results in excess amounts of most amino acids, and elevated levels of nitrogen in the manure. The National Academy of Sciences currently recommends three feeding regimes for broilers based upon age interval. Recommended Crude Protein (CP) levels for broilers 0 to 3, 3 to 6, and 6 to 8 weeks of age are 23.00, 20.00, and 18.00%, respectively (National Research Council, 1994). Within the 19-21% CP range, a 7% reduction in litter N content can be obtained for every percentage point reduction in dietary CP (supplementation with amino acids is typically required) (Ferguson et al., 1998).

If amino acids are supplemented to the feed, overall CP levels can be reduced while still supplying all necessary amino acids. In typical corn and soybean based diets methionine and lysine are the most limiting amino acids (Patterson, 2001). For example, a layer diet consisting of 12.7% protein supplemented with 150g methionine/ton resulted in a 9.89% reduction in fecal nitrogen, with no detrimental effects, compared to a 15.5% protein diet (Sloan et al., 1995). However, in the first few weeks of life, broilers require more protein in their diet. Reducing CP levels to 18.8% (with amino acid supplementation) decreased performance in broilers less than 3 weeks of age due to a decreased feed intake (Ferguson et al., 1998). After the first three weeks, the 18.8% CP diet had no adverse effect on feed intake or weight gain, indicating care must be taken when trying to decrease CP levels.

2.2.2 Phosphorus

Phosphorus is another element that is an essential component of poultry feed, but which creates many challenges when dealing with the excreted portion in an environmentally responsible manner. Cereal grains make up the major component in poultry feed and contain significant quantities of phosphorus. Unfortunately, two-thirds of the total phosphorous within these grains is in the form of phytic acid, or phytate (Simons et al., 1990), which is largely unavailable to monogastric animals. Studies have found the capability of digesting phytate ranging from 0-61% (Nelson, 1976; Edwards, 1982; Nahm and Carlson, 1998). This results in phosphorous passing through the animal and potentially becoming a pollutant. To provide poultry with the phosphorous they need to grow, feed companies traditionally add inorganic phosphorous as a supplement (Sebastian et al., 1998). Over half of the phosphorus consumed is passed into the feces (Saylor, 2000).

The amount of phosphorus needed by poultry depends on several things including species and age. For example broilers require 0.30-0.45% phosphorus in their feed, while turkeys and mature laying hens require 0.25-0.60% and 0.21-0.31% respectively (National Research Council, 1994). However, to have a diet with 0.32% phosphorus availability, broilers typically need a 0.70% phosphorus diet to compensate for what is lost and unabsorbed (Saylor, 2000). While some may argue that within a species there is variation in phosphorus requirements, research among leghorn layers indicated that levels of available dietary P as low as 0.28% had no negative effect on any of the varieties tested (Leeson and Caston, 1996).

2.2.3 Phytase

To enable poultry to utilize phytic acid, either the phytase enzyme is being added to poultry feed or diets with endogenous phytase are being formulated. This allows for better conversion of phytic acid, and therefore less (or no) inorganic phosphorous needs to be added to the feed. While phytase is present in some feed ingredients, the amounts vary greatly between grain types (Table 2-2). A diet developed by Temperton et al. (1965) containing 32% wheat and 10% barley allowed chicks to utilize phytate phosphorus for bone calcification (no animal feedstuffs or inorganic phosphorus was added to the feed). It has also been shown that wheat phytase has the ability to act upon phytate from other sources (Scheuermann et al., 1988). Therefore, by using a careful blend of grains in poultry feed, it may be possible to eliminate inorganic phosphorous additions.

Table 2-2: Phytase activity in selected feed grains (Sebastian et al., 1998)

Grain	Activity (units/kg)
Rye	5130
Triticale	1688
Wheat	1193
Barley	582
Maize	*
Oats	*
Sorghum	*
Oilseeds	*

*indicates grain was found to contain little or no phytase

Phytase incorporation, in those diets not formulated from low phytate feedstuffs, is generally reported to improve phosphorus availability by 20-40% (Kovar et al., 1999); some studies have found the improvement to be as high as 69% (Simons et al., 1990). In addition, significant improvements in weight gains occur when phytase is added to the diet. Anywhere from 11-77%

Table 2-3: Influence of phytase on performance of poultry fed maize-soybean diets (Sebastian et al., 1998)

Source	Age of Birds	Phytase	Non-phytate P in diet	% Improvement's		
		(units/kg)	(%)	BW gain	FCR	P retention
Simons et al. (1990)	28	750	0.16	38	0.63	20
Bronz et al. (1994)	22	500	-	13	3.4	15
Aoyagi and Baker (1995)	20	600	-	77	3.7	-
Sebastian et al. (1996)	21	600	0.3	13.2	0.67	24
Komegay et al. (1996)	21	600	0.2	36	2.6	5.3
Yi et al. (1996)	20	600	0.45	11	3.53	-

FCR = Food conversion ratio

gains have been documented (Table 2-3). Phytase also decreases calcium, zinc, copper, and perhaps nitrogen excretion.

2.3 Poultry Waste Disposal

Over 90% of poultry litter produced ends up being land applied (Moore et al., 1995). The standard disposal method for poultry litter is land application to permanent pastures (Sauer et al., 1999), either directly from the poultry house or from storage locations. This disposal method has been shown to increase yields from the fields in question. Bermudagrass, tall fescue, and tall fescue-clover yields have been increased by 306, 215, and 51%, respectively, by 13 Mg/ha litter applications (Huneycutt et al., 1988). At the same application rate orchard grass yields have been increased by 172% (Hileman, 1973). Field application of poultry litter to cropland also increases yield, even when compared to urea ammonium nitrate fertilizer applied at the same N application rate (Chinkuyu et al., 2000).

At the same time, concern has arisen that significant pollution can result from improperly handling waste. Nitrogen presents problems for both surface and groundwater pollution. As a result, streams flowing from agricultural areas typically have significantly increased nitrate levels compared to forested backgrounds (Kunishi, 1988; Miller et al., 1997). Furthermore, when comparing nitrate levels in ground water and surface water in agricultural areas, concentrations in surface runoff are typically much lower than in groundwater (Staver et al., 1989). In addition to being an environmental pollutant as mentioned above, nitrogen is a contaminant for which the EPA has set a maximum drinking water standard of 10 mg/L as N. In children and young animals, levels higher than 10 mg/L may cause methemoglobinemia, or blue baby syndrome (Williams et al., 1999).

2.4 Nutrient Characteristics

2.4.1 Nutrient Solubility

The solubility of nutrients in poultry waste has a direct impact upon the quantities of nutrients transported off-site. A study by Sauer et al. (1999) indicated that the percentage of exported nutrients in runoff was higher from poultry litter amended plots, compared to dairy feces and urine amended plots. The plots treated with poultry litter lost 5.0, 29.5, and 21.9% of the applied TN, NH4-N, and soluble reactive phosphorous as compared to losses of 3.9, 5.0, and 15.3% respectively for the dairy waste. However, it should be noted that the poultry litter application rate was much higher than the dairy waste application rate.

Soluble phosphorus levels are particularly high in poultry wastes. This material can become dissolved in water and transported more easily than non-soluble phosphorus that is attached to particulate material. Unfortunately, the majority of the total phosphorus in poultry wastes is soluble (Moore et al., 1995; Vervoort et al., 1998; Sharpley and Moyer, 2000). In fact, concentrations of water-soluble phosphorus ranging from 2000 to over 7430 mg/kg have been reported in poultry manure, litter, and composts (Moore et al., 1995; Sharpley and Moyer, 2000). Soluble phosphorous concentrations from pasture runoff, where litter application of 20 and 10 Mg/ha occurred, were as high as 3.8 and 1.6 mg/liter in a watershed scale study (Vervoort et al., 1998). These concentrations were well above the EPA recommended total phosphorus guidelines of 0.05 and 0.1 mg/L, which were established to prevent eutrophication of lakes and streams (Sharpley et al., 1996). The highest subsurface nitrate-N concentrations occurred during the first winter after application, and were 4.3 and 1.1 mg/L for the 20 and 10 Mg/ha application rates (Vervoort et al., 1998).

In order to decrease nutrient transport, incorporation is often recommended following land application. A study by Nicholes et al. (1994) concluded that incorporation of poultry litter or commercial fertilizer within the top 2-3 cm of pasture by rotary tillage had no significant impact upon runoff quality. It was thought that tillage interfered with the natural retention and infiltration characteristics of the native fescue, offsetting any gains incorporation may have produced. Nitrogen and phosphorous losses were no greater than 1.3 and 1.9% respectively, regardless of whether it was incorporated or not.

2.4.2 Nitrogen Movement

Since the nitrate form of nitrogen is highly mobile, much research has been done on nitrogen movement in poultry producing regions. A series of 200 groundwater monitoring wells in Delaware, varying in depth from 6 to 34 m were studied for nitrogen contamination (Ritter and Chirnside, 1987). Wells located in areas with poultry production had significantly higher nitrate concentrations than other agricultural areas. Two wells, located down slope of a field where poultry litter was applied, showed higher concentrations of nitrates than wells at the top of the field. More than one-third of the wells had nitrate concentrations greater than the EPA drinking water standard of 10 ppm.

Due to the high nitrogen content of poultry litter, it is not surprising that research has been conducted on groundwater leaching as a result of poultry waste land application. The rate of land application has proven critical in reducing nutrient runoff. A study at the University of Arkansas was conducted to determine if the application rate of poultry litter affected leaching of nitrates to groundwater (Adams et al., 1994). Poultry litter application rates of 10 and 20 Mg/ha (440 and 880 kg N/ha respectively) and poultry manure at a rate of 20 Mg/ha (880 kg N/ha) were broadcast onto 1.5 x 6-m plots. Water samples were collected for two years throughout the test plots from suction-cup lysimeters located at depths of 60 and 120 cm. Nitrate levels as high as 13, 54, and 41 mg/L were reported at a depth of 60 cm; concentrations of 8, 24, and 37 mg/L for the 120 cm depth were found for the poultry litter 10 Mg/ha, poultry litter 20 Mg/ha, and poultry manure 20 Mg/ha plots.

When equal amounts of poultry litter or manure are applied with respect to the nitrogen content, there is no significant difference in nitrate leaching (Adams et al., 1994). They found that both litter and manure spread at 220 and 440 kg N/ha resulted in vadose water nitrate contamination. There was a significant effect between the amount of litter applied and the nitrate concentrations in the water. The difference between the control (no litter applied) and treatments increased during the winter months. It was also determined that June applications of 4.5 and 3.8 Mg litter/ha of poultry litter and manure did not result in significant nitrate leaching.

The degree to which groundwater becomes contaminated with nitrate depends on both soil type and depth to groundwater. Liebhardt et al. (1979) applied poultry manure to large plots of a loamy sand soil for four years to investigate the effects of ammonium and nitrate in shallow groundwater. Five wells were installed per plot at three depths: 3, 4.5, and 6 m. Samples collected at the shallowest depth showed significantly higher nitrate concentrations than the lower depths. The reduction in nitrogen concentrations with depth was thought to be caused by lateral movement of water in the soil, due to a drainage ditch reducing the amount of runoff that was introduced to the areas below 3 m.

The impacts of commercial fertilization and poultry manure upon groundwater under irrigated coastal plain soils in Maryland were examined by Weil et al. (1990). Four fields were studied, two of which received commercial fertilizer only, and two which received commercial fertilizer and poultry litter. Concentrations of phosphate-P and ammonium-N in groundwater under the four crop fields in questions were minimal, generally being under 0.1 mg/L. It was found that groundwater nitrate concentrations in all fields exceeded the EPA standard of 10 mg/L at almost every sampling event. The fields receiving poultry litter were found to have significantly higher nitrate concentrations than those receiving commercial fertilizer only. This was attributed to the higher overall N application rate.

Litter amendment materials, such as alum, ferrous sulfate, or zeolite, while typically being studied to reduce phosphorus levels in runoff, also have impacts upon litter nitrogen content as well. The producer typically mixes these items into the litter between flocks. Shreve et al. (1995) found that litter amended with alum or ferrous sulfate resulted in higher N concentrations in runoff, probably because of the higher overall nitrogen content of the litter due to decreased ammonia volatilization. Alum and Ferrous sulfate have been found to reduce ammonia volatilization by 99 and 58%, respectively (Moore et al., 1995)

2.4.3 Phosphorus Movement

Since phosphorous is a positively charged molecule, it behaves differently than nitrogen when being transported. It’s positive charge allows it to sorb strongly to the cation exchange sites on soil particles upon contact. Phosphorous can also precipitate out of solution when reacting with metals such as iron. As a result, phosphorous was not considered a serious groundwater pollution problem in the past (Horton and Eichbaum, 1991). However, new studies have shown that soils do have a limited holding capacity of phosphorous. Once this limit is reached, phosphorous starts to become much more mobile and can be leached just like many negatively changed molecules (Reddy et al. 1978; Sims et al. 1998; De Haan and Zee, 1994). This has primarily been seen in areas where heavy applications of animal manure have occurred.

Few studies have looked at the long-term implications of land applying poultry litter. Ritter and Chirnside (1987) examined a field that received poultry litter applications at least biannually, for 15 years. Two wells located down gradient from the field at a depth of 4.6 and 15.2 m had average nitrate concentrations of 12.3 and 10.3 mg/L. The corresponding wells above the field had nitrate concentrations of 3.70 and 1.78 mg/L. However, there was not a large difference in the concentrations above and below the field at a depth of 7.6 m. Ammonia concentrations were low in all wells, generally less than 0.05 mg/L. To further illustrate that areas of broiler production result in high nitrate concentrations, wells were classified with respect to their proximity to broiler houses. For one area of poultry production, wells within 152 m of poultry houses averaged 15.13 mg nitrate/L. In the same area, wells located more than 305 m from poultry houses averaged only 4.33 mg nitrate/L (Ritter and Chirnside, 1987). Poultry litter was identified as at least one of the probable major causes of groundwater contamination in four of the top five areas with groundwater problems (Ritter and Chirnside, 1983).

2.5 Soil Influence upon Nutrients

A study by Vervoort (1998) looked at nutrient loss due to poultry litter application on a large, polypedon scale. Two soil series, both classified as a sandy loam, formed the upper layer at all three watersheds investigated. A subsurface clay layer was located at a depth of 100 cm. Runoff and subsurface samples were taken automatically over a period of a year. By comparing both surface and subsurface nutrient samples, it was determined that the physical makeup of soil due to differences in soil series greatly affected the movement of the nutrients. In contrast, Sharpley

(1997) found soil type to have little impact upon nitrogen transport; concluding it was more a function of litter application rate.

A study by Mosaffari and Sims (1996) examined phosphorous additions and transformations to three different soil types, Evesboro loamy sand, Matawan loamy sand, and Pocomoke sandy loam. Their experiment was carried out in the lab, and designed to simulate 18 and 36 Mg/ha application rates. They found that the percentage of soluble P added by the poultry litter that was immediately leached varied due to application rates, similar to the findings of Sharpley (1997); however, they also observed variation due to soil type, which Sharpley (1997) did not. Matawan soil, having low clay and aluminum and iron oxides, released more soluble phosphorus over the 100 day incubation study than the other two soils (Mosaffari and Sims, 1996).

While total phosphorus losses are mainly a function of sediment loss (Reddy et al., 1978; Cox and Hendricks, 2000), dissolved phosphorus concentrations increase with greater soil test phosphorus levels (Field et al., 1985; Cox and Hendricks, 2000). Furthermore, greater increases in extractable phosphorus concentrations will be found in soils with lower clay contents compared to fine textured soils (Cox and Hendricks, 2000). Field et al. (1985), found that the addition of 1 g poultry manure solids to 1 kg of Hayesville loam soil resulted in increases in extractable phosphorus of 3-6 mg P/kg soil.

2.6 Bacteria

In Virginia, over 3,000 stream and river miles are not fully supporting their designated use classification due to pathogen indicators (DEQ, 2000). The presence of pathogen indicators raises concerns for human health reasons. Since testing for every possible human pathogen would be nearly impossible, pathogen indicators such as fecal coliform bacteria are used to indicate the presence of fecal material, and therefore the potential presence of pathogens. While bacteria are typically considered a surface water concern, research has shown the potential for movement through the soil column (Smith et al., 1985; McMurry et al., 1998).

One of the major sources of bacteria (both pathogenic and non-pathogenic) comes from land application of animal waste (Crane et al., 1980). As a result, concern has risen about bacterial loadings from poultry litter, which contains a vast assortment of microbes, some of which may be pathogenic to humans. Bacterial levels have been reported as high as 165 000 000 total bacteria CFU/g (Martin et al., 1998), 100 000 000 total coliform bacteria CFU/g (Kelley et al., 1984), with typical values being somewhat lower.

It is thought that storage can have a significant impact upon the amount of bacteria present in poultry litter. In fact, statistically significant reductions in bacterial concentrations have been shown to occur during a storage period of four months (Kelley et al., 1984). Seven out of twelve samples tested showed statistically significant reductions in fecal coliform bacteria during the two to sixteen weeks of storage. Specifically, fecal coliform concentrations decreased from a range of 10^ ^{2} - 10^ ^{5}, to below the detection limit of 30 CFU/g dry litter. Another study indicates similar findings with half of the fresh litter samples, and all but 1 sample from stacked poultry litter, having fecal coliform levels that were below detection (Hartel et al., 2000). The stacked litter sample found to have fecal coliform bacteria present was obtained from the exterior of the pile, with none being detected in the interior. However, a survey that included 86 poultry litter samples from throughout Georgia found composting vs. non-composting, and length of composting time, had no steady influence on bacteria populations (Martin et al., 1998). Coliforms could only be found in 5 of the 86 samples tested, typically being non-pathogenic *E. coli*.

To further confuse the issue, debate exists on the possibility of bacterial re-growth. First-order kinetics are often used to model bacterial populations from poultry litter and manure (Reddy et al., 1981; Smith et al., 1985; and Edwards and Daniel, 1992). However, research has shown fecal coliform re-growth following a seven-day period of die-off (Crane et al., 1980). This re-growth was seen from fecal coliforms in all six plots; but not with fecal streptococcal bacteria, which followed the typical decay curves. Other studies have also indicated bacterial re-growth (Cuthbert et al., 1955; Van Donsel et al., 1967; Giddens and Rao, 1975).

2.7 Storage

While many studies have examined the effects of poultry litter on the environment, few have examined effects from various storage procedures utilized before land application occurs. Currently little data exists to show the benefits, if any, of various poultry litter storage management practices upon nutrient or pathogen losses. According to Sims and Wolf (1994), solid litter is typically stored in roofed sheds, tarpaulin-covered stacks, or windrowed piles.

2.7.1 Economic Considerations

Due to economic considerations, some producers choose to store their animal wastes in stockpiles. The estimated cost for storing poultry litter in a plastic-covered stockpile is \$5/Mg, as compared to \$116/Mg for shed storage (Costello et al., 2001; and Costello, 2000). Costs may be reduced even further if the stockpile remains uncovered, however this is now illegal in several states including Virginia.

2.7.2 In-House

Unlike most animal wastes, poultry wastes are allowed to remain in the growing house for extended periods of time. The exact length of time is usually determined, at least in part, by the contract company, and ranges from six weeks to one year or more. Vertical movement of nitrogen has been found beneath poultry houses (Ritter et al., 1994; Lomax et al., 1997). Lomax et al. (1997) observed nutrient levels below loose and compacted soil surfaces of 1063 and 1077 mg of TKN/kg dry soil, 404 and 460 mg of NH_4-N/kg dry soil, and 245 and 263 mg of NO_3-N/kg dry soil respectively (Lomax et al., 1997). Concrete floors installed with moisture barriers reduced TKN levels in the underlying soils by 80%, while NH_4 and NO_3 had reductions of 94%.

Another study found the soil columns under dirt floor poultry houses to average 2384 mg NO_3-N/kg dry soil, compared to a background average of 19.1 mg NO_3-N/kg dry soil (Ritter et al., 1994; as cited by Lomax et al., 1997). It was felt that transport occurred by diffusion as ammonia, or ammonium moving with the soil water once soil particle exchange sites become saturated (Ritter et al, 1994).

2.7.3 Uncovered Stockpiles

Inconclusive results have been reported by researchers examining uncovered poultry litter stockpiles. A study by Costello et al. (2001) reported surface runoff characteristics similar to liquid animal wastes. At the same time, analysis of soil water indicated there was no vertical movement of nutrients into the soil profile. In contrast, work by Weil et al. (1990) inadvertently observed significant leaching of nitrate from poultry litter stockpiles. The researchers were examining how field application of poultry litter affects groundwater when the cooperating farmer placed a stockpile of manure approximately 20 m from two of their monitoring wells in December. Prior to the stockpile placement in November, the concentration of nitrate in the two wells was 13.3 and 13.2 mg/liter. By February, the concentrations had risen to 104.1 and 74.0 mg/liter respectively.

Further support of vertical movement of nutrients from stockpiles has been determined by examining soil nutrient levels to indicate nutrient additions or movement. Zebarth et al. (1999) examined a site in British Columbia for both nitrogen and phosphorous loss where uncovered poultry litter storage had been occurring for six years. No significant differences in soil nitrate concentrations were found between the up-gradient, down-gradient, or storage location itself. However, substantial increases in soil inorganic N from elevated ammonium levels were documented. Soil total N concentrations taken from 60-370 cm were elevated at the down-gradient site compared to the up-gradient area, and at the storage location relative to the non-storage areas. It was thought that the high levels of ammonia proved to be toxic to nitrifying bacteria, inhibiting nitrification. The extractable soil P levels were found to be higher under the storage location, relative to non-storage location, from a depth of 0-180 cm only. The concentration was the highest from 0-60 cm (730 mg P/kg). At 60-180 cm the concentration was down to 105 mg P/kg. Below 180 cm there was no difference between the three areas. The increase in soil ammonium was determined to occur while the piles were in place, and not after their removal. The timing of this increase is in contrast to what Ritter et al. (1994) hypothesized.

2.7.4 Covered Stockpiles

Dews (1995) examined covering cattle manure heaps, and the nitrogen losses that resulted. Protection of the manure heaps with plastic sheeting did not significantly reduce leachate concentrations of nitrogen (Dews 1995; and Dewes et al., 1991). The reason is that the quantity of leachate arising from precipitation was small, compared to the total leachate lost. Much of the leachate resulted from the aerobic decomposition of the manure. Uncovered piles had a 28.2% N loss, while covered piles had a 43.1% N loss. Volatilization was determined to be the main mechanism of nitrogen loss. However, since cattle manure has a higher moisture content than poultry litter, significant differences between the loss mechanisms may exist between the two waste types.

2.7.5 Covered Vs. Uncovered Stockpiles

A three-year study conducted by Ritter et al. (1994) supports the work of Weil et al. (1990). Groundwater was monitored from May 1987 to March 1988, and from July 1989 to May 1990, under three covered and three uncovered litter stockpiles. During this time, the farmer periodically removed the litter from the site for land application. When no litter was present, the covers were removed from the site. It was found that ammonia concentrations were low, all below 1.5 mg/liter. However, both storage methods increased nitrate concentrations in the ground water. This contradicts their earlier work where no increase in nitrate concentration was found (Ritter and Chirnside, 1987). There was no significant difference between covered and uncovered piles.

2.7.6 Ground-lined Stockpiles

Ritter and Chirnside (1987) examined groundwater around six poultry manure storage piles, as well as near field application sites. Two of the piles were lined between the soil surface and the manure with 4mil polyethylene, which would address the leaching problem encountered by Dews (1995). The concentrations of both nitrate and ammonia around all piles did not significantly increase over the one-year period of study, although some wells already had nitrate concentrations above 10 mg/liter. The researchers proposed that one of the reasons a significant increase was not observed was the short time of study, which did not allow the nitrate to leach to a sufficient depth.

3 Methodology

3.1 Field Stockpile Study

3.1.1 Pile construction

Six stockpiles were constructed on six runoff plots at each of two study sites to allow for the evaluation of covered and uncovered stockpiles; with a seventh runoff plot acting as a control and receiving no litter. Treatments were randomly distributed among the seven experimental plots at each study site. One study site was near the Virginia Tech campus in the Ridge and Valley physiographic province, with the other being at the Southern Piedmont Agricultural Research and Extension Center located within the Piedmont physiographic province. Piles consisted of approximately 11,790 kg of litter each in a 6.1 x 6.1 m runoff plot (Figure 3-1). In order to allow for the operation of machinery, a 0.9 m spacing was maintained between piles. All piles were covered with tarpaulins between rainfall simulator runs. Tarpaulins were removed from three piles, previously chosen at random to receive the uncovered treatment at each study site, prior to each rainfall simulation.

Due to the location and timing of the two field stockpile studies, poultry litter used originated from two separate sources. The Ridge and Valley simulation occurred during June 2000; the poultry litter was trucked in by a litter broker from the Shenandoah Valley. This litter came directly from a cleanout operation and had not undergone any previous storage. Litter used in the Piedmont simulation was purchased in June 2001 from a local grower in Nottoway County. In this instance, the litter had been stored in a litter storage shed for 3 months prior to pile formation.

The tarpaulins used on the covered treatment during rainfall simulation were placed so that they covered the pile surface to within 10 cm of the soil surface (approximately 95% coverage) prior to each simulation event. This was done to mimic conditions that were observed and thought to occur regularly on poultry farms when litter piles were covered. The study was planned prior to the Virginia HB1207 regulation being passed, which requires coverage preventing litter from coming into contact with precipitation or runoff, if piles are to remain in the field 14 days or longer.

3.1.2 Soil Moisture Modification

To simulate litter being piled under “dry” and “wet” conditions, it was necessary to increase the soil moisture level under the piles after the dry run had been initially made. To accomplish this without disturbing the litter pile, drip irrigation tubing was installed within the experimental area, prior to pile formation.

To minimize water movement into the litter piles by capillary action, the drip tubing was buried to a depth of 10.16 cm. A 0.61 m spacing between drip tubing laterals was maintained to insure uniform moisture distribution throughout the soil. Approximately 350 m of drip tubing was used at each experimental site.

Queen Gil® medium flow, 121 liters per hour per 30 meters, drip tubing was used for the Ridge and Valley simulation. The drip tubing header was broken up into four zones due to inadequate water supply volumes. There were two plots per zone, with the exception of plot A, which was in a zone to itself. Since flow volumes were low, the drip tubing header consisted of 1.6 cm PVC pipe. Plots received a total of 6 hours of irrigation, in 4- and 2-hour blocks of time. Unfortunately, the well serving our drip tubing system ran dry so irrigation time was not able to exceed 6 hours.

The Piedmont Experimental site did not have water limitations like the Ridge and Valley site. T-Tape® drip tubing with a flow rate of 76 liters per hour per 30 meters was used with a 5.1 cm PVC drip tubing header. Soil water was applied to the plots four hours a day during the two days prior to the wet simulation run.

3.1.3 Soil Moisture Determination

Soil moisture determination was made by a combination of oven drying and granular matrix (Watermark$^{®}$) sensors. For the Ridge and Valley site, random soil samples from depths of 10.2, 30.5, and 61.0 cm were oven dried to determine initial dry run moisture content. Five granular matrix sensors were installed under each of the seven plots and were used to determine when sufficient irrigation had occurred, as well as the soil moisture content during the second run. Granular matrix sensors were used because they operate over a wider range of soil moisture conditions than most tensiometers, and they could be buried under the piles. For each plot, two sensors were randomly located at both 10.2 and 30.5 cm below the surface, while an additional sensor was located at a depth of 61.0 cm, for a total of five sensors per plot.

Prior to installation, granular matrix sensors were allowed to soak overnight. During installation, a soil slurry was used to seat the sensors, insuring proper contact with the surrounding soil. In order to allow for readings during the experiment, sensor wires were buried along with the lysimeter tubing (described below) and surfaced outside of the poultry litter pile perimeter.

At the Piedmont site, soil moisture determination was made by taking samples from beneath the edge of the pile and oven drying them. Two sample boreholes were used for each plot, with samples being taken from 10.2, 30.5, and 61.0 cm; resulting in a total of 6 soil samples per plot. Three granular matrix sensors were also installed under the piles to evaluate the soil moisture application effectiveness. They were not directly used in soil moisture determination because of the inability to construct a calibration curve for soil on this site due to logistical problems created by the travel distance to the Piedmont experimental site.

3.1.4 Borders

Impervious borders were installed around each pile to prevent surface water movement between piles, as well as to keep litter material within the plots. Borders were located 0.46 m from the edge of each pile. To minimize subsurface water flow between plots, borders were installed to a minimum depth of 10 cm. At the base of each plot, an outlet was constructed to channel flow into a 15.3 cm H-flume where a water level stage recorder was located. Including the 4 m^2 outlet area, each flume drained a 41 m^2 area.

Due to slope variability over the Piedmont experimental area, modifications were needed in several of the plots to assure proper water flow. Plots A, B, and C required the addition of soil to the lower corner to prevent surface water ponding.

3.1.5 Simulator Setup

A rainfall simulator (Dillaha et al., 1988) was used at each study site to create the precipitation events. To minimize complexity of simulator setup, all 7 plots were placed between two laterals (Figure 3-1). Each lateral consisted of 58 or 61 m of 7.62 cm Wade Rain pipe that allowed for sufficient overlap. Also, to assure sufficient sprinkler overlap and proper distribution of the rainfall, laterals were installed above and below the two previously mentioned laterals, for a total of 4 laterals.

Risers were set up in a triangular pattern, spaced 6.10 meters apart. Nine or ten risers were needed per lateral, for a total of 38 risers at each experimental site.

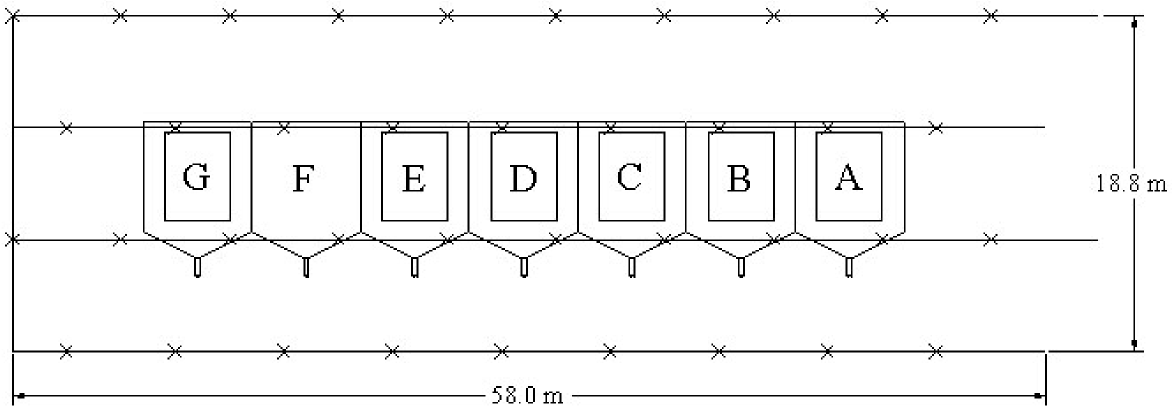

Figure 3-1: Ridge and Valley Rainfall Simulator Layout

3.1.6 Simulation Events

Piles at each site were subjected to two rainfall events, of sufficient duration to each result in at least 60 minutes of runoff from all plots. The rainfall simulator's design rainfall intensity is 50 mm/h (Dillaha et al., 1988), typical of a 5-10 year, one hour rainfall in Southwest Virginia (USDC, 1961). Two rain gauges were installed in each plot to determine the amount of rainfall received.

The first simulator run occurred on soil with low moisture content, a condition typically found in summer months. After the simulation run on low moisture soil, the sites were prepared for the wet soil moisture run. This was accomplished by using the drip irrigation tubing spaced at 0.61 m intervals under the study area. Soil matrix sensors were used to indicate when irrigation had been sufficient to elevate the soil moisture content to near field capacity.

3.2 Lysimeter Construction

3.2.1 Materials

High flow porous-cups (B0 .5M2 0.5 bar) from Soil Moisture Equipment Corporation were used to construct the lysimeters used in this experiment. These were installed into PVC pipe with Epoxy adhesive, also obtained from Soil Moisture Equipment Corporation. NALGENE® Teflon FEP tubing (3.18 mm O.D.) was used for the semi-rigid sample tubing. This tubing was inserted through a rubber stopper and extended to the bottom of the ceramic cup. Polyethylene tubing (6.35 mm O.D.) was also inserted so it extended just through the rubber stopper for use in applying a vacuum.

Both tubing lines were semi-rigid material, which is able to withstand heavy weight, such as farm machinery, without collapsing. Flexible tubing was used to connect any joints that were necessary, and at the ends where sample collection and suction application occurred. Connecting the smaller diameter sample line was 2.38 mm I.D. Tygon® Formulation R-3603 tubing, while 4.76 mm I.D. rubber vacuum hose was used to connect the larger vacuum line.

3.2.2 Lysimeter Preparation

Approximately 40 lysimeters were used throughout this experiment. Due to the high number of lysimeters required, both new and old lysimeters were used which, unfortunately, can lead to inconsistency in the raw data (Debyle et al., 1988). To correct for differences in old and new lysimeters, all lysimeters were washed with 0.5 L 1 *N* HCl acid solution to minimize any differences between new and old samplers. The lysimeters were then rinsed with 0.5 L of deionized, distilled water (DDW).

Typically, after ceramic porous cups have been washed in the above manner, the first one or two samples may have lower solute concentrations than that in the soil solution (Debyle et al., 1988). This is because the cation exchange sites within the ceramic matrix are only filled with hydrogen ions. To eliminate this problem, Debyle et al., (1988) suggested using a nutrient solution similar to the expected soil solution to flush the lysimeters. Therefore, a dilute nutrient solution was filtered from poultry litter and passed through the porous cups, allowing the H^+ ions to be replaced with more representative ions of the experimental conditions. This nutrient solution was made by taking 150 g of poultry litter and 0.5 L of DDW, separating the filtrate, and diluting with 11.5 L of DDW. A final rinse of DDW was performed to remove any excess material.

3.2.3 Lysimeter Installation

Prior to construction of the piles, three porous cup lysimeters were installed under each pile at a depth of 0.61 m. One lysimeter was installed in the center of the litter pile, with a second lysimeter being installed halfway between the edge of the pile and the center. Finally, the last lysimeter was installed at the edge of the pile. The exact placement of these three lysimeters was done by randomly choosing a line of placement.

To assure proper contact of the porous cup with the surrounding soil matrix, a soil slurry was utilized. To prevent contamination between soil layers, the material was saved from the borehole corresponding to the depth from which it was removed. The lower section was used to produce the soil slurry, with the upper portion being packed into the remaining void between the lysimeter and soil column, and filling it flush to the surrounding surface. The soil used to fill the void between the lysimeter and the surrounding soil was compacted to prevent runoff from short-circuiting the soil matrix. This procedure was followed for all three lysimeters in each plot.

3.3 Stockpile Sample Collection/Analysis

3.3.1 Surface Runoff and Quality

Grab samples were taken upon initiation of runoff, and then at ten-minute intervals based upon the rainfall simulation start time. The rainfall simulation continued until runoff from all plots was present for a minimum of one hour, with sample collection continuing until runoff ceased from each plot. Surface runoff samples were analyzed individually in an attempt to isolate trends in runoff concentrations. All surface runoff was channeled through the 15 cm H-flume where the stage height was recorded onto a hydrograph chart. Later, this hydrograph was digitized to provide flow data from each plot.

3.3.2 Soil Water Samples

Soil water samples were collected before and after each simulation run. The pre-run sample was taken by applying a vacuum to each lysimeter 24 h before the simulation, with the soil water being collected the morning of the simulation.

The timing of the post-run soil water sample collection varied from 5 to 28 days, depending upon soil characteristics. The sample collection time was selected to insure that the wetting front from the simulation had infiltrated past the sampled depth, and was estimating using hydraulic conductivities from the respective soil surveys. Soil from the Ridge and Valley site had a low permeability due to clay content, so 27 and 28-day delays, respectively, were allowed before sampling following the two runs. Due to the sandy soil at the Piedmont location, samples were taken 5 days after both simulation events.

Samples from both surface and subsurface flow were analyzed for nutrient concentrations. Nutrient analysis encompassed nitrate-N, ammonical nitrogen (ammonium + ammonia), Total

Kjeldahl Nitrogen (TKN), ortho-phosphate, and total phosphorus. Since much of the impairment of Virginia's waters is due to bacteria, the runoff was also examined for total fecal coliforms. Upon collection, the samples were placed on ice and transported to the Water Quality Laboratory of the Virginia Tech Biological Systems Engineering Department for analysis.

3.3.3 Litter Sampling

Six litter samples were composited from each litter pile prior to each rainfall event. These samples were collected by core sampling with a 76.2 cm steel pipe driven to a depth of 0.61 m so the entire pile was equally represented. Composited litter samples were shipped to the Maryland Cooperative Extension Soil Testing Laboratory for analysis.

3.3.4 Soil Sampling

To reduce sample analysis costs, the soil for the pre-litter application analysis was composited into one sample representing the entire study site. After the simulations were completed, six samples were randomly taken from each plot and composited for determining how much soil nutrient addition occurred during the experiment. Soil testing was performed at the Virginia Tech Soil Testing and Plant Analysis Laboratory, with soil NO_3 testing performed by the Biological Systems Engineering Water Quality Laboratory.

3.4 Litter Storage Shed Study

Six poultry litter sheds were monitored in an observational study from July 2001 to March 2002. They were selected such that three were in the Piedmont and three in the Ridge and Valley provinces, with all sheds presently used for litter storage.

Three lysimeters were installed at each shed. Placement was at the center of the shed, the edge of a randomly selected quadrant, and in a background location. Installation procedures were the same as those for the previous field study with the following exceptions.

The central lysimeter was installed such that the entire apparatus, including tubing, was buried below the soil surface, with the porous cup being 0.61 m below the surface. Both suction and sample collection tubes were buried in a covered trench, leading to the wall of the shed.

The lysimeter installed at the edge of the shed was installed from the outside, angling under the shed at 45°, also to a vertical depth of 0.61 m. At sheds constructed with a concrete footer, the edge lysimeter was installed vertically as close to the shed wall as possible. Tubing was clamped and allowed to remain at the soil surface.

Finally, the background lysimeter was installed vertically to a depth of 0.61 m. The background lysimeters were installed at an area up-gradient from the others as determined by topography, and typically within 30 m of the litter shed.

Sampling was conducted once a month for the duration of the study. To collect as much soil water as possible, a vacuum of 45 cbar was applied to the lysimeter approximately 24 h before sample collection.

Samples were analyzed for the same constituents as described in the previous stockpile study, with the exception of fecal coliform testing. Samples from the poultry litter sheds could not be examined for fecal coliforms due to the small size of sample volumes obtained.

3.5 Laboratory Analytical Methods

The Biological Systems Engineering Water Quality Laboratory analyzed surface and subsurface water samples for Total Kjeldahl Nitrogen (TKN), Ammonical Nitrogen (NH_x), Nitrate (NO_3), Total Phosphorous (TP), Total Suspended Solids (TSS), Volatile Suspended Solids (VSS), and Fecal Coliforms (FC). A Bran & Luebbe Traacs 800 analyzer was used for all nutrient analysis performed by the Biological Systems Engineering Water Quality Laboratory. The procedures used were based upon EPA methods (EPA, 1983), but modified by Bran & Luebbe for use with their equipment.

3.5.1 Total Kjeldahl Nitrogen:

Total Kjeldahl Nitrogen was found by using the colorimetric method US-786-86B from Bran & Luebbe (modified from EPA 351.2), which results in the production of an emerald-green color. The ammonia, sodium salicylate, sodium nitroprusside, and hypochlorite react to form the green ammonia salicylate complex, which was read at a wavelength of 660 nm. This reaction occurred in a buffered medium with a pH range of 12.8 – 13.1. Detection limits for this test procedure are 0.04-2.0 mg/L.

3.5.2 Total Phosphorus:

The colorimetric test for total phosphorus was method US-787-86C developed by Bran & Luebbe (modified from EPA 365.4). Total phosphorus was converted to ortho-phosphate by digestions with sulfuric acid. This ortho-phosphate was then measured by reacting it with molybdate, antimony, and reducing it with ascorbic acid to produce a blue color read at 660 nm. Sample concentrations ranging from 0.01-2.0 mg/L can be analyzed with this method.

3.5.3 Ammonia:

Ammonia was analyzed using Bran & Luebbe method US-780-86C (modified from EPA 350.1), which utilizes the Berthelot Reaction. The reaction occurs when ammonium salt was added to sodium phenoxide, followed by sodium hypochlorite. EDTA was added to prevent any unwanted precipitation, and sodium nitroprusside is added to intensify the blue color produced. Measurement occurs at a wavelength of 660 nm, with detection limits of 0.008-3.0 mg/L.

3.5.4 Nitrate:

Bran & Luebbe method 782-86T (modified from EPA 353.1) was used as the colorimetric procedure to measure nitrate. This was done by converting both nitrate and nitrite ions in solution to the nitrite ion. The nitrite then reacted with sulfanilamide in an acidic solution to form a soluble azo dye, measured at 520 nm. Detection limits for this procedure were 0.002-2.0 mg/L.

3.5.5 Ortho-phosphate:

Bran & Leubbe modified EPA Method 365.1 in their US-781-86D method for this colorimetric test procedure. This test was based upon the reaction of orthophosphate in the sample with molybdate and antimony ions, and then becoming reduced by ascorbic acid, producing a blue phospho-molybdenum complex. The Traacs 800 analyzer was set to read a wavelength of 660 nm for this test. In order to use this test, samples must have contained between 0.01-2.0 mg/L orthophosphate.

3.5.6 Total Suspended Solids:

EPA Method 160.2 was used to determine the amount of solid material that was suspended in the sample. This procedure involved taking a known volume, filtering it, and drying. A glass fiber filter was used to filter the sample, and then dried at 103-105°C until a constant weight was obtained.

3.5.7 Volatile Suspended Solids:

The amount of organic material in the sample was determined by EPA Method 160.4, which determines volatile suspended solids. This test method was used to obtain a rough estimation of the amount of TSS that was actually organic material and not mineral soil particles. This was done by placing the dry residue in a muffle furnace at 550°C. The amount of mass lost due to combustion was reported as volatile residue.

3.5.8 Fecal Coliform Bacteria:

Analysis for fecal coliform bacterial was performed using a membrane filtration method from Standard Methods for the Examination of Water and Wastewater (1998), Method 9222 D. Commercially prepared M-FC liquid medium with the addition of rosolic acid, was applied to an absorbent pad within a Petri dish. Upon passing a given amount of sample though a 0.45 µm filter, the filter was placed upon the absorbent pad. This Petri dish assembly was then sealed and placed in a 44.5°C incubator for 24 hours.

3.5.9 Sample Dilution

Samples were generally diluted prior to nutrient testing with the previous methods since the upper detection limit is well below the nutrient concentrations expected from manure runoff. Dilutions were created using a Hamilton Microlab 500 series sample diluter, and using water or acid as the dilutant, depending upon the test procedure being performed.

3.6 Statistical Analysis

All statistical tests were analyzed at the $\alpha = 0.05$ level to determine if differences existed.

3.6.1 Rainfall Analysis

A uniformity coefficient (UC) was utilized to determine if rainfall was evenly distributed between plots, calculated as follows:

$$UC = 1 - {}^{x}\!/_{y}$$

where:

x = the average absolute deviation from the mean of the rainfall depth in the plot rain gauges
y = average rainfall caught in plot rain gauges

3.6.2 Stockpile Surface Runoff Data

The SAS (Statistical Analysis Software) program using the MIXED procedure was used to analyze runoff data. There were three replications of the covered and uncovered treatments, and one replicate of the control treatment at both experimental locations. Treatment, moisture, and sample time were included in the model statement as independent effects (Appendix J). Soil was assigned to be a random variable since the locations within the provinces examined were fixed, and soil type could not be chosen randomly for the experimental area. A repeated measures statement was used to account for the correlation of runoff and sample time.

Concentrations of pollutants were converted into mass loadings using flow measurements, and both data sets were analyzed. As a result of the extreme ranges in fecal coliform results, a log transformation (log FC + 1) was performed on both the fecal coliform concentration and mass loading results.

3.6.3 Stockpile Lysimeter Data

Plot lysimeter data was analyzed for the frequency of samples actually obtained per trial attempt, and for the concentrations of those samples collected. Chi-Square tests were performed to determine if statistical differences were present between sample collection frequencies (Appendix J).

As with the runoff samples, the MIXED procedure, was used to analyze the lysimeter sample concentrations. Pollutants were modeled using treatment, location, and moisture condition as independent effects (Appendix J). Difficulty analyzing the complete data set due to blocks of missing data from unsuccessful sample attempts arose. Therefore, in some instances, analyses were conducted on more complete subsets of the entire dataset to obtain LSMean statements and p-values.

3.6.4 Soil Data

The nutrient contents of the soil samples taken upon completion of the experiment were compared to the nutrient levels in soil samples taken prior to the experiment using a two-sample paired t-test. To reduce sampling costs, pre-experiment soil samples were composited into one sample that was then sent to the lab. For statistical analysis, this composite value was assumed to represent the starting soil nutrient values for each plot.

3.6.5 Litter Data

The General Linear Model (GLM) procedure within SAS was used to examine how the treatment effects changed litter composition. Litter composition was modeled using site, treatment, and moisture conditions as independent effects (Appendix J). Since the GLM procedure was being used, the error term was specified as plot(treatment*site).

3.6.6 Shed Data

As with the plot lysimeter data, the shed lysimeter data was analyzed both for the proportions of samples actually obtained to the number of trial attempts, and for the concentrations of nutrients in the samples collected. The frequency analysis code is the same as reported for the stockpile portion of the study.

Concentration data were analyzed with site and location being independent effects in the model statement (Appendix J). Both shed and site were specified as being random effects due to this being an observational study.

4 Site Description

4.1 Ridge and Valley Field Site

The Ridge and Valley experimental plots were constructed at Virginia Polytechnic Institute and State University's Prices Fork Research Center located near Blacksburg, Virginia (Figure 4-1). This site had an average slope of 9.1% (Appendix B) and was on a Groseclose soil (USDA, 1985). The site had been used for hay production, and had not been fertilized for several years. Vegetation consisted primarily of Orchardgrass, Fescue, and clover.

Groseclose soil has a loam surface layer, typically extending to a depth of 10 inches. Underlying this loam layer is a clay subsoil which is sticky and plastic. Groseclose series soils are classified as hydraulic group "C", with permeability ranging from 5.1-15.2 cm/h in the surface layer, to 0.15-0.05 cm/h in the clay subsurface layer. As expected, surface runoff is often rapid.

Figure 4-1: Experimental Sites

4.2 Piedmont Field Site

Piedmont experimental plots were constructed at Virginia Tech's Southern Piedmont Agricultural Research and Extension Center located near Blackstone, VA. The site had an average slope of 5.9% (Appendix B) and was on a Durham, undulating phase soil (USDA, 1960). The site had not been fertilized in several years.

Durham soil is a sandy loam with slow to very slow surface runoff, due to the rapid permeability in the surface layer and moderately rapid permeability in the subsoil. From 0-41 cm, the permeability is 5.1-15.2 cm/h. From 41-91 cm, the clay content increases to 18-35%, causing the permeability to drop to 1.5-5.1 cm/h.

4.3 Piedmont Litter Sheds

All three sheds within the Piedmont study area were under the operation of the same poultry integrator. The first two sheds were located in Amelia County, while the third was located within Cumberland County. Soil characteristic data was obtained from the Amelia and Cumberland County Soil Surveys, which have not been published yet.

4.3.1 Shed 1

This litter shed was relatively new, being approximately 5 years old. From the soil bored out of the lysimeter holes, it appears the shed was constructed on earthen fill with the ceramic cups just extending into the old surface layer. The floor of the shed was not heavily compacted and appears to receive moderate usage. Material was mostly clay mixed with sand lenses, changing to predominantly sand near 0.61 m deep. The background lysimeter was located down gradient from the existing poultry houses.

The shed was built on Winnsboro series, sandy loam soil, which is assigned to a C hydraulic soil group. Clay content in the upper 23 cm of this soil ranges from 10-20%, and increases to 35-60% below 23 cm. Saturated hydraulic conductivity is 5.04-15.12 cm/h in the upper 23 cm of the soil, decreasing to 0.15-0.50 cm/h in the 23 to 61-cm range.

4.3.2 Shed 2

This litter shed was heavily used; litter was spilling over the sides and remaining at the edges of the building during the first four months of sampling. The floor was heavily compacted with charring and staining of the top portions of the soil indicating heavy litter shed usage. Soil surrounding both shed lysimeters was highly sandy. The background lysimeter was located down slope from a beef cattle pasture, and had a higher clay content compared to the other two lysimeter locations.

The second Piedmont shed was located on an Appling fine sandy loam, which is a hydraulic soil group B soil. Clay content in the upper 28 cm ranges from 5-20%, and increases to 35-60% below 28 cm. Saturated hydraulic conductivity is 5.04-15.12 cm/h in the upper 28 cm of the soil, decreasing to 1.44-5.04 cm/h in the 28 to 61-cm range.

4.3.3 Shed 3

This last piedmont shed was actively used for litter storage serving four broiler houses. Unfortunately, after the fourth sampling date, the farmer requested that all samplers be removed from his property due to frustration with current environmental regulations.

Lysimeters were installed in Creedmoor fine sandy loam soil with a hydraulic classification of C at this location. In the upper 13 cm of soil the clay content ranges from 7-20%. Lower in the profile the clay content ranges from 20-25% (13-36 cm) and 35-60% (below 36 cm). Saturated hydraulic conductivity is 5.04-15.12 cm/h in the upper 13 cm of the soil, 0.50-1.44 cm/h from 13-36 cm, and 0.47-0.54 cm/h in the remainder of the sampling depth.

4.4 Ridge and Valley Litter Sheds

All three sheds within the Ridge and Valley province are located within Rockingham County, with soil characteristic data obtained from the Rockingham County Soil Survey (USDA, 1982). All three Ridge and Valley sheds were under the operation of different poultry integrator companies.

4.4.1 Shed 4

The first Ridge and Valley shed was located on a broiler breeder farm. The shed was being used to store litter from two houses and has a concrete footer. The background lysimeter was located between the broiler houses and the litter shed.

Soil underlying this shed was a Sequoia silt loam classified as a hydrologic group C soil. Sequoia soils are well drained and formed from weathered shale. Clay contents range from 15-60% within the sampling depth. Hydraulic conductivity ranges from 1.5-5.1 cm/h at the zero to 23-cm depth, and 0.51-1.5 cm/h from 23 cm through the sampling depth.

4.4.2 Shed 5

Shed 5 is located on a turkey operation, serving two houses. This shed location was excavated into an embankment, with the center lysimeter installed into rocky subsoil conditions. The edge lysimeter was located at the front of the shed near the drip edge since the soil level at all other sides was well above the floor elevation. Finally, the background lysimeter was located on undisturbed soil upslope from the shed.

The shed is located on a Timberville Variant silt loam, which is a hydrologic group B soil. This soil is deep and well drained, formed in alluvium derived from limestone, sandstone, and shale; clay contents ranged from 6-25% in the sampled depths. Hydraulic conductivity is 5.1-15.3 cm/h at the 0 to 20-cm depth, and 1.5-5.1 cm/h from 20-152 cm (center and edge lysimeters are estimated to be at a depth of 76-152 cm from the original soil surface due to construction excavation).

4.4.3 Shed 6

Litter storage from a single broiler house is contained within this structure. The shed is located up-slope from the broiler house.

Frederick and Lodi silty clay loam, hydrologic group B soil underlies this location. These soils are deep and well drained, formed out of weathered limestone or inter-bedded limestone and sandstone, with clay contents ranging from 20-75% over the sampled depth. Hydraulic conductivity ranges from 1.5-5.1 cm/h within the lysimeter depth.

5 Results and Discussion

5.1 Rainfall Events

5.1.1 Ridge and Valley

The rainfall simulations lasted for 1.6 and 2.2 hours for the respective dry and wet simulation events (Table 5-1). Extremely dry conditions during the first rainfall simulation event were thought to have caused the soil to become slightly hydrophobic; partly explaining why the wet simulation event took longer to achieve runoff. Upon completion of each simulation event, readings were taken from all rain gauges, located near the top and bottom of each plot. Overall average rainfall amounts for the dry and wet simulations were 76.5 and 108.3 mm, respectively. Rainfall intensities were 45.8 and 49.9 mm/h, representative of 25- and 100-year return period storms, for the dry and wet event simulation durations, respectively.

Both simulation runs yielded uniformity coefficients above 0.9, indicating satisfactory rainfall distribution among plots.

Table 5-1: Ridge and Valley Rainfall Data

Ridge and Valley Simulation Site Rainfall Data										
RUN 1						RUN 2				
Length	1.67	Hours	Absolute Deviation from Mean			Length	2.17	Hours	Absolute Deviation from Mean	
	Top	Bottom	Top	Bottom			Top	Bottom	Top	Bottom
	mm	mm					mm	mm		
Plot A	64	79	13.0	2.23		Plot A	97	96	11.74	12.75
Plot B	75	81	1.58	4.77		Plot B	136	139	27.63	30.93
Plot C	75	81	1.32	4.01		Plot C	107	107	1.58	0.82
Plot D	78	77	1.47	0.45		Plot D	110	110	2.23	2.23
Plot E	74	75	2.09	1.32		Plot E	97	103	11.74	5.39
Plot F	77	81	0.20	4.01		Plot F	100	108	7.93	0.31
Plot G	78	77	1.72	0.45		Plot G	94	112	14.28	3.50
	Mean (mm)	76.51	Sum of Abs Values	38.64			Mean (mm)	108.26	Sum of Abs Values	133.06
			Avg of Abs Values	2.76					Avg of Abs Values	9.50
			Uniformity Coefficient	0.96					Uniformity Coefficient	0.91

5.1.2 Piedmont

The rainfall simulations lasted for 2.0 and 1.3 hours for the dry and wet simulation events, respectively, at the Piedmont simulation site (Table 5-2). Runoff occurred more rapidly during the wet simulation event compared to the Ridge and Valley site due to soil moisture modification attempts being more effective in bringing the soil to field capacity prior to the rainfall event. Overall, average rainfall amounts for the dry and wet simulations were 73.1 and 55.3 mm, respectively. Rainfall application rates were lower at this site due to lower water pressures resulting in decreasing nozzle output. Rainfall intensities were 36.6 and 41.6 mm/h, representative of 6-year return period storms, for the dry and wet simulation durations, respectively.

Simulation runs yielded uniformity coefficients at or above 0.9, indicating the simulator was evenly distributing rainfall between plots even at the lower operating pressure.

Table 5-2: Piedmont Rainfall Data

Piedmont Simulation Site Rainfall Data				
RUN 1				
Length	2	Hours	Absolute Deviation from Mean	
	Top	Bottom	Top	Bottom
	mm	mm		
Plot A	89	76	15.9	2.9
Plot B	68	69	5.1	4.1
Plot C	63	77	10.1	3.9
Plot D	70	77	3.1	3.9
Plot E	84	75	10.9	1.9
Plot F	60	83	13.1	9.9
Plot G	55	78	18.1	4.9
	Mean (mm)	73.14	Sum of Abs Values	107.71
			Avg of Abs Values	7.69
			Uniformity Coefficient	0.90

RUN 2				
Length	1.33	Hours	Absolute Deviation from Mean	
	Top	Bottom	Top	Bottom
	mm	mm		
Plot A	54	50	1.3	5.3
Plot B	54	52	1.3	3.3
Plot C	62	54	6.7	1.3
Plot D	50	61	5.3	5.7
Plot E	50	58	5.3	2.7
Plot F	54	62	1.3	6.7
Plot G	50	63	5.3	7.7
	Mean (mm)	55.29	Sum of Abs Values	59.14
			Avg of Abs Values	4.22
			Uniformity Coefficient	0.92

5.2 Litter Analyses

Compositional analyses of the litter for both sites is presented in Appendix H. Plot litter pile composition was found to be statistically different for moisture, K_2O, P_2O_5, Ca, S, Mn, and Zn between the Ridge and Valley, and Piedmont experimental sites. This result was expected considering the material came from two different sources, in two separate regions of the state. Nitrogen and ammonium were not significantly different between the two sites. With the exception of nitrogen and moisture content, the Piedmont poultry litter had the highest constituent concentrations. Phosphorus and potassium levels were 1.5 and 1.6 times greater in the Piedmont litter, with increases ranging as high as 3.3 times for copper.

Litter composition was also examined to determine if changes occurred between the first and second rainfall simulations. A significant condition (before or after the initial rainfall simulation) effect was found for moisture and calcium (Table 5-3). Moisture increases were expected as a result of the rainfall events and condensation under the plastic tarpaulins. However, calcium levels showed an increase from 1.42%, before the simulation, to 1.68%, following the rainfall event from the combined Ridge and Valley and Piedmont data. Sampling error was thought to account for this increase.

Since the uncovered treatment was exposed to the precipitation event resulting in leaching, while covered piles were protected, treatment differences were expected to interact with the pile condition (before or after the initial rainfall simulation). Statistically significant interactions between treatment and condition effects were found for potassium, nitrogen, and moisture (Table 5-3). Uncovered litter piles exhibited greater losses following the rainfall simulation than did covered piles for both potassium and nitrogen. As a result of rainfall saturating the exterior of the uncovered litter piles, moisture content was significantly elevated from the pre-simulation uncovered pile condition.

Constituents which did not show significant differences were either non-soluble, or the total amount of material within the sampled depth of litter masked any losses. This result was not unexpected, since the greatest leaching probably occurs near the surface of the pile, while sampling was done to a depth of 0.61 meters.

Table 5-3: Litter Analysis Results

Litter LSMean Estimates				
	Covered		Uncovered	
Constituent	Before	After	Before	After
Moisture (%)^{1,2}	33.73	34.08	35.43	45.47
N (%)^{2}	3.14	3.33	3.21	2.81
NH (%)	0.69	0.80	0.80	0.79
P_2O_5 (%)	2.49	2.53	2.21	2.22
K_2O (%)^{2}	2.33	2.59	2.23	1.93
Ca (%)^{1}	1.49	1.76	1.35	1.60
Mg (%)	0.78	0.87	0.71	0.72
S (%)	0.40	0.39	0.40	0.32
Mn (ppm)	357.18	346.97	343.23	306.35
Zn (ppm)	353.08	343.58	360.08	298.58
Cu (ppm)	490.63	453.65	464.03	414.23

^{1} significant condition effect
^{2} significant condition*treatment interaction

5.3 Soil Moisture Levels

5.3.1 Ridge and Valley

The moisture content of the soil prior to the dry run for depths of 10, 30, and 61 cm was 14.2, 14.5, and 24.0% moisture, respectively, as determined by gravimetric analysis (oven drying). After soil moisture modification, in preparation for the second run, soil moisture levels were 8.7, 8.4, and 6.9 cbars for depths of 10, 30, and 61 cm, respectively, as determined by granular matrix sensors (Appendix C contains raw sensor data).

In order to convert the granular matrix sensor readings into percent moisture values for comparison to the first run, a calibration curve was constructed from in-situ soil (Appendix A). An exponential best-fit line was obtained with the equation as follows:

$$y = 25.38e^{-0.007x}$$

where : $y = \%$ moisture

$x =$ Sensor reading

This equation had a R^2 value of 0.76, yielding 23.9% moisture for the 10 and 30 cm depths, and 24.2% moisture levels for the 61-cm depth.

Inaccuracy in constructing a calibration curve was thought to be due to the high level of salts present in litter leachate interfering with moisture sensor readings. Variances between soil moisture tension readings from the granular matrix sensors were observed between plots containing litter and the control at the Piedmont experimental site. Samples analyzed gravimetrically did not appear to have this variance between the control plot and litter applied plots.

5.3.2 Piedmont

The average moisture content of the soil at the time of the dry run for depths of 10, 30, and 61 cm was 9.3, 9.8, and 15.7 % moisture, respectively. After moisture adjustment with drip tubing in preparation for the second run, soil moisture levels were 12.6, 10.2, and 16.6% for depths of 10, 30, and 61 cm, respectively. Gravimetric analysis was performed in both instances at this experimental site since it was not possible to construct a calibration curve for the granular matrix sensors with in-situ soil.

5.4 Soil Nutrient Levels

Two-sample paired t-tests using the combined data from both experimental sites indicated that pH, K, Ca, Zn, and Mn levels were statistically different upon completion of the poultry litter experiment. Of these statistically different parameters, all post-experiment values were elevated from the pre-experiment levels, with the exception of calcium (Table 5-4). Calcium levels decreased from 416 ppm in the pre-experiment samples, to 351 ppm post-experiment (Appendix I).

Table 5-4: Combined Soil Nutrient Level t-test Results

Parameter	Mean difference (before-after)	Pr>|t|
PH*	-0.90	0.0032
P	-7.47	0.2828
K*	-305.21	0.0150
Ca*	64.93	0.0431
Mg	8.00	0.1663
Zn*	-1.61	0.0003
Mn*	-2.16	0.0221
NO_3	4.48	0.3537
* Indicates statistical significance		

Phosphorus concentrations were not statistically different between pre- and post-experimental conditions. The phosphorus content of the pre-experiment Ridge and Valley soil was 28.5 ppm, which is classified as a high level by the Virginia Tech Soil Testing Laboratory (DCR, 1995). While this level may not be excessively elevated (fields with a history of heavy manure applications can often have phosphorus levels over 100 ppm), it is surprisingly high for a soil that has not undergone fertilizer application for several years. This level seems to indicate a poorly representative composite sample, or an occurrence of sample contamination. Soil sampling at the Ridge and Valley experimental site occurred as pile formation was commencing, possibly allowing for some poultry litter to become mixed within the soil sample. The pre-experiment soil condition at the Piedmont location was 2.6 ppm, with increases of a factor of 10 or more often present in the post-experiment samples.

As with phosphorus, Ridge and Valley nitrate levels in the pre-experiment condition (30.3 ppm) were elevated above what would typically be found in an unfertilized hay field. The average nitrate level for post-experimental soil conditions was lower (10.9 ppm) at the Ridge and Valley site. Post-experimental Piedmont soil conditions were more typical, exhibiting higher nitrate levels following the experiment.

Due to the apparent contamination of the Ridge and Valley soil sample, the Piedmont site data was analyzed separately (Table 5-5). As expected, both phosphorus and nitrate levels were statistically higher in the post-experimental Piedmont soil conditions, with average increases of 23.57 and 10.43 ppm, respectively.

Table 5-5: Piedmont Soil Nutrient t-test Results

Parameter	Mean difference (before-after)	Pr>|t|
pH*	-1.24	0.0209
P*	-23.57	0.0409
K*	-615.57	0.0044
Ca	-17.57	0.3872
Mg	-5.14	0.3742
Zn*	-0.62	0.0144
Mn*	-4.40	0.0084
NO_3*	-10.43	0.0121
* Indicates statistical significance		

5.5 Stockpile Surface Runoff

5.5.1 Concentration Data

The treatment effect was statistically significant ($\alpha=0.05$) for most measured concentration variables (Table 5-6); raw data is found in Appendix D. Runoff from the uncovered litter piles was highly colored and found to be higher in pollutant concentrations than covered plot runoff, with the exception of nitrate. Uncovered runoff was similar in appearance to coffee (Figure 5-1). Due to the extremely high variance between high and low fecal coliform (FC) levels, this data underwent a log transformation before statistical analysis.

Least squares means from SAS, which estimate the marginal means based upon the model statement, are presented for concentration data in place of arithmetic means of observations. These data are presented to better represent what is thought to occur with poultry litter piles in general.

Table 5-6: P-values and LSMeans for Runoff Concentrations

Variable	Pr>F	Least Squares Means		
		Covered	Uncovered	Control
Volume (L)*	0.0307	57.7	20.5	47.9
NO_3 (ppm)	0.2924	2.5	1.6	0.6
NH_x (ppm)*	0.0161	36.2	99.1	13.4
TKN (ppm)*	0.0211	457	1,176	104
OP (ppm)*	0.0066	31.0	53.8	9.7
TP (ppm)*	<0.0001	40.1	74.1	9.1
TSS (ppm)	0.1149	1,023	2,397	945
VSS (ppm)*	0.0098	515	1080	229
Log FC (col./100ml +1)*	<0.0001	4.76	5.10	2.85
*Indicates statistical significance				

Figure 5-1: Uncovered Plot Runoff

No treatment effect was found for total suspended solid concentrations, but volatile suspended solids had a statistically significant treatment effect. Volatile suspended solid concentrations were 37 and 67% of the total suspended solid levels for the Ridge and Valley and Piedmont experimental locations, respectively. Since broiler litter averages 80% volatile solids on a dry basis (NC State University, Animal and Poultry Manure Production and Characterization, 1994), much of the suspended solid material was soil particles. Unlike TSS analysis, which occurred for each sample taken, only the first and third samples from each plot were analyzed for VSS concentrations due to the laboratory analysis expense.

Drip tubing installation resulted in disturbed soil being present on the ground surface from trench construction and backfilling. This material was present without respect to treatment condition, partially explaining the absence of statistical significance. Volatile material being present in larger percentages in the Piedmont can be explained by experimental site slope differences. The lower slope of the Piedmont site allowed the higher density soil particles to settle out of the lower velocity runoff when compared to the Ridge and Valley site. Lower intensity rainfalls, and soil with a larger particle size distribution, are other influences that may have resulted in the Piedmont samples having lower soil particle concentrations.

Nitrate was the other constituent whose concentration did not show a statistically significant treatment effect. Nitrate levels were low for all treatments, especially during the first dry simulation (Figure 5-2). Much of the nitrate present in runoff from the control plots originated from the raw simulation water, which had nitrate concentrations of 0.33 ppm for the Ridge and Valley simulation, and 0.03 ppm at the Piedmont simulation.

During the Ridge and Valley dry soil simulation, some of this nitrate was either sorbed to the litter, or utilized by the bacteria present in the litter for respiration, causing the nitrate to be lower in the runoff from plots containing poultry litter stockpiles than from the control plot. Since this trend did not occur at the Piedmont experimental site, it is thought to be mainly caused by different bacterial populations that were present in the Ridge and Valley litter, which had not undergone storage like the Piedmont litter. Storage of the Piedmont poultry litter may have eliminated denitrification bacteria, such as *Pseudomonas*, which may have used the nitrate from the Ridge and Valley precipitation as a terminal electron acceptor. The second simulation event yielded higher nitrate levels than the first rainfall at both experimental sites. Increased moisture levels and oxic conditions near the litter surface are thought to have allowed nitrification to occur, resulting in more nitrite and nitrate during the second run.

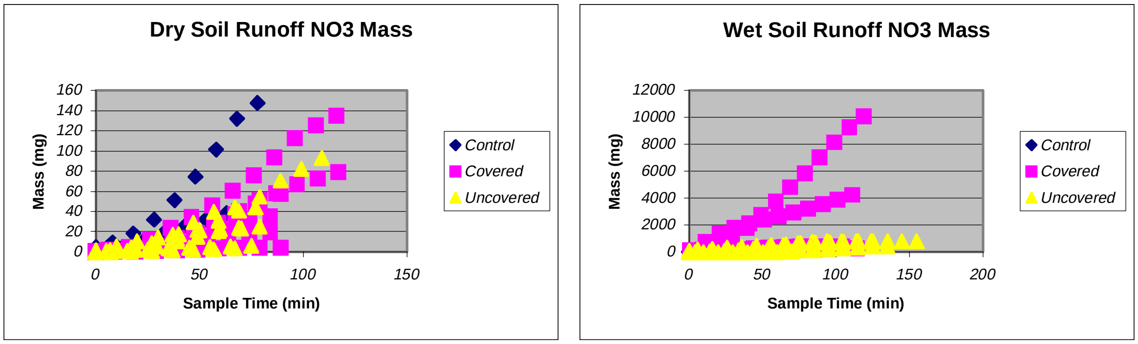

Figure 5-2: Nitrate Runoff Masses

The remaining constituents were found to have statistically significant treatment effects, with nutrient and bacterial levels being higher from uncovered plots. In contrast, volume measurements from covered plots were elevated over those of the uncovered plots. Volume was analyzed by examining the amount of runoff that occurred between sample collections. The uncovered poultry litter piles absorbed much of the precipitation, resulting in lower runoff volumes.

5.5.2 Mass Loading Data

Since total mass loadings are more important than pollutant runoff concentrations, from an environmental perspective, the volume and concentration data were combined to yield total mass loadings (Appendix E & F). When looking at total pollutant loadings, treatment effects were found to be statistically significant for only the fecal coliform parameter.

The log transformed fecal coliform averages for the covered, uncovered, and control treatment were $10^{9.9}$, $10^{10.8}$, and $10^{8.3}$ respectively. Fecal coliform bacteria present in the control plots is thought to be from aerial deposition during pile construction and leachate seeping under plot borders. Specifically, the Piedmont control plot had ponding occur behind the upper border, which had been contaminated with litter spilled during the pile formation process. This ponding allowed for seepage to occur under the border in buried drip tubing and sample collection line trenches. The result was substantially higher nutrient levels from the Piedmont control plot compared to the Ridge and Valley control plot.

Table 5-7: P-values and Pollutant Mass Loadings

Treatment P-values		Dry Run Averages			Wet Run Averages		
Variable	Pr>F	Covered	Uncovered	Control	Covered	Uncovered	Control
Volume (L)	0.1041	626	319	444	989	435	635
NO_3 (mg)	0.5553	55	33	93	2,615	500	221
NH_x (mg)	0.7943	22,365	18,203	2,516	38,332	41,298	21,789
TKN (mg)	0.6412	74,606	67,998	7,307	888,601	1,079,284	135,484
OP (mg)	0.2000	15,119	9,620	1,703	26,584	17,265	624
TP (mg)	0.3507	22,445	18,908	2,464	41,603	36,516	984
TSS (mg)	0.7057	442,834	710,487	407,054	1,359,474	1,018,035	76,128
Log FC (col.)	0.0003	10.03	10.66	8.16	9.65	10.89	8.37

While not statistically significant, averages for the covered treatments are generally higher than uncovered treatments for both wet and dry simulations (Table 5-7). However, when looking at averages between experimental sites, the Ridge and Valley site generally yielded higher uncovered plot averages while the Piedmont site had higher covered plot averages. The difference in slope between the two experimental sites is one possible explanation for this occurrence. The lower slope of the Piedmont plots appeared to allow precipitation longer periods of contact with the litter before exiting the plot. This longer period of contact time allowed the larger runoff volume from the covered piles to become more pollutant laden compared to the Ridge and Valley site.

Differences in plot runoff volumes explain the apparent contradiction between the statistical analysis results of concentration and mass loading data. An overall average of 3200 L of precipitation was added to each plot, with average values of 807 and 377 L (25 and 12% of the applied volume) of runoff originating from covered and uncovered treatments. The uncovered poultry litter piles absorbed a larger percentage of the precipitation, resulting in lower runoff volumes. The higher runoff volumes from the covered plots counteracted the lower pollutant concentrations, yielding higher overall pollutant loadings at times.

Surprisingly, the antecedent moisture condition was only statistically significant for the TKN variable (p=0.0471). When compared to the Ridge and Valley site, the wet run TKN loadings had a greater magnitude of increase over the dry run simulation loadings at the Piedmont site (Table 5-8). This occurrence was likely due to increased organic material decomposition as a result of high temperatures. The daily temperatures between the dry and wet runs for the Ridge and Valley simulation were unseasonably cool compared to those during the Piedmont runs.

Extreme variability within the data sets was observed, and was thought to have limited the factors that gained statistical significance in many instances. Increases between the high and low mass loadings originating from plots with the same treatment, for the same rainfall event, ranged as high as a factor of ten or more (Table 5-8). Variances of mass loadings within a treatment can be linked to the volume of runoff that originated from each individual plot in most cases. It is unknown whether these differences are due to inaccuracies in flow measurements, or natural variances in litter and soil infiltration. Mechanical failures with the stage recorders, and sediment blocking the entrance to the recorder well, forced some hydrographs to be modified following the simulation. When major modification was needed, field observations and other hydrographs that were representative of the plot in question were used as guidance. This type of modification occurred on 4 of the 28 hydrograph charts used in this study.

Table 5-8: Ridge and Valley and Piedmont Pollutant Mass Loadings

Ridge and Valley Dry Simulation

	Plot	Volume (L)	NO3 (mg)	NHX (mg)	TKN (mg)	OP (mg)	TP (mg)	TSS (mg)	FC
Covered	QFA	197.56	4.30	3,634.44	9,925.28	1,004.14	3,732.47	197,555.48	2.26E+10
	QFD	667.26	19.23	20,079.13	61,507.48	6,620.76	19,141.53	899,367.18	3.71E+10
	QFG	839.30	35.50	12,624.93	42,756.17	3,501.07	15,886.26	841,821.48	4.73E+09
	Average	**568.04**	**19.68**	**12,112.83**	**38,062.98**	**3,708.66**	**12,920.09**	**646,248.05**	**2.15E+10**
Uncovered	QFB	351.25	6.16	15,682.79	59,208.76	5,490.71	14,644.61	944,011.03	2.28E+11
	QFC	96.46	3.40	4,993.42	21,083.72	2,238.89	6,609.33	216,465.09	2.71E+10
	QFE	732.77	23.27	41,434.66	161,583.55	13,184.23	44,452.22	2,528,978.17	1.86E+10
	Average	**393.49**	**10.94**	**20,703.62**	**80,625.34**	**6,971.28**	**21,902.05**	**1,229,818.10**	**9.12E+10**
Control	QFF	343.85	147.48	1,953.26	1,732.97	11.31	651.20	795,211.02	2.90E+08

Table 5-8: Ridge and Valley and Piedmont Pollutant Mass Loadings Cont.

Ridge and Valley Wet Simulation

	Plot	Volume (L)	NO3 (mg)	NHX (mg)	TKN (mg)	OP (mg)	TP (mg)	TSS (mg)	FC
Covered	QFA	348.87	266.10	1,935.19	12,101.37	1,576.18	4,082.68	201,077.78	5.13E+09
	QFD	623.43	4,252.43	24,089.20	75,678.61	9,292.74	13,936.64	241,495.58	3.67E+09
	QFG	1,253.37	10,095.03	34,591.06	106,604.74	12,645.68	18,476.76	432,298.00	1.70E+10
	Average	**741.89**	**4,871.19**	**20,205.15**	**64,794.91**	**7,838.20**	**12,165.36**	**291,623.79**	**8.61E+09**
Uncovered	QFB	453.86	712.61	11,137.99	42,110.34	3,642.34	10,289.09	281,450.65	1.77E+10
	QFC	73.24	20.65	13,440.21	34,017.17	1,251.94	3,063.60	55,012.91	4.36E+11
	QFE	430.02	293.90	104,514.74	291,131.43	4,955.21	25,797.09	894,250.03	1.64E+10
	Average	**319.04**	**342.39**	**43,030.98**	**122,419.65**	**3,283.17**	**13,049.93**	**410,237.86**	**1.57E+11**
Control	QFF	470.37	205.79	1,486.93	784.58	12.30	229.88	46,270.60	4.70E+08

Piedmont Dry Simulation

	Plot	Volume (L)	NO3 (mg)	NHX (mg)	TKN (mg)	OP (mg)	TP (mg)	TSS (mg)	FC
Covered	BSC	729.38	57.75	24,853.24	83,350.62	21,234.67	24,988.83	174,611.64	4.10E+07
	BSE	563.14	79.26	27,759.23	93,734.59	20,311.46	23,582.14	115,131.11	3.12E+07
	BSG	757.29	135.20	45,238.13	156,363.11	38,044.75	47,341.12	428,514.64	5.05E+08
	Average	**683.27**	**90.74**	**32,616.87**	**111,149.44**	**26,530.29**	**31,970.70**	**239,419.13**	**1.92E+08**
Uncovered	BSA	172.79	44.35	11,011.51	38,762.93	8,850.89	11,115.39	79,361.57	1.18E+08
	BSB	183.70	25.05	7,240.78	26,275.04	7,184.95	8,559.31	86,576.24	8.32E+07
	BSF	375.83	93.38	28,856.72	101,071.31	20,768.95	28,069.50	407,529.55	2.76E+08
	Average	**244.11**	**54.26**	**15,703.00**	**55,369.76**	**12,268.26**	**15,914.73**	**191,155.79**	**1.59E+08**
Control	BSD	543.99	38.60	3,078.55	12,880.57	3,395.44	4,276.56	18,896.26	2.01E+06

Piedmont Wet Simulation

	Plot	Volume (L)	NO3 (mg)	NHX (mg)	TKN (mg)	OP (mg)	TP (mg)	TSS (mg)	FC
Covered	BSC	932.60	387.93	71,433.42	1,544,030.77	38,563.10	56,561.62	5,141,362.01	8.91E+07
	BSE	1,113.11	287.41	50,794.57	1,650,982.91	39,029.67	71,869.84	718,572.70	9.47E+07
	BSG	1,660.34	398.26	47,147.19	1,942,207.35	58,397.57	84,688.89	1,422,037.81	6.48E+08
	Average	**1,235.35**	**357.87**	**56,458.39**	**1,712,407.01**	**45,330.11**	**71,040.12**	**2,427,324.17**	**2.77E+08**
Uncovered	BSA	571.24	781.52	62,328.07	2,053,707.44	35,112.31	47,276.64	1,440,976.65	1.06E+08
	BSB	253.61	410.09	27,129.97	934,365.76	19,473.02	26,234.65	1,591,867.48	4.31E+07
	BSF	829.68	783.97	29,238.46	3,120,371.55	39,156.03	106,433.38	1,844,653.47	2.17E+08
	Average	**551.51**	**658.53**	**39,565.50**	**2,036,148.25**	**31,247.12**	**59,981.55**	**1,625,832.53**	**1.22E+08**
Control	BSD	800.32	235.68	42,090.23	270,182.60	1,235.57	1,737.41	105,984.75	2.84E+06

5.5.2.1 Treatment*Time Interactions

While the overall treatment effect is the primary method used to determine differences between treatments, the interaction between treatments and sample time can also be important in determining the environmental impact of poultry litter storage methods. The overall treatment effect determines if there is a statistically significant difference between the average pollutant loadings originating from the plots during the simulations. The treatment*time interaction will indicate if one, or more, of the treatments is becoming different as the sampling event continues. Therefore with a longer simulation event, an interaction could lead to the overall treatment effect becoming statistically significant.

Total phosphorus, orthophosphorus, and volume were found to have significant treatment*time interactions from the full model. To determine if the difference was between the covered and uncovered piles, or involved with the control plots, a separate analysis was run on covered and uncovered data. No treatment*time interaction between covered and uncovered plots for total phosphorus or orthophosphorus occurred, indicating the control treatment was causing the statistical difference in the complete data set.

Volume was found to have a significant treatment*time interaction between covered and uncovered treatments, with a p-value of <0.0001. There is a noticeable difference between covered and uncovered treatments as seen in the graph displaying volume versus time (Figure 5-3). This result indicates that while the overall treatment effect for volume may not be significant, as time passes the rate of increase in runoff volume is accelerating more rapidly from covered piles than uncovered piles. The small portion of litter exposed in the covered piles absorbed precipitation at the beginning of the simulation event, but quickly became saturated and resulted in a greater percentage of the precipitation becoming runoff. At the same time, sufficient rainfall was not achieved during the simulation events to completely saturate the uncovered piles, which could result in a similar increase in runoff volumes as seen with the covered piles.

Longer precipitation events could potentially bring the uncovered piles up to their saturation point, resulting in significant increases in runoff volumes and mass loadings compared to what were seen in this study. Litter used in this study had an average moisture content of 34.6%; based upon bench tests conducted at Virginia Tech, poultry litter has a field capacity of 63%

(Lori S. Marsh, unpublished data, 2001). To increase the moisture content of the stockpiles in this study from 34.6 to 63%, 9047 L of water would be required; with additional water needed to achieve complete saturation. During the two rainfall simulations, 3880 and 2700 L of precipitation were added to the uncovered piles at the Ridge and Valley and Piedmont study sites, respectively. As expected, runoff volumes indicate that uncovered piles did not reach their saturation point, as previously stated. Furthermore, when the Piedmont uncovered litter piles were removed following the experiment, it was observed that the precipitation only infiltrated the outer 20-25 cm of the pile. Assuming 100% infiltration of the applied precipitation, 43 cm of rainfall would be needed to bring the stockpiles to field capacity. Since annual rainfall amounts in the two provinces are approximately 70-80 cm, stockpiles achieving saturation will depend upon evaporative losses not measured in this study.

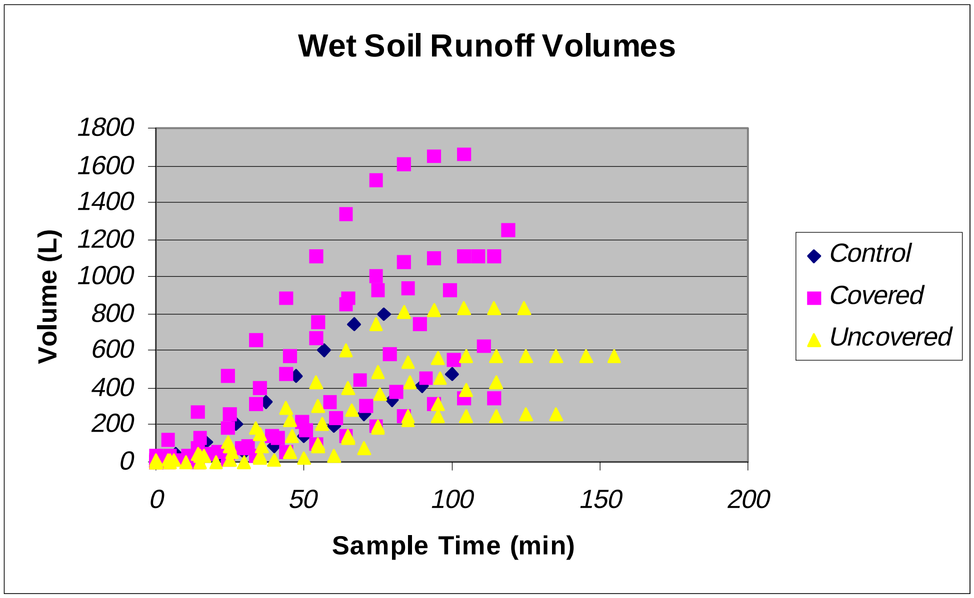

Figure 5-3: Treatment * Sample Time Interaction

The treatment*time interaction also became significant for nitrate once the control plots were removed from the data set. Mass loadings of nitrate appeared to increase more rapidly from covered piles than uncovered piles. This trend appeared to be similar to the volume treatment*time interaction, and probably is directly related to the increased volume originating from the covered plots. Unlike the other constituents, nitrate levels were very low (concentration estimates were under 2.5 ppm), resulting in the raw simulation water nitrate concentrations having more influence on the mass loadings.

5.6 Stockpile Lysimeters

5.6.1 Sample Frequency Analysis

In many instances, even though a sampling attempt was made, no soil water could be collected for laboratory analysis. This result indicates that minimal movement of soil water, and any pollutants carried with it, was occurring.

As expected, the moisture condition of the experimental site was a significant factor in sample collection frequency (Chi Square = 0.003). Sample attempts on dry soil conditions prior to the experiment were extremely ineffective. In fact, no samples were collected from the Ridge and Valley field site under the dry condition. After the addition of water to the soil from the rainfall simulation and the drip tubing system, sample frequency noticeably increased.

Treatment and location were not found to be significant factors in sample collection frequency.

5.6.2 Sample Concentration Analysis

The data set containing field lysimeter concentrations (Appendix G) was analyzed in several different forms including the complete set, the complete set minus the dry moisture condition data, and each experimental site individually. No treatment effects were found to be statistically significant from the stockpile lysimeter concentrations under any circumstances.

While not statistically significant, lysimeter samples from uncovered poultry litter piles did exhibit higher nitrogen concentration estimates than the covered piles (Table 5-9).

Table 5-9: Stockpile Lysimeter Treatment Concentration Estimates

Stockpile Lysimeter LS Mean Concentration Estimates

Treatment	NO_3	NH_x	TKN	OP	TP	TSS	FC
Uncovered	4.7	10.8	52.2	0.2	0.7	31.0	1.6
Covered	1.7	4.0	13.2	0.6	1.1	22.0	1.8
Control	0.3	0.3	1.4	0.2	0.3	13.1	1.3

*All values in ppm with the exception of FC which is Log(CFU/100ml +1)

While examining the Piedmont experimental site data subset, lysimeter location was statistically significant for TKN and NO_3. The lysimeter sites at the edge of the piles had elevated pollutant levels compared to the two other sites located farther within the piles perimeter (Table 5-10). By analyzing covered and uncovered treatments individually, it was determined that the location effect was only statistically significant in the uncovered treatment. This result, in combination with the estimates of sample concentration by treatment, seems to indicate that uncovered piles are releasing the water they absorbed during the simulation into the subsurface environment. This process occurs near the outer perimeter of the pile, and not uniformly throughout the basal area.

Therefore, even though the uncovered piles were no worse than the covered piles with respect to surface runoff loadings, more environmental pollution may be resulting from uncovered piles as a result of subsurface losses. This result, along with nitrogen volatilization, would explain why the nitrogen content of the uncovered piles is statistically lower than that of the covered piles. Since mass loadings to the subsurface environment could not be obtained from the porous cup lysimeter data, the magnitude of this impact is uncertain.

Table 5-10: Stockpile Lysimeter Concentration Estimates by Location

Stockpile Lysimeter LS Mean Concentration Estimates

Location	**NO_3**	**NH_x**	**TKN**	**OP**	**TP**	**TSS**	**FC**
Center	**0.3**	**2.1**	**4.4**	**0.3**	**0.6**	**16.3**	**1.4**
Middle	**1.6**	**1.0**	**9.4**	**0.1**	**0.4**	**33.0**	**1.8**
Edge	**4.8**	**12.0**	**53.0**	**0.5**	**1.1**	**16.9**	**1.6**

***All values in ppm with the exception of FC which is Log(CFU/100ml +1)**

This nutrient concentration effect near the perimeter of the piles might make a systematic sampling procedure a better choice when looking at soil nutrients, rather than the random soil sampling performed. Based on this discovery, it is probable that some areas of the soil had nutrient concentrations much higher than the averages reported for the composited samples.

5.7 Storage Sheds

5.7.1 Shed Sample Frequency Analysis

All sheds were sampled once a month from July until March, except for Piedmont Shed three which was sampled from July to October. At this shed, after the fourth sampling date, the producer requested that the monitoring equipment be removed from his property. A suitable replacement shed was not located. Unfortunately, an outbreak of Avian influenza, and the related biosecurity concerns, prevented any sampling after March. The intent was to sample until June, which would have given a year of data.

As with the field study lysimeters, a sampling event in which no soil water was collected is thought to be environmentally positive. Both experimental location and lysimeter location were statistically significant in sample collection frequency (Chi Square <0.0001).

One factor thought to have influenced the collection frequency was drought, which was impacting both experimental sites during the study period. Precipitation levels were 31.01 and 39.14 cm below average for weather stations located in the Ridge and Valley, and Piedmont study locations respectively, from July through February (data is unavailable for the last March sampling date at this time).

Sheds located in the Piedmont were constructed on coarser textured soils, and yielded samples more frequently than those located in the Ridge and Valley province. Piedmont sheds yielded samples 63% of the time, while Ridge and Valley sheds had a sample collection rate of only 10% even though the departure from normal precipitation totals was lower in the Ridge and Valley area. It appears that the Ridge and Valley soils with high clay contents are effective in minimizing soil water movement near poultry litter storage sheds.

The other significant factor in sample frequency was lysimeter location. Lysimeters located at the edge of the litter storage shed yielded more samples per attempt (58%) than those in the center (31%) or background (13%) locations. In most cases, the lysimeter located at the edge of the litter shed was at the roof drip edge. This feature would magnify the effect of even small precipitation events in the soil surrounding the edge lysimeter.

5.7.2 Shed Pollutant Concentrations

The Biological Systems Engineering Water Quality Laboratory attempted to perform the same nutrient analyses on the shed samples as for the field study. Due to low sample volumes, no testing for fecal coliform bacteria occurred from the shed samples.

Methods previously used for the field study would give neither reproducible, nor reliable results with the shed lysimeter samples. In fact, analysis of some samples indicated higher ammonical and orthophosphorus levels than Total Kjeldahl Nitrogen and total phosphorus levels, respectively (Table 5-11). Since this result is an impossibility, it was thought that inaccuracies may have occurred as a result of high nitrate levels, which is a known interference in Kjeldahl digestion (Standard Methods for the Examination of Water and Wastewater, 1998).

As a result of the inability of the Water Quality Laboratory to obtain valid results, the remaining samples were sent to the Virginia Tech Forage Testing Laboratory, which performed a digestion/distillation method often used in manure testing. This method determines TKN, similar to method 4500-N_{org}C in Standard Methods for the Examination of Water and Wastewater (1998). This procedure also failed to give reproducible results, indicating that nitrate was not causing the interference.

Several samples were also sent to University of Maryland’s Biological Resources Engineering Department Water Quality Laboratory for nitrate testing. This laboratory also indicated difficulty getting duplicate samples results to be equivalent. More study is needed to determine which compound within the sample caused these difficulties. It is not clear why the lysimeter samples from the shed portion of the study exhibit this behavior when the surface runoff and lysimeter samples from the stockpile study were treated in the same way, with the same procedures yielding satisfactory results. Unfortunately, the small sample volumes obtained makes further analysis impossible.

Due to the unreliability of the shed data, no attempt was made to analyze the reported results. These results seem to indicate significant concentrations of nitrogen may be present in the areas surrounding poultry litter sheds. However, even background samples which were located up-gradient from the litter sheds appear to have high nutrient concentrations. If this data is reasonably representative even with the analysis difficulties, then high levels of nutrients may be originating from other sources besides the litter shed, such as the poultry houses themselves.

Table 5-11: Shed Lysimeter Pollutant Concentrations

Shed	Site	Month	Lys. Loc.	OP(mg/L)	TP(mg/L)	NO$_3$(mg/L)	NH$_x$(mg/L)	TKN(mg/L)
1	Piedmont	July	Edge	2.38	13.01	10.36	19.56	317.40
2	Piedmont	July	Edge	0.05	12.47	504.08	87.08	554.29
3	Piedmont	July	Edge	0.05	0.00	19.79	19.55	263.78
2	Piedmont	July	Center	0.10	2.44	41.42	29.49	410.22
1	Piedmont	August	Background	13.84	12.76	27.67	0.15	31.70
1	Piedmont	August	Center	0.26	0.22	330.34	0.82	3.56
1	Piedmont	August	Edge	1.94	1.60	4.19	2.31	21.24
2	Piedmont	August	Center	0.00	0.25	44.97	44.13	35.52
2	Piedmont	August	Edge	0.21	0.64	716.83	98.34	50.11
3	Piedmont	August	Edge	0.00	0.02	20.55	10.23	7.25
5	Ridge and Valley	August	Edge	0.08	IS	107.53	0.28	IS
1	Piedmont	September	Center	0.00	0.14	334.17	1.07	4.00
2	Piedmont	September	Center	0.00	0.00	58.96	42.89	12.92
1	Piedmont	September	Edge	0.00	0.59	0.02	8.98	21.19
2	Piedmont	September	Edge	1.28	0.77	842.36	133.48	49.34
3	Piedmont	September	Edge	0.08	IS	21.03	9.24	IS
4	Ridge and Valley	September	Background	0.05	IS	51.00	2.81	IS
5	Ridge and Valley	September	Edge	0.03	0.14	104.29	0.11	1.99
1	Piedmont	October	Center	0.04	0.08	339.06	0.60	2.17
2	Piedmont	October	Center	0.00	0.00	60.72	42.92	24.51
1	Piedmont	October	Edge	0.01	0.00	4.33	2.40	11.63
2	Piedmont	October	Edge	0.79	0.53	816.17	116.08	26.34
3	Piedmont	October	Edge	0.04	IS	12.91	11.62	IS
5	Ridge and Valley	October	Edge	0.14	IS	106.26	0.60	IS
1	Piedmont	November	Center	0.03	0.00	4070.17	0.28	2.03
2	Piedmont	November	Center	0.01	0.16	0.04	47.87	22.89
1	Piedmont	November	Edge	0.02	0.00	1.03	0.69	10.22
2	Piedmont	November	Edge	1.40	0.71	953.76	105.53	50.26

1	Piedmont	December	Background	0.10	IS	1030.69	1.77	IS
1	Piedmont	December	Center	0.00	0.01	406.60	0.31	0.18
2	Piedmont	December	Center	0.00	IS	12.52	17.18	IS
1	Piedmont	December	Edge	0.03	0.02	51.75	0.64	7.41
2	Piedmont	December	Edge	1.52	1.09	762.33	82.47	47.14
5	Ridge and Valley	December	Edge	0.09	0.08	169.68	1.296	0.07
1	Piedmont	January	Background	10.41	10.57	133.90	0.000	6.85
2	Piedmont	January	Background	0.09	0.05	5.49	0.078	1.23
1	Piedmont	January	Center	0.21	0.12	404.01	0.352	0.03
1	Piedmont	January	Edge	0.15	0.04	91.90	0.055	6.13
2	Piedmont	January	Edge	1.31	0.35	698.16	80.87	26.66
5	Ridge and Valley	January	Edge	0.16	0.09	197.61	11.33	13.23
1	Piedmont	February	Background	6.03	6.94	95.94	0.083	5.61
2	Piedmont	February	Background	0.29	0.45	0.86	0.066	1.00
1	Piedmont	February	Center	0.14	0.00	520.35	0.695	1.95
2	Piedmont	February	Center	0.05	IS	56.87	42.95	IS
1	Piedmont	February	Edge	0.24	0.00	115.74	0.086	4.99
2	Piedmont	February	Edge	1.82	1.88	1123.21	63.89	34.80
1	Ridge and Valley	February	Background	0.11	0.25	60.52	0.082	7.63
5	Ridge and Valley	February	Background	0.10	IS	0.00	1.215	IS
5	Ridge and Valley	February	Edge	0.03	0.11	11.07	0.133	25.43
1	Piedmont	March	Background	5.71	5.89	73.61	0.442	4.99
2	Piedmont	March	Background	0.32	IS	3.36	1.357	IS
1	Piedmont	March	Center	0.13	0.00	372.22	0.394	0.13
2	Piedmont	March	Center	0.01	IS	37.43	47.487	IS
1	Piedmont	March	Edge	2.47	3.22	104.94	27.591	12.84
2	Piedmont	March	Edge	1.73	0.80	857.76	62.276	30.12
5	Ridge and Valley	March	Background	0.17	IS	5.72	1.070	IS
5	Ridge and Valley	March	Edge	0.15	0.06	167.79	0.000	0.14

*** Orange values indicate OP values higher than TP values**

*** Purple values indicate NHx values higher than TKN values**

6 Summary and Conclusions

The goal of this study was to evaluate three of the most common poultry litter storage methods for areas in Virginia. To accomplish this goal, pollutant losses from covered and uncovered stockpiles, and from litter storage sheds were examined.

Covering poultry litter stockpiles, with the 95% coverage technique used in this experiment and thought to be typical of many operations, was not sufficient to reduce potential surface water pollution. Increased runoff volumes from the covered piles overwhelmed the elevated pollutant concentrations from uncovered piles, resulting in similar mass loadings from both covered and uncovered treatments. Covering the litter piles did result in a statistically significant reduction in fecal coliform bacteria originating from the plots, but both treatments showed extremely high bacteria loadings. Runoff volumes and pollutant loadings showed a high degree of variability between plots receiving the same treatment, during the same simulation.

Subsurface sampling with porous cup lysimeters proved extremely difficult throughout this study, especially on the Ridge and Valley province soils that typically have higher clay contents than Piedmont soils. In fact, no samples were collected from the Ridge and Valley stockpile experiment under the dry condition. Looking only at the data from the Piedmont province, where sampling was more successful, lysimeters at the edge of the uncovered stockpiles had elevated concentrations of nitrogen. While there was not a statistical difference between treatments with respect to surface runoff mass loading data, it appears that this excess water, and pollutants being carried with it, is being released into the subsurface environment.

Apparent contamination of the pre-experiment Ridge and Valley soil sample prevented significant findings with regard to soil test nutrient additions at that site. Statistically significant soil nutrient additions of both nitrate and phosphorus occurred following the simulations at the Piedmont experimental site. Stockpiling of poultry litter in one location on a continuous cycle may pose a greater environmental threat due to this soil nutrient buildup.

Six poultry litter sheds in two Virginia provinces were monitored for this experiment. Litter sheds located within the Piedmont province yielded more samples than the Ridge and Valley sheds, indicating a greater potential for groundwater contamination problems due to increased soil water availability. Unfortunately, no laboratory method yielded reliable results when the samples were analyzed for nutrient concentrations. The results that were obtained seem to indicate the presence of significant quantities of nitrogen in soil water near litter sheds and background locations as well.

In conclusion, protecting poultry litter piles with the 95% coverage technique used in this study was unsuccessful in reducing environmental pollution. It is recommended that poultry litter be stored in a litter shed, or other method, which prevents all contact from precipitation and runoff. Greater care should be taken in regions with course-textured soils, such as the Piedmont province of Virginia, as it appears those regions are at a greater risk of groundwater pollution from both stockpiles and litter sheds.

Recommendations for Future Study:

- Comparison between uncovered and 100% covered stockpiles with respect to nutrient and pathogen loss.
- Examination of uncovered piles during longer periods of precipitation to determine if, and when, they would become saturated during the course of a typical wet season.
- Calculation of subsurface mass loading data for stockpiles and litter sheds to determine potential groundwater impacts.
- Determination of the origin of nutrients in soil water near poultry litter sheds.

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Appendix

Appendix A: Grannular Matrix Sensor Calibration

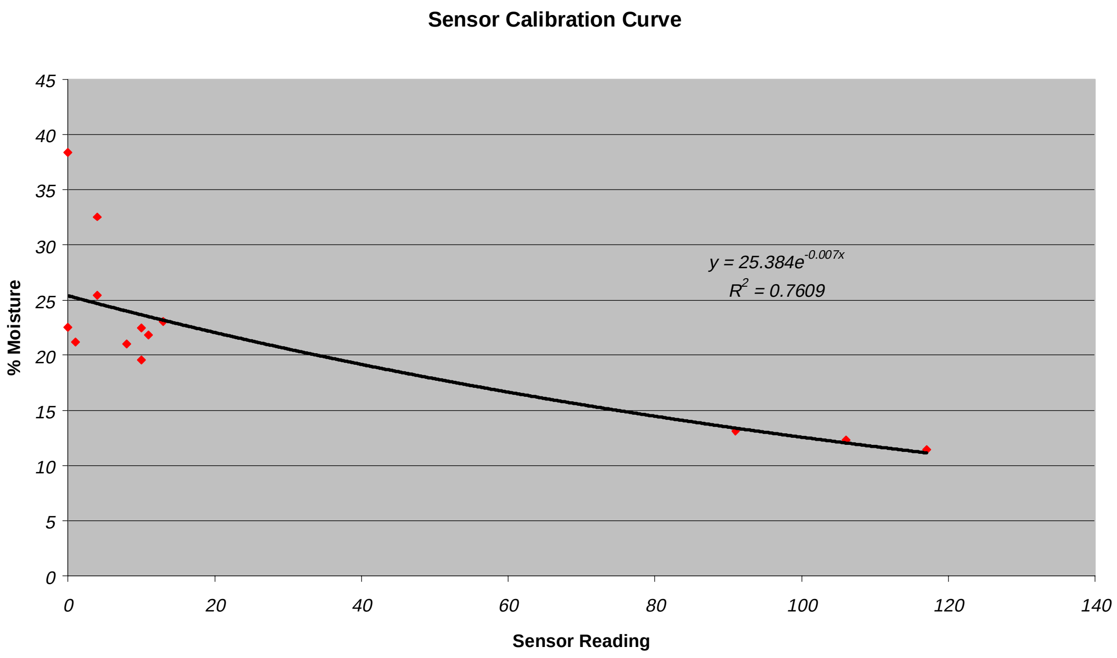
In order to obtain soil moisture contents on a weight basis, a calibration curve was constructed to relate the granular matrix sensor (Watermark) readings to percent moisture. This was done upon the completion of our experiment when the litter piles had been removed from the Ridge and Valley field site. Unfortunately, during the litter removal process nearly all of the granular matrix sensors were damaged or destroyed by the front-end loader. Those sensors that could be located and/or repaired were used in this calibration. Upon determining the depth and reading of a sensor in question, a soil auger was used to obtain a soil sample corresponding to that depth. The sample hole was augured a maximum distance of 10 cm away from the original soil sensor borehole to insure the soil sample obtained was representative of the soil surrounding the sensor. The soil sample was placed in a watertight sample bag, and transported back to the lab for analysis in accordance with ASTM D 2216 as referenced by Liu and Evvett (1990). Results are reported in Table A-1.

Originally, the soil moisture content and sensor readings from the Ridge and Valley dry run were to be used in calibration of the Watermark Sensors. However, incorporation of this data significantly lowers the R^2 value. This was thought to occur for two reasons. First, the salts leached from the poultry litter appeared to alter conductivity, decreasing sensor readings. Secondly, due to the poultry litter piles being on the plot, we were unable to obtain soil samples in close proximity to the sensors. As a result, data obtained during the first simulation event was excluded from the calibration.

An exponential best-fit line was most appropriate for the calibration data collected:
$y = 25.383e^{-0.007x}$

Table A-1: Watermark Calibration Data

Depth (Ft.)	Sensor Reading	Container Wt. (g.)	Cont. & Wet Soil (g.)	Cont. & Dry Soil (g.)	Soil Moisture (g.)	% Moisture
0.25	11.00	2.64	58.29	48.32	9.97	21.8
1.00	1.00	2.64	93.89	77.95	15.94	21.2
1.00	10.00	2.64	93.17	78.36	14.81	19.26
1.00	4.00	2.64	83.80	67.35	16.45	25.4
0.25	10.00	2.60	48.08	39.73	8.35	22.5
2.00	4.00	2.60	79.38	60.53	18.85	32.5
1.00	0.00	2.62	84.94	69.79	15.15	22.6
2.00	0.00	2.62	88.56	64.72	23.84	38.4
0.25	106.00	2.63	67.65	60.52	7.13	12.3
0.25	117.00	2.62	61.37	55.34	6.03	11.4
1.00	13.00	2.63	79.81	65.35	14.46	23.1
1.00	91.00	2.60	54.81	48.75	6.06	13.1
1.00	8.00	2.63	61.58	51.34	10.24	21.0


Sensor Calibration Curve
% Moisture
Sensor Reading
45
40
35
30
25
20
15
10
5
0
0
20
40
60
80
100
120
140
$y = 25.384e^{-0.007x}$
$R^2 = 0.7609$

Appendix B: Plot Survey Data

Ridge and Valley Survey Data

	Plot A ft.	Plot B ft.	Plot C ft.	Plot D ft.	Plot E ft.	Plot F ft.	Plot G ft.
Bottom Left	9.970	9.750	9.460	9.640	10.130	10.170	10.420
Bottom Right	10.200	9.850	9.750	9.450	9.740	10.180	10.310
Top Left	8.680	8.530	8.270	8.070	8.300	8.590	8.820
Top Right	8.660	8.660	8.460	8.140	8.230	8.450	8.710
Average Slope	0.088	0.075	0.078	0.090	0.104	0.103	0.100
Ridge and Valley Overall Average Slope:				0.091			

Piedmont Survey Data

	Plot A ft.	Plot B ft.	Plot C ft.	Plot D ft.	Plot E ft.	Plot F ft.	Plot G ft.
Bottom Left	9.450	8.590	7.920	7.180	6.840	6.780	7.050
Bottom Right	8.590	7.920	7.180	6.840	6.780	7.050	7.180
Top Left	8.540	7.510	6.720	5.950	5.800	5.730	5.580
Top Right	7.510	6.720	5.950	5.800	5.730	5.580	5.600
Average Slope	0.050	0.057	0.061	0.057	0.052	0.063	0.076
Piedmont Overall Average Slope:				0.059			

Appendix C: Ridge and Valley Run 2 Soil Moisture Sensor Readings

Ridge and Valley Second Run Moisture Sensor Readings

Plot	A	B	C	D	E	F	G
Sensor 1 (Surface)	0	0	11	20	2	52	0
Sensor 2 (Surface)	no data	0	3	0	25	0	0
Sensor 1 (1 foot)	5	17	10	9	24	11	0
Sensor 2 (1 foot)	5	12	no data	0	2	14	0
Sensor 1 (2 foot)	1	0	1	26	7	13	0
Surface Average	8.692						
One-foot Average	8.385						
Two-foot Average	6.857						

Appendix D: Field Stockpile Runoff Concentration Raw Data

For the Ridge and Valley site in Blacksburg, plots A, D, and G were randomly chosen to receive the covered treatment, plots B, C, and E were selected to remain uncovered, and plot F was chosen as the control. A two-letter prefix of QF was added to all plot identification letters for hydrograph and laboratory analysis. Plots C, E, and G received the covered treatment in the Piedmont experimental design setup. The uncovered treatment was applied to plots A, B, and F, with plot D remaining the control. A BS prefix was added to all plot letters from the Piedmont providence to obtain a three-letter plot identifier similar to the Ridge and Valley plots.

Plot	Volume (l)	NO3 (ppm)	NH (ppm)	TKN (ppm)	OP (ppm)	TP (ppm)	TSS (ppm)	FC (CFU/100ml)	LFC (log FC+1)	VSS (ppm)	Treat	Soil	Moisture	sastime	Samptime
QFA	3.37	0.01	24.75	69.68	2.81	13.15	1040.00	67000.00	4.83	200	1	1	Dry	0	1
QFA	7.52	0.02	15.99	48.15	3.91	13.87	960.00	380000.00	5.58		1	1	Dry	9	2
QFA	18.67	0.02	18.76	51.99	4.98	17.84	1308.00	220000.00	5.34	340	1	1	Dry	19	3
QFA	23.25	0.02	20.61	56.28	5.45	21.53	1372.00	340000.00	5.53		1	1	Dry	29	4
QFA	27.52	0.03	18.06	46.31	4.09	16.08	900.00	50000.00	4.70		1	1	Dry	39	5
QFA	40.09	0.02	19.35	55.11	5.66	21.32	1016.00	45000.00	4.65		1	1	Dry	49	6
QFA	39.76	0.03	18.01	46.77	5.37	18.86	896.00	60000.00	4.78		1	1	Dry	59	7
QFA	24.50	0.02	17.65	49.23	5.61	20.00	840.00	38000.00	4.58		1	1	Dry	69	8
QFA	10.37	0.03	14.25	39.16	4.38	16.85	716.00	80000.00	4.90		1	1	Dry	79	9
QFA	2.51	0.03	12.81	37.44	3.83	15.61	552.00	73000.00	4.86		1	1	Dry	89	10
QFB	29.55	0.03	13.03	39.11	1.65	12.49	1668.00	3604.00	3.56	330	2	1	Dry	0	1
QFB	12.48	0.01	32.70	146.25	6.08	28.39	3675.00	200000.00	5.30		2	1	Dry	5	2
QFB	22.29	0.03	45.89	192.61	9.83	33.61	2895.00	600000.00	5.78	1000	2	1	Dry	15	3
QFB	30.36	0.03	49.97	209.56	12.47	42.50	2860.00	2600000.00	6.41		2	1	Dry	25	4
QFB	37.44	0.03	47.63	199.33	15.27	46.83	2755.00	780000.00	5.89		2	1	Dry	35	5
QFB	44.98	0.02	44.01	172.87	16.08	45.43	2525.00	410000.00	5.61		2	1	Dry	45	6
QFB	52.01	0.01	44.62	140.86	16.16	26.12	2755.00	650000.00	5.81		2	1	Dry	55	7
QFB	59.48	0.01	53.46	167.18	21.24	42.48	2835.00	500000.00	5.70		2	1	Dry	65	8
QFB	62.65	0.01	49.26	208.51	21.86	67.05	2695.00	350000.00	5.54		2	1	Dry	75	9
QFC	0.09	0.04	54.73	211.81	16.97	44.27	1910.00	70000.00	4.85	780	2	1	Dry	0	1
QFC	0.99	0.05	52.26	243.68	21.72	55.87	2333.33	420000.00	5.62		2	1	Dry	7	2
QFC	3.98	0.07	56.57	253.94	21.72	58.71	1853.33	500000.00	5.70	1000	2	1	Dry	17	3
QFC	7.10	0.08	57.33	272.00	26.94	80.93	2560.00	410000.00	5.61		2	1	Dry	27	4
QFC	10.90	0.07	54.14	229.30	23.66	60.65	2290.00	600000.00	5.78		2	1	Dry	37	5
QFC	17.36	0.04	49.71	218.36	22.98	64.40	2220.00	370000.00	5.57		2	1	Dry	47	6
QFC	23.50	0.02	52.32	227.73	23.98	75.60	2473.33	280000.00	5.45		2	1	Dry	57	7
QFC	32.54	0.02	49.85	191.79	22.06	67.20	2053.33	68000.00	4.83		2	1	Dry	67	8
QFD	3.34	0.02	23.28	55.92	0.77	8.96	1766.67	20000.00	4.30	370	1	1	Dry	0	1

QFD	14.71	0.02	52.61	168.61	6.15	15.19	1806.67	41000.00	4.61		1	1	Dry	4	2
QFD	39.96	0.03	43.81	161.92	12.74	34.38	1906.67	20000.00	4.30	940	1	1	Dry	14	3
QFD	63.17	0.02	37.04	117.06	11.27	30.22	1300.00	21000.00	4.32		1	1	Dry	24	4
QFD	76.90	0.02	31.76	92.70	9.38	27.02	1133.33	31000.00	4.49		1	1	Dry	34	5
QFD	85.83	0.02	30.16	87.34	10.98	29.08	1333.33	80000.00	4.90		1	1	Dry	44	6
QFD	100.11	0.03	27.67	70.93	8.87	23.58	1133.33	70000.00	4.85		1	1	Dry	54	7
QFD	112.75	0.03	27.86	90.60	10.55	35.65	1426.67	62000.00	4.79		1	1	Dry	64	8
QFD	109.03	0.04	25.81	81.22	9.48	29.42	1420.00	79000.00	4.90		1	1	Dry	74	9
QFD	61.47	0.05	22.47	68.02	8.67	23.50	1266.67	40000.00	4.60		1	1	Dry	84	10
QFE	28.36	0.07	71.24	289.12	20.32	54.25	4800.00	1200.00	3.08	1500	2	1	Dry	0	1
QFE	71.37	0.05	70.33	257.17	18.20	56.05	3586.67	26000.00	4.41		2	1	Dry	10	2
QFE	105.20	0.05	69.36	273.69	18.62	72.19	4350.00	29000.00	4.46	140	2	1	Dry	20	3
QFE	132.24	0.03	65.01	212.06	19.79	50.89	3600.00	23423.00	4.37		2	1	Dry	30	4
QFE	143.73	0.02	47.21	207.07	17.25	62.60	3033.33	30000.00	4.48		2	1	Dry	40	5
QFE	144.19	0.02	45.69	197.48	17.06	62.45	2920.00	28000.00	4.45		2	1	Dry	50	6
QFE	89.09	0.02	47.82	188.26	16.64	61.82	3326.67	23000.00	4.36		2	1	Dry	60	7
QFE	18.60	0.02	46.68	171.54	16.79	58.12	2680.00	10000.00	4.00		2	1	Dry	70	8
QFF	15.98	0.30	5.29	6.12	0.04	1.82	1984.00	0.00	0.00	180	0	1	Dry	0	1
QFF	11.25	0.41	6.10	6.19	0.03	2.13	2844.00	0.00	0.00		0	1	Dry	8	2
QFF	20.08	0.44	6.25	6.23	0.01	2.03	3156.00	0.00	0.00	300	0	1	Dry	18	3
QFF	31.65	0.44	5.57	5.61	0.02	1.97	2848.00	0.00	0.00		0	1	Dry	28	4
QFF	43.62	0.44	6.23	5.09	0.01	1.89	2328.00	0.00	0.00		0	1	Dry	38	5
QFF	52.26	0.44	5.83	4.60	0.06	1.73	1996.00	91.00	1.96		0	1	Dry	48	6
QFF	61.72	0.44	6.42	4.52	0.02	1.85	2316.00	818.00	2.91		0	1	Dry	58	7
QFF	68.27	0.45	4.41	4.71	0.03	1.89	2068.00	1727.00	3.24		0	1	Dry	68	8
QFF	39.02	0.40	5.78	5.15	0.08	2.05	2256.00	3000.00	3.48		0	1	Dry	78	9
QFG	1.69	0.05	9.62	27.10	0.51	6.05	1560.00	69000.00	4.84	270	1	1	Dry	0	1
QFG	11.90	0.04	23.04	72.60	3.73	17.01	1886.67	42000.00	4.62		1	1	Dry	4	2
QFG	27.78	0.03	17.98	59.68	3.29	16.50	1246.67	30000.00	4.48	380	1	1	Dry	14	3
QFG	43.72	0.04	15.15	48.03	2.93	15.14	1213.33	20000.00	4.30		1	1	Dry	24	4
QFG	72.89	0.03	20.10	62.23	4.90	21.32	1546.67	1636.00	3.21		1	1	Dry	34	5
QFG	102.89	0.04	17.98	56.69	4.89	19.05	786.67	1000.00	3.00		1	1	Dry	44	6
QFG	129.62	0.04	15.36	54.66	4.63	19.92	926.67	636.00	2.80		1	1	Dry	54	7
QFG	158.18	0.05	14.49	50.11	4.40	19.42	1080.00	6000.00	3.78		1	1	Dry	64	8
QFG	170.52	0.04	12.36	44.28	3.61	18.59	766.67	1364.00	3.14		1	1	Dry	74	9
QFG	120.12	0.05	12.22	42.97	3.87	18.46	946.67	7700.00	3.89		1	1	Dry	84	10
QFA	0.02	17.62	17.05	57.84	4.31	10.11	360.00	0.00	0.00	170	1	1	Wet	0	1
QFA	0.15	15.07	20.95	75.91	7.20	15.54	533.33	5600.00	3.75		1	1	Wet	4	2
QFA	3.08	8.40	17.75	62.47	7.45	16.51	673.33	6000.00	3.78	260	1	1	Wet	14	3
QFA	10.31	0.44	9.29	50.57	6.43	16.56	626.67	7100.00	3.85		1	1	Wet	24	4
QFA	17.44	0.67	6.53	39.20	4.60	13.39	606.67	9500.00	3.98		1	1	Wet	34	5
QFA	24.73	0.19	5.98	35.82	4.46	12.63	640.00	73000.00	4.86		1	1	Wet	44	6
QFA	36.95	0.38	5.23	33.18	4.36	10.83	560.00	6900.00	3.84		1	1	Wet	54	7
QFA	46.57	0.42	5.70	34.28	4.11	12.19	633.33	12000.00	4.08		1	1	Wet	64	8
QFA	52.55	0.61	5.03	32.72	4.03	12.02	533.33	10000.00	4.00		1	1	Wet	74	9
QFA	60.18	0.80	4.98	32.41	4.50	10.84	586.67	10800.00	4.03		1	1	Wet	84	10

QFA	61.80	1.04	4.88	32.95	4.49	10.77	553.33	10900.00	4.04		1	1	Wet	94	11
QFA	32.50	1.13	5.54	36.23	5.18	11.13	520.00	11000.00	4.04		1	1	Wet	104	12
QFA	2.60	0.99	5.90	39.00	5.43	13.19	553.33	19000.00	4.28		1	1	Wet	114	13
QFB	9.89	9.59	7.11	19.04	2.37	4.96	420.00	1636.00	3.21	330	2	1	Wet	0	1
QFB	5.81	9.90	5.50	18.91	2.53	5.23	224.00	1000.00	3.00		2	1	Wet	6	2
QFB	11.53	7.61	5.68	24.09	3.41	7.83	264.00	25000.00	4.40	83	2	1	Wet	16	3
QFB	21.88	4.49	13.85	46.45	5.79	14.49	206.67	22000.00	4.34		2	1	Wet	26	4
QFB	36.46	1.29	19.44	71.50	7.40	15.79	680.00	20000.00	4.30		2	1	Wet	36	5
QFB	53.24	1.26	24.24	85.15	8.31	19.00	600.00	60000.00	4.78		2	1	Wet	46	6
QFB	67.95	0.84	25.41	96.19	8.92	22.10	653.33	40000.00	4.60		2	1	Wet	56	7
QFB	77.75	0.87	25.66	99.38	8.46	24.74	746.67	42000.00	4.62		2	1	Wet	66	8
QFB	85.68	0.95	26.00	107.88	8.53	28.31	640.00	49000.00	4.69		2	1	Wet	76	9
QFB	64.09	0.76	31.36	115.95	8.69	29.87	606.67	38000.00	4.58		2	1	Wet	86	10
QFB	19.57	0.29	36.23	124.76	8.91	23.05	793.33	20000.00	4.30		2	1	Wet	96	11
QFC	0.05	0.03	11.11	378.24	4.78	92.51	1026.67	0.00	0.00	450	2	1	Wet	0	1
QFC	0.28	0.09	55.27	188.71	14.76	36.85	766.67	1400000.00	6.15		2	1	Wet	10	2
QFC	1.31	0.10	80.39	259.99	16.69	38.72	693.33	6000000.00	6.78	430	2	1	Wet	20	3
QFC	3.14	0.17	123.57	318.03	15.55	41.12	600.00	5000000.00	6.70		2	1	Wet	30	4
QFC	4.94	0.23	159.55	403.55	18.46	40.44	713.33	4000000.00	6.60		2	1	Wet	40	5
QFC	9.21	0.24	159.50	399.85	17.44	47.46	633.33	3000000.00	6.48		2	1	Wet	50	6
QFC	15.65	0.29	186.26	462.85	17.71	35.40	646.67	9000000.00	6.95		2	1	Wet	60	7
QFC	38.67	0.31	200.66	509.17	16.76	43.41	840.00	5800000.00	6.76		2	1	Wet	70	8
QFD	11.94	10.28	19.82	48.87	2.28	6.64	520.00	0.00	0.00	200	1	1	Wet	0	1
QFD	16.57	37.09	47.66	155.38	12.13	21.45	600.00	4500.00	3.65		1	1	Wet	11	2
QFD	25.12	25.29	42.57	141.96	14.35	23.51	573.33	4900.00	3.69	230	1	1	Wet	21	3
QFD	33.59	12.76	40.95	137.78	16.18	25.06	493.33	5500.00	3.74		1	1	Wet	31	4
QFD	40.21	8.35	39.01	132.38	16.08	23.57	480.00	3400.00	3.53		1	1	Wet	41	5
QFD	48.28	5.76	38.64	127.00	16.32	23.86	420.00	3300.00	3.52		1	1	Wet	51	6
QFD	57.21	4.20	34.62	122.09	15.95	24.08	440.00	6100.00	3.79		1	1	Wet	61	7
QFD	64.97	4.39	33.71	113.90	15.36	21.12	293.33	6900.00	3.84		1	1	Wet	71	8
QFD	75.11	3.83	36.44	115.94	14.97	22.15	333.33	7000.00	3.85		1	1	Wet	81	9
QFD	84.66	3.79	36.13	114.58	15.08	21.72	313.33	4546.00	3.66		1	1	Wet	91	10
QFD	89.09	3.94	39.38	119.49	14.57	22.19	346.67	8181.00	3.91		1	1	Wet	101	11
QFD	76.67	4.60	48.38	123.05	14.57	22.74	366.67	7272.00	3.86		1	1	Wet	111	12
QFE	0.03	0.38	126.65	423.88	11.01	52.79	2557.14	0.00	0.00	1200	2	1	Wet	0	1
QFE	0.19	0.34	89.50	53.50	15.29	6.20	2966.67	0.00	0.00		2	1	Wet	5	2
QFE	1.49	0.28	63.92	246.37	17.98	50.80	2369.23	20000.00	4.30	1200	2	1	Wet	15	3
QFE	8.26	0.24	60.34	261.46	13.90	46.94	2692.31	21000.00	4.32		2	1	Wet	25	4
QFE	17.25	0.37	151.66	503.60	11.74	57.53	2230.00	28000.00	4.45		2	1	Wet	35	5
QFE	23.74	0.45	173.25	592.68	11.56	80.51	1790.00	29000.00	4.46		2	1	Wet	45	6
QFE	33.23	0.54	189.91	599.84	12.96	60.28	1700.00	39000.00	4.59		2	1	Wet	55	7
QFE	47.31	0.63	212.36	673.19	13.13	48.57	2220.00	32000.00	4.51		2	1	Wet	65	8
QFE	55.36	0.70	245.76	671.88	12.72	51.14	2050.00	36000.00	4.56		2	1	Wet	75	9
QFE	59.08	0.67	225.44	645.44	11.56	64.86	2570.00	31000.00	4.49		2	1	Wet	85	10
QFE	67.21	0.76	257.93	721.87	10.88	75.30	1920.00	45000.00	4.65		2	1	Wet	95	11
QFE	71.76	0.80	283.48	713.01	11.36	51.54	2100.00	48000.00	4.68		2	1	Wet	105	12

QFE	45.12	0.89	359.31	865.13	7.73	59.95	1780.00	43000.00	4.63		2	1	Wet	115	13
QFF	1.45	0.05	1.47	5.55	0.08	1.35	548.00	0.00	0.00	74	0	1	Wet	0	1
QFF	6.17	0.11	2.30	1.64	0.04	0.62	276.00	0.00	0.00		0	1	Wet	10	2
QFF	17.30	0.41	2.33	1.71	0.01	0.50	204.00	0.00	0.00	76	0	1	Wet	20	3
QFF	29.10	0.49	2.46	1.73	0.00	0.51	144.00	0.00	0.00		0	1	Wet	30	4
QFF	37.19	0.52	3.90	1.57	0.00	0.47	104.00	950.00	2.98		0	1	Wet	40	5
QFF	47.26	0.48	4.14	1.59	0.04	0.43	76.00	1000.00	3.00		0	1	Wet	50	6
QFF	57.07	0.47	4.38	1.63	0.07	0.42	100.00	1350.00	3.13		0	1	Wet	60	7
QFF	63.41	0.48	3.46	1.55	0.02	0.48	104.00	1490.00	3.17		0	1	Wet	70	8
QFF	70.63	0.41	4.12	1.74	0.06	0.54	92.00	1400.00	3.15		0	1	Wet	80	9
QFF	75.42	0.38	2.64	2.00	0.01	0.53	64.00	690.00	2.84		0	1	Wet	90	10
QFF	65.37	0.41	0.91	1.36	0.00	0.49	76.00	1000.00	3.00		0	1	Wet	100	11
QFG	4.31	22.70	10.77	74.24	13.60	18.57	386.67	29000.00	4.46	250	1	1	Wet	0	1
QFG	11.34	5.14	16.87	63.55	14.71	19.31	300.00	40000.00	4.60		1	1	Wet	9	2
QFG	23.03	2.99	9.87	59.26	11.56	16.84	320.00	28000.00	4.45	210	1	1	Wet	19	3
QFG	39.92	13.58	30.74	86.48	11.23	15.96	326.67	17000.00	4.23		1	1	Wet	29	4
QFG	59.26	17.13	34.00	94.53	10.89	15.98	380.00	14000.00	4.15		1	1	Wet	39	5
QFG	79.44	12.34	29.55	84.41	10.48	14.32	380.00	10000.00	4.00		1	1	Wet	49	6
QFG	102.43	9.79	26.22	79.18	10.17	14.92	400.00	12000.00	4.08		1	1	Wet	59	7
QFG	123.33	8.57	27.21	79.44	10.21	15.01	400.00	19000.00	4.28		1	1	Wet	69	8
QFG	143.17	7.08	26.54	80.51	10.54	14.60	360.00	15000.00	4.18		1	1	Wet	79	9
QFG	161.34	7.31	27.49	84.31	10.27	14.79	300.00	14000.00	4.15		1	1	Wet	89	10
QFG	174.45	6.48	26.14	83.67	9.69	14.44	340.00	8000.00	3.90		1	1	Wet	99	11
QFG	184.44	6.21	26.42	86.08	9.07	13.54	306.67	7900.00	3.90		1	1	Wet	109	12
QFG	146.91	5.47	32.87	101.63	9.53	14.97	326.67	18182.00	4.26		1	1	Wet	119	13
BSA	3.04	0.10	31.46	111.31	29.28	34.04	472.00	300000.00	5.48	400	2	2	Dry	0	1
BSA	8.11	0.17	44.71	153.65	40.66	46.84	220.00	500000.00	5.70		2	2	Dry	7	2
BSA	14.54	0.17	42.77	155.01	38.91	45.30	460.00	550000.00	5.74	360	2	2	Dry	17	3
BSA	21.88	0.20	53.07	177.46	44.55	53.94	456.00	600000.00	5.78		2	2	Dry	27	4
BSA	34.32	0.25	62.01	213.57	50.49	61.98	408.00	620000.00	5.79		2	2	Dry	37	5
BSA	40.77	0.30	73.85	258.82	55.89	72.30	400.00	750000.00	5.88		2	2	Dry	47	6
BSA	35.25	0.30	72.98	262.51	57.28	72.90	532.00	800000.00	5.90		2	2	Dry	57	7
BSA	14.87	0.30	71.14	262.56	57.89	77.22	700.00	830000.00	5.92		2	2	Dry	67	8
BSA	0.00	0.50	99.57	332.18	72.16	89.20	144.00	840000.00	5.92		2	2	Dry	77	9
BSB	1.00	0.08	25.96	96.70	17.65	22.22	944.00	250000.00	5.40	640	2	2	Dry	0	1
BSB	4.61	0.14	37.26	145.60	29.99	38.10	1056.00	320000.00	5.51		2	2	Dry	9	2
BSB	11.56	0.11	39.30	133.17	27.04	33.38	532.00	310000.00	5.49	480	2	2	Dry	19	3
BSB	20.05	0.16	41.26	157.26	35.65	43.05	280.00	420000.00	5.62		2	2	Dry	29	4
BSB	29.43	0.17	41.94	163.10	41.19	49.01	676.00	380000.00	5.58		2	2	Dry	39	5
BSB	35.85	0.13	41.38	131.34	39.41	43.59	496.00	450000.00	5.65		2	2	Dry	49	6
BSB	44.05	0.12	37.48	137.86	40.43	48.43	412.00	500000.00	5.70		2	2	Dry	59	7
BSB	31.34	0.12	36.23	138.20	41.52	52.17	396.00	530000.00	5.72		2	2	Dry	69	8
BSB	5.82	0.17	44.24	155.10	50.69	58.29	132.00	610000.00	5.79		2	2	Dry	79	9
BSC	2.81	0.20	59.74	222.73	46.93	55.49	548.00	20000.00	4.30	400	1	2	Dry	0	1
BSC	7.30	0.11	37.11	140.83	34.97	39.51	444.00	30000.00	4.48		1	2	Dry	9	2
BSC	18.13	0.07	28.51	111.02	28.40	35.07	612.00	60000.00	4.78	520	1	2	Dry	19	3

BSC	39.80	0.10	43.53	138.57	30.78	36.19	388.00	68000.00	4.83		1	2	Dry	29	4
BSC	71.19	0.10	39.58	126.59	31.19	34.68	296.00	62000.00	4.79		1	2	Dry	39	5
BSC	94.12	0.06	29.34	97.45	24.22	28.49	204.00	64000.00	4.81		1	2	Dry	49	6
BSC	108.69	0.09	36.19	127.00	30.40	36.11	288.00	60000.00	4.78		1	2	Dry	59	7
BSC	140.56	0.08	36.15	118.15	30.53	36.43	244.00	50000.00	4.70		1	2	Dry	69	8
BSC	144.08	0.08	32.11	111.70	29.99	34.76	120.00	51000.00	4.71		1	2	Dry	79	9
BSC	102.69	0.06	28.67	92.30	26.20	31.79	196.00	54000.00	4.73		1	2	Dry	89	10
BSD	0.11	0.34	5.57	21.99	2.52	3.90	56.00	2800.00	3.45	40	0	2	Dry	0	1
BSD	4.86	0.27	6.25	24.45	2.97	4.96	568.00	3000.00	3.48		0	2	Dry	3	2
BSD	38.48	0.10	3.95	20.74	4.64	6.47	264.00	3600.00	3.56	200	0	2	Dry	13	3
BSD	76.37	0.07	6.59	27.50	7.43	9.75	32.00	4100.00	3.61		0	2	Dry	23	4
BSD	92.56	0.10	6.56	23.48	6.83	8.37	28.00	4000.00	3.60		0	2	Dry	33	5
BSD	109.21	0.06	4.79	21.09	5.72	7.26	4.00	3800.00	3.58		0	2	Dry	43	6
BSD	123.86	0.05	4.55	19.77	4.77	6.20	4.00	3600.00	3.56		0	2	Dry	53	7
BSD	98.55	0.06	7.10	29.78	7.99	9.37	0.00	3200.00	3.51		0	2	Dry	63	8
BSE	3.84	0.05	19.58	83.33	15.78	17.65	1132.00	30000.00	4.48	1000	1	2	Dry	0	1
BSE	2.40	0.15	49.97	170.30	29.90	36.41	928.00	40000.00	4.60		1	2	Dry	7	2
BSE	3.56	0.28	92.97	295.96	46.55	61.30	616.00	71000.00	4.85	600	1	2	Dry	17	3
BSE	7.88	0.27	93.40	285.88	45.45	59.99	328.00	76000.00	4.88		1	2	Dry	27	4
BSE	19.65	0.21	73.92	239.12	38.87	50.09	352.00	70000.00	4.85		1	2	Dry	37	5
BSE	40.18	0.17	58.98	194.29	36.99	45.01	376.00	64000.00	4.81		1	2	Dry	47	6
BSE	61.91	0.18	53.43	184.10	39.67	46.20	104.00	63000.00	4.80		1	2	Dry	57	7
BSE	77.62	0.15	48.71	175.05	37.21	42.94	272.00	58000.00	4.76		1	2	Dry	67	8
BSE	85.36	0.13	45.77	163.28	35.86	42.92	228.00	55000.00	4.74		1	2	Dry	77	9
BSE	85.22	0.12	44.86	151.94	34.20	39.89	172.00	53000.00	4.72		1	2	Dry	87	10
BSE	83.86	0.10	42.82	135.77	33.20	37.01	192.00	51000.00	4.71		1	2	Dry	97	11
BSE	65.50	0.09	38.51	127.20	32.12	34.43	48.00	42000.00	4.62		1	2	Dry	107	12
BSE	26.15	0.24	66.61	214.29	45.79	50.76	32.00	58000.00	4.76		1	2	Dry	117	13
BSF	0.64	0.15	58.06	195.16	33.87	39.88	16.00	780000.00	5.89	12	2	2	Dry	0	1
BSF	3.87	0.24	81.39	288.12	46.97	66.17	2128.00	760000.00	5.88		2	2	Dry	9	2
BSF	8.54	0.25	79.09	278.35	47.08	62.58	1104.00	730000.00	5.86	800	2	2	Dry	19	3
BSF	12.96	0.30	74.48	280.26	48.17	66.36	980.00	770000.00	5.89		2	2	Dry	29	4
BSF	20.35	0.30	78.47	277.80	49.64	66.88	1084.00	760000.00	5.88		2	2	Dry	39	5
BSF	31.73	0.27	74.52	266.52	50.51	68.52	1164.00	770000.00	5.89		2	2	Dry	49	6
BSF	36.15	0.25	73.88	269.10	50.42	70.47	1168.00	700000.00	5.85		2	2	Dry	59	7
BSF	42.18	0.23	71.56	260.92	52.23	73.49	1364.00	740000.00	5.87		2	2	Dry	69	8
BSF	59.89	0.23	76.07	278.29	54.20	82.02	1092.00	750000.00	5.88		2	2	Dry	79	9
BSF	75.27	0.21	73.00	238.14	57.00	68.17	1036.00	660000.00	5.82		2	2	Dry	89	10
BSF	58.53	0.20	76.77	265.87	57.32	81.75	1212.00	700000.00	5.85		2	2	Dry	99	11
BSF	25.74	0.43	103.79	343.11	78.12	92.64	160.00	960000.00	5.98		2	2	Dry	109	12
BSG	2.44	0.28	81.93	329.77	46.43	71.19	1480.00	750000.00	5.88	400	1	2	Dry	0	1
BSG	4.34	0.45	92.50	366.83	76.12	95.16	660.00	800000.00	5.90		1	2	Dry	6	2
BSG	5.92	0.38	92.11	370.77	79.36	101.90	484.00	960000.00	5.98	360	1	2	Dry	16	3
BSG	19.93	0.39	81.99	335.61	74.80	96.17	1336.00	950000.00	5.98		1	2	Dry	26	4
BSG	37.15	0.31	74.53	281.15	68.62	82.93	748.00	800000.00	5.90		1	2	Dry	36	5
BSG	49.66	0.21	61.26	210.77	57.98	66.23	276.00	770000.00	5.89		1	2	Dry	46	6

BSG	62.61	0.19	57.67	209.62	51.17	61.76	544.00	790000.00	5.90		1	2	Dry	56	7
BSG	73.74	0.19	59.72	212.02	51.77	63.15	564.00	700000.00	5.85		1	2	Dry	66	8
BSG	87.33	0.18	59.83	210.69	48.35	61.65	500.00	710000.00	5.85		1	2	Dry	76	9
BSG	112.48	0.16	58.75	204.64	45.90	60.12	656.00	600000.00	5.78		1	2	Dry	86	10
BSG	148.96	0.13	54.70	176.89	44.15	56.46	620.00	630000.00	5.80		1	2	Dry	96	11
BSG	117.90	0.11	52.44	169.52	43.10	55.10	528.00	520000.00	5.72		1	2	Dry	106	12
BSG	34.84	0.28	70.85	219.91	61.63	65.70	96.00	600000.00	5.78		1	2	Dry	116	13
BSA	1.24	0.48	81.90	1866.76	19.03	55.59	11350.00	280000.00	5.45	2000	2	2	Wet	0	1
BSA	8.31	0.58	89.76	2046.75	35.07	51.23	6880.00	211000.00	5.32		2	2	Wet	5	2
BSA	26.82	0.55	95.69	2039.61	34.54	61.42	4580.00	260000.00	5.41	3000	2	2	Wet	15	3
BSA	49.10	0.77	116.58	2500.73	49.25	63.80	2880.00	110000.00	5.04		2	2	Wet	25	4
BSA	63.06	0.95	114.49	2971.66	37.60	68.75	2340.00	350000.00	5.54		2	2	Wet	35	5
BSA	74.12	1.31	117.99	3512.11	53.87	71.18	2150.00	80000.00	4.90		2	2	Wet	45	6
BSA	82.52	1.38	119.92	3718.08	57.16	77.48	2330.00	90000.00	4.95		2	2	Wet	55	7
BSA	92.07	1.51	111.17	4163.94	62.60	82.55	2750.00	200000.00	5.30		2	2	Wet	65	8
BSA	89.17	1.46	90.32	4159.35	64.54	88.64	180.00	150000.00	5.18		2	2	Wet	75	9
BSA	53.02	1.52	107.37	4165.35	87.76	125.90	3252.00	350000.00	5.54		2	2	Wet	85	10
BSA	19.43	2.93	95.06	4000.00	128.09	120.00	3772.00	140000.00	5.15		2	2	Wet	95	11
BSA	7.64	3.46	105.58	4000.00	135.34	120.00	7170.00	300000.00	5.48		2	2	Wet	105	12
BSA	2.74	4.09	164.84	4000.00	139.58	120.00	7520.00	200000.00	5.30		2	2	Wet	115	13
BSA	0.91	4.22	103.65	4000.00	144.76	120.00	7390.00	325000.00	5.51		2	2	Wet	125	14
BSA	0.39	4.42	122.49	4000.00	148.88	120.00	7370.00	100000.00	5.00		2	2	Wet	135	15
BSA	0.42	4.73	154.64	4000.00	154.13	120.00	8840.00	60000.00	4.78		2	2	Wet	145	16
BSA	0.27	4.72	124.77	4000.00	142.20	120.00	9380.00	49000.00	4.69		2	2	Wet	155	17
BSB	0.25	0.43	98.92	1397.88	22.58	26.28	8160.00	250000.00	5.40	2000	2	2	Wet	0	1
BSB	0.54	0.80	88.76	1991.65	46.16	61.57	8690.00	180000.00	5.26		2	2	Wet	5	2
BSB	0.83	0.60	86.07	1788.36	38.75	66.32	7880.00	40000.00	4.60	3000	2	2	Wet	15	3
BSB	4.80	0.72	94.96	2029.23	41.92	63.61	7340.00	280000.00	5.45		2	2	Wet	25	4
BSB	14.53	0.89	95.45	2496.28	42.00	79.18	7300.00	290000.00	5.46		2	2	Wet	35	5
BSB	28.90	1.15	100.21	2868.53	53.75	78.26	7150.00	100000.00	5.00		2	2	Wet	45	6
BSB	42.71	1.46	100.79	3497.13	66.91	91.09	7160.00	195000.00	5.29		2	2	Wet	55	7
BSB	52.43	1.61	101.93	4010.66	65.26	103.49	7230.00	90000.00	4.95		2	2	Wet	65	8
BSB	49.92	1.73	95.79	4168.32	73.26	121.41	1870.00	260000.00	5.41		2	2	Wet	75	9
BSB	34.54	1.61	120.55	4000.00	102.39	120.00	7280.00	120000.00	5.08		2	2	Wet	85	10
BSB	16.41	2.88	154.39	4000.00	146.22	120.00	8270.00	190000.00	5.28		2	2	Wet	95	11
BSB	5.22	2.92	147.57	4000.00	148.75	120.00	8450.00	180000.00	5.26		2	2	Wet	105	12
BSB	2.11	3.11	135.28	4000.00	154.92	120.00	8460.00	20000.00	4.30		2	2	Wet	115	13
BSB	0.31	3.61	152.96	4000.00	153.96	120.00	8830.00	350000.00	5.54		2	2	Wet	125	14
BSB	0.11	4.33	135.07	4000.00	192.18	120.00	5206.67	370000.00	5.57		2	2	Wet	135	15
BSC	2.35	0.19	85.64	746.18	19.24	21.23	5653.33	60000.00	4.78	2000	1	2	Wet	0	1
BSC	33.90	0.50	90.54	1887.81	48.99	58.63	5700.00	70000.00	4.85		1	2	Wet	5	2
BSC	92.90	0.57	87.46	1929.49	44.61	60.11	5900.00	100000.00	5.00	670	1	2	Wet	15	3
BSC	128.10	0.52	81.98	2025.84	40.95	64.10	5706.67	125000.00	5.10		1	2	Wet	25	4
BSC	145.27	0.45	78.33	1316.65	44.87	42.91	5440.00	90000.00	4.95		1	2	Wet	35	5
BSC	167.23	0.37	74.76	1772.11	40.89	70.57	5420.00	95000.00	4.98		1	2	Wet	45	6
BSC	184.18	0.36	73.99	1609.93	37.27	66.27	5440.00	93000.00	4.97		1	2	Wet	55	7

BSC	134.79	0.33	65.58	1455.94	41.72	59.92	5440.00	88000.00	4.94		1	2	Wet	65	8
BSC	41.61	0.30	72.08	1321.24	36.54	54.66	5366.67	76000.00	4.88		1	2	Wet	75	9
BSC	2.26	0.48	83.72	1837.66	45.54	61.08	233.33	80000.00	4.90		1	2	Wet	85	10
BSD	13.19	0.32	57.18	332.77	0.79	1.41	984.00	2000.00	3.30	800	0	2	Wet	0	1
BSD	30.69	0.78	63.72	637.13	6.80	8.05	420.00	6000.00	3.78		0	2	Wet	7	2
BSD	66.59	0.47	55.97	397.39	3.56	6.41	204.00	3500.00	3.54	120	0	2	Wet	17	3
BSD	97.22	0.37	54.10	338.99	1.91	2.53	156.00	3000.00	3.48		0	2	Wet	27	4
BSD	120.90	0.30	52.30	319.95	1.27	1.56	112.00	8000.00	3.90		0	2	Wet	37	5
BSD	135.78	0.27	50.57	334.13	0.98	1.46	92.00	3000.00	3.48		0	2	Wet	47	6
BSD	143.42	0.23	50.61	317.66	0.94	1.36	92.00	5000.00	3.70		0	2	Wet	57	7
BSD	130.77	0.18	51.28	295.03	0.87	1.11	72.00	100.00	2.00		0	2	Wet	67	8
BSD	61.76	0.17	52.45	301.67	0.96	1.15	44.00	0.00	0.00		0	2	Wet	77	9
BSE	0.06	0.32	74.94	1734.18	27.03	41.06	506.67	79000.00	4.90	460	1	2	Wet	0	1
BSE	16.31	0.40	85.49	1986.14	40.46	71.14	946.67	85000.00	4.93		1	2	Wet	4	2
BSE	60.93	0.37	61.28	2027.18	42.79	76.14	546.67	84000.00	4.92	470	1	2	Wet	14	3
BSE	103.98	0.35	48.32	1946.94	39.50	78.22	626.67	80000.00	4.90		1	2	Wet	24	4
BSE	135.28	0.29	46.17	1565.43	36.23	67.24	920.00	76000.00	4.88		1	2	Wet	34	5
BSE	162.68	0.25	47.83	1415.40	35.02	66.92	700.00	70000.00	4.85		1	2	Wet	44	6
BSE	186.77	0.23	42.10	1527.00	32.91	67.71	566.67	96000.00	4.98		1	2	Wet	54	7
BSE	190.33	0.22	46.52	1394.06	32.94	64.66	666.67	94000.00	4.97		1	2	Wet	64	8
BSE	145.61	0.19	36.81	1240.99	32.73	57.83	580.00	89000.00	4.95		1	2	Wet	74	9
BSE	75.82	0.30	41.52	1055.57	36.19	39.04	553.33	86000.00	4.93		1	2	Wet	84	10
BSE	26.50	0.20	39.74	1127.06	31.84	46.84	240.00	83000.00	4.92		1	2	Wet	94	11
BSE	7.39	0.20	38.32	1082.13	32.45	43.49	93.33	77000.00	4.89		1	2	Wet	104	12
BSE	1.45	0.19	35.55	939.87	31.36	39.30	80.00	70000.00	4.85		1	2	Wet	114	13
BSF	0.50	0.30	41.28	1702.11	25.45	78.32	4280.00	100000.00	5.00	3000	2	2	Wet	0	1
BSF	12.13	0.37	38.81	2265.30	33.01	98.97	3170.00	130000.00	5.11		2	2	Wet	4	2
BSF	34.49	0.58	39.36	3241.00	43.33	145.24	3120.00	142000.00	5.15	2000	2	2	Wet	14	3
BSF	59.58	0.66	44.45	3148.68	43.73	136.83	3040.00	148000.00	5.17		2	2	Wet	24	4
BSF	80.82	0.71	41.81	3633.60	41.95	141.01	2180.00	260000.00	5.41		2	2	Wet	34	5
BSF	100.85	0.87	33.95	3578.50	43.19	124.89	2480.00	254000.00	5.40		2	2	Wet	44	6
BSF	141.70	0.89	39.99	3619.69	46.99	119.78	2230.00	272000.00	5.43		2	2	Wet	54	7
BSF	177.71	1.03	33.39	3973.86	48.81	131.62	2110.00	276000.00	5.44		2	2	Wet	64	8
BSF	137.70	1.10	26.80	4161.68	49.57	144.80	2470.00	281000.00	5.45		2	2	Wet	74	9
BSF	59.97	1.40	31.54	4087.87	57.39	92.84	690.00	340000.00	5.53		2	2	Wet	84	10
BSF	18.39	1.33	30.04	4161.33	54.96	89.44	780.00	330000.00	5.52		2	2	Wet	94	11
BSF	4.47	1.08	32.82	4155.68	49.07	90.06	390.00	390000.00	5.59		2	2	Wet	104	12
BSF	1.23	1.13	42.06	4153.35	48.34	88.01	310.00	380000.00	5.58		2	2	Wet	114	13
BSF	0.12	1.76	39.47	4159.28	53.92	109.89	470.00	411000.00	5.61		2	2	Wet	124	14
BSG	32.33	0.28	44.51	1635.22	30.69	54.14	940.00	500000.00	5.70	800	1	2	Wet	0	1
BSG	81.21	0.33	34.34	1879.97	34.43	74.18	1453.33	804000.00	5.91		1	2	Wet	4	2
BSG	157.65	0.35	35.20	1654.71	37.64	66.14	1060.00	580000.00	5.76	930	1	2	Wet	14	3
BSG	187.66	0.31	27.78	1478.55	39.91	64.73	1066.67	160000.00	5.20		1	2	Wet	24	4
BSG	203.44	0.26	27.53	1259.08	36.81	54.72	906.67	300000.00	5.48		1	2	Wet	34	5
BSG	218.20	0.22	25.87	1080.79	36.08	50.35	820.00	400000.00	5.60		1	2	Wet	44	6
BSG	225.53	0.20	24.53	975.19	34.00	44.86	713.33	450000.00	5.65		1	2	Wet	54	7

BSG	228.18	0.19	22.92	924.82	33.93	44.32	820.00	350000.00	5.54		1	2	Wet	64	8
BSG	182.05	0.16	28.16	830.17	30.72	39.72	953.33	370000.00	5.57		1	2	Wet	74	9
BSG	94.24	0.19	36.53	826.29	32.25	31.59	133.33	360000.00	5.56		1	2	Wet	84	10
BSG	37.14	0.21	33.03	914.58	34.79	34.78	200.00	300000.00	5.48		1	2	Wet	94	11
BSG	12.72	0.22	28.04	978.51	38.54	38.82	113.33	250000.00	5.40		1	2	Wet	104	12

Appendix E: Field Stockpile Runoff Mass Loading Raw Data

Plot	Volume (l)	NO3 (mg)	NH (mg)	TKN (mg)	OP (mg)	TP (mg)	TSS (mg)	FC (CFU)	LFC (log FC +1)	Treatment	Soil	Moisture	sastime	Samptime
QFA	3.37	0.03	83.45	234.90	9.46	44.32	3506.19	225879485.42	8.35	1	1	Dry	0	1
QFA	10.89	0.18	203.76	597.08	38.87	148.62	10727.92	3084480971.14	9.49	1	1	Dry	9	2
QFA	29.56	0.48	554.06	1567.77	131.83	481.61	35149.21	7192037534.52	9.86	1	1	Dry	19	3
QFA	52.81	0.92	1033.26	2876.08	258.57	981.99	67043.53	15095876724.96	10.18	1	1	Dry	29	4
QFA	80.33	1.70	1530.44	4150.54	371.16	1424.56	91814.34	16472032797.92	10.22	1	1	Dry	39	5
QFA	120.43	2.46	2306.19	6360.15	598.14	2279.18	132550.38	18276286772.66	10.26	1	1	Dry	49	6
QFA	160.19	3.45	3022.37	8219.59	811.72	3028.80	168172.76	20661714218.29	10.32	1	1	Dry	59	7
QFA	184.68	3.97	3454.65	9425.52	949.16	3518.72	188749.29	21592557279.63	10.33	1	1	Dry	69	8
QFA	195.05	4.22	3602.33	9831.41	994.54	3693.34	196171.51	22421855071.00	10.35	1	1	Dry	79	9
QFA	197.56	4.30	3634.44	9925.28	1004.14	3732.47	197555.48	22604880352.87	10.35	1	1	Dry	89	10
QFB	29.55	0.77	384.91	1155.77	48.88	368.95	49292.42	106504720.73	8.03	2	1	Dry	0	1
QFB	42.04	0.89	793.16	2981.57	124.76	723.38	95171.56	2603328939.19	9.42	2	1	Dry	5	2
QFB	64.33	1.45	1816.31	7275.80	343.85	1472.71	159715.38	15980285302.93	10.20	2	1	Dry	15	3
QFB	94.69	2.30	3333.10	13637.29	722.48	2762.86	246534.68	94906923300.36	10.98	2	1	Dry	25	4
QFB	132.12	3.35	5116.33	21099.38	1294.07	4515.84	349673.04	124107619943.87	11.09	2	1	Dry	35	5
QFB	177.11	4.11	7096.27	28875.82	2017.37	6559.48	463258.55	142551208837.06	11.15	2	1	Dry	45	6
QFB	229.12	4.63	9416.59	36201.62	2857.61	7917.66	606539.64	176356184302.87	11.25	2	1	Dry	55	7
QFB	288.59	5.47	12596.19	46145.05	4120.97	10443.96	775157.97	206094866106.47	11.31	2	1	Dry	65	8
QFB	351.25	6.16	15682.79	59208.76	5490.71	14644.61	944011.03	228023834736.12	11.36	2	1	Dry	75	9
QFC	0.09	0.00	4.83	18.69	1.50	3.91	168.55	6177174.26	6.79	2	1	Dry	0	1
QFC	1.07	0.05	56.37	259.02	22.92	59.01	2469.85	420411213.00	8.62	2	1	Dry	7	2
QFC	5.06	0.32	281.60	1270.06	109.38	292.74	9848.75	2411122414.20	9.38	2	1	Dry	17	3
QFC	12.15	0.87	688.42	3200.17	300.53	866.98	28014.42	5320467673.49	9.73	2	1	Dry	27	4
QFC	23.05	1.60	1278.62	5699.74	558.39	1528.12	52977.47	11861005127.24	10.07	2	1	Dry	37	5
QFC	40.41	2.24	2141.70	9490.68	957.42	2646.08	91518.83	18284565587.72	10.26	2	1	Dry	47	6
QFC	63.91	2.69	3371.23	14842.40	1520.88	4422.58	149642.80	24864636956.74	10.40	2	1	Dry	57	7
QFC	96.46	3.40	4993.42	21083.72	2238.89	6609.33	216465.09	27077583162.45	10.43	2	1	Dry	67	8

QFD	3.34	0.08	77.71	186.65	2.55	29.91	5896.69	66755009.25	7.82	1	1	Dry	0	1
QFD	18.04	0.36	851.40	2666.12	93.02	253.29	32465.22	669693935.33	8.83	1	1	Dry	4	2
QFD	58.01	1.36	2602.18	9137.22	601.97	1627.08	108664.70	1468989139.40	9.17	1	1	Dry	14	3
QFD	121.17	2.49	4941.95	16531.37	1314.04	3535.94	190779.85	2795464639.50	9.45	1	1	Dry	24	4
QFD	198.07	4.03	7384.26	23659.66	2034.94	5613.29	277928.99	5179249922.29	9.71	1	1	Dry	34	5
QFD	283.90	6.00	9972.84	31156.41	2976.97	8109.35	392374.55	12045983704.29	10.08	1	1	Dry	44	6
QFD	384.01	8.51	12742.74	38256.59	3865.13	10469.90	505830.60	19053563496.18	10.28	1	1	Dry	54	7
QFD	496.76	11.89	15883.74	48470.85	5054.27	14489.31	666682.14	26043840763.41	10.42	1	1	Dry	64	8
QFD	605.79	16.03	18698.13	57326.25	6087.87	17696.97	821504.35	34657188736.11	10.54	1	1	Dry	74	9
QFD	667.26	19.23	20079.13	61507.48	6620.76	19141.53	899367.18	37116015131.23	10.57	1	1	Dry	84	10
QFE	28.36	1.87	2019.96	8198.00	576.13	1538.29	136106.42	34026604.17	7.53	2	1	Dry	0	1
QFE	99.73	5.44	7039.46	26551.80	1874.77	5538.56	392085.82	1889639370.63	9.28	2	1	Dry	10	2
QFE	204.92	10.59	14336.07	55342.37	3833.63	13132.66	849688.56	4940324294.66	9.69	2	1	Dry	20	3
QFE	337.16	14.56	22932.88	83384.81	6450.62	19862.26	1325746.25	8037740761.85	9.91	2	1	Dry	30	4
QFE	480.89	17.72	29718.17	113146.10	8929.75	28858.78	1761714.25	12349512214.69	10.09	2	1	Dry	40	5
QFE	625.08	21.04	36306.63	141621.31	11389.10	37863.62	2182757.51	16386913312.25	10.21	2	1	Dry	50	6
QFE	714.17	22.82	40566.38	158392.57	12871.88	43371.04	2479123.58	18435937225.35	10.27	2	1	Dry	60	7
QFE	732.77	23.27	41434.66	161583.55	13184.23	44452.22	2528978.17	18621961841.98	10.27	2	1	Dry	70	8
QFF	15.98	4.83	84.58	97.73	0.70	29.09	31709.85	0.00	0.00	0	1	Dry	0	1
QFF	27.24	9.47	153.22	167.40	1.00	53.06	63715.88	0.00	0.00	0	1	Dry	8	2
QFF	47.32	18.27	278.61	292.38	1.24	93.82	127083.35	0.00	0.00	0	1	Dry	18	3
QFF	78.96	32.10	454.87	469.92	1.74	156.00	217209.64	0.00	0.00	0	1	Dry	28	4
QFF	122.58	51.38	726.60	691.70	2.27	238.43	318745.97	0.00	0.00	0	1	Dry	38	5
QFF	174.83	74.58	1031.05	931.82	5.25	328.84	423052.30	4755448.84	6.68	0	1	Dry	48	6
QFF	236.55	101.55	1427.05	1210.80	6.42	442.72	565998.44	55243334.26	7.74	0	1	Dry	58	7
QFF	304.83	132.07	1727.93	1532.03	8.19	571.41	707187.72	173151406.78	8.24	0	1	Dry	68	8
QFF	343.85	147.48	1953.26	1732.97	11.31	651.20	795211.02	290203668.14	8.46	0	1	Dry	78	9
QFG	1.69	0.08	16.23	45.71	0.87	10.21	2631.79	116405993.97	8.07	1	1	Dry	0	1
QFG	13.58	0.53	290.30	909.47	45.20	212.52	25078.50	616103055.43	8.79	1	1	Dry	4	2
QFG	41.36	1.48	789.78	2567.28	136.61	670.87	59708.71	1449450373.85	9.16	1	1	Dry	14	3
QFG	85.08	3.05	1451.93	4666.82	264.62	1332.53	112752.95	2323806031.56	9.37	1	1	Dry	24	4
QFG	157.97	5.31	2917.07	9202.92	621.50	2886.24	225493.16	2443057964.70	9.39	1	1	Dry	34	5
QFG	260.86	9.02	4767.21	15035.17	1124.73	4845.75	306432.42	2545946847.93	9.41	1	1	Dry	44	6

QFG	390.48	14.20	6758.23	22119.29	1724.98	7427.04	426542.42	2628382056.41	9.42	1	1	Dry	54	7
QFG	548.65	22.27	9050.06	30044.76	2421.59	10498.84	597373.78	3577445186.37	9.55	1	1	Dry	64	8
QFG	719.17	29.26	11157.51	37594.50	3036.31	13668.80	728105.34	3810033677.00	9.58	1	1	Dry	74	9
QFG	839.30	35.50	12624.93	42756.17	3501.07	15886.26	841821.48	4734978315.55	9.68	1	1	Dry	84	10
QFA	0.02	0.32	0.31	1.05	0.08	0.18	6.54	0.00	0.00	1	1	Wet	0	1
QFA	0.16	2.51	3.35	12.08	1.13	2.44	84.06	813933.55	5.91	1	1	Wet	4	2
QFA	3.24	28.38	58.05	204.54	24.07	53.31	2158.46	19298738.21	7.29	1	1	Wet	14	3
QFA	13.55	32.91	153.85	725.87	90.33	223.97	8618.85	92493581.40	7.97	1	1	Wet	24	4
QFA	30.99	44.66	267.80	1409.48	170.52	457.48	19198.42	258162540.11	8.41	1	1	Wet	34	5
QFA	55.72	49.28	415.61	2295.16	280.91	769.81	35025.27	2063413168.18	9.31	1	1	Wet	44	6
QFA	92.67	63.21	608.94	3521.03	442.16	1170.00	55718.08	2318378112.20	9.37	1	1	Wet	54	7
QFA	139.25	82.63	874.17	5117.31	633.76	1737.72	85214.17	2877251464.91	9.46	1	1	Wet	64	8
QFA	191.80	114.43	1138.61	6836.83	845.50	2369.14	113242.28	3402778458.42	9.53	1	1	Wet	74	9
QFA	251.98	162.51	1438.06	8786.91	1116.30	3021.17	148546.78	4052702321.57	9.61	1	1	Wet	84	10
QFA	313.77	226.90	1739.76	10822.83	1393.71	3686.73	182741.51	4726297220.31	9.67	1	1	Wet	94	11
QFA	346.27	263.53	1919.87	12000.15	1562.09	4048.46	199641.63	5083799882.99	9.71	1	1	Wet	104	12
QFA	348.87	266.10	1935.19	12101.37	1576.18	4082.68	201077.78	5133113459.03	9.71	1	1	Wet	114	13
QFB	9.89	94.87	70.30	188.33	23.47	49.06	4154.40	16182381.58	7.21	2	1	Wet	0	1
QFB	15.70	152.43	102.25	298.22	38.19	79.43	5456.46	21995154.47	7.34	2	1	Wet	6	2
QFB	27.24	240.19	167.72	576.04	77.48	169.73	8501.03	310306457.70	8.49	2	1	Wet	16	3
QFB	49.12	338.38	470.85	1592.54	204.17	486.83	13023.68	791750228.76	8.90	2	1	Wet	26	4
QFB	85.58	385.23	1179.76	4199.50	474.05	1062.36	37817.10	1520968245.83	9.18	2	1	Wet	36	5
QFB	138.82	452.15	2470.15	8732.49	916.36	2073.63	69760.17	4715275793.62	9.67	2	1	Wet	46	6
QFB	206.77	509.51	4196.95	15268.78	1522.28	3575.37	114155.44	7433353313.06	9.87	2	1	Wet	56	7
QFB	284.52	576.76	6191.89	22994.72	2179.85	5498.78	172205.23	10698654283.72	10.03	2	1	Wet	66	8
QFB	370.20	657.90	8419.27	32237.61	2911.06	7924.00	227041.37	14897046132.33	10.17	2	1	Wet	76	9
QFB	434.29	706.86	10428.90	39668.39	3467.86	9838.01	265921.93	17332421544.61	10.24	2	1	Wet	86	10
QFB	453.86	712.61	11137.99	42110.34	3642.34	10289.09	281450.65	17723901987.91	10.25	2	1	Wet	96	11
QFC	0.05	0.00	0.52	17.67	0.22	4.32	47.96	0.00	0.00	2	1	Wet	0	1
QFC	0.33	0.03	15.91	70.24	4.33	14.59	261.54	390004981.10	8.59	2	1	Wet	10	2
QFC	1.64	0.16	121.49	411.68	26.25	65.44	1172.09	8269795342.05	9.92	2	1	Wet	20	3
QFC	4.78	0.70	510.06	1411.74	75.15	194.74	3058.81	23992416836.42	10.38	2	1	Wet	30	4
QFC	9.72	1.86	1297.68	3403.86	166.25	394.37	6580.21	43738610863.46	10.64	2	1	Wet	40	5

QFC	18.93	4.03	2766.08	7084.97	326.81	831.26	12410.90	71357649823.57	10.85	2	1	Wet	50	6
QFC	34.57	8.58	5680.24	14326.43	603.95	1385.03	22528.24	212166077577.85	11.33	2	1	Wet	60	7
QFC	73.24	20.65	13440.21	34017.17	1251.94	3063.60	55012.91	436464985019.52	11.64	2	1	Wet	70	8
QFD	11.94	122.81	236.71	583.66	27.21	79.25	6211.02	0.00	0.00	1	1	Wet	0	1
QFD	28.51	737.34	1026.27	3157.80	228.16	434.52	16151.08	74550447.44	7.87	1	1	Wet	11	2
QFD	53.64	1372.77	2095.77	6724.40	588.69	1025.06	30555.49	197657896.85	8.30	1	1	Wet	21	3
QFD	87.22	1801.24	3471.11	11351.81	1132.26	1866.58	47124.93	382384735.88	8.58	1	1	Wet	31	4
QFD	127.43	2137.14	5039.49	16674.44	1778.94	2814.10	66425.12	519094426.83	8.72	1	1	Wet	41	5
QFD	175.71	2415.00	6904.90	22806.20	2566.80	3966.10	86703.40	678423787.93	8.83	1	1	Wet	51	6
QFD	232.92	2655.17	8885.53	29790.84	3479.28	5343.40	111875.33	1027398316.49	9.01	1	1	Wet	61	7
QFD	297.89	2940.19	11075.45	37190.85	4477.27	6715.23	130933.01	1475686753.57	9.17	1	1	Wet	71	8
QFD	373.00	3227.79	13812.47	45899.38	5601.86	8378.59	155970.46	2001473292.22	9.30	1	1	Wet	81	9
QFD	457.67	3548.92	16870.95	55599.71	6878.16	10217.06	182498.39	2386354125.59	9.38	1	1	Wet	91	10
QFD	546.76	3899.69	20379.74	66245.12	8176.08	12193.61	213384.34	3115232623.87	9.49	1	1	Wet	101	11
QFD	623.43	4252.43	24089.20	75678.61	9292.74	13936.64	241495.58	3672755324.46	9.56	1	1	Wet	111	12
QFE	0.03	0.01	3.29	11.00	0.29	1.37	66.37	0.00	0.00	2	1	Wet	0	1
QFE	0.21	0.07	20.01	21.00	3.14	2.53	620.76	0.00	0.00	2	1	Wet	5	2
QFE	1.71	0.48	115.56	389.31	30.02	78.47	4162.71	29899599.79	7.48	2	1	Wet	15	3
QFE	9.97	2.43	613.85	2548.59	144.79	466.14	26397.74	203332851.27	8.31	2	1	Wet	25	4
QFE	27.22	8.87	3229.84	11235.38	347.25	1458.49	64863.84	686315205.91	8.84	2	1	Wet	35	5
QFE	50.95	19.55	7342.38	25304.41	621.61	3369.64	107354.85	1374717154.72	9.14	2	1	Wet	45	6
QFE	84.18	37.56	13652.87	45236.67	1052.13	5372.55	163845.11	2670670146.70	9.43	2	1	Wet	55	7
QFE	131.49	67.51	23699.21	77083.58	1673.24	7670.29	268868.45	4184520105.78	9.62	2	1	Wet	65	8
QFE	186.85	106.31	37303.61	114275.75	2377.20	10500.91	382347.82	6177328431.69	9.79	2	1	Wet	75	9
QFE	245.93	145.95	50622.37	152407.88	3059.86	14332.53	534182.75	8008800385.86	9.90	2	1	Wet	85	10
QFE	313.14	196.70	67958.65	200927.94	3790.96	19393.77	663234.41	11033448572.28	10.04	2	1	Wet	95	11
QFE	384.90	253.96	88301.19	252092.85	4606.35	23091.87	813928.39	14477882467.93	10.16	2	1	Wet	105	12
QFE	430.02	293.90	104514.74	291131.43	4955.21	25797.09	894250.03	16418236721.64	10.22	2	1	Wet	115	13
QFF	1.45	0.07	2.12	8.03	0.12	1.96	793.65	0.00	0.00	0	1	Wet	0	1
QFF	7.62	0.72	16.29	18.15	0.34	5.78	2497.11	0.00	0.00	0	1	Wet	10	2
QFF	24.92	7.74	56.51	47.65	0.50	14.35	6026.58	0.00	0.00	0	1	Wet	20	3
QFF	54.02	22.00	127.94	97.84	0.62	29.18	10216.26	0.00	0.00	0	1	Wet	30	4
QFF	91.20	41.45	272.82	156.04	0.62	46.66	14083.77	35328245.88	7.55	0	1	Wet	40	5

QFF	138.46	63.89	468.27	230.94	2.51	66.98	17675.18	82583628.98	7.92	0	1	Wet	50	6
QFF	195.53	90.77	718.03	323.97	6.27	90.67	23382.58	159633496.09	8.20	0	1	Wet	60	7
QFF	258.94	121.08	937.49	421.94	7.54	120.79	29977.16	254113610.02	8.41	0	1	Wet	70	8
QFF	329.58	150.26	1228.78	544.84	11.92	158.58	36475.36	352999269.05	8.55	0	1	Wet	80	9
QFF	404.99	178.99	1427.50	695.67	12.30	198.17	41302.15	405038120.94	8.61	0	1	Wet	90	10
QFF	470.37	205.79	1486.93	784.58	12.30	229.88	46270.60	470412350.06	8.67	0	1	Wet	100	11
QFG	4.31	97.87	46.46	320.13	58.66	80.08	1667.44	125057931.11	8.10	1	1	Wet	0	1
QFG	15.66	156.16	237.79	1041.08	225.58	299.15	5070.85	578846648.74	8.76	1	1	Wet	9	2
QFG	38.69	224.97	464.99	2405.89	491.86	686.98	12440.69	1223707305.36	9.09	1	1	Wet	19	3
QFG	78.60	767.01	1692.08	5857.92	940.29	1323.86	25480.30	1902299195.48	9.28	1	1	Wet	29	4
QFG	137.87	1782.28	3706.81	11459.95	1585.35	2270.57	47999.84	2731966371.49	9.44	1	1	Wet	39	5
QFG	217.31	2762.65	6054.26	18165.47	2417.64	3408.15	78186.98	3526364789.37	9.55	1	1	Wet	49	6
QFG	319.73	3765.21	8739.79	26275.63	3458.92	4935.85	119157.73	4755487504.01	9.68	1	1	Wet	59	7
QFG	443.06	4822.60	12094.86	36072.61	4718.07	6786.96	168487.92	7098671383.13	9.85	1	1	Wet	69	8
QFG	586.23	5836.82	15894.74	47599.25	6226.37	8876.53	220029.22	9246225710.65	9.97	1	1	Wet	79	9
QFG	747.57	7016.88	20329.92	61202.13	7883.53	11262.00	268432.32	11505036656.63	10.06	1	1	Wet	89	10
QFG	922.03	8146.99	24890.46	75798.59	9573.10	13780.22	327746.25	12900658614.87	10.11	1	1	Wet	99	11
QFG	1106.47	9291.46	29762.71	91675.46	11245.82	16277.58	384308.82	14357759548.81	10.16	1	1	Wet	109	12
QFG	1253.37	10095.03	34591.06	106604.74	12645.68	18476.76	432298.00	17028798297.37	10.23	1	1	Wet	119	13
BSA	3.04	0.31	95.77	338.85	89.12	103.64	1436.92	913298.35	5.96	2	2	Dry	0	1
BSA	11.16	1.72	458.50	1585.31	418.94	483.62	3221.65	4969489.76	6.70	2	2	Dry	7	2
BSA	25.70	4.24	1080.48	3839.38	984.69	1142.35	9910.58	12967121.57	7.11	2	2	Dry	17	3
BSA	47.57	8.70	2241.41	7721.52	1959.24	2322.35	19886.14	26092866.77	7.42	2	2	Dry	27	4
BSA	81.89	17.11	4369.48	15051.20	3692.11	4449.36	33888.88	47371535.57	7.68	2	2	Dry	37	5
BSA	122.67	29.30	7380.71	25604.32	5970.97	7397.44	50198.22	77951555.81	7.89	2	2	Dry	47	6
BSA	157.92	39.95	9953.76	34859.15	7990.20	9967.34	68953.82	106155466.17	8.03	2	2	Dry	57	7
BSA	172.79	44.35	11011.51	38762.93	8850.89	11115.39	79361.57	118496078.63	8.07	2	2	Dry	67	8
BSA	172.79	44.35	11011.51	38762.93	8850.89	11115.39	79361.57	118496078.63	8.07	2	2	Dry	77	9
BSB	1.00	0.08	25.86	96.34	17.58	22.13	940.48	249068.44	5.40	2	2	Dry	0	1
BSB	5.61	0.71	197.61	767.56	155.83	197.78	5808.62	1724260.45	6.24	2	2	Dry	9	2
BSB	17.16	2.03	651.76	2306.53	468.26	583.51	11956.70	5306791.98	6.72	2	2	Dry	19	3
BSB	37.21	5.29	1479.02	5459.35	1183.02	1446.64	17570.20	13727035.98	7.14	2	2	Dry	29	4
BSB	66.64	10.21	2713.53	10259.92	2395.33	2889.13	37467.36	24911831.76	7.40	2	2	Dry	39	5

BSB	102.50	14.87	4196.98	14968.92	3808.30	4451.85	55250.42	41045654.21	7.61	2	2	Dry	49	6
BSB	146.54	20.33	5847.90	21041.22	5588.88	6585.02	73397.20	63068444.62	7.80	2	2	Dry	59	7
BSB	177.88	24.09	6983.34	25372.42	6889.99	8220.09	85808.06	79678942.63	7.90	2	2	Dry	69	8
BSB	183.70	25.05	7240.78	26275.04	7184.95	8559.31	86576.24	83228882.99	7.92	2	2	Dry	79	9
BSC	2.81	0.57	167.75	625.47	131.78	155.83	1538.91	56164.45	4.75	1	2	Dry	0	1
BSC	10.11	1.36	438.70	1653.82	387.15	444.33	4781.01	275225.79	5.44	1	2	Dry	9	2
BSC	28.24	2.70	955.69	3666.67	902.09	1080.25	15877.19	1363086.45	6.13	1	2	Dry	19	3
BSC	68.04	6.64	2688.26	9182.07	2127.13	2520.63	31320.59	4069660.94	6.61	1	2	Dry	29	4
BSC	139.23	13.40	5506.09	18194.06	4347.19	4989.14	52392.78	8483431.71	6.93	1	2	Dry	39	5
BSC	233.36	19.14	8267.84	27366.60	6626.75	7670.79	71593.81	14507283.27	7.16	1	2	Dry	49	6
BSC	342.05	28.71	12201.80	41171.07	9931.15	11595.95	102897.69	21028925.25	7.32	1	2	Dry	59	7
BSC	482.61	40.37	17282.64	57778.27	14222.18	16716.28	137194.42	28056942.26	7.45	1	2	Dry	69	8
BSC	626.69	51.18	21909.08	73872.42	18543.75	21724.68	154484.14	35405076.48	7.55	1	2	Dry	79	9
BSC	729.38	57.75	24853.24	83350.62	21234.67	24988.83	174611.64	40950408.66	7.61	1	2	Dry	89	10
BSD	0.11	0.04	0.59	2.32	0.27	0.41	5.91	295.55	2.47	0	2	Dry	0	1
BSD	4.97	1.36	30.99	121.27	14.72	24.51	2768.86	14888.61	4.17	0	2	Dry	3	2
BSD	43.45	5.14	182.81	919.39	193.17	273.47	12928.58	153430.18	5.19	0	2	Dry	13	3
BSD	119.82	10.56	686.32	3019.73	760.60	1017.70	15372.44	466549.43	5.67	0	2	Dry	23	4
BSD	212.38	19.44	1293.22	5193.14	1393.04	1792.58	17964.01	836774.04	5.92	0	2	Dry	33	5
BSD	321.59	26.10	1816.21	7496.64	2017.15	2585.09	18400.84	1251760.23	6.10	0	2	Dry	43	6
BSD	445.44	32.30	2379.38	9945.50	2608.07	3352.99	18896.26	1697638.25	6.23	0	2	Dry	53	7
BSD	543.99	38.60	3078.55	12880.57	3395.44	4276.56	18896.26	2012982.67	6.30	0	2	Dry	63	8
BSE	3.84	0.20	75.19	320.08	60.62	67.79	4348.16	115233.80	5.06	1	2	Dry	0	1
BSE	6.24	0.56	194.89	727.99	132.24	154.99	6570.93	211043.20	5.32	1	2	Dry	7	2
BSE	9.80	1.55	526.02	1782.15	298.03	373.32	8765.02	463933.04	5.67	1	2	Dry	17	3
BSE	17.68	3.65	1262.47	4036.23	656.40	846.31	11351.23	1063177.18	6.03	1	2	Dry	27	4
BSE	37.33	7.82	2715.13	8735.05	1420.27	1830.54	18268.31	2438732.99	6.39	1	2	Dry	37	5
BSE	77.52	14.49	5085.12	16541.76	2906.50	3639.27	33376.57	5010351.50	6.70	1	2	Dry	47	6
BSE	139.43	25.63	8392.88	27939.81	5362.65	6499.34	39815.52	8910868.73	6.95	1	2	Dry	57	7
BSE	217.05	37.04	12174.08	41528.05	8251.18	9832.73	60929.13	13413035.76	7.13	1	2	Dry	67	8
BSE	302.41	48.31	16081.19	55465.02	11311.79	13496.14	80390.83	18107743.86	7.26	1	2	Dry	77	9
BSE	387.63	58.28	19904.18	68413.30	14226.18	16895.68	95048.43	22624330.04	7.35	1	2	Dry	87	10
BSE	471.49	67.00	23494.80	79799.13	17010.29	19999.55	111150.25	26901376.11	7.43	1	2	Dry	97	11

BSE	536.99	73.09	26017.31	88130.81	19114.12	22254.89	114294.30	29652422.33	7.47	1	2	Dry	107	12
BSE	563.14	79.26	27759.23	93734.59	20311.46	23582.14	115131.11	31169133.19	7.49	1	2	Dry	117	13
BSF	0.64	0.10	36.92	124.11	21.54	25.36	10.18	496039.54	5.70	2	2	Dry	0	1
BSF	4.50	1.02	351.51	1237.70	203.09	281.11	8234.91	3433445.04	6.54	2	2	Dry	9	2
BSF	13.04	3.15	1026.75	3614.23	605.07	815.46	17660.88	9666197.01	6.99	2	2	Dry	19	3
BSF	25.99	7.04	1991.62	7245.01	1229.16	1675.20	30356.95	19641679.43	7.29	2	2	Dry	29	4
BSF	46.34	13.12	3588.16	12896.98	2239.08	3035.88	52411.69	35104410.78	7.55	2	2	Dry	39	5
BSF	78.07	21.65	5952.79	21353.45	3841.71	5209.97	89345.06	59536279.98	7.77	2	2	Dry	49	6
BSF	114.22	30.84	8623.24	31080.91	5664.34	7757.41	131566.20	84840045.69	7.93	2	2	Dry	59	7
BSF	156.39	40.71	11641.17	42085.06	7867.28	10856.87	189093.24	116049730.38	8.06	2	2	Dry	69	8
BSF	216.28	54.72	16197.03	58751.42	11112.97	15768.64	254490.95	160965737.31	8.21	2	2	Dry	79	9
BSF	291.55	70.60	21691.54	76676.29	15403.00	20899.67	332470.98	210644136.57	8.32	2	2	Dry	89	10
BSF	350.08	82.37	26184.78	92237.88	18757.70	25684.56	403410.35	251615723.74	8.40	2	2	Dry	99	11
BSF	375.83	93.38	28856.72	101071.31	20768.95	28069.50	407529.55	276330881.41	8.44	2	2	Dry	109	12
BSG	2.44	0.67	200.12	805.53	113.43	173.90	3615.23	1832044.57	6.26	1	2	Dry	0	1
BSG	6.78	2.61	601.59	2397.59	443.81	586.89	6479.65	5304061.81	6.72	1	2	Dry	6	2
BSG	12.70	4.84	1146.91	4592.78	913.64	1190.19	9345.23	10987866.99	7.04	1	2	Dry	16	3
BSG	32.64	12.53	2781.24	11282.51	2404.63	3107.04	35975.45	29924022.14	7.48	1	2	Dry	26	4
BSG	69.79	24.05	5550.01	21727.24	4953.99	6187.95	63763.46	59643825.19	7.78	1	2	Dry	36	5
BSG	119.44	34.52	8591.97	32193.07	7832.83	9476.74	77468.43	97878708.05	7.99	1	2	Dry	46	6
BSG	182.05	46.36	12202.48	45317.18	11036.82	13343.26	111528.08	147340322.72	8.17	1	2	Dry	56	7
BSG	255.79	60.51	16605.85	60950.54	14854.43	17999.55	153115.20	198955544.86	8.30	1	2	Dry	66	8
BSG	343.12	76.23	21830.71	79349.67	19076.32	23383.34	196779.39	260958692.46	8.42	1	2	Dry	76	9
BSG	455.59	94.00	28439.19	102366.66	24239.47	30145.36	270564.41	328444989.23	8.52	1	2	Dry	86	10
BSG	604.55	112.92	36587.36	128715.78	30816.55	38556.14	362920.26	422290453.27	8.63	1	2	Dry	96	11
BSG	722.45	125.30	42769.76	148701.09	35897.55	45052.15	425169.87	483596891.61	8.68	1	2	Dry	106	12
BSG	757.29	135.20	45238.13	156363.11	38044.75	47341.12	428514.64	504501670.67	8.70	1	2	Dry	116	13
BSA	1.24	0.60	101.70	2318.12	23.63	69.03	14094.27	347700.10	5.54	2	2	Wet	0	1
BSA	9.55	5.43	847.57	19326.01	315.05	494.77	71265.14	2101050.77	6.32	2	2	Wet	5	2
BSA	36.37	20.13	3413.44	74018.65	1241.25	2141.78	194078.79	9073004.66	6.96	2	2	Wet	15	3
BSA	85.46	58.03	9136.98	196798.19	3659.49	5274.13	335479.59	14473729.76	7.16	2	2	Wet	25	4
BSA	148.52	117.93	16356.24	384183.93	6030.20	9609.36	483034.14	36543855.48	7.56	2	2	Wet	35	5
BSA	222.65	215.04	25102.39	644516.36	10023.06	14885.84	642401.41	42473800.11	7.63	2	2	Wet	45	6

BSA	305.17	329.08	34998.54	951332.94	14739.99	21279.72	834673.26	49900610.06	7.70	2	2	Wet	55	7
BSA	397.23	467.73	45233.33	1334687.17	20503.18	28879.32	1087852.65	68313656.08	7.83	2	2	Wet	65	8
BSA	486.40	597.48	53287.13	1705591.22	26258.62	36783.25	1103903.89	81689688.66	7.91	2	2	Wet	75	9
BSA	539.42	678.01	58979.39	1926427.11	30911.31	43458.23	1276316.17	100245746.70	8.00	2	2	Wet	85	10
BSA	558.86	735.01	60826.89	2004165.90	33400.72	45790.39	1349623.86	102966604.63	8.01	2	2	Wet	95	11
BSA	566.50	761.44	61633.81	2034736.68	34435.07	46707.51	1404421.98	105259413.10	8.02	2	2	Wet	105	12
BSA	569.24	772.65	62085.94	2045708.22	34817.91	47036.66	1425048.46	105807989.75	8.02	2	2	Wet	115	13
BSA	570.15	776.48	62180.08	2049341.38	34949.39	47145.65	1431760.72	106103183.89	8.03	2	2	Wet	125	14
BSA	570.55	778.23	62228.41	2050919.52	35008.13	47193.00	1434668.46	106142637.59	8.03	2	2	Wet	135	15
BSA	570.97	780.24	62294.13	2052619.32	35073.63	47243.99	1438425.01	106168134.49	8.03	2	2	Wet	145	16
BSA	571.24	781.52	62328.07	2053707.44	35112.31	47276.64	1440976.65	106181463.97	8.03	2	2	Wet	155	17
BSB	0.25	0.11	24.82	350.74	5.67	6.59	2047.44	62727.85	4.80	2	2	Wet	0	1
BSB	0.79	0.54	72.87	1428.96	30.65	39.93	6751.95	160174.62	5.20	2	2	Wet	5	2
BSB	1.62	1.03	143.92	2905.14	62.64	94.67	13256.38	193192.01	5.29	2	2	Wet	15	3
BSB	6.42	4.46	599.61	12643.12	263.82	399.92	48480.00	1536872.65	6.19	2	2	Wet	25	4
BSB	20.94	17.42	1986.13	48903.01	873.88	1550.03	154516.70	5749289.26	6.76	2	2	Wet	35	5
BSB	49.84	50.77	4882.00	131795.42	2426.95	3811.47	361131.18	8639002.27	6.94	2	2	Wet	45	6
BSB	92.55	113.08	9186.85	281157.02	5284.49	7702.01	666933.04	16967404.98	7.23	2	2	Wet	55	7
BSB	144.98	197.29	14530.98	491442.10	8706.23	13128.39	1046013.08	21686243.65	7.34	2	2	Wet	65	8
BSB	194.90	283.75	19312.97	699522.30	12363.33	19189.35	1139362.41	34665294.46	7.54	2	2	Wet	75	9
BSB	229.44	339.47	23477.27	837696.95	15900.08	23334.59	1390840.29	38810534.18	7.59	2	2	Wet	85	10
BSB	245.85	386.66	26011.06	903341.96	18299.70	25303.94	1526561.34	41928671.98	7.62	2	2	Wet	95	11
BSB	251.08	401.92	26781.63	924229.22	19076.46	25930.56	1570685.67	42868598.54	7.63	2	2	Wet	105	12
BSB	253.18	408.46	27066.50	932652.26	19402.68	26183.25	1588500.41	42910713.78	7.63	2	2	Wet	115	13
BSB	253.50	409.59	27114.48	933907.09	19450.98	26220.89	1591270.44	43020511.13	7.63	2	2	Wet	125	14
BSB	253.61	410.09	27129.97	934365.76	19473.02	26234.65	1591867.48	43062938.27	7.63	2	2	Wet	135	15
BSC	2.35	0.46	201.41	1754.81	45.25	49.92	13295.00	141102.61	5.15	1	2	Wet	0	1
BSC	36.25	17.44	3270.60	65751.57	1705.98	2037.44	206524.60	2514097.65	6.40	1	2	Wet	5	2
BSC	129.16	70.67	11395.64	245009.36	5849.97	7621.97	754659.59	11804521.17	7.07	1	2	Wet	15	3
BSC	257.25	137.80	21896.93	504513.96	11095.30	15832.50	1485668.61	27816693.22	7.44	1	2	Wet	25	4
BSC	402.52	202.73	33275.72	695784.52	17613.47	22066.12	2275943.18	40891088.60	7.61	1	2	Wet	35	5
BSC	569.76	264.27	45777.97	992137.80	24451.41	33867.06	3182339.18	56778103.41	7.75	1	2	Wet	45	6
BSC	753.94	329.84	59405.26	1288654.49	31316.35	46072.65	4184277.97	73906836.34	7.87	1	2	Wet	55	7

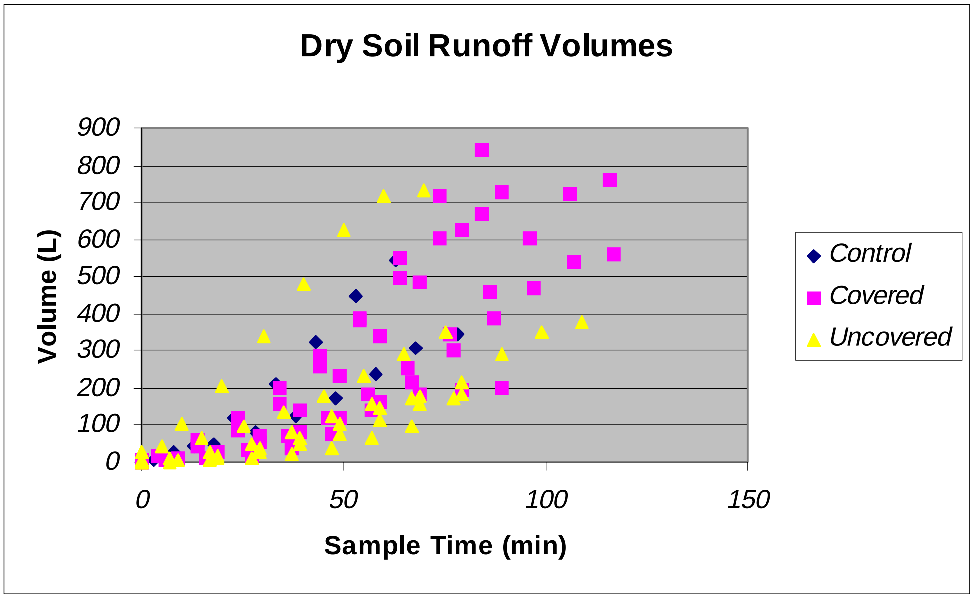
BSC	888.72	374.32	68244.84	1484896.10	36939.78	54149.10	4917517.84	85768069.54	7.93	1	2	Wet	65	8
BSC	930.33	386.85	71244.09	1539875.12	38460.11	56423.49	5140834.36	88930564.33	7.95	1	2	Wet	75	9
BSC	932.60	387.93	71433.42	1544030.77	38563.10	56561.62	5141362.01	89111474.70	7.95	1	2	Wet	85	10
BSD	13.19	4.18	754.53	4390.91	10.40	18.54	12983.72	26389.68	4.42	0	2	Wet	0	1
BSD	43.89	28.18	2710.44	23946.69	219.24	265.76	25874.93	210549.83	5.32	0	2	Wet	7	2
BSD	110.48	59.22	6437.69	50409.19	455.96	692.86	39459.34	443615.74	5.65	0	2	Wet	17	3
BSD	207.69	94.89	11697.30	83364.66	642.04	938.64	54625.12	735265.19	5.87	0	2	Wet	27	4
BSD	328.60	131.65	18020.44	122047.39	795.10	1127.60	68166.32	1702493.68	6.23	0	2	Wet	37	5
BSD	464.37	168.85	24886.62	167414.32	928.30	1326.13	80657.70	2109821.30	6.32	0	2	Wet	47	6
BSD	607.79	201.69	32145.17	212971.47	1062.39	1521.55	93851.92	2826898.81	6.45	0	2	Wet	57	7
BSD	738.56	225.36	38850.92	251552.07	1176.16	1666.13	103267.36	2839975.81	6.45	0	2	Wet	67	8
BSD	800.32	235.68	42090.23	270182.60	1235.57	1737.41	105984.75	2839975.81	6.45	0	2	Wet	77	9
BSE	0.06	0.02	4.67	108.03	1.68	2.56	31.56	4921.46	3.69	1	2	Wet	0	1
BSE	16.37	6.54	1399.20	32504.81	661.69	1162.92	15473.04	1391392.22	6.14	1	2	Wet	4	2
BSE	77.31	29.27	5132.78	156024.20	3268.77	5801.99	48782.33	6509648.16	6.81	1	2	Wet	14	3
BSE	181.29	65.87	10156.59	358467.33	7376.10	13935.46	113943.31	14828071.52	7.17	1	2	Wet	24	4
BSE	316.57	104.70	16402.36	570243.80	12277.69	23031.38	238404.07	25109612.55	7.40	1	2	Wet	34	5
BSE	479.25	145.69	24183.00	800500.08	17974.90	33917.18	352279.90	36497195.63	7.56	1	2	Wet	44	6
BSE	666.01	187.72	32045.10	1085691.96	24121.36	46562.18	458113.90	54426720.22	7.74	1	2	Wet	54	7
BSE	856.35	229.97	40899.51	1351026.01	30391.64	58869.52	585001.50	72317871.42	7.86	1	2	Wet	64	8
BSE	1001.95	257.20	46258.70	1531722.84	35157.05	67290.62	669453.28	85276852.49	7.93	1	2	Wet	74	9
BSE	1077.77	280.25	49406.78	1611755.14	37900.63	70250.31	711406.38	91797274.26	7.96	1	2	Wet	84	10
BSE	1104.27	285.65	50459.92	1641626.03	38744.53	71491.61	717767.21	93997059.96	7.97	1	2	Wet	94	11
BSE	1111.67	287.13	50743.18	1649624.51	38984.35	71813.03	718457.08	94566198.50	7.98	1	2	Wet	104	12
BSE	1113.11	287.41	50794.57	1650982.91	39029.67	71869.84	718572.70	94667370.22	7.98	1	2	Wet	114	13
BSF	0.50	0.15	20.75	855.36	12.79	39.36	2150.82	50252.88	4.70	2	2	Wet	0	1
BSF	12.63	4.65	491.54	28336.56	413.28	1240.01	40607.32	1627333.34	6.21	2	2	Wet	4	2
BSF	47.13	24.76	1849.25	140127.75	1907.99	6249.70	148224.82	6525309.30	6.81	2	2	Wet	14	3
BSF	106.71	63.78	4497.28	327722.19	4513.55	14401.67	329344.24	15342965.30	7.19	2	2	Wet	24	4
BSF	187.53	120.84	7875.96	621389.55	7903.95	25797.87	505531.68	36356145.22	7.56	2	2	Wet	34	5
BSF	288.38	208.28	11300.30	982290.40	12259.46	38393.72	755645.69	61972660.90	7.79	2	2	Wet	44	6
BSF	430.08	334.11	16966.52	1495204.72	18917.87	55366.03	1071639.70	100515428.23	8.00	2	2	Wet	54	7
BSF	607.79	517.69	22900.75	2201415.75	27592.45	78756.73	1446616.63	149564543.23	8.17	2	2	Wet	64	8

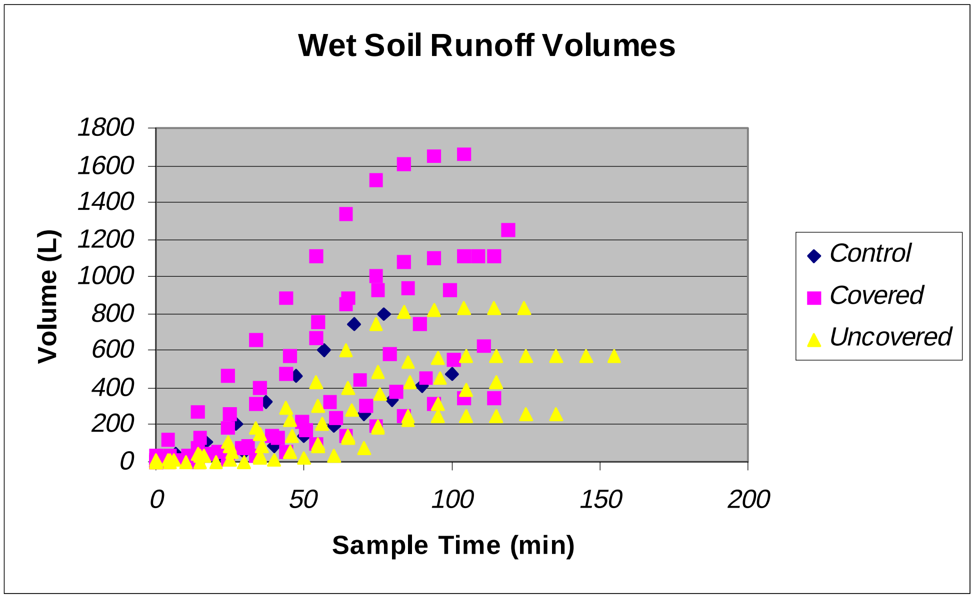
BSF	745.50	668.89	26591.19	2774492.12	34417.98	98696.45	1786743.29	188259114.46	8.27	2	2	Wet	74	9
BSF	805.47	753.03	28482.85	3019660.51	37860.05	104264.43	1828125.81	208650500.32	8.32	2	2	Wet	84	10
BSF	823.87	777.57	29035.47	3096207.04	38870.97	105909.73	1842473.70	214720762.83	8.33	2	2	Wet	94	11
BSF	828.33	782.37	29182.02	3114765.89	39090.11	106311.91	1844215.40	216462464.97	8.34	2	2	Wet	104	12
BSF	829.56	783.75	29233.59	3119858.73	39149.38	106419.83	1844595.52	216928421.52	8.34	2	2	Wet	114	13
BSF	829.68	783.97	29238.46	3120371.55	39156.03	106433.38	1844653.47	216979096.20	8.34	2	2	Wet	124	14
BSG	32.33	9.09	1439.22	52874.30	992.48	1750.51	30394.63	16167358.97	7.21	1	2	Wet	0	1
BSG	113.54	36.21	4227.45	205540.75	3788.18	7774.44	148415.01	81457532.16	7.91	1	2	Wet	4	2
BSG	271.19	91.54	9776.65	466402.36	9721.73	18200.48	315521.52	172893168.40	8.24	1	2	Wet	14	3
BSG	458.85	150.09	14989.18	743861.11	17210.91	30347.06	515688.58	202918226.56	8.31	1	2	Wet	24	4
BSG	662.29	203.19	20590.40	1000012.40	24700.49	41480.01	700144.20	263951336.98	8.42	1	2	Wet	34	5
BSG	880.49	251.63	26235.87	1235840.17	32573.35	52465.68	879067.83	351231155.48	8.55	1	2	Wet	44	6
BSG	1106.02	296.74	31767.45	1455774.48	40242.28	62582.20	1039946.01	452719729.51	8.66	1	2	Wet	54	7
BSG	1334.20	339.86	36996.36	1666798.23	47983.42	72695.56	1227051.31	532581747.23	8.73	1	2	Wet	64	8
BSG	1516.24	369.35	42121.91	1817928.85	53576.47	79926.37	1400603.44	599939391.02	8.78	1	2	Wet	74	9
BSG	1610.48	387.54	45563.89	1895794.90	56615.30	82903.35	1413168.27	633864444.03	8.80	1	2	Wet	84	10
BSG	1647.62	395.49	46790.64	1929763.78	57907.49	84195.19	1420596.56	645006878.30	8.81	1	2	Wet	94	11
BSG	1660.34	398.26	47147.19	1942207.35	58397.57	84688.89	1422037.81	648186099.82	8.81	1	2	Wet	104	12

Appendix F: Mass Loading Graphs

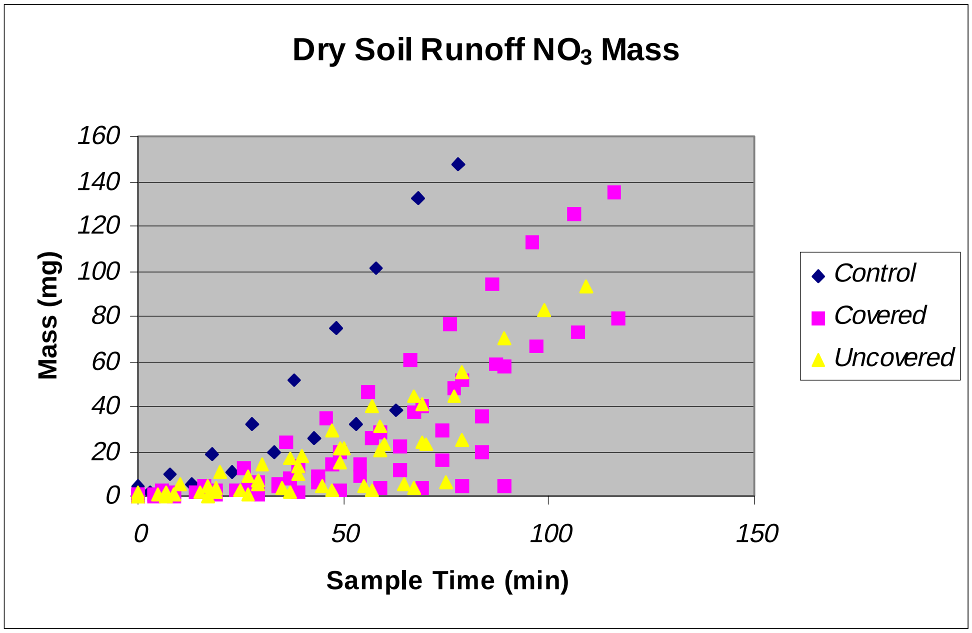
* Note: Each graph contains the combined data from both the Ridge and Valley and Piedmont experimental sites.

Volume

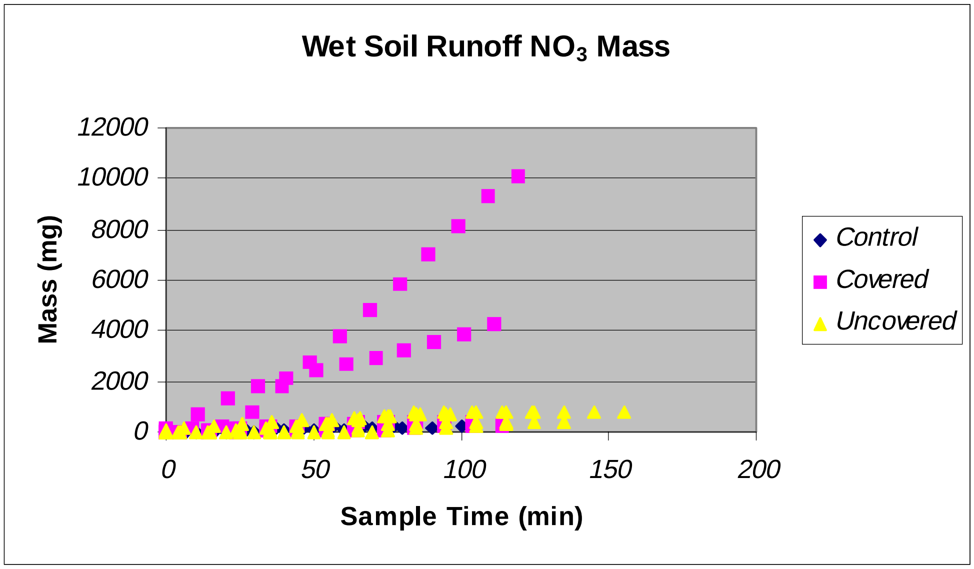




Nitrate

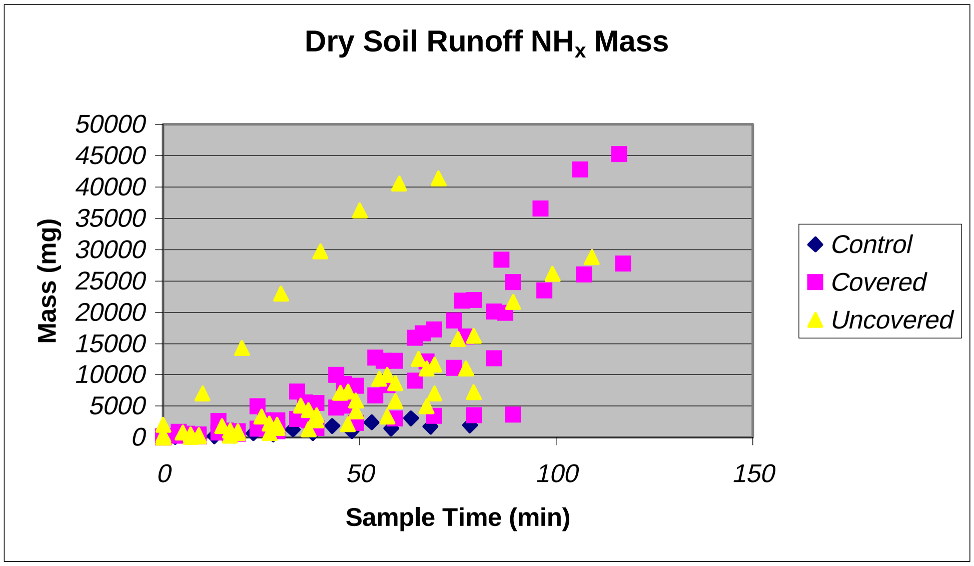


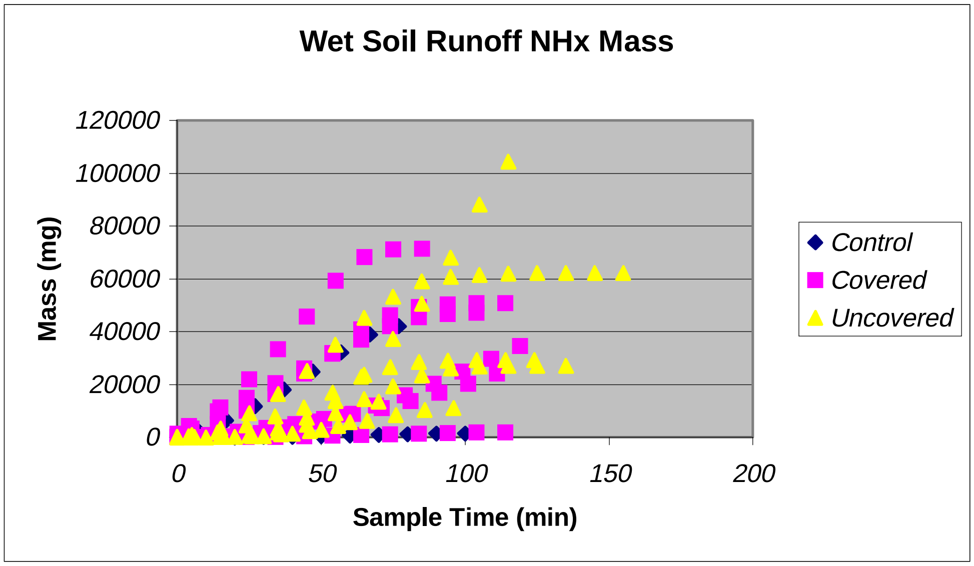
Dry Soil Runoff NO3 Mass
Mass (mg)
160
140
120
100
80
60
40
20
0
0
50
100
150
Sample Time (min)
Control
Covered
Uncovered



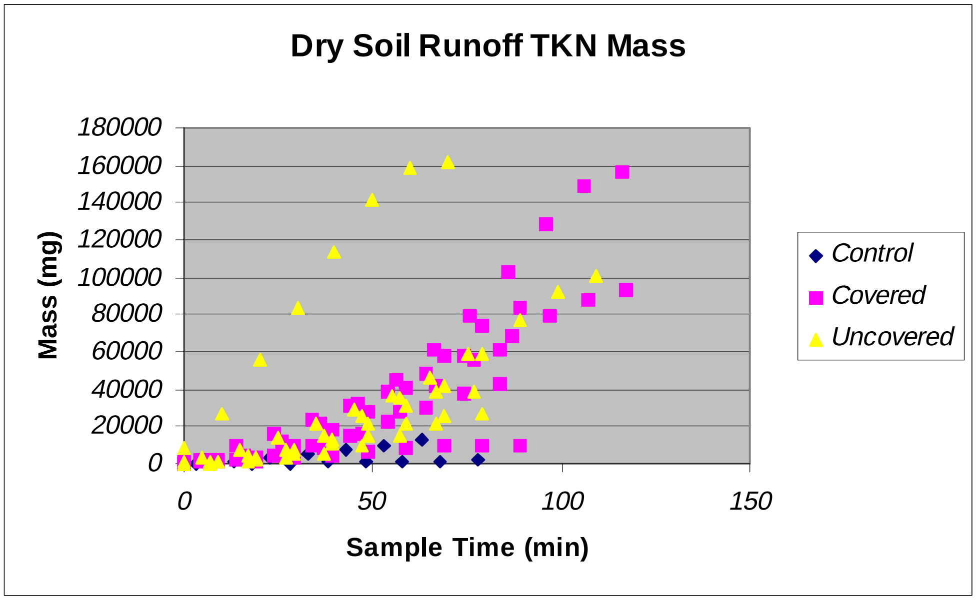
Wet Soil Runoff NO3 Mass
Mass (mg)
12000
10000
8000
6000
4000
2000
0
0
50
100
150
200
Sample Time (min)
Control
Covered
Uncovered

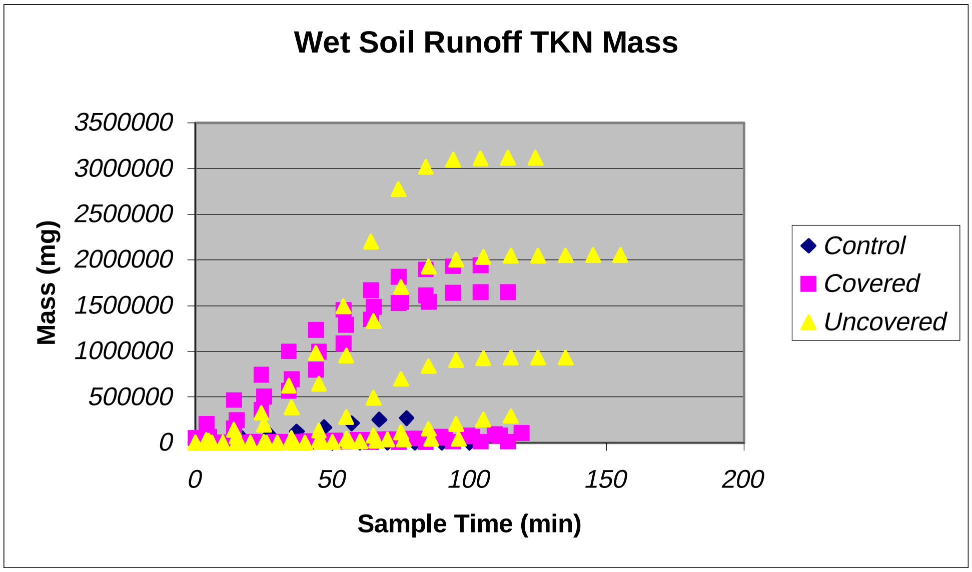
Ammonical Nitrogen



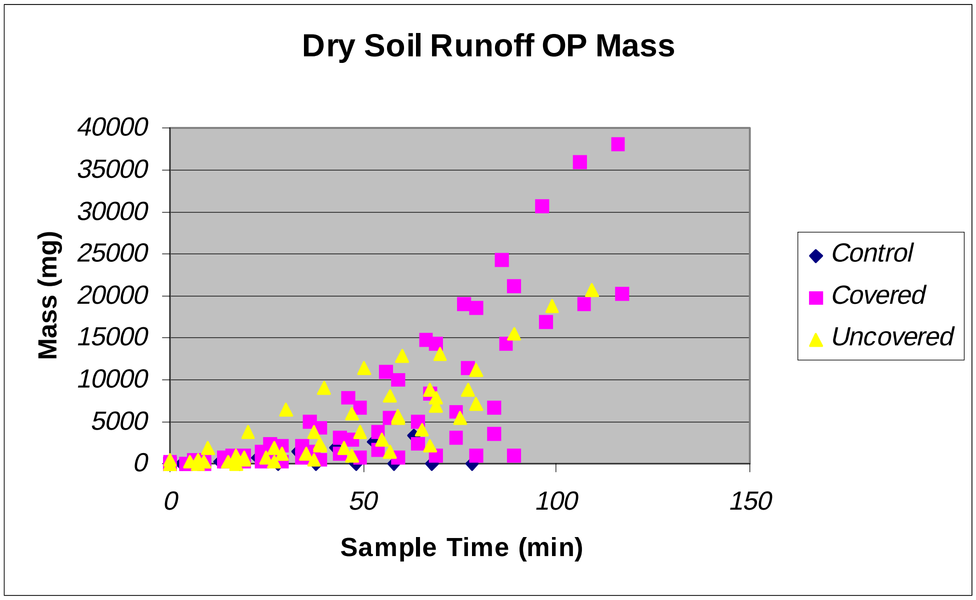


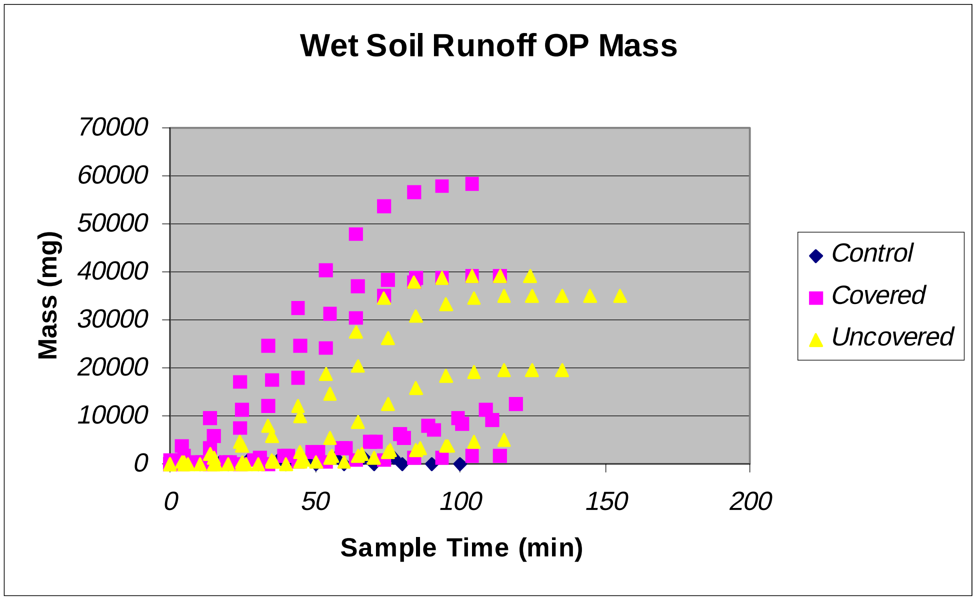
Total Kjeldahl Nitrogen



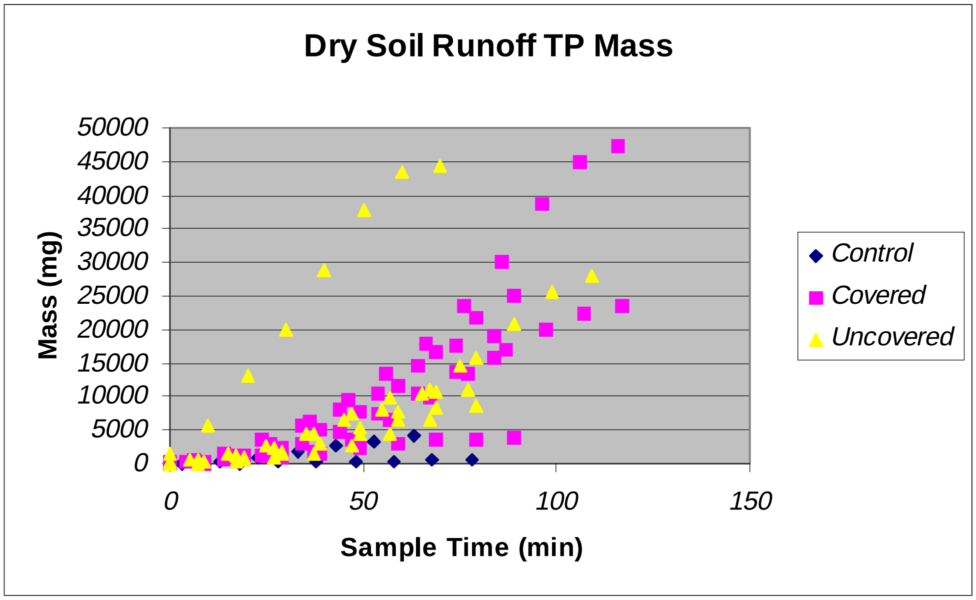


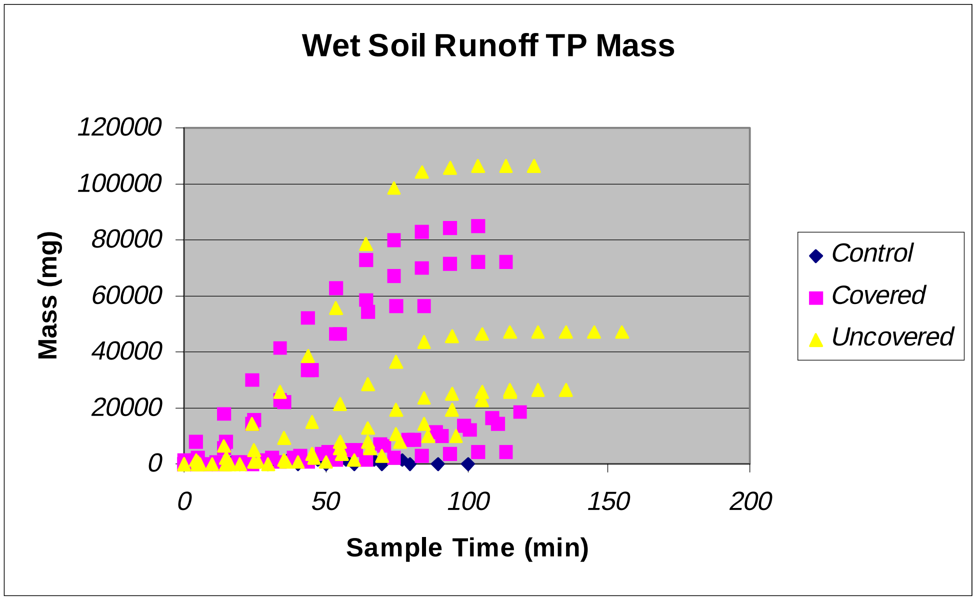
Ortho-phosphate



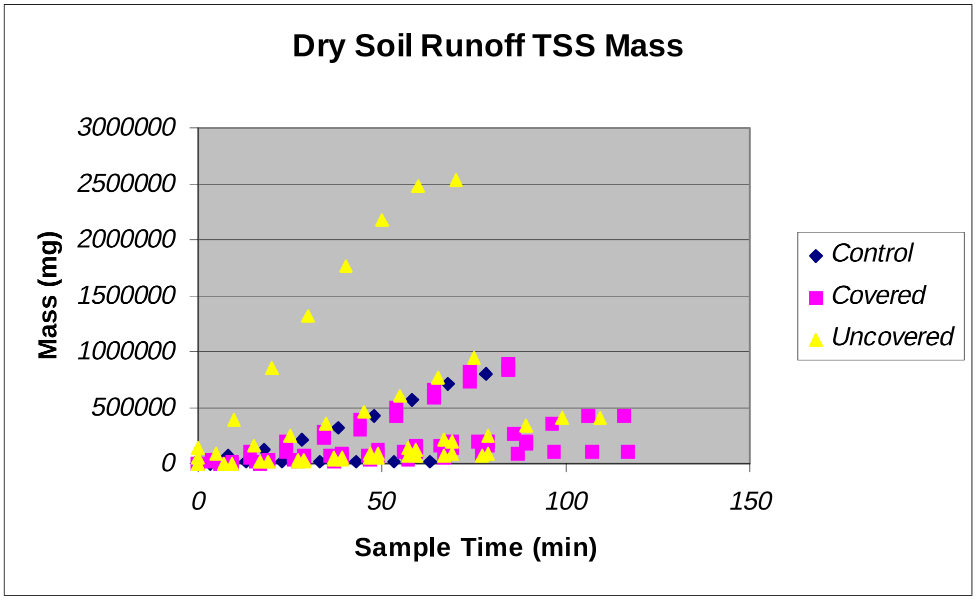


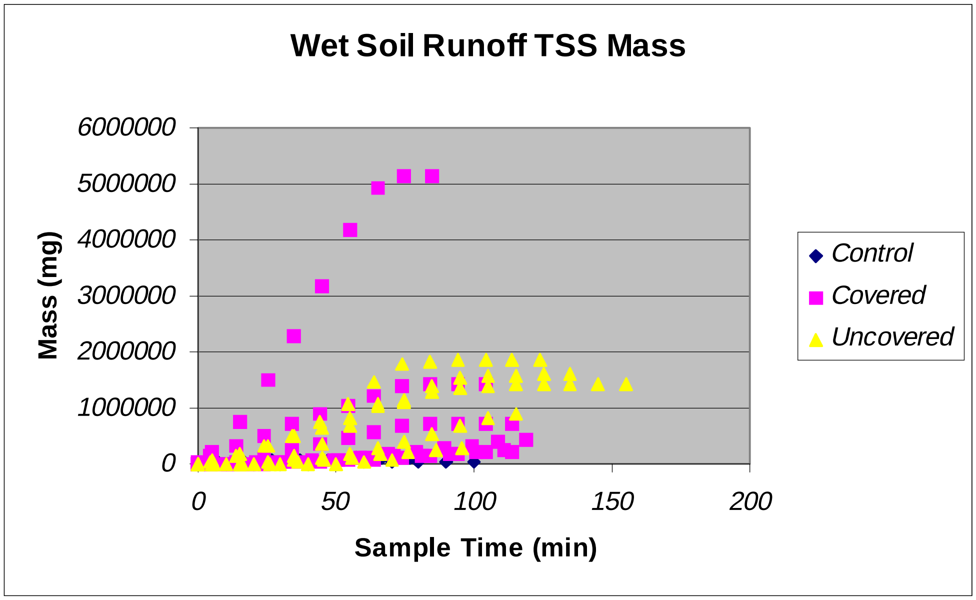
Total Phosphorus



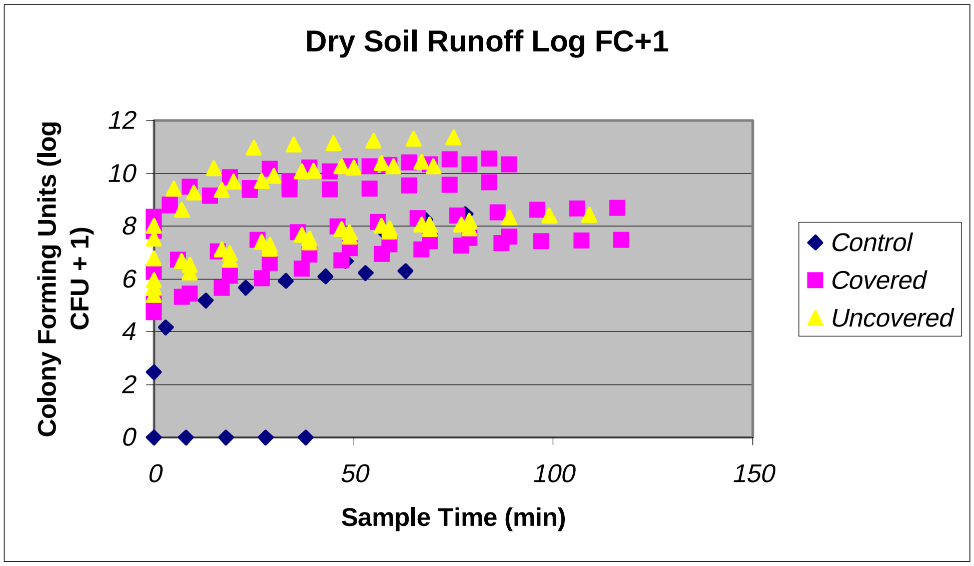


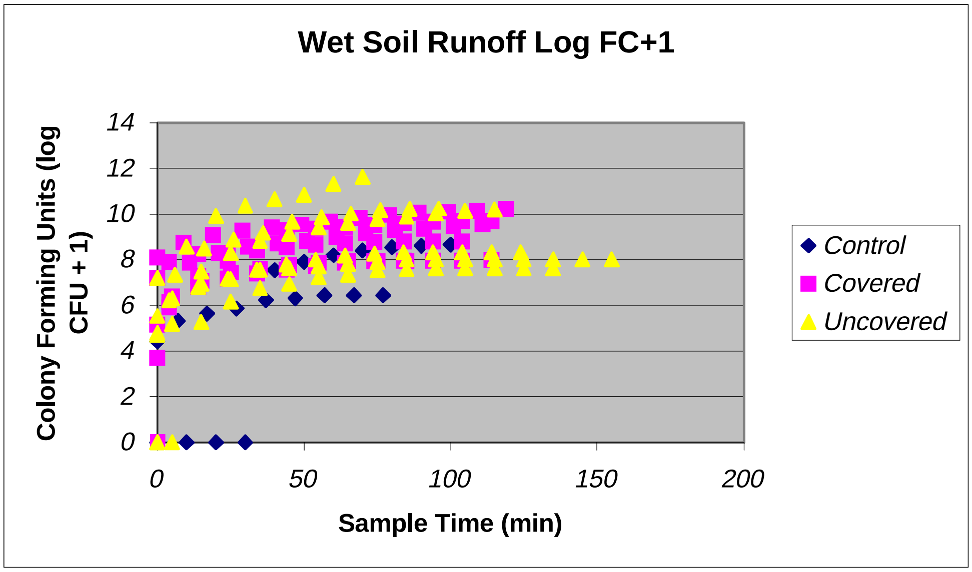
Total Suspended Solids





Fecal Coliforms





Appendix G: Stockpile Lysimeter Concentration Data

Plot	NO3 (ppm)	NH (ppm)	TKN (ppm)	OP (ppm)	TP (ppm)	TSS (ppm)	FC (CFU/100ml)	LFC (log FC + 1)	Treatment	Soil	Location	Moisture
QFA	0.24	2.27	4.67	0.11	0.59	40.00	100.00	2.00	1	1	Center	Pre wet
QFA	0.39	1.97	3.92	0.17	0.52	20.00	1000.00	3.00	1	1	Middle	Pre wet
QFA	0.15	12.08	24.42	0.28	0.76	40.00	7500.00	3.88	1	1	Edge	Pre wet
QFB	0.00	1.61	3.25	0.12	0.87	30.00	29000.00	4.46	2	1	Middle	Pre wet
QFB	0.03	13.05	31.12	0.03	0.81	110.00	40000.00	4.60	2	1	Edge	Pre wet
QFC	0.03	1.20	2.97	0.14	0.83	70.00	85000.00	4.93	2	1	Middle	Pre wet
QFC	0.05	1.03	2.81	0.11	0.64	30.00	50000.00	4.70	2	1	Edge	Pre wet
QFD	0.00	0.86	5.41	0.20	1.27	130.00	5000.00	3.70	1	1	Middle	Pre wet
QFE	0.00	1.19	4.08	0.15	0.85	150.00	15000.00	4.18	2	1	Middle	Pre wet
QFF	0.00	0.69	0.96	0.25	0.52	160.00	710.00	2.85	0	1	Middle	Pre wet
QFF	0.07	0.31	1.05	0.02	0.53	30.00	680.00	2.83	0	1	Edge	Pre wet
QFA	0.02	3.59	6.52	0.01	0.56	58.00	45000.00	4.65	1	1	Center	Post wet
QFA	0.02	4.64	6.18	0.02	0.36	0.00	75000.00	4.88	1	1	Middle	Post wet
QFA	15.51	7.72	9.85	0.09	0.42	0.00	636.00	2.80	1	1	Edge	Post wet
QFB	0.04	5.43	23.85	0.10	1.54	15.00	600.00	2.78	2	1	Middle	Post wet
QFB	0.15	242.78	987.81	0.53	6.57	62.00	0.00	0.00	2	1	Edge	Post wet
QFC	0.01	4.82	32.72	0.04	0.63	0.00	.	.	2	1	Middle	Post wet
QFC	0.01	46.21	123.23	0.16	2.11	46.00	9000.00	3.95	2	1	Edge	Post wet
QFD	0.01	2.95	4.43	0.03	0.51	9.00	6000000.00	6.78	1	1	Middle	Post wet
QFD	0.27	68.61	246.94	14.38	20.36	161.00	500000.00	5.70	1	1	Edge	Post wet
QFF	0.01	0.72	0.35	0.02	0.67	.	.	.	0	1	Middle	Post wet
QFF	0.02	0.25	1.16	0.01	0.48	.	364.00	2.56	0	1	Edge	Post wet
BSA	0.68	0.12	1.03	0.00	0.00	0.00	0.00	0.00	2	2	Center	Dry
BSA	0.54	0.26	1.17	0.10	0.00	0.00	0.00	0.00	2	2	Edge	Dry
BSB	1.06	0.00	1.03	0.00	0.00	0.00	0.00	0.00	2	2	Center	Dry
BSC	0.00	0.53	1.41	0.16	0.00	0.00	0.00	0.00	1	2	Middle	Dry
BSC	0.15	0.25	0.62	0.00	0.00	0.00	0.00	0.00	1	2	Edge	Dry
BSD	0.73	0.35	3.09	0.49	0.10	0.00	0.00	0.00	0	2	Center	Dry
BSD	0.11	0.11	0.39	0.00	0.16	0.00	0.00	0.00	0	2	Middle	Dry
BSD	0.77	0.38	3.11	0.59	0.13	0.00	0.00	0.00	0	2	Edge	Dry
BSE	1.18	0.35	0.70	0.00	0.04	0.00	0.00	0.00	1	2	Center	Dry
BSE	0.56	0.04	0.94	0.00	0.07	0.00	0.00	0.00	1	2	Middle	Dry
BSE	0.19	0.13	0.71	0.00	0.01	0.00	0.00	0.00	1	2	Edge	Dry
BSF	3.15	1.63	4.75	1.67	0.10	0.00	0.00	0.00	2	2	Center	Dry
BSF	1.09	0.05	1.77	0.00	0.32	0.00	0.00	0.00	2	2	Middle	Dry
BSG	0.26	0.01	0.31	0.00	0.05	0.00	0.00	0.00	1	2	Center	Dry
BSG	0.30	0.04	0.21	0.00	0.04	0.00	0.00	0.00	1	2	Middle	Dry
BSG	0.36	0.12	0.34	0.00	0.04	0.00	0.00	0.00	1	2	Edge	Dry
BSA	0.11	0.63	1.28	0.00	0.00	0.00	0.00	0.00	2	2	Center	Pre wet
BSA	0.03	1.04	2.23	0.00	0.04	0.00	.	.	2	2	Edge	Pre wet
BSB	0.00	1.23	1.16	0.00	0.00	0.00	.	.	2	2	Center	Pre wet
BSB	0.02	4.38	27.83	0.02	0.07	0.00	290.00	2.46	2	2	Middle	Pre wet

BSB	0.01	0.26	1.22	0.01	0.00	0.00	60.00	1.79	2	2	Edge	Pre wet
BSC	0.00	3.33	8.37	0.03	0.15	0.00	90.00	1.96	1	2	Middle	Pre wet
BSC	0.11	14.73	33.46	0.04	0.13	0.00	0.00	0.00	1	2	Edge	Pre wet
BSD	0.16	0.55	1.23	0.02	0.00	0.00	0.00	0.00	0	2	Center	Pre wet
BSD	0.28	0.08	0.36	0.02	0.00	0.00	0.00	0.00	0	2	Middle	Pre wet
BSD	0.23	0.05	0.91	0.13	0.15	0.00	0.00	0.00	0	2	Edge	Pre wet
BSE	0.14	0.35	0.31	0.02	0.00	0.00	0.00	0.00	1	2	Center	Pre wet
BSE	0.08	0.72	1.22	0.03	0.00	0.00	0.00	0.00	1	2	Middle	Pre wet
BSE	0.04	5.31	20.35	0.04	0.02	0.00	0.00	0.00	1	2	Edge	Pre wet
BSF	0.02	2.11	2.92	0.87	0.91	0.00	2.00	0.48	2	2	Center	Pre wet
BSF	0.06	1.97	0.00	0.03	0.20	0.00	.	.	2	2	Middle	Pre wet
BSG	0.10	0.07	0.46	0.05	0.08	0.00	60.00	1.79	1	2	Center	Pre wet
BSG	0.05	0.48	0.29	0.04	0.08	0.00	4.00	0.70	1	2	Middle	Pre wet
BSG	0.04	0.66	1.17	0.06	0.11	0.00	2.00	0.48	1	2	Edge	Pre wet
BSA	1.16	0.00	8.58	0.09	0.00	60.61	0.00	0.00	2	2	Center	Post wet
BSA	26.20	0.17	103.99	0.17	0.00	61.64	0.00	0.00	2	2	Middle	Post wet
BSA	78.44	0.12	213.01	0.23	0.00	65.91	0.00	0.00	2	2	Edge	Post wet
BSB	3.29	0.00	6.23	0.02	0.00	IS	0.00	0.00	2	2	Center	Post wet
BSB	1.81	0.00	28.12	0.08	0.00	5.56	0.00	0.00	2	2	Middle	Post wet
BSB	71.09	0.00	163.97	0.08	0.00	0.00	0.00	0.00	2	2	Edge	Post wet
BSC	6.49	0.03	.	.	0.00	.	0.00	0.00	1	2	Center	Post wet
BSC	17.40	0.05	56.15	0.13	0.00	155.00	0.00	0.00	1	2	Middle	Post wet
BSC	17.81	0.03	49.32	0.13	0.00	4.92	0.00	0.00	1	2	Edge	Post wet
BSD	0.38	0.00	1.34	0.02	0.16	22.97	0.00	0.00	0	2	Center	Post wet
BSD	0.45	0.00	0.73	0.02	0.00	0.00	0.00	0.00	0	2	Middle	Post wet
BSD	0.39	0.00	1.24	0.03	0.00	0.00	0.00	0.00	0	2	Edge	Post wet
BSE	1.57	0.00	2.38	0.02	0.00	0.00	0.00	0.00	1	2	Center	Post wet
BSE	2.21	0.00	10.49	0.03	0.00	143.21	0.00	0.00	1	2	Middle	Post wet
BSE	2.47	0.00	30.44	0.06	0.00	76.92	0.00	0.00	1	2	Edge	Post wet
BSF	26.35	0.00	54.58	0.25	0.00	121.74	0.00	0.00	2	2	Center	Post wet
BSF	35.61	0.00	59.39	0.08	0.00	214.89	0.00	0.00	2	2	Middle	Post wet
BSG	0.58	0.00	2.23	0.04	0.00	0.00	0.00	0.00	1	2	Center	Post wet
BSG	1.76	0.00	3.09	0.03	0.00	0.00	0.00	0.00	1	2	Edge	Post wet

. Indicates insufficient sample volume for laboratory analysis

Appendix H: Raw Litter Analysis Data

Ridge and Valley Experimental Site

Pre-Run1

Plot	QFA[1]	QFB	QFC	QFD[1]	QFE	QFG[1]	Avg
N, %	3.43	3.23	3.32	3.45	3.08	2.8	3.22
NH_4-N, %	0.75	0.73	0.78	0.83	0.75	0.33	0.70
P_2O_5, %	1.87	1.74	2.04	2.12	1.64	1.81	1.87
K_2O, %	1.79	1.68	1.79	1.81	1.57	1.71	1.73
Ca, %	1.14	1.11	1.26	1.22	1.00	1.04	1.13
Mg, %	0.7	0.64	0.67	0.68	0.66	0.64	0.67
S, %	0.34	0.34	0.36	0.49	0.40	0.33	0.38
Mn, ppm	276.6	336.1	257.7	287.3	217.9	238.4	269.0
Zn, ppm	202.1	295.6	249.1	237.3	196.9	230.5	235.25
Cu, ppm	228.1	224.9	279.9	183	223.8	205.7	224.23
% moisture	33.5	35.7	38.3	37.5	34.4	39.3	36.45

Pre-Run 2

Plot	QFA[1]	QFB	QFC	QFD[1]	QFE	QFG[1]	Avg
N, %	3.59	2.43	2.67	3.27	2.9	3.63	3.08
NH_4-N, %	0.81	0.78	0.79	0.73	0.77	0.81	0.78
P_2O_5, %	2.19	1.94	1.88	1.71	1.64	2.43	1.97
K_2O, %	2.02	1.29	1.29	1.77	1.68	2.22	1.71
Ca, %	1.73	1.56	1.64	1.71	1.61	2.15	1.73
Mg, %	0.63	0.57	0.80	1.10	0.76	1.02	0.81
S, %	0.33	0.26	0.19	0.38	0.30	0.32	0.30
Mn, ppm	265.0	241.9	225.2	271.2	250.5	311.4	260.87
Zn, ppm	312.8	219.3	306.2	241.1	238.8	270.9	264.85
Cu, ppm	213.3	195.3	182.2	210.9	203.1	246.3	208.52
% moisture	35.4	51.9	50.6	37.2	44.2	33.6	42.15

Piedmont Experimental Site

Pre-Run 1

Plot	BSA	BSB	BSC[1]	BSE[1]	BSF	BSG[1]	Avg
N, %	3.33	3.26	3.23	2.97	3.08	2.95	3.14
NH_4-N, %	0.83	0.81	0.77	0.75	0.88	0.7	0.79
P_2O_5, %	2.62	2.69	3.37	2.73	2.5	3.03	2.82
K_2O, %	2.78	2.93	2.89	2.8	2.63	3.03	2.84
Ca, %	1.62	1.58	2.22	1.62	1.53	1.68	1.71
Mg, %	0.79	0.76	0.95	0.8	0.75	0.88	0.82
S, %	0.49	0.44	0.41	0.34	0.38	0.46	0.42
Mn, ppm	390.7	464.5	485.5	424.1	392.5	431.2	431.42
Zn, ppm	683.2	377.4	460.1	469.4	358.3	519.1	477.92
Cu, ppm	688.5	680.4	849.7	733.0	686.7	744.3	730.43
% moisture	32.8	33.6	29.4	31.4	37.8	31.3	32.72

Pre-Run 2

Plot	BSA	BSB	BSC[1]	BSE[1]	BSF	BSG[1]	Avg
N, %	3.14	2.91	3.20	3.17	2.79	3.12	3.06
NH_4-N, %	0.85	0.73	0.73	0.90	0.81	0.82	0.81
P_2O_5, %	2.95	2.5	2.94	2.95	2.39	2.97	2.78
K_2O, %	2.76	1.91	3.25	3.27	2.62	3.03	2.81
Ca, %	1.82	1.60	1.72	1.60	1.34	1.65	1.62
Mg, %	0.81	0.72	0.79	0.84	0.64	0.84	0.77
S, %	0.33	0.43	0.42	0.46	0.41	0.42	0.41
Mn, ppm	433.2	372.3	423.5	395.4	315.0	415.3	392.45
Zn, ppm	424.6	338.7	396.7	350.8	263.9	489.2	377.32
Cu, ppm	729.7	635.1	747.8	653.1	540.0	650.5	659.37
% moisture	39.0	37.7	33.0	32.5	49.4	32.8	37.4

[1] indicates stockpiles which received the covered treatment

Appendix I: Soil Test Results

Plot	Site	Treatment	Condition	pH	P	K	Ca	Mg	Zn	Mn	NO3
	Ridge and Valley		Before	7.05	28.50	157.00	696.00	120.00	3.00	16.10	30.25
QFA	Ridge and Valley	Covered	After	7.90	34.00	157.00	432.00	70.00	6.10	16.10	24.00
QFB	Ridge and Valley	Uncovered	After	7.80	39.00	157.00	624.00	117.00	6.10	16.10	4.00
QFC	Ridge and Valley	Uncovered	After	8.00	23.00	157.00	564.00	105.00	6.10	16.10	5.00
QFD	Ridge and Valley	Covered	After	7.90	17.00	157.00	516.00	99.00	6.10	16.10	3.00
QFE	Ridge and Valley	Uncovered	After	7.90	10.00	157.00	492.00	93.00	5.00	16.10	4.00
QFF	Ridge and Valley	Control	After	6.00	5.00	121.00	684.00	120.00	6.10	15.50	20.00
QFG	Ridge and Valley	Covered	After	7.80	11.00	157.00	528.00	88.00	3.70	16.10	16.00
	Piedmont		Before	6.16	2.57	30.86	135.43	35.29	0.64	2.61	3.71
BSA	Piedmont	Uncovered	After	8.70	77.00	1167.00	225.00	61.00	2.20	10.90	15.00
BSB	Piedmont	Uncovered	After	7.90	18.00	577.00	161.00	44.00	1.10	10.10	3.00
BSC	Piedmont	Covered	After	7.20	27.00	1001.00	150.00	43.00	1.30	8.80	13.00
BSD	Piedmont	Control	After	5.30	4.00	62.00	199.00	53.00	1.20	3.60	8.00
BSE	Piedmont	Covered	After	7.80	27.00	511.00	106.00	29.00	1.10	6.60	12.00
BSF	Piedmont	Uncovered	After	7.20	21.00	754.00	150.00	33.00	1.30	5.80	24.00
BSG	Piedmont	Covered	After	7.70	9.00	453.00	80.00	20.00	0.60	3.30	24.00

Appendix J: SAS Code

Stockpile Surface Runoff Code:

```
proc mixed data=mass scoring=5 order=data;
 class samptime plot treatment soil moisture;
 model TKN = treatment|moisture|samptime / ddfm=satterth;
 random soil;
 repeated samptime/subject=plot(treatment*soil*moisture) type=sp(pow)(sastime) r;
run;
```

Stockpile Lysimeter Sample Frequency Code:

```
proc freq data=moisture;
  tables  moisture*Sample /nopercent norow nocol Chisq Exact;
  weight freq;
run;
```

Stockpile Lysimeter Concentration Code:

```
proc mixed data=fieldlys;
 class plot treatment moisture location;
 model TKN = treatment|location|moisture /ddfm=satterth;
 random plot(treatment);
 run;
```

Stockpile Litter Composition Code:

```
proc glm data=litteranalysis;
class site treatment condition plot;
model N = site treatment treatment*site plot(treatment*site) condition condition*treatment;
test h=site E=plot(treatment*site);
test h=treatment E=plot(treatment*site);
test h=condition E=plot(treatment*site);
test h=treatment*condition E=plot(treatment*site);
lsmeans treatment site treatment*condition;
run;
```

Storage Shed Concentration Code:

```
  proc mixed data=shed;
    class site location shed;
    model volume=site|location;
    random shed site;
  run;
```

VITA

Mathew J. Habersack, son of James and Vickie Habersack, was born on June 1, 1976 in Cumberland, Maryland. After graduating from Fort Hill High school in 1994, he entered Frostburg State University where he double majored in Wildlife and Fisheries Management, and Environmental Analysis and Planning. After graduating with a B.S. degree from Frostburg State University, he decided to continue his education at Virginia Polytechnic Institute and State University by pursuing a Masters of Science degree in the Biological Systems Engineering Department. Upon completion of his Masters degree, Matt plans to stay and continue his graduate studies in the Biological Systems Engineering Department.