Soil-test Phosphorus Status in the Haynes Creek M1 Subbasin

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ABSTRACT

Water quality issues are a major concern within Alberta watersheds. Watersheds with agricultural activity can increase the contribution of contaminants to water such as pesticides, excess nutrients, and eroded sediment. The loss of soil phosphorus from agricultural land has been of particular concern regarding degradation of surface water quality. The movement of phosphorus from land to water is controlled by source and transport factors. Knowing the status of soil-test phosphorus (STP) within watersheds may be useful to better understand source factors. The purpose of this study was to assess the STP status of one agricultural watershed in Alberta.

The M1 subbasin within the Haynes Creek watershed was selected for the study. The M1 subbasin is a few kilometers east of Lacombe, Alberta. The subbasin is relatively small (24 km^2) and has extensive agricultural activity, including livestock, perennial crops, and annual crops. Soil samples were collected from 353 sites within the subbasin. At each site, soil was sampled from the 0- to 5-cm layer and from the 0- to 15-cm layer. For each layer, 10 cores were collected and a composite sample prepared. Samples were air dried, ground, and analyzed for STP using the modified Kelowna extraction procedure. Landuse and landscape field notes and land-owner survey data were also collected. The data were analyzed according to sampling depth (0 to 5 cm, 0 to 15 cm), landuse (annual crop, perennial crop, wooded), manure intensity (no manure, trace manure, manure), and landscape position (upper, mid, lower, riparian).

Soil-test phosphorus ranged from 2.5 mg kg^{-1} (half the detection limit) to 453 mg kg^{-1}, and STP concentration was generally higher in the 0- to 5-cm layer compared to the 0- to 15-cm layer. The STP values from the two soil layers were linearly correlated. For the whole data set, the 0- to 5-cm layer was enriched about 1.41 times more than the 0- to 15-cm layer. Most of the land area in the subbasin contained 60 mg kg^{-1} or less in the 0- to 15-cm soil layer (89% of the samples). A large part of the subbasin had STP levels of 20 mg kg^{-1} or less (45% of the samples). Therefore, most of the land base may benefit from applied phosphorus to meet optimum crop requirements. The few samples (< 8%) that contained greater than 100 mg kg^{-1} STP were most likely influenced by livestock manure, either by mechanical application or grazing. Some of the no-manure samples also contained very high STP values (e.g., 453 mg kg^{-1}). This indicates that collecting information about field management during the 5-yr period before soil sampling may not necessarily reveal the true history of management practices. This also indicates that once phosphorus levels are allowed to build up to high concentrations, these high concentrations can persist for several years. There were significant differences among the treatments and significant interactions among the main effects (landuse, manure intensity, and landscape position). Soil-test phosphorus content can be influenced by several factors, including land management practices.

ACKNOWLEDEGMENTS

We would like to express our gratitude to the producer cooperators for providing land access and management data. This project was initiated by the Soil Phosphorous Limits Committee and funding was provided by the AESA (Alberta Environmentally Sustainable Agriculture) Program and by the Canada Adaptation and Rural Development (CARD) Fund. Many thanks go to all the Alberta Agriculture, Food and Rural Development sampling crews for their long, strenuous hours in the field, and Tony Brierley, of Agriculture and Agri-Food Canada, for soil classification. We also like to thank Tim Martin for generating the phosphorus distribution maps.

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INTRODUCTION

Water quality in Alberta streams has been degrading and the need to assess water quality in agricultural areas is growing (Anderson 2000). Of particular concern is the movement of phosphorus from agriculture land to surface water. Water quality studies in Alberta have shown that as agriculture intensified in watersheds, the amount of phosphorus increased in streams (CAESA 1998; Depoe 2004). The movement of phosphorus from agricultural land to surface water can lead to accelerated eutrophication (Correll 1998), which is a major water quality issue in many jurisdictions. Since stream flow comes from a range of agricultural systems within a watershed, there is a need to conduct water quality studies at the watershed level.

During 1998 and 1999, attempts were made to develop regulations for the intensive livestock industry under the guidance of the Intensive Livestock Stakeholder Advisory Committee (ILSAC). During this process, the Technical Expert Committee drafted the Standards Document, which was designed to support the regulations and replace the 1995 Code of Practice for the Safe and Economic Handling of Animal Manures. Though phosphorus limits were not included in the draft guidelines, the ILSAC requested, upon advice from the Technical Expert Committee, that phosphorus guidelines be developed based on research in Alberta. In response to this, Alberta Agriculture, Food and Rural Development (AAFRD) took the lead role and started the Alberta Soil Phosphorus Limits Project in 1999.

At the time the Alberta Soil Phosphorus Limits Project was started, an existing research study was being carried out in Alberta to develop a phosphorus export model to predict phosphorus movement from agricultural land on a site-specific basis (i.e., edge-of-field). This study was referred to as the Phosphorus Mobility Study (Wright et al. 2003). The phosphorus export model was developed based on extensive analysis of soils collected throughout Alberta, laboratory rainfall simulations, field rainfall simulations, and limited monitoring of natural runoff from a few small field catchments. The main objective of the Phosphorus Mobility Study was to develop an understanding of the relationship between phosphorus in soil and phosphorus in surface runoff.

A key component in the soil-runoff phosphorus relationship is the amount and distribution of phosphorus in surface soil within a watershed. The purpose of this study was to quantify the status of soil-test phosphorus (STP) in a small, agricultural watershed in central Alberta. The effects of major soil and landscape features and land management upon STP levels were also determined.

MATERIALS AND METHODS

Site Description

The M1 subbasin within the Haynes Creek Watershed was selected for this study (Fig. 1). The site is a few kilometres east of Lacombe, Alberta. The watershed is in the Aspen Parkland Ecoregion. Within the ecoregion, the M1 subbasin is in the northeast portion of the Pine Lake Upland Ecodistrict. The Haynes Creek Watershed has been the site of previous and ongoing water-quality studies (Ahmed and MacAlpine 1998; CAESA 1998; Wuite 2003; Depoe 2004; Anderson et al. year unknown).

The M1 subbasin occupies about 14% of the Haynes Creek watershed. The subbasin is in the northwest portion of the watershed in the upper corner of the stream network (Fig. 1). The drainage area is 24 km^2 (2400 ha), with an average annual runoff of 552,350 m^3 yr^{-1} (10-yr average, 1995 to 2004; HyDat System and R. Pikering, Alberta Environment, personal communication, January 2006). There are 29 quarter sections of land (1885 ha) completely contained in the subbasin, all of which were soil sampled. There are 16 partial quarter sections on the edge of the subbasin, and six of these were soil sampled.

Soil Sampling Strategy

In designing the sampling strategy, several factors affecting STP levels were considered.

Soil type. As the M1 subbasin is relatively small (24 km^2) and in the Thick Black Soil Zone, there was little variation expected due to soil type. About 75% of the M1 subbasin is within one Agricultural Region of Alberta Soil Inventory Database (AGRASID) soil map unit (Fig. 2), with small parts of four other map units (Canada-Alberta Environmental Sustainable Agriculture Soil Inventory Project Working Group 1998). An initial field inspection revealed there was significant variability within the subbasin (Appendix 1). Changing soil textures were observed in the upland areas due to bedrock and the stream channel proximities.

Slope. In other parts of Alberta, soil specialists have observed that soil phosphorus levels can be less in upper landform positions and higher in lower positions (Nolan et al. 1999; Campbell et al. 2003; Penney et al. 2003). This is especially true on hummocky landscapes with erodable soils. It was felt that transects stratified by landform position should be sampled to investigate this possibility.

Tillage. Soil phosphorus can be moved across landforms by tillage. Tillage can make the soils more prone to erosive forces that will move soil (and thus phosphorus). The entire subbasin was under conventional cultivation so there was no need to stratify on the basis of tillage systems.

Landuse. Significant amounts of hay and pasture and improved pasture were present in the subbasin. The majority of the hay and pasture fields were rotated into annual cereal crops for a couple of years before being seeded back to forage. It was decided to group all forages (native and tame grasses) into one treatment, as there was not enough fields of differing forage types to

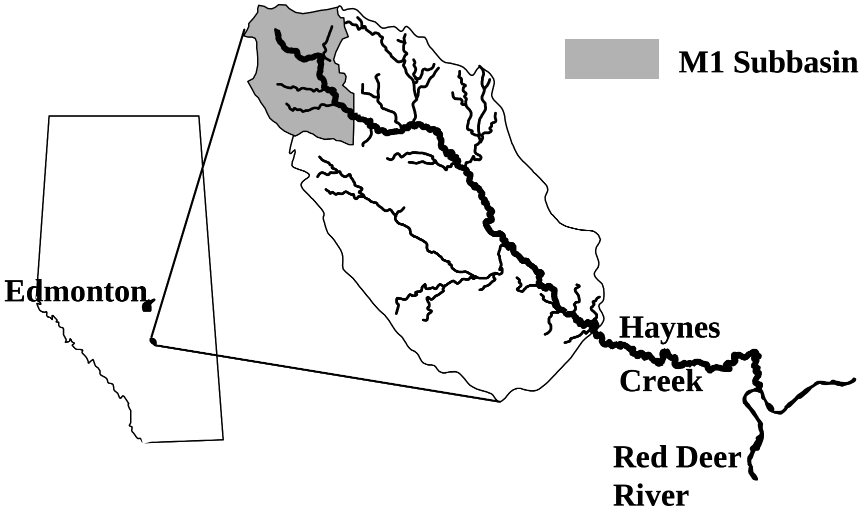

Fig. 1. The Haynes Creek Watershed and the M1 subbasin in Alberta.

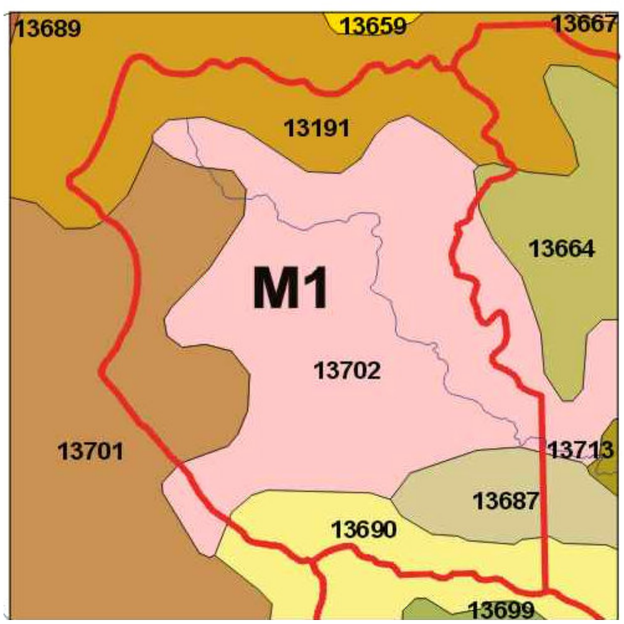

Fig. 2. Agricultural Region of Alberta Soil Inventory Database (AGRASID) map units in the M1 subbasin (Canada-Alberta Environmental Sustainable Agriculture Soil Inventory Project Working Group 1998). The M1 subbasin is within the enclosed red line.

further differentiate. At the time of sampling, management practices were assessed on crop type (barley or canola) or forage. Woodlot areas were identified as a third landuse type. Some woodlots were lightly grazed by livestock.

Manure application. The application of manure on farmland can have a distinct effect on the amount of STP. Three levels of this treatment were selected: no manure, trace manure, and manure. The trace manure class was land grazed by either cattle or horses. History of manure application was only known with certainty for the last 5 yr. Some of the fields classed as no manure or trace manure may have had manure applications at some time in the past.

Soil-sampling depth. Soils are often taken from the 0- to 15-cm layer for the purpose of determining fertilizer recommendations. However, the top few centimeters of soil interact with and contribute phosphorus to surface runoff water (Sharpley et al. 1993). Thus, it was decided to collect soil samples from the 0- to 5-cm and 0- to 15-cm layers.

Soil-sampling Locations

Soil samples were taken at 353 sites within the M1 subbasin. Transects were used as a guide to sample all combinations of landuse, manure intensity, and landscape position (Fig. 3). The sampling design was stratified by four landscape positions (upper slope, middle slope, lower slope, and riparian) and by several landuse types.

Satellite imagery from IKONOS was acquired in mid-September, 2000, covering a 65 km^2 area centered over the M1 subbasin. The IKONOS data provided 1-m black and white (panchromatic) imagery and multispectral imagery at 4-m resolution (three colour bands plus infrared band).

Preliminary scouting information, farmer survey data, and aerial photo interpretation were used to mark general transects on the aerial photo. These transects were used as a guide for potential soil-sampling locations and as a reference for sampling crews. When sampling locations were positioned in the field, a more accurate assessment of landuse and topography was made. Transects were added or altered once positioning started, to accommodate management practices and landscape positions.

All sites were geo-referenced to sub-metre accuracy using a Differential Global Positioning Satellite (DGPS) System. Each transect was labeled according to transect and sampling point number and recorded on a data logger. Attribute information at each sampling point was recorded on field data sheets when positions were geo-referenced. Attribute information was recorded a second time on field sheets by the sampling teams at the time of soil sampling. Attribute information collected included topography, slope, aspect, vegetation, cultivation, and manure. An example of the field data sheet is shown in Appendix 2 and some of the data are shown in Appendix Table A3.3.

Soil Sampling

Soil samples were collected from October 11 to 20, 2000. Weather conditions were not a limiting factor. The daily temperature for the sampling period ranged from 5 to 20º C. There was no precipitation during the 2-wk period. All producers had finished combining by the second week and only a few bales were left in the fields.

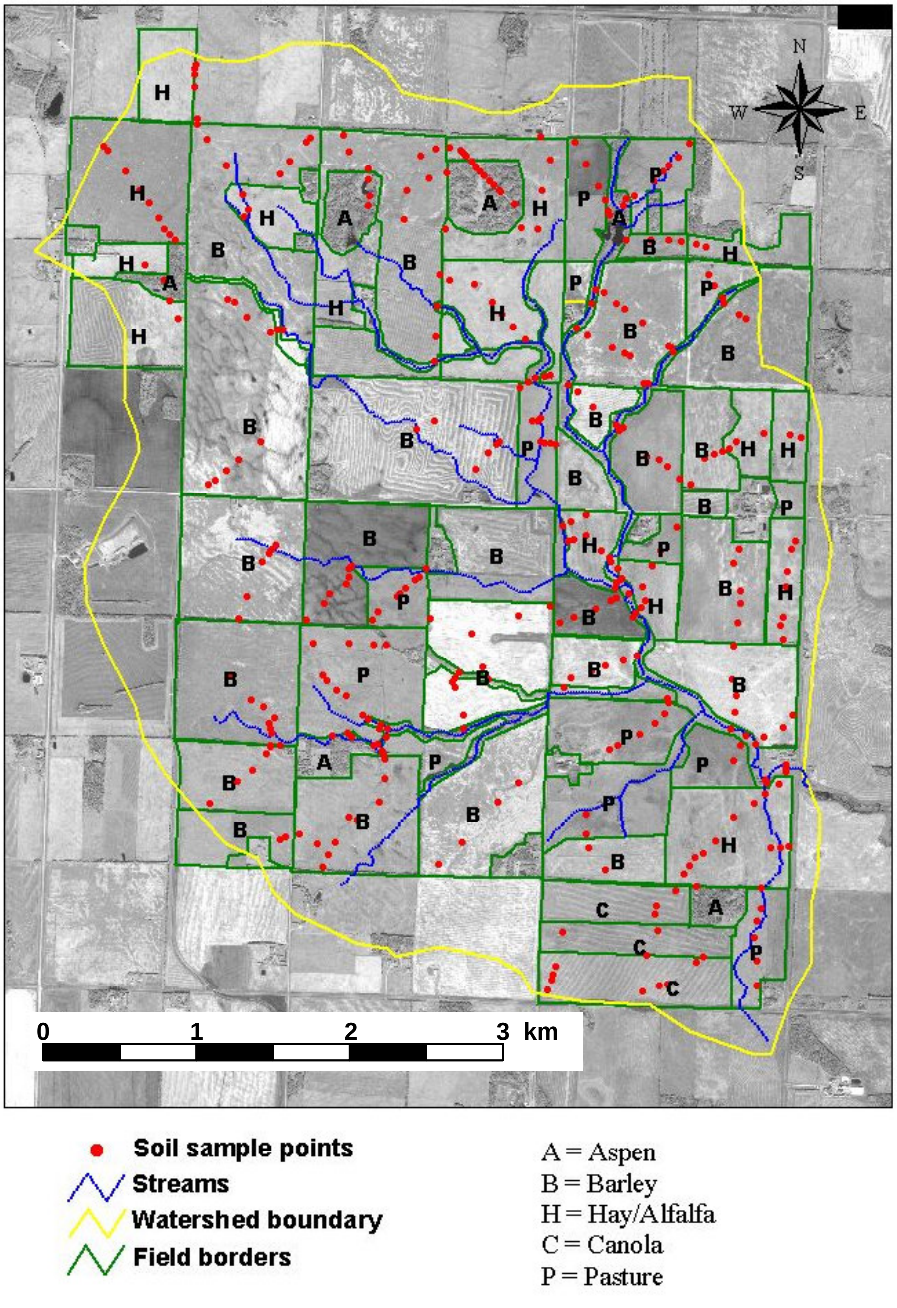

Fig. 3. Soil-sampling points within the M1 subbasin.

At each of the 353 sampling points, soil samples were collected from 0 to 5 cm and from 0 to 15 cm. This gave a total of 706 soil samples. For each soil sample layer (0 to 5 and 0 to 15 cm), 10 soil cores were collected in a 1-m radius using a hand-held, 5-cm diameter, core tube. The core samples were mixed and a composite sample was placed into plastic bags, tagged, stored in a cooler, and delivered to the laboratory each day. Sampling crews consisted of two to three individuals with two crews working in different areas of the subbasin.

All soil samples were analyzed for STP by Norwest Labs in Edmonton, Alberta. Samples were dried with forced air at 45 ^{o}C and then pulverized and sieved (<2 mm). The 0- to 15-cm layer soil samples were analyzed for STP, extractable nitrate nitrogen, extractable potassium, and pH. The 0- to 5-cm soil samples were analyzed only for STP. The modified Kelowna extraction procedure (Ashworth and Mrazek 1995) was used for the extractable nutrient analyses. Subsamples (5 g) were shaken for 30 min with the extraction solution (50 mL) and then filtered through a Whatman #40 filter paper. Filtrates were analyzed using standard autoanalyzer colorimetric methods. Soil pH was determined using the 1:2 soil-water ratio method. Only the STP results are discussed in this report. Results of all measured parameters are shown in Appendix 3.

Management Survey

A landuse management survey of the 10 farmers in the M1 subbasin was carried out. Information was collected on cropping practices, fertilizer and manure application, livestock numbers, and grazing intensity. Data were compiled for the fields sampled to determine manure application, grazed areas, and crop rotations. A sample of the management survey sheet is shown in Appendix 2.

Statistical Analysis

The factors that were assessed in the statistical analysis included landuse (annual, perennial, wooded), manure intensity (no manure, trace manure, manure), and landscape position (upper, mid, lower, riparian). The possible maximum combinations, or treatments, of these factors is 32 (3 by 3 by 4). However, there were no wooded/manure/(all landscape positions), annual/trace-manure/upper, annual/trace-manure/lower, and wooded/trace-manure/upper treatments, leaving a total of 29 treatments. All statistical analysis was carried out using the Statistical Analysis System (SAS Institute Inc. 2000).

The MEANS procedure was used for descriptive statistics, and the REG procedure was used for regression analysis between the 0- to 5-cm and 0- to 15-cm soil layer data sets. The INSIGHT and GPLOT SAS procedures were used to test for normality of distribution. The data set was found not to be normally distributed, and as a result the data were log transformed to normalize the data set (Appendix 4). The Mixed Model procedure, after taking into account spatial variability, was used for analysis of variance to test for treatment effects. Contrast statements were used to answer specific questions regarding differences among treatments.

RESULTS AND DISCUSSION

Landuse in the M1 Subbasin

About 56% of the subbasin was in annual crops (1402 ha), and another 33% was in hay and pasture (828 ha: 425 ha alfalfa, 403 ha pasture), with field sizes ranged from 4 to 81 ha (Fig. 4). Less than 10% was in trees or wetlands/riparian (165 ha). There were 10 producers and a few acreage owners (57 ha). Farm size ranged from 65 to 583 ha, with an average size of about 259 ha. There were 81 different management fields within the subbasin, of which 64 were soil sampled (26 barley, 15 hay/alfalfa, 14 pasture, 6 aspen, and 3 canola).

Based on farmer surveys, approximately 125 cow-calf pairs were summer-grazed in the M1 subbasin. The number of cattle increased to approximately 900 during the winter. Many producers had summer grazing pastures outside the subbasin. There were approximately 1500 hogs in the subbasin, with new hog developments planned at the time of soil sampling. There were a few hobby-farms with horses throughout the subbasin. Manure from wintering sites, and hog operations in the subbasin and surrounding area, were spread on several cultivated and forage fields within the subbasin.

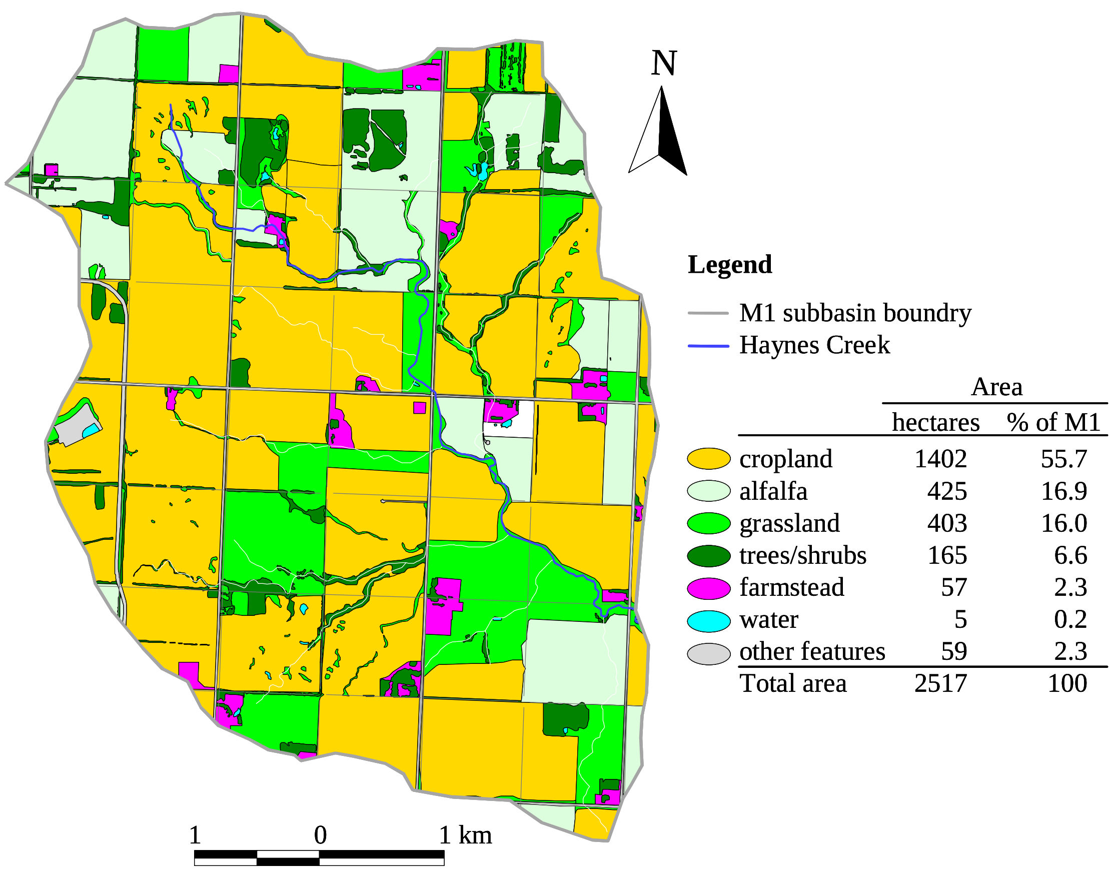

Fig. 4. Landuse distribution within the M1 subbasin (adapted from Kwasny et al. 2001).

Soil-test Phosphorus Content

Results from 2 of the 353 sample points were discarded because of impossible concentration values. The two sample points were T-19-11 and T-20-1 (Appendix 3). The STP concentration was 468 mg ha^{-1} in the 0- to 5-cm layer and 62 mg kg^{-1} in the 0- to 15-cm layer at the T-19-11 site. The STP concentration was 483 mg ha^{-1} in the 0- to 5-cm layer and 28 mg kg^{-1} in the 0- to 15-cm layer at the T-20-1 site. The values for the 0- to 5-cm layers cannot be greater than three times the value in the 0- to 15-cm layers. The amount of STP in the 5- to 15-cm layer would have to be zero if the phosphorus content in the top 5 cm of soil is three times the amount in the 0- to 15-cm layer.

Thirteen other samples (listed below) had a problem similar to the T-19-11 and T-20-1 samples. However, the discrepancy was not as great for these samples compared to the two that were deleted. The two sampling depths were collected separately (0 to 5 cm and 0 to 15 cm) as opposed to collecting the samples in incremental layers (0 to 5 cm and 5 to 15 cm). In the latter case, values for the 0- to 15-cm layer would have to be calculated using the values from the incremental layers. Because the two depths were collected separately, the discrepancies may have been caused, in part, by spatial variation. Therefore, it was decided to keep these 13 samples in the data set.

T-6-1	T-7-4	T-8-2	T-15-7	T-17-6
T-25-7	T-26-4	T-35-1	T-38-6	T-48-3
T-48-6	T-48-7(B)	T-49-2		

For the remaining samples (351 samples per soil layer), STP ranged from 2.5 (half the detection limit) to 453 mg kg^{-1} for the 0- to 5-cm soil layer, and from 2.5 to 358 mg kg^{-1} for the 0- to 15-cm soil layer (Table 1). Data were highly skewed towards lower STP values (Fig. 5). The median STP values were 35 mg kg^{-1} for the 0 to 5-cm soil layer and 23 mg kg^{-1} for the 0 to 15-cm soil layer (Fig. 6). About 78% of the 0- to 5-cm soil layer samples and 89% of the 0- to 15-cm soil layer samples contained STP values of 60 mg kg^{-1} or less. About 21% of the 0- to 5-cm soil layer samples and about 10% of the 0- to 15-cm soil layer samples contained STP values greater than 60 to 140 mg kg^{-1}. About 1% of the samples from both soil layers contained STP values more than 140 mg kg^{-1}. The average STP concentration in the 0- to 5-cm layer (45.7 mg kg^{-1}) was 1.41 times more than STP in the 0- to 15-cm layer (32.4 mg kg^{-1}). The agronomic threshold for STP in the top 15-cm of soil is about 60 mg kg^{-1} (Howard 2006). This means that adding additional phosphorus to soil with 60 mg kg^{-1} or more STP will probably not result in a crop response. Therefore, most of the land in the subbasin would benefit from phosphorus application to meet crop phosphorus requirements for optimum yield.

Manunta et al. (2000) examined 280,000 analytical records of STP in Alberta for two time periods (1963 to 1967; 1993 to 1997). They concluded that the majority of ecodistricts had a mean STP concentration in the top 15-cm soil layer between 25 and 30 mg kg^{-1} in 1993 to 1997. The mean value for the M1 subbasin (32 mg kg^{-1}) was comparable to their findings. The range of STP (1 to 400 mg kg^{-1}) for the 1993 to 1997 records reported by Manunta et al. (2000) was similar to the range found in the Haynes Creek M1 subbasin. The high phosphorus

Treatment	Soil layer (cm)	n	Mean (mg kg^{-1})	Minimum (mg kg^{-1})	Maximum (mg kg^{-1})	Standard deviation
			All treatments			
All treatments	0 to 5	351	45.7	2.5	453	42.6
All treatments	0 to 15	351	32.4	2.5	358	34.4
			Manure intensity			
No manure	0 to 5	145	37.0	2.5	453	41.5
	0 to 15	145	28.2	2.5	358	34.9
Trace manure	0 to 5	73	43.2	2.5	135	30.9
	0 to 15	73	28.3	2.5	108	23.2
Manure	0 to 5	133	56.5	9.1	321	47.0
	0 to 15	133	39.1	6.0	273	38.0
			Landuse			
Annual	0 to 5	160	45.8	8.4	271	32.3
	0 to 15	160	33.0	5.2	196	24.8
Perennial	0 to 5	155	48.1	2.5	453	54.3
	0 to 15	155	32.9	2.5	358	44.3
Wooded	0 to 5	36	34.9	2.5	70	17.7
	0 to 15	36	27.4	2.5	103	19.8
			Landscape position			
Upper	0 to 5	107	51.0	2.5	453	59.6
	0 to 15	107	32.2	2.5	358	46.3
Mid	0 to 5	113	45.4	8.4	321	38.4
	0 to 15	113	33.2	2.5	273	32.6
Lower	0 to 5	61	43.5	5.1	133	29.7
	0 to 15	61	33.0	2.5	105	24.3
Riparian	0 to 5	70	39.9	2.5	110	22.5
	0 to 15	70	30.6	2.5	138	21.8

Table 1. Soil-test phosphorus in the 0- to 5-cm and 0- to 15-cm soil layers in the M1 subbasin.

concentrations are most likely associated with animal manure application. Whalen and Chang (2001) reported that after 16 yr of annual cattle manure application on continuous cropped land, STP (extractable Olsen phosphorus) in the 0- to 15-cm soil layer ranged from 317 to 964 mg kg^{-1}, which varied with manure application rate (30 to 180 Mg ha^{-1} yr^{-1} wet-weight basis).

Two methods were used to generate STP distribution maps for the 0- to 5-cm soil layer data (Fig. 7). The first map was created using the inverse-distance-weighted alogrithum without regard to management units (Fig. 7a). The second map was created by assigning to each management unit (i.e., field) the average STP value from soil samples within each management unit. The maps show that most of the subbasin had STP values less than 70 mg kg^{-1} in the top 5 cm. There were some higher STP concentrations in the extreme northeast part and a central

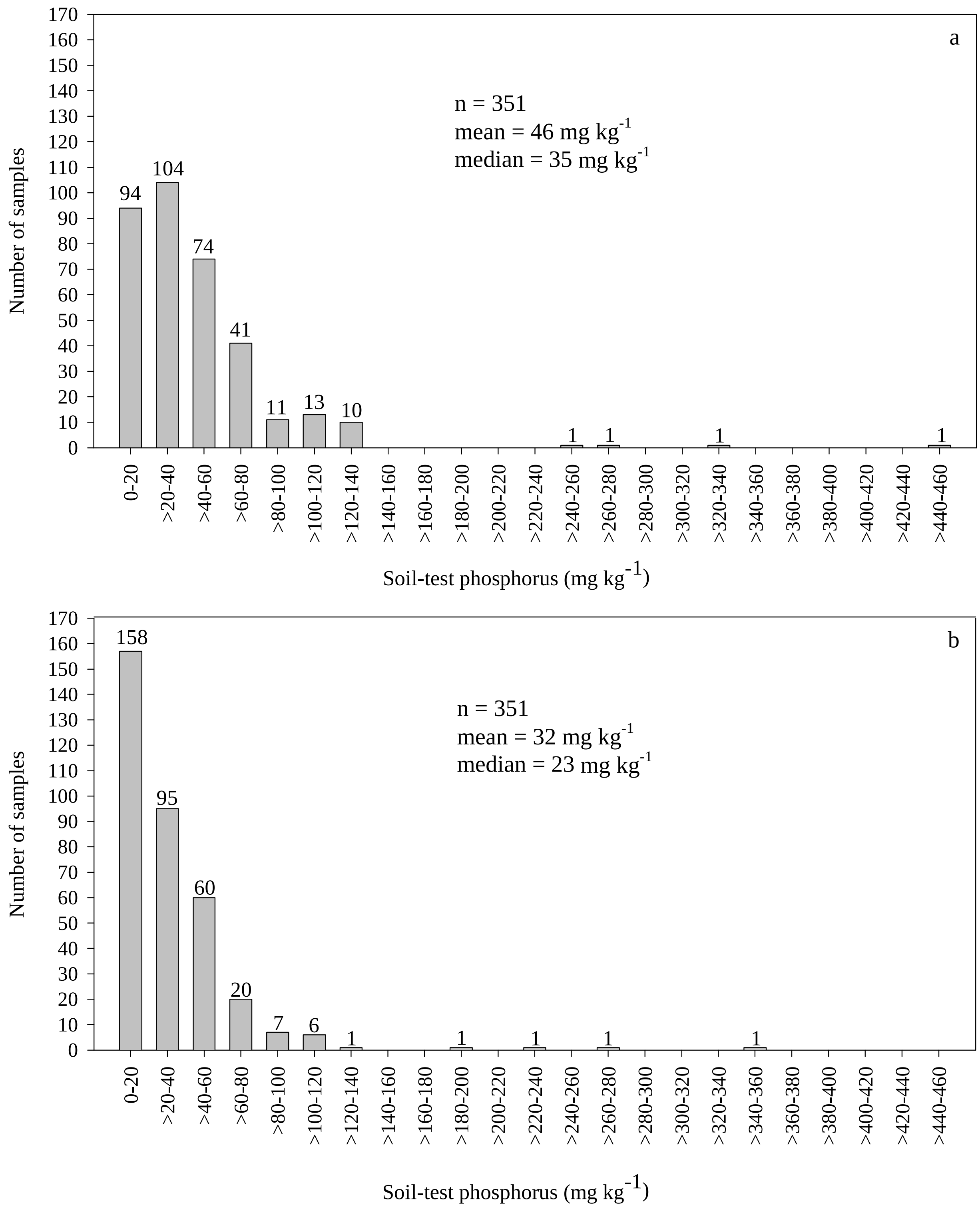

Fig. 5. Frequency distribution of soil-test phosphorus in (a) the 0- to 5-cm and (b) the 0- to 15-cm soil layers.

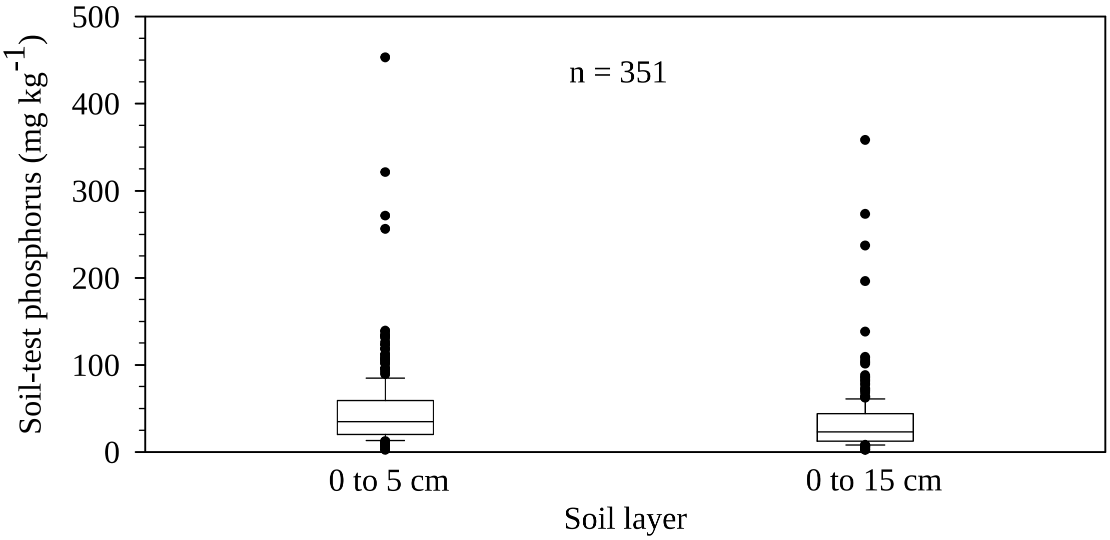

Fig. 6. Box and whisker plots of the soil-test phosphorus data for the 0- to 5-cm and 0- to 15-cm soil layers. The bottom of the boxes is the 25th percentile, the top of the boxes is the 75th percentile. The bottom whisker is the 10th percentile and the top whisker is 90th percentile. The horizontal line through the boxes is the median value.

region of the subbasin.

The two depths were positively correlated with a correlation coefficient (r) of 0.92 (r^2 = 0.85) (Fig. 8). Mean STP concentration in the 0- to 5-cm layer was 1.41 times more than STP in the 0- to 15-cm layer (Table 1). Phosphorus is relatively immobile in soil and does not readily move downwards (Beegle 2005). As a result, phosphorus concentration often is stratified in soil and decreases with depth (Beegle 2005). This stratification was expected as some fields had recent manure application. Manure may have the greatest effect on phosphorus stratification, or enrichment of the surface layer.

No-manure samples are those with no reported manure application or grazing in the past 5 yr. A few high values were observed for the no-manure samples, and these are most likely due to manure application or livestock grazing prior to 5 yr before soil sampling. This underlines the importance of collecting not only accurate field histories but perhaps a longer history of field management. It also indicates that high STP concentrations can persist for several years.

Additional regression analyses were carried out by grouping according to manure intensity, landuse, and landscape position. The slopes were greater than 1, except for the wooded and riparian treatments (Table 2). A slope greater than 1 signifies that the STP concentration was higher in the 0- to 5-cm layer compared to the 0- to 15-cm layer. The opposite was observed for the wooded and riparian treatments. All relationships had a significant, positive intercept ranging

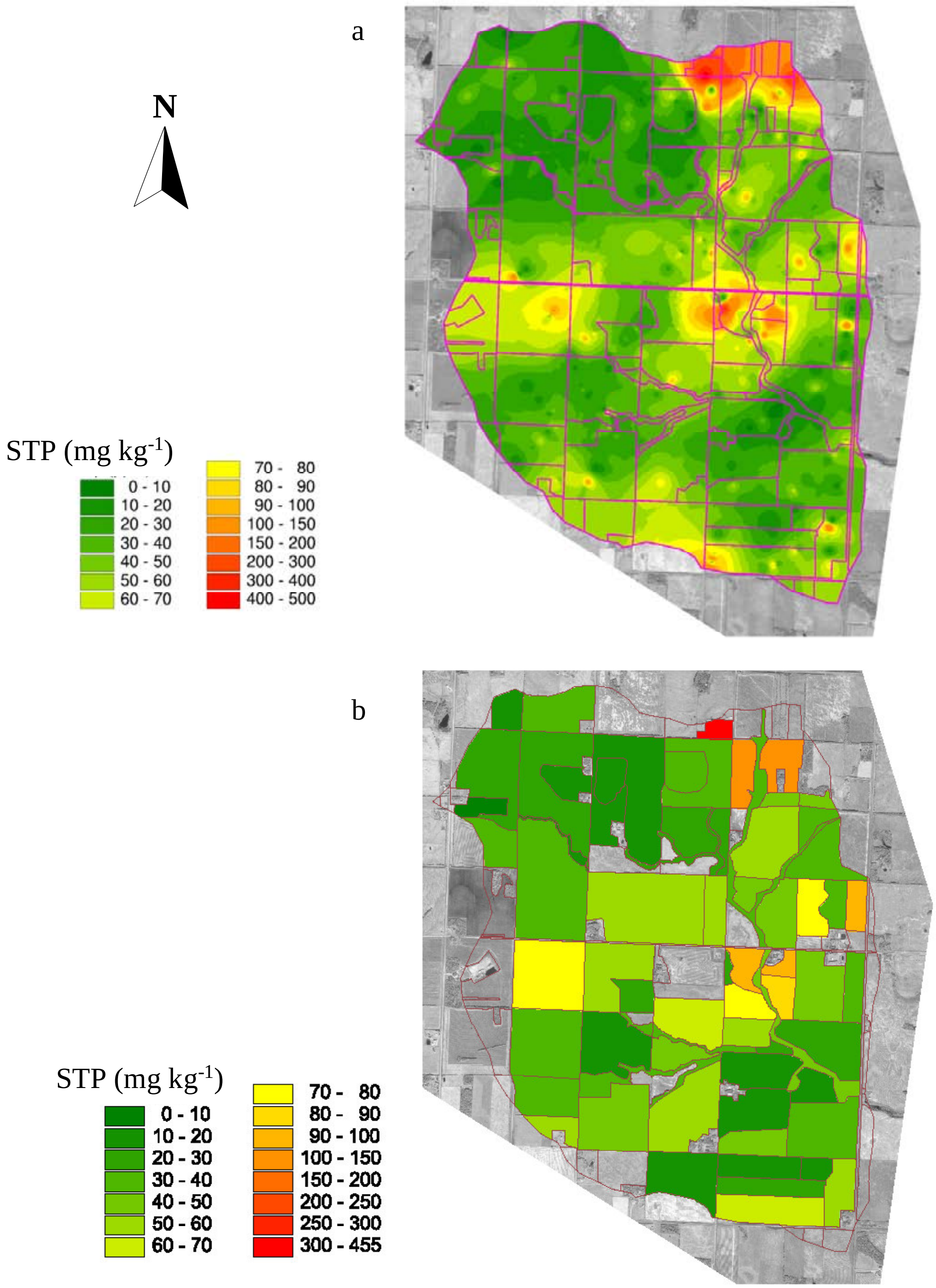

Fig. 7. Soil-test phosphorus (STP) distribution for the 0- to 5-cm soil layer in the M1 subbasin shown by (a) the inverse-distance-weighted method, and (b) on a per field or land management unit basis.

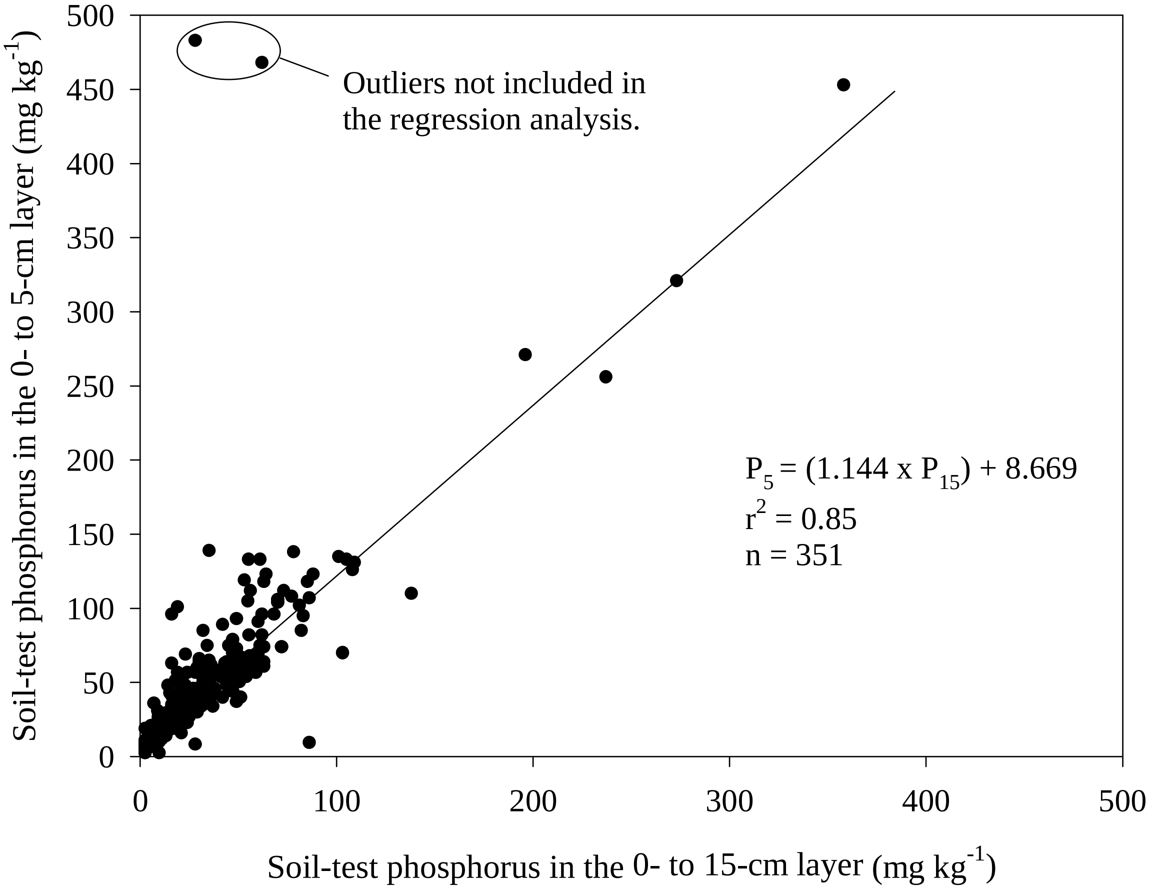

Fig. 8. Regression analysis of the 0- to 5-cm soil layer (P_5) versus the 0- to 15-cm soil layer (P_{15}) soil-test phosphorus data.

from 4.6 to 16 mg kg^{-1}. This indicates that at very low levels of STP in the 0- to 15-cm layer (i.e., at or below the detection limit), there was a measureable amount of STP in the 0- to 5-cm layer.

The analysis of variance showed, with log-transformed data and after accounting for spatial variability, that there was a significant treatment effect on phosphorus levels in the 0- to 5-cm soil layer (Appendix 4). Without accounting for spatial variability, treatment effects were not significant. Similar results were found for the 0- to 15-cm soil layer using log-transformed data; however, treatment effects were significant without accounting for spatial variability.

The use of contrasts showed that there are significant main effects and interactions among manure intensity, landuse, and landscape positions (Appendix 4). Significant effects were observed among combinations of manure intensity and landscape position. Appendix Figs. A4.3 and A4.9 show where the interaction effects exist for the 0- to 5-cm and 0- to 15-cm soil layers, respectively.

Table 2. Linear regression analysis of the 0- to 5-cm (P_5) and 0- to 15-cm (P_{15}) soil layer data.

Treatment	n	Equation	r^2
		All treatments	
All treatments	351	$P_5 = (1.144 \times P_{15}) + 8.669$	0.85
		Manure intensity	
No manure	145	$P_5 = (1.149 \times P_{15}) + 4.599$	0.93
Trace manure	73	$P_5 = (1.136 \times P_{15}) + 11.04$	0.73
Manure	133	$P_5 = (1.117 \times P_{15}) + 12.81$	0.82
		Landuse	
Annual	160	$P_5 = (1.151 \times P_{15}) + 7.856$	0.78
Perennial	155	$P_5 = (1.154 \times P_{15}) + 10.08$	0.89
Wooded	36	$P_5 = (0.778 \times P_{15}) + 13.58$	0.76
		Landscape position	
Upper	107	$P_5 = (1.220 \times P_{15}) + 11.68$	0.90
Mid	113	$P_5 = (1.115 \times P_{15}) + 8.342$	0.90
Lower	61	$P_5 = (1.081 \times P_{15}) + 7.800$	0.78
Riparian	70	$P_5 = (0.783 \times P_{15}) + 15.98$	0.58

CONCLUSIONS

Within a small (24 km^2) agricultural subbasin in central Alberta, STP ranged from 2.5 mg kg^{-1} (half the detection limit) to 453 mg kg^{-1}. Soil-test phosphorus content was higher in the 0- to 5-cm layer compared to the 0- to 15-cm layer. The STP values from the two soil layers were linearly correlated. For the whole data set, the 0- to 5-cm layer was enriched 1.41 times more than the 0- to 15-cm layer. Soil-test phosphorus content in the soil was 60 mg kg^{-1} or less in the 0- to 15-cm soil layer for the majority of the subbasin (89% of the samples). A large part of the basin had STP levels of 20 mg kg^{-1} or less (45% of the samples). This suggests that most of the land base may benefit from applied phosphorus to meet crop requirements. The few samples (< 8%) that had STP values greater than 100 mg kg^{-1} were most likely influenced by livestock manure, either by mechanical application or grazing. Some of the no-manure samples also contained very high STP values (e.g., 453 mg kg^{-1}). This indicated that collecting information about field management during the 5-yr period before soil sampling may not necessarily reveal the true history of management practices. This also indicated that once phosphorus levels build up to high concentrations, these high concentrations can persist for several years. The analysis of variance showed significant differences among the treatments and significant interactions among the main effects (landuse, manure intensity, and landscape position). Soil-test phosphorus content can be influenced by several factors, including land management practices.

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Appendix 1. Soils investigation of the M1 subbasin.

Soil inspections were conducted along established transects in October 2000. This was carried out by Tony Brierley of Agriculture and Agri-Food Canada, Edmonton, Alberta, and the following is a summary of the soil descriptions and comments provided by Tony Brierley.

SE4-40-25 W4

Transect 13

Site 1

Macro landscape position: Upper
Micro landscape position: Upper
Landscape description: rolling, 8% slope, NE aspect
Profile:

Ap	0-15 cm, 10YR4/2d, scl (B horizon material mixed within Ap)
Bm	15-45 cm, scl
IIBC	45-120 cm, sl, weathered sandstone

Parent material: Till veneer over residual
Soil name: Eroded phase of Orthic Black Chernozem (ATLerxp)

Orthic Black Chernozems present in this area, however due to erosion the surface layer does not have enough organic matter to really qualify as a Black. Surface layer actually dark brown.

Site 2

Macro landscape position: Upper
Micro landscape position: Mid
Landscape description: rolling, 10% slope, NE aspect
Profile:

Ap	0-15 cm, 10YR4/2d, cl
Bm	15-90cm, cl
Ck	90+ cm, cl till

Parent material: Till
Soil name: Eroded phase of Orthic Black Chernozem (ATLer)

Site 3

Macro landscape position: Upper
Micro landscape position: Lower to dep
Landscape description: rolling, 1% slope, NE aspect
Profile:

Ap	0-15 cm, 10YR2/2, l
Ah	15-50cm, l
Bg1	50-70 cm
Bg2	70-100+ cm, cl

Parent material: “Slope wash” material over till
Soil name: Humic Gleysol (closest name TUTzz)

The Bg1 horizon exhibits some platy structure indicative of an upper slope depressional area (a recharge area).

SE9-40-25-W4
Transect 16

Site 4
Macro landscape position: Lower
Micro landscape position: Mid
Landscape description: 1% slope
Profile:

Ap	0-15 cm, 10YR3/2d, l
Ah1	15-30
Ah2	30-45
Bgj	45-90 cm, cl
Ckg	90-100 cm, cl

Parent material: Lacustrine
Soil name: Gleyed Black Chernozem (PEDgl)

Site 5a
Macro landscape position: Lower
Micro landscape position: Upper (slight rise adjacent to creek)
Landscape description: 4% slope
Profile:

Ap	0-15 cm, 10YR2/2d, l
Ah	15-25cm, l
Bm	25-50 cm, sl
IIBm	50-100 cm, ls-s

Parent material: Coarse textured fluvial
Soil name: Orthic Black Chernozem (MGS)

This ridge is next to the creek. The real extent of these coarse textured fluvial materials may be rather limited. However the presence of these soils warrants further investigation before applications of manure.

Site 5b (just west of previous site on another ridge)
Macro landscape position: Lower
Micro landscape position: Upper
Landscape description: 4% slope
Profile:

Ap	0-15 cm, 10YR2/2d, l
Bm	15-70 cm
Ck	70+ cm, cl

Parent material: Medium textured till
Soil name: Orthic Black Chernozem (ATL)

This site is indicative of the variability of soils in this polygon.

NE17-40-25-W4
Transect 28

Site 6
Macro landscape position: Mid
Micro landscape position: Lower
Landscape description: undulating, 3% slope
Profile:

Ap	0-15 cm, 10YR2/2d, l
Ah	15-70cm, l
Bg1	70-90 cm
Bg2	90-100 cm, cl

Parent material: Medium textured lacustrine
Soil name: Gleyed Black Chernozem (PEDgl)

C17-40-25-W4

Site 7
Macro landscape position: Mid
Micro landscape position: Mid
Landscape description: Rolling, 2% slope, E aspect
Profile:

Ap	0-15 cm, 10YR3/2d, l
Ah	15-25cm, l
Bm1	25-50 cm, cl
Bm2	50-100 cm, cl
Ck	110+cm, cl

Parent material: Medium textured till
Soil name: Orthic Black Chernozem (ATL)

SW20-40-25-W4
Close to Transect 40

Site 8a
Macro landscape position: Up
Micro landscape position: Up
Landscape description: Rolling, 15%, S aspect
Profile:

Ap	0-15 cm, 10YR4/2d, l
Bm	15-30 cm, cl
IIBm	30-60 cm, l-sl
IICk	60-100cm, l

Parent material: Medium textured till over residual
Soil name: Eroded phase of an Orthic Black Chernozem (ATLerxp)
Called this a Black, even though the surface colour is actually dark brown.

Site 8b (13 meters from pervious site)
Macro landscape position: Up
Micro landscape position: Up

Landscape description: rolling, 15%, S aspect
Profile:

Ap	0-15 cm, 10YR3/2d, l
Ah	15-40
Bm	40-70 cm, cl-l (till)
IIBm	70-90 cm, l
IICk	90+cm, l

Parent material: Medium textured till over residual
Soil name: Orthic Black Chernozem (ATLxp)

Surprised at the variability in profiles, literally 13 paces apart, on top of the same knoll.

Overall Comments

In AGRASID (Agricultural Region of Alberta Soil Inventory Database), the CYLP10/U1hc soil landscape model describes the majority of the area within the M1 subbasin. Polygons described with the CYG4/M1mr model occurred in the adjacent areas to the north and south of this previously mentioned polygon. The CYLP10 polygon by definition contains dominantly Eluviated and Orthic Black Chernozems developed on medium texture till and medium textured lacustrine veneer over till. Solonetzic and Gleysolic soils developed on similar materials are also present as significant components of this polygon.

For the soil sampling project of the M1 subbasin, further field investigations within the CYLP10 polygon are warranted. Due to the intensity level of the sampling program and the probable variability in textures and parent material in this lower portion of the M1 subbasin additional soil landscape polygons may be delineated within this large AGRASID polygon. For example, the presence of “sandy” ridges adjacent to the creek could be investigate. Similarly, the various natural springs and the possible adjacent saline areas could be delineated as separate polygons.

The upland ridge areas occupying the north and south portions of the M1 subbasin may also be described in more detail. The proximity of underlying bedrock, actually poking out at the surface was somewhat surprising based on the AGRASID descriptions. Also with the presence of eroded soils in these areas, the actual proportion of calcareous surface layers may warrant more characterization (field by field basis), especially in light of phosphorus fixation with $CaCO_3$.

In AGRASID, the soils in this watershed were mapped as dominantly Eluviated Black Chernozems, thus most of the map symbols are CYG. Based on this limited number of field investigations, no E. Bl’s were observed. Just the reason why the soils developed on till are labeled ATL and not CYG.

In the southwestern portion of the M1 subbasin, the boundary between the CYLP10/U1hc and the CYG4/M1mr area may possibly be modified. Based on the landscape and possible influence of underlying bedrock within the M1 subbasin, this boundary could possibly be altered, if evidence to support this theory is justified, based upon further investigations.

Soil Abbreviations

AGRASID	Agricultural Region of Alberta Soil Inventory Database. The official soil survey for the province of Alberta. Most of the M1 subbasin is as a combination of CYG and LPN (expressed as CYLP). It uses a subdesignation of 10 (CYLP10) to indicate minor amounts of wet areas and Solonetzic soils (sodium enriched hardpan).
ATL	Antler soil series. These are clay-loam textured Black soils (Chernozem) with a normal profile (Orthic) formed on till. They are well drained good quality soils, but may have some stones at the surface.
CYG	Cygnet soil series. These soils are similar to the ATL soil series but are eluviated, meaning that downward movement of water over time has leached fine particles and organic matter to lower levels. This series is mapped on the provincial soils map for the M1 area but was not found in the field investigations.
LPN	Lonepine soil series. This is a similar soil to the Penhold soil series. They are medium textured soils formed on the layers of glacial lake deposits over the till. The lake deposits are generally less than a metre in thickness.
MGS	Morningside soil series. These are coarse textured, normal, Black soils formed on sandy deposits that are either wind blown or stream depositions. In the M1 subbasin, these have been found along the stream channels.
PED	Penhold soil series. These are loam textured soils formed on glacial lake deposits more than 1-m thick overlying the till. They have a normal soil profile (Orthic Black Chernozems) and are good quality soils. They are well drained and have no stones at the surface.
TUT	Tuttle soil series. These are soils formed on medium to moderately-fine glacial lake deposits. They are poorly drained Gleysolic soils associated with lower landscape and depressional positions. They are not saline but may have higher levels of calcium carbonate (free lime) that has moved down slope with soil water.

Appendix 2. Examples of the field data and landuse management survey sheets.

FIELD DATA SHEET

LEGAL: ______________________________ **DATE:** /00

FIELD TAG: __________ **Position:** U M L Dep Riparian **Overall Position:** U M L Dep Riparian

Aspect:		**% Slope:**		**Curvature:**		**Stone Class:**	**Proportion:**
	N		0-0.5		NONE	<8 cm	0-1%
	NE		0.5-2		CONCAVE	8-25 cm	1-5%
	E		2-5		CONVEX	>25 cm	5-15%
	SE		5-10				>15%
	S		10-15				
	SW		15-30				
	W			**Magnitude:**	m^2		
	NW			**Topography:**	rolling undulating		

Crop Type:	Cereal:		Forage:		Native:			% Cover:
		Wheat		ALFALFA		GRASS	FALLOW	100
		BARLEY		TIMOTHY		ASPEN	CULTIVATED	90
		OATS		BROME				80
		TRITICLE		MIXED				70
		CANOLA						60
								50

Manure Type:		Animal:		% Manure:			
	FRESH		COW		30	Depth to $CaCO_3$:	40
	OLD		HORSE		20		30
			SHEEP		10	Depth to B:	20
			OTHER		5		10
	SPREAD Y / N				2	Weeds:	5
	INCORPORATED Y / N				0		0

NOTES: ____

____

____

____

____

LANDUSE MANAGEMENT SURVEY SHEET

Producer's Name:

General Questions:

How long have you farmed here?
Has the amount of land you manage changed in the past 5 years?
If so, what new land are you managing?
What land are you no longer managing?
What are the crop rotations for the annually cropped fields?
Have you summerfallowed in th past 5 years?
If so which years?
Did you use chem-fallow or tillage?
Which is the most common residue management practice for you? (baled, spread, grazed, burned)
Which are the most common weeds?
Do you practice direct seeding?
If so, when did you start?
On which fields (use legal or locate on air photo)

If you have livestock:

What grazing practice (continuous or rotational) do you use?
Where are they wintered? (locate all sites on air photo)
Where are they pastured/grazed during the spring-fall period?
Are the fields subdivided for grazing?
Where are the subdivisions (locate on air photo)?
Where are lagoons located?
How is the lagoon managed?

Other features:

Do you have grassed waterways
Where are they? (locate on air photo)
How long have they been there?
How wide are they?

Is there anything else we should know about the sub-basin that may have contributed to P to the stream?

Producer's Name:

Field (legal location):

	1995	1996	1997	1998	1999	2000
1. Annual Crops:						
What were the crops grown? (include silage)						
Seeding date						
Harvest date						
Fertilizer						
Spring application						
Type (analysis e.g. 11-51-0)						
How applied (e.g. banded)						
Rates (lbs/ac)						
Date of application						
Fall application						
Type (analysis e.g. 11-51-0)						
How applied (e.g. banded)						
Rates (lbs/ac)						
Date of application						
Cultivation						
Fall cultivation						
Pass No. 1						
Equipment used						
Date of cultivation						
Pass No. 2						
Equipment used						
Date of cultivation						
Pass No. 3						
Equipment used						
Date of cultivation						
Spring cultivation						
Pass No. 1						
Equipment used						
Date of cultivation						
Pass No. 2						
Equipment used						
Date of cultivation						
Other cultivation (e.g. summerfallow)						
Pass No. 1						
Equipment used						
Date of cultivation						
Pass No. 2						
Equipment used						
Date of cultivation						

	1995	1996	1997	1998	1999	2000
Manure application						
What rates are applied?						
When is it spread?						
When is it incorporated?						
2. Livestock:						
Cattle						
How many head? -spring-fall						
How many head at each grazing/pasture area:						
Site 1?						
Site 2?						
Site 3? (add any other sites at bottom of page)						
How many head? -winter						
How many head at each wintering site:						
Site 1?						
Site 2?						
Site 3? (add any other sites at bottom of page)						
Was all the manure spread on land in the sub-basin?						
How much manure was composted?						
How much manure was hauled away from the sub-basin?						
How much manure was stockpiled?						
When were cattle brought in to the field?						
When were cattle taken out of the field?						
3. Perennial Crops						
Fertilizer						
Type (analysis e.g. 11-51-0)						
How applied (e.g. banded)						
Rates						
Date of application						
Harvesting						
When was the 1st cut						
When was the 2nd cut						
When was the 3rd cut						
4. Weather						
Were three any heavy snow accumulations in the field?						
Were there any unusually heavy rainfalls?						
What dates were they (approximately)?						

Appendix 3. Soil and landscape data.

Table A3.1. Soil-test phosphorus value for 0- to 5-cm layer soil samples from the M1 subbasin (Page 1 of 4).

Sample ID[z]	Lab lot no.	Lab no. within lot no.	Soil layer (cm)	Soil-test phosphorus (mg kg^{-1})	Sample ID[z]	Lab lot no.	Lab no. within lot no.	Soil layer (cm)	Soil-test phosphorus (mg kg^{-1})
T-1-1	89667	1	0 - 5	64.0	T-8-3	88594	57	0 - 5	28.0
T-1-2	89667	3	0 - 5	24.0	T-9-1	90699	1	0 - 5	26.0
T-1-3	88637	1	0 - 5	32.0	T-9-2	90699	3	0 - 5	18.0
T-1-4	88637	3	0 - 5	68.0	T-9-3	90699	5	0 - 5	14.0
T-1-5	88637	5	0 - 5	30.0	T-9-4	90699	7	0 - 5	12.0
T-1-6	88637	7	0 - 5	50.8	T-9-5	90699	9	0 - 5	25.0
T-2-1	88637	9	0 - 5	89.0	T-9-6	90699	11	0 - 5	13.0
T-2-2	88637	11	0 - 5	20.0	T-9-7	90699	13	0 - 5	27.0
T-2-3	88637	13	0 - 5	44.0	T-9-8	90699	15	0 - 5	42.0
T-2-4	88637	15	0 - 5	34.0	T-9-9	90699	17	0 - 5	63.0
T-2-5	88637	17	0 - 5	33.0	T-9-10	90699	19	0 - 5	32.0
T-2-6	88637	19	0 - 5	21.0	T-9-11	90699	21	0 - 5	25.0
T-3-1	88637	21	0 - 5	75.0	T-9-12	90699	23	0 - 5	33.0
T-3-2	88637	23	0 - 5	112.0	T-9-13	90699	25	0 - 5	20.0
T-3-3	88637	25	0 - 5	26.0	T-9-14	90699	27	0 - 5	64.0
T-4-1	88637	27	0 - 5	15.0	T-9-15	90699	29	0 - 5	34.0
T-4-2	88594	1	0 - 5	50.5	T-9-16	90699	31	0 - 5	95.0
T-4-3	88594	3	0 - 5	75.0	T-9-17	90862	15	0 - 5	27.0
T-4-4	88594	5	0 - 5	65.0	T-9-18	90862	17	0 - 5	56.6
T-4-5	88594	7	0 - 5	104.0	T-10-1	88594	59	0 - 5	31.0
T-4-6	88594	9	0 - 5	62.0	T-10-2	88594	61	0 - 5	37.0
T-5-1	88594	11	0 - 5	17.0	T-10-3	88594	63	0 - 5	13.0
T-5-2	88594	13	0 - 5	20.0	T-11-1	90699	33	0 - 5	75.0
T-5-3	88594	15	0 - 5	123.0	T-11-2	90699	35	0 - 5	16.0
T-5-4	88594	17	0 - 5	14.0	T-11-3	90699	37	0 - 5	60.0
T-5-5	88594	19	0 - 5	18.0	T-11-4	90699	39	0 - 5	131.0
T-5-6	88594	21	0 - 5	11.0	T-11-5	90699	41	0 - 5	12.0
T-5-7	88594	23	0 - 5	57.5	T-11-6	90699	43	0 - 5	34.0
T-6-1	88594	25	0 - 5	17.0	T-12-1	90699	45	0 - 5	32.0
T-6-2	88594	27	0 - 5	12.0	T-12-2	90699	47	0 - 5	85.0
T-6-3	88594	29	0 - 5	12.0	T-12-3	90699	49	0 - 5	30.0
T-6-4	88594	31	0 - 5	56.0	T-12-4	90699	51	0 - 5	75.0
T-6-5	88594	33	0 - 5	11.0	T-12-5	90699	53	0 - 5	29.0
T-6-6	88594	35	0 - 5	39.0	T-13-1	90699	55	0 - 5	133.0
T-6-7	88594	37	0 - 5	29.0	T-13-2	90699	57	0 - 5	46.0
T-6-8	88594	39	0 - 5	41.0	T-13-3	90699	59	0 - 5	133.0
T-6-9	88594	41	0 - 5	60.0	T-13-4	90699	61	0 - 5	66.0
T-6-10	88594	43	0 - 5	56.9	T-13-5	90699	63	0 - 5	25.0
T-7-1	88594	45	0 - 5	19.0	T-14-1	88594	65	0 - 5	18.0
T-7-2	88594	47	0 - 5	40.0	T-14-2	88594	67	0 - 5	19.0
T-7-3	88594	49	0 - 5	33.0	T-14-3	88594	69	0 - 5	54.9
T-7-4	88594	51	0 - 5	36.0	T-14-4	88594	71	0 - 5	29.0
T-8-1	88594	53	0 - 5	27.0	T-15-1	88637	29	0 - 5	22.0
T-8-2	88594	55	0 - 5	10.0	T-15-2	88637	31	0 - 5	5.1

[z] T = transect; first number is the transect number; second number is the sample-point number within a transect.

Table A3.1. Soil-test phosphorus value for 0- to 5-cm layer soil samples from the M1 subbasin (Page 2 of 4).

Sample ID[z]	Lab lot no.	Lab no. within lot no.	Soil layer (cm)	Soil-test phosphorus (mg kg^{-1})	Sample ID[z]	Lab lot no.	Lab no. within lot no.	Soil layer (cm)	Soil-test phosphorus (mg kg^{-1})
T-15-3	88637	33	0 - 5	6.8	T-21-6	88594	95	0 - 5	29.0
T-15-4	88637	35	0 - 5	5.4	T-21-7	88594	97	0 - 5	40.0
T-15-5	88637	37	0 - 5	35.0	T-22-1	88594	99	0 - 5	32.0
T-15-6	88637	39	0 - 5	9.0	T-22-2	88594	101	0 - 5	61.0
T-15-7	88637	41	0 - 5	101.0	T-22-3	88594	103	0 - 5	26.0
T-16-1	88594	73	0 - 5	23.0	T-23-1	89667	5	0 - 5	106.0
T-16-2	88594	75	0 - 5	58.2	T-23-2	89667	7	0 - 5	35.0
T-16-3	88594	77	0 - 5	56.8	T-23-3	89667	9	0 - 5	96.0
T-16-4	88594	79	0 - 5	67.0	T-23-4	89667	11	0 - 5	41.0
T-16-5	88594	81	0 - 5	43.0	T-23-5	89667	13	0 - 5	57.5
T-16-6	88594	83	0 - 5	67.0	T-23-6	89667	15	0 - 5	62.0
T-17-1	90431	3	0 - 5	63.0	T-23-7	89667	17	0 - 5	20.0
T-17-2	90431	5	0 - 5	63.0	T-24-1	90431	47	0 - 5	24.0
T-17-3	90431	7	0 - 5	73.0	T-24-2	90431	49	0 - 5	28.0
T-17-4	90431	9	0 - 5	63.0	T-24-3	90431	51	0 - 5	48.0
T-17-5	90431	11	0 - 5	118.0	T-24-4	90431	53	0 - 5	56.9
T-17-6	90431	13	0 - 5	63.0	T-24-5	90431	55	0 - 5	61.0
T-18-1	90699	65	0 - 5	51.7	T-24-6	90431	57	0 - 5	52.5
T-18-2	90699	67	0 - 5	34.0	T-24-7	90431	59	0 - 5	36.0
T-18-3	90699	69	0 - 5	43.0	T-24-8	90431	61	0 - 5	24.0
T-18-4	90699	71	0 - 5	69.0	T-25-1	88637	43	0 - 5	7.8
T-18-5	90699	73	0 - 5	112.0	T-25-2	88637	45	0 - 5	48.0
T-18-6	90699	75	0 - 5	118.0	T-25-3	88637	47	0 - 5	9.5
T-18-7	90431	15	0 - 5	133.0	T-25-4	88637	49	0 - 5	85.0
T-18-8	90431	17	0 - 5	56.7	T-25-5	88637	51	0 - 5	119.0
T-19-1	90431	19	0 - 5	33.0	T-25-6	88637	53	0 - 5	135.0
T-19-2	90431	21	0 - 5	20.0	T-25-7	88637	55	0 - 5	139.0
T-19-3	90431	23	0 - 5	39.0	T-25-8	88637	57	0 - 5	256.0
T-19-4	90431	25	0 - 5	57.9	T-26-1	88637	59	0 - 5	271.0
T-19-5	90431	27	0 - 5	70.0	T-26-2	88637	61	0 - 5	105.0
T-19-6	90431	29	0 - 5	70.0	T-26-3	88637	63	0 - 5	54.0
T-19-7	90431	31	0 - 5	56.7	T-26-4	88637	65	0 - 5	96.0
T-19-8	90431	33	0 - 5	62.0	T-26-5	88637	67	0 - 5	22.0
T-19-9	90431	35	0 - 5	138.0	T-26-6	88637	69	0 - 5	54.9
T-19-10	90431	37	0 - 5	321.0	T-27-1	89667	19	0 - 5	12.0
T-19-11	90431	39	0 - 5	468.0	T-27-2	89667	21	0 - 5	44.0
T-20-1	90431	41	0 - 5	483.0	T-27-3	89667	23	0 - 5	64.0
T-20-2	90431	43	0 - 5	21.0	T-27-4	89667	25	0 - 5	63.0
T-20-3	90431	45	0 - 5	26.0	T-27-5	89667	27	0 - 5	58.5
T-21-1	88594	85	0 - 5	46.0	T-27-6	89667	29	0 - 5	70.0
T-21-2	88594	87	0 - 5	50.0	T-27-7	89667	31	0 - 5	58.9
T-21-3	88594	89	0 - 5	59.9	T-27-8	89667	33	0 - 5	14.0
T-21-4	88594	91	0 - 5	59.7	T-27-9	89667	35	0 - 5	26.0
T-21-5	88594	93	0 - 5	20.0	T-27-10	89667	37	0 - 5	21.0

[z] T = transect; first number is the transect number; second number is the sample-point number within a transect.

Table A3.1. Soil-test phosphorus value for 0- to 5-cm layer soil samples from the M1 subbasin (Page 3 of 4).

Sample ID[z]	Lab lot no.	Lab no. within lot no.	Soil layer (cm)	Soil-test phosphorus (mg kg^{-1})	Sample ID[z]	Lab lot no.	Lab no. within lot no.	Soil layer (cm)	Soil-test phosphorus (mg kg^{-1})
T-27-11	89667	39	0 - 5	19.0	T-35-7	90862	31	0 - 5	23.0
T-27-12	89667	41	0 - 5	2.5	T-35-8	90862	33	0 - 5	35.0
T-27-13	89667	43	0 - 5	9.2	T-35-9	90862	35	0 - 5	28.0
T-27-14	89667	45	0 - 5	39.0	T-35-10	90862	37	0 - 5	16.0
T-28-1	88594	105	0 - 5	21.0	T-36-1	90699	85	0 - 5	64.0
T-28-2	88594	107	0 - 5	18.0	T-36-2	90699	87	0 - 5	68.0
T-28-3	88594	109	0 - 5	16.0	T-36-3	90699	89	0 - 5	45.0
T-28-4	88637	71	0 - 5	25.0	T-36-4	90699	91	0 - 5	74.0
T-28-5	88637	73	0 - 5	16.0	T-37-1	90699	93	0 - 5	37.0
T-28-6	88637	75	0 - 5	39.0	T-37-2	90699	95	0 - 5	60.0
T-29-1	90431	63	0 - 5	40.0	T-37-3	90699	97	0 - 5	33.0
T-29-2	90431	65	0 - 5	20.0	T-37-4	90699	99	0 - 5	20.0
T-29-3	90431	67	0 - 5	27.0	T-37-5	90699	101	0 - 5	50.5
T-29-4	90431	69	0 - 5	69.0	T-37-6	90699	103	0 - 5	39.0
T-29-5	90431	71	0 - 5	19.0	T-38-1	90862	39	0 - 5	24.0
T-29-6	90431	73	0 - 5	58.7	T-38-2	90699	105	0 - 5	50.5
T-29-7	90431	75	0 - 5	52.2	T-38-3	90699	107	0 - 5	18.0
T-30-1	90431	77	0 - 5	28.0	T-38-4	90699	109	0 - 5	41.0
T-30-2	90431	79	0 - 5	61.0	T-38-5	90699	111	0 - 5	22.0
T-30-3	90431	81	0 - 5	82.0	T-38-6	90699	113	0 - 5	19.0
T-30-4	90431	83	0 - 5	20.0	T-38-7	90699	115	0 - 5	46.0
T-31-1	90431	85	0 - 5	82.0	T-38-8	90699	117	0 - 5	17.0
T-31-2	90431	87	0 - 5	27.0	T-39-1	90862	41	0 - 5	22.0
T-31-3	90431	89	0 - 5	56.8	T-39-2	90862	43	0 - 5	53.3
T-32-1	90431	91	0 - 5	58.3	T-39-3	90862	45	0 - 5	96.0
T-32-2	90431	93	0 - 5	126.0	T-39-4	90862	47	0 - 5	74.0
T-32-3	90431	95	0 - 5	58.4	T-39-5	90862	49	0 - 5	42.0
T-32-4	90431	97	0 - 5	34.0	T-39-6	90862	51	0 - 5	43.0
T-33-1	90431	99	0 - 5	60.0	T-39-7	90862	53	0 - 5	56.6
T-33-2	90431	101	0 - 5	56.2	T-40-1	89667	47	0 - 5	19.0
T-33-3	90431	103	0 - 5	54.0	T-40-2	89667	49	0 - 5	18.0
T-33-4	90431	105	0 - 5	57.2	T-40-3	89667	51	0 - 5	15.0
T-33-5	90431	107	0 - 5	91.0	T-40-4	89667	53	0 - 5	15.0
T-33-6	90431	109	0 - 5	44.0	T-40-5	89667	55	0 - 5	8.4
T-34-1	90699	77	0 - 5	67.0	T-40-6	89667	57	0 - 5	37.0
T-34-2	90699	79	0 - 5	74.0	T-40-7	89667	59	0 - 5	43.0
T-34-3	90699	81	0 - 5	41.0	T-40-8	89667	61	0 - 5	10.0
T-34-4	90699	83	0 - 5	21.0	T-40-9	89667	63	0 - 5	8.8
T-35-1	90862	19	0 - 5	48.0	T-40-10	89667	65	0 - 5	34.0
T-35-2	90862	21	0 - 5	46.0	T-40-11	89667	67	0 - 5	13.0
T-35-3	90862	23	0 - 5	102.0	T-40-12	89667	69	0 - 5	26.0
T-35-4	90862	25	0 - 5	9.5	T-41-1	89667	71	0 - 5	28.0
T-35-5	90862	27	0 - 5	17.0	T-41-2	89667	73	0 - 5	23.0
T-35-6	90862	29	0 - 5	35.0	T-41-3	89667	75	0 - 5	16.0

[z] T = transect; first number is the transect number; second number is the sample-point number within a transect.

Table A3.1. Soil-test phosphorus value for 0- to 5-cm layer soil samples from the M1 subbasin (Page 4 of 4).

Sample ID[z]	Lab lot no.	Lab no. within lot no.	Soil layer (cm)	Soil-test phosphorus (mg kg^{-1})	Sample ID[z,y]	Lab lot no.	Lab no. within lot no.	Soil layer (cm)	Soil-test phosphorus (mg kg^{-1})
T-41-4	89667	77	0 - 5	36.0	T-48-7A	88637	127	0 - 5	46.0
T-41-5	89667	79	0 - 5	21.0	T-48-7B	88637	129	0 - 5	31.0
T-41-6	89667	81	0 - 5	13.0	T-48-9	88637	131	0 - 5	14.0
T-42-1	88637	77	0 - 5	30.0	T-49-1	89667	83	0 - 5	6.6
T-42-2	88637	79	0 - 5	17.0	T-49-2	89667	85	0 - 5	8.4
T-42-3	88637	81	0 - 5	17.0	T-49-3	89667	87	0 - 5	14.0
T-42-4	88637	83	0 - 5	11.0	T-49-4	89667	89	0 - 5	20.0
T-42-5	88637	85	0 - 5	32.0	T-49-5	89667	91	0 - 5	64.0
T-42-6	88637	87	0 - 5	10.0	T-49-6	89667	93	0 - 5	34.0
T-43-1	88637	89	0 - 5	123.0	T-49-7	89667	95	0 - 5	19.0
T-43-2	88637	91	0 - 5	18.0	T-49-8	89667	97	0 - 5	40.0
T-43-3	88637	93	0 - 5	15.0	T-49-9	89667	99	0 - 5	23.0
T-43-4	88637	95	0 - 5	41.0	T-50-1	89667	101	0 - 5	14.0
T-43-5	88637	97	0 - 5	56.8	T-50-2	89667	103	0 - 5	12.0
T-44-1	90862	55	0 - 5	50.0	T-50-3	89667	105	0 - 5	30.0
T-44-2	90862	57	0 - 5	69.0	T-50-4	89667	107	0 - 5	14.0
T-44-3	90862	59	0 - 5	68.0	T-50-5	89667	109	0 - 5	14.0
T-44-4	90862	61	0 - 5	37.0	T-50-6	89667	111	0 - 5	11.0
T-44-5	90862	63	0 - 5	108.0	T-51-1	89667	113	0 - 5	453.0
T-44-6	90862	65	0 - 5	93.0	T-51-2	89667	115	0 - 5	29.0
T-44-7	90862	67	0 - 5	107.0	T-51-3	89667	117	0 - 5	110.0
T-45-1	88637	99	0 - 5	44.0	T-52-1	90862	75	0 - 5	34.0
T-45-2	88637	101	0 - 5	31.0	T-52-2	90862	77	0 - 5	42.0
T-45-3	88637	103	0 - 5	15.0	T-52-3	90862	79	0 - 5	44.0
T-45-4	88637	105	0 - 5	15.0	T-53-1	90862	81	0 - 5	19.0
T-45-5	90862	69	0 - 5	19.0	T-53-2	90862	83	0 - 5	36.0
T-45-6	90862	71	0 - 5	36.0	T-53-3	90862	85	0 - 5	11.0
T-45-7	90862	73	0 - 5	42.0	T-53-4	90862	87	0 - 5	30.0
T-46-1	90699	119	0 - 5	16.0	T-53-5	90862	89	0 - 5	9.1
T-46-2	90699	121	0 - 5	30.0	T-53-6	90862	91	0 - 5	79.0
T-46-3	90699	123	0 - 5	61.0	T-53-7	90862	93	0 - 5	15.0
T-46-4	90699	125	0 - 5	18.0	T-53-8	90862	95	0 - 5	53.4
T-46-5	90699	127	0 - 5	34.0	T-54-1	90862	97	0 - 5	19.0
T-46-6	90699	129	0 - 5	55.4	T-54-2	90862	99	0 - 5	22.0
T-46-7	90699	131	0 - 5	55.2	T-54-3	90862	101	0 - 5	14.0
T-47-1	88637	107	0 - 5	2.5	T-54-4	90862	103	0 - 5	40.0
T-47-2	88637	109	0 - 5	59.4	R1	90431	1	0 - 5	57.1
T-47-3	88637	111	0 - 5	24.0	R2	90862	1	0 - 5	30.0
T-47-4	88637	113	0 - 5	2.5	R3	90862	3	0 - 5	29.0
T-48-1	88637	115	0 - 5	26.0	R4	90862	5	0 - 5	27.0
T-48-2	88637	117	0 - 5	9.7	R5	90862	7	0 - 5	59.2
T-48-3	88637	119	0 - 5	11.0	R6	90862	9	0 - 5	19.0
T-48-4	88637	121	0 - 5	21.0	R7	90862	11	0 - 5	21.0
T-48-5	88637	123	0 - 5	20.0	R8	90862	13	0 - 5	27.0
T-48-6	88637	125	0 - 5	21.0					

[z] T = transect; first number is the transect number; second number is the sample-point number within a transect.
[y] R = riparian land.

Table A3.2. Soil-test phosphorus, extractable nitrate nitrogen (N), extractable potassium, and pH value for 0- to 15-cm layer soil samples from the M1 subbasin (Page 1 of 8).

Sample ID[z]	Lab lot no.	Lab no. within lot no.	Soil layer (cm)	Soil-test phosphorus (mg kg^{-1})	Extractable Nitrate N (mg kg^{-1})	Extractable potassium (mg kg^{-1})	pH
T-1-1	89667	2	0 - 15	32.0	2.1	373	6.5
T-1-2	89667	4	0 - 15	15.0	1.7	364	6.3
T-1-3	88637	2	0 - 15	20.0	4.5	286	6.2
T-1-4	88637	4	0 - 15	58.0	19.7	448	6.1
T-1-5	88637	6	0 - 15	14.0	2.8	164	6.4
T-1-6	88637	8	0 - 15	34.0	10.8	361	6.2
T-2-1	88637	10	0 - 15	42.0	1.4	354	7.0
T-2-2	88637	12	0 - 15	15.0	1.2	325	6.4
T-2-3	88637	14	0 - 15	47.0	11.1	308	7.5
T-2-4	88637	16	0 - 15	28.0	4.0	261	6.3
T-2-5	88637	18	0 - 15	25.0	16.5	312	5.9
T-2-6	88637	20	0 - 15	11.0	2.0	169	6.4
T-3-1	88637	22	0 - 15	34.0	4.3	178	6.5
T-3-2	88637	24	0 - 15	73.0	6.2	160	6.5
T-3-3	88637	26	0 - 15	15.0	2.2	173	6.3
T-4-1	88637	28	0 - 15	13.0	1.2	126	6.5
T-4-2	88594	2	0 - 15	32.0	4.9	138	7.9
T-4-3	88594	4	0 - 15	45.0	9.4	196	6.1
T-4-4	88594	6	0 - 15	35.0	4.1	166	6.0
T-4-5	88594	8	0 - 15	70.0	18.8	195	7.6
T-4-6	88594	10	0 - 15	36.0	6.2	183	6.4
T-5-1	88594	12	0 - 15	8.5	2.7	157	7.6
T-5-2	88594	14	0 - 15	17.0	7.0	170	7.8
T-5-3	88594	16	0 - 15	64.0	18.8	421	8.0
T-5-4	88594	18	0 - 15	13.0	2.7	254	7.2
T-5-5	88594	20	0 - 15	14.0	6.4	183	7.5
T-5-6	88594	22	0 - 15	6.1	3.9	132	6.8
T-5-7	88594	24	0 - 15	41.0	5.3	172	7.1
T-6-1	88594	26	0 - 15	5.2	3.9	175	7.9
T-6-2	88594	28	0 - 15	7.0	10.8	171	5.8
T-6-3	88594	30	0 - 15	7.7	8.6	174	6.0
T-6-4	88594	32	0 - 15	50.8	30.2	270	6.0
T-6-5	88594	34	0 - 15	6.8	15.4	155	6.2
T-6-6	88594	36	0 - 15	18.0	16.4	127	6.3
T-6-7	88594	38	0 - 15	12.0	9.7	125	6.0
T-6-8	88594	40	0 - 15	21.0	14.3	127	6.1
T-6-9	88594	42	0 - 15	29.0	13.8	155	7.6
T-6-10	88594	44	0 - 15	19.0	6.0	143	6.6
T-7-1	88594	46	0 - 15	13.0	8.4	166	6.1
T-7-2	88594	48	0 - 15	51.1	16.1	500	6.7
T-7-3	88594	50	0 - 15	19.0	8.8	235	6.8
T-7-4	88594	52	0 - 15	7.0	4.3	80	8.1
T-8-1	88594	54	0 - 15	21.0	2.9	160	8.0
T-8-2	88594	56	0 - 15	2.5	1.4	227	6.4

[z] T = transect; first number is the transect number; second number is the sample-point number within a transect.

Table A3.2. Soil-test phosphorus, extractable nitrate nitrogen (N), extractable potassium, and pH value for 0- to 15-cm layer soil samples from the M1 subbasin (Page 2 of 8).

Sample ID[z]	Lab lot no.	Lab no. within lot no.	Soil layer (cm)	Soil-test phosphorus (mg kg^{-1})	Extractable Nitrate N (mg kg^{-1})	Extractable potassium (mg kg^{-1})	pH
T-8-3	88594	58	0 - 15	18.0	2.5	186	7.9
T-9-1	90699	2	0 - 15	17.0	9.5	169	5.9
T-9-2	90699	4	0 - 15	13.0	13.4	159	6.2
T-9-3	90699	6	0 - 15	9.7	8.1	170	6.3
T-9-4	90699	8	0 - 15	7.8	6.2	113	6.2
T-9-5	90699	10	0 - 15	14.0	0.5	247	7.0
T-9-6	90699	12	0 - 15	10.0	5.1	598	6.5
T-9-7	90699	14	0 - 15	16.0	2.2	213	6.7
T-9-8	90699	16	0 - 15	24.0	6.3	316	7.7
T-9-9	90699	18	0 - 15	61.0	16.7	375	7.8
T-9-10	90699	20	0 - 15	18.0	0.5	210	6.2
T-9-11	90699	22	0 - 15	10.0	4.0	167	6.5
T-9-12	90699	24	0 - 15	25.0	1.3	228	7.9
T-9-13	90699	26	0 - 15	9.4	4.2	112	6.9
T-9-14	90699	28	0 - 15	44.0	5.4	223	8.0
T-9-15	90699	30	0 - 15	20.0	3.4	321	6.2
T-9-16	90699	32	0 - 15	83.0	4.2	803	7.2
T-9-17	90862	16	0 - 15	22.0	0.5	200	7.9
T-9-18	90862	18	0 - 15	39.0	3.0	331	8.1
T-10-1	88594	60	0 - 15	29.0	4.0	199	6.7
T-10-2	88594	62	0 - 15	27.0	4.3	358	6.9
T-10-3	88594	64	0 - 15	7.7	1.9	141	5.9
T-11-1	90699	34	0 - 15	61.0	0.5	824	7.0
T-11-2	90699	36	0 - 15	12.0	0.5	474	6.8
T-11-3	90699	38	0 - 15	52.8	8.1	1120	6.9
T-11-4	90699	40	0 - 15	109.0	55.7	151	6.9
T-11-5	90699	42	0 - 15	8.4	0.5	634	6.5
T-11-6	90699	44	0 - 15	22.0	9.7	549	7.0
T-12-1	90699	46	0 - 15	18.0	8.3	200	6.2
T-12-2	90699	48	0 - 15	82.0	0.5	551	6.3
T-12-3	90699	50	0 - 15	27.0	6.3	234	6.0
T-12-4	90699	52	0 - 15	61.0	4.4	452	6.1
T-12-5	90699	54	0 - 15	24.0	28.0	234	5.8
T-13-1	90699	56	0 - 15	55.1	13.5	139	6.3
T-13-2	90699	58	0 - 15	21.0	4.3	103	6.0
T-13-3	90699	60	0 - 15	105.0	15.9	428	6.4
T-13-4	90699	62	0 - 15	30.0	21.1	131	5.9
T-13-5	90699	64	0 - 15	16.0	29.9	172	6.2
T-14-1	88594	66	0 - 15	9.0	2.0	110	8.2
T-14-2	88594	68	0 - 15	13.0	6.3	506	7.1
T-14-3	88594	70	0 - 15	32.0	19.6	307	6.2
T-14-4	88594	72	0 - 15	21.0	15.2	286	6.6
T-15-1	88637	30	0 - 15	12.0	3.1	87	8.5
T-15-2	88637	32	0 - 15	2.5	1.6	158	6.1

[z] T = transect; first number is the transect number; second number is the sample-point number within a transect.

Table A3.2. Soil-test phosphorus, extractable nitrate nitrogen (N), extractable potassium, and pH value for 0- to 15-cm layer soil samples from the M1 subbasin (Page 3 of 8).

Sample ID[z]	Lab lot no.	Lab no. within lot no.	Soil layer (cm)	Soil-test phosphorus (mg kg^{-1})	Extractable Nitrate N (mg kg^{-1})	Extractable potassium (mg kg^{-1})	pH
T-15-3	88637	34	0 - 15	2.5	2.0	114	6.8
T-15-4	88637	36	0 - 15	2.5	2.1	154	6.9
T-15-5	88637	38	0 - 15	16.0	3.9	207	8.4
T-15-6	88637	40	0 - 15	5.8	5.7	175	8.1
T-15-7	88637	42	0 - 15	19.0	16.5	935	6.6
T-16-1	88594	74	0 - 15	11.0	5.9	105	7.9
T-16-2	88594	76	0 - 15	35.0	29.5	148	6.4
T-16-3	88594	78	0 - 15	28.0	25.3	265	7.0
T-16-4	88594	80	0 - 15	55.0	28.0	346	7.6
T-16-5	88594	82	0 - 15	26.0	16.0	322	5.8
T-16-6	88594	84	0 - 15	51.2	12.7	242	7.4
T-17-1	90431	4	0 - 15	33.0	32.9	215	6.5
T-17-2	90431	6	0 - 15	55.8	32.0	286	7.3
T-17-3	90431	8	0 - 15	49.0	39.0	779	6.6
T-17-4	90431	10	0 - 15	43.0	27.0	166	7.3
T-17-5	90431	12	0 - 15	63.0	25.5	159	7.5
T-17-6	90431	14	0 - 15	16.0	3.9	216	7.9
T-18-1	90699	66	0 - 15	18.0	29.5	198	5.7
T-18-2	90699	68	0 - 15	22.0	8.1	211	7.5
T-18-3	90699	70	0 - 15	32.0	1.4	171	6.1
T-18-4	90699	72	0 - 15	48.0	0.5	517	6.0
T-18-5	90699	74	0 - 15	56.0	2.0	367	5.9
T-18-6	90699	76	0 - 15	85.0	0.5	324	5.9
T-18-7	90431	16	0 - 15	61.0	39.7	930	6.4
T-18-8	90431	18	0 - 15	24.0	1.6	257	6.1
T-19-1	90431	20	0 - 15	27.0	6.0	225	7.2
T-19-2	90431	22	0 - 15	14.0	3.2	282	7.3
T-19-3	90431	24	0 - 15	30.0	6.9	207	7.8
T-19-4	90431	26	0 - 15	28.0	1.7	303	7.0
T-19-5	90431	28	0 - 15	47.0	0.5	366	6.7
T-19-6	90431	30	0 - 15	103.0	3.9	210	7.8
T-19-7	90431	32	0 - 15	58.9	16.2	337	7.7
T-19-8	90431	34	0 - 15	59.5	3.6	461	6.8
T-19-9	90431	36	0 - 15	78.0	0.5	361	6.0
T-19-10	90431	38	0 - 15	273.0	0.5	180	6.5
T-19-11	90431	40	0 - 15	62.0	2.6	164	7.5
T-20-1	90431	42	0 - 15	28.0	0.5	194	6.5
T-20-2	90431	44	0 - 15	7.2	1.2	217	6.8
T-20-3	90431	46	0 - 15	12.0	2.2	94	7.9
T-21-1	88594	86	0 - 15	27.0	13.7	119	6.1
T-21-2	88594	88	0 - 15	19.0	6.8	158	6.1
T-21-3	88594	90	0 - 15	30.0	16.7	213	6.0
T-21-4	88594	92	0 - 15	46.0	18.0	284	6.3
T-21-5	88594	94	0 - 15	9.3	10.6	145	6.2

[z] T = transect; first number is the transect number; second number is the sample-point number within a transect.

Table A3.2. Soil-test phosphorus, extractable nitrate nitrogen (N), extractable potassium, and pH value for 0- to 15-cm layer soil samples from the M1 subbasin (Page 4 of 8).

Sample ID[z]	Lab lot no.	Lab no. within lot no.	Soil layer (cm)	Soil-test phosphorus (mg kg^{-1})	Extractable Nitrate N (mg kg^{-1})	Extractable potassium (mg kg^{-1})	pH
T-21-6	88594	96	0 - 15	18.0	17.2	165	5.9
T-21-7	88594	98	0 - 15	28.0	22.4	145	7.8
T-22-1	88594	100	0 - 15	23.0	70.5	138	7.7
T-22-2	88594	102	0 - 15	44.0	16.3	156	5.7
T-22-3	88594	104	0 - 15	16.0	17.0	172	5.8
T-23-1	89667	6	0 - 15	70.0	4.8	304	7.7
T-23-2	89667	8	0 - 15	19.0	8.0	143	6.2
T-23-3	89667	10	0 - 15	68.0	13.9	155	7.9
T-23-4	89667	12	0 - 15	31.0	7.4	170	6.3
T-23-5	89667	14	0 - 15	39.0	8.0	148	6.3
T-23-6	89667	16	0 - 15	55.2	14.1	321	6.4
T-23-7	89667	18	0 - 15	13.0	23.9	129	7.1
T-24-1	90431	48	0 - 15	20.0	8.4	138	7.4
T-24-2	90431	50	0 - 15	14.0	5.1	127	6.5
T-24-3	90431	52	0 - 15	23.0	5.5	229	6.5
T-24-4	90431	54	0 - 15	30.0	6.0	218	6.1
T-24-5	90431	56	0 - 15	63.0	14.0	299	7.3
T-24-6	90431	58	0 - 15	32.0	8.2	216	6.1
T-24-7	90431	60	0 - 15	24.0	8.9	217	6.0
T-24-8	90431	62	0 - 15	13.0	5.7	252	6.7
T-25-1	88637	44	0 - 15	7.4	12.0	167	7.9
T-25-2	88637	46	0 - 15	44.0	1.0	454	6.6
T-25-3	88637	48	0 - 15	7.6	6.7	141	6.6
T-25-4	88637	50	0 - 15	32.0	12.5	193	6.6
T-25-5	88637	52	0 - 15	53.0	1.9	362	6.9
T-25-6	88637	54	0 - 15	101.0	55.5	798	6.1
T-25-7	88637	56	0 - 15	35.0	8.4	363	6.4
T-25-8	88637	58	0 - 15	237.0	3.5	452	6.9
T-26-1	88637	60	0 - 15	196.0	79.3	319	6.0
T-26-2	88637	62	0 - 15	54.8	71.2	260	5.9
T-26-3	88637	64	0 - 15	54.0	107.0	259	7.2
T-26-4	88637	66	0 - 15	16.0	2.8	173	6.2
T-26-5	88637	68	0 - 15	7.9	1.2	223	6.0
T-26-6	88637	70	0 - 15	22.0	4.6	160	7.8
T-27-1	89667	20	0 - 15	9.7	0.5	126	6.5
T-27-2	89667	22	0 - 15	27.0	0.5	143	7.7
T-27-3	89667	24	0 - 15	63.0	0.5	186	6.5
T-27-4	89667	26	0 - 15	54.6	0.5	291	6.3
T-27-5	89667	28	0 - 15	41.0	0.5	533	6.7
T-27-6	89667	30	0 - 15	103.0	2.2	474	6.5
T-27-7	89667	32	0 - 15	29.0	0.5	268	6.5
T-27-8	89667	34	0 - 15	6.6	0.5	461	6.4
T-27-9	89667	36	0 - 15	15.0	2.5	322	6.9
T-27-10	89667	38	0 - 15	8.9	0.5	329	6.7

[z] T = transect; first number is the transect number; second number is the sample-point number within a transect.

Table A3.2. Soil-test phosphorus, extractable nitrate nitrogen (N), extractable potassium, and pH value for 0- to 15-cm layer soil samples from the M1 subbasin (Page 5 of 8).

Sample ID[z]	Lab lot no.	Lab no. within lot no.	Soil layer (cm)	Soil-test phosphorus (mg kg^{-1})	Extractable Nitrate N (mg kg^{-1})	Extractable potassium (mg kg^{-1})	pH
T-27-11	89667	40	0 - 15	7.7	0.5	311	6.4
T-27-12	89667	42	0 - 15	2.5	0.5	143	8.0
T-27-13	89667	44	0 - 15	6.5	1.9	168	6.5
T-27-14	89667	46	0 - 15	24.0	48.2	198	7.7
T-28-1	88594	106	0 - 15	11.0	1.6	112	5.9
T-28-2	88594	108	0 - 15	15.0	8.2	134	7.4
T-28-3	88594	110	0 - 15	8.2	4.1	266	5.9
T-28-4	88637	72	0 - 15	15.0	8.2	123	6.7
T-28-5	88637	74	0 - 15	5.9	4.9	193	6.1
T-28-6	88637	76	0 - 15	23.0	2.5	61	7.0
T-29-1	90431	64	0 - 15	32.0	1.6	109	5.5
T-29-2	90431	66	0 - 15	12.0	1.4	86	5.7
T-29-3	90431	68	0 - 15	18.0	5.3	185	7.3
T-29-4	90431	70	0 - 15	23.0	1.6	278	6.3
T-29-5	90431	72	0 - 15	15.0	18.3	136	5.7
T-29-6	90431	74	0 - 15	49.0	15.5	147	6.2
T-29-7	90431	76	0 - 15	43.0	7.6	192	7.4
T-30-1	90431	78	0 - 15	24.0	16.6	230	6.1
T-30-2	90431	80	0 - 15	61.0	25.2	186	6.1
T-30-3	90431	82	0 - 15	62.0	30.7	247	6.4
T-30-4	90431	84	0 - 15	17.0	19.1	134	5.9
T-31-1	90431	86	0 - 15	55.3	8.9	339	5.8
T-31-2	90431	88	0 - 15	9.1	0.5	124	6.3
T-31-3	90431	90	0 - 15	58.8	7.8	217	7.4
T-32-1	90431	92	0 - 15	57.3	10.3	444	6.3
T-32-2	90431	94	0 - 15	108.0	16.7	595	6.3
T-32-3	90431	96	0 - 15	52.9	0.5	247	5.8
T-32-4	90431	98	0 - 15	30.0	4.0	217	7.0
T-33-1	90431	100	0 - 15	59.0	30.4	214	7.1
T-33-2	90431	102	0 - 15	48.0	18.2	192	6.3
T-33-3	90431	104	0 - 15	41.0	29.0	237	5.9
T-33-4	90431	106	0 - 15	47.0	25.6	194	5.8
T-33-5	90431	108	0 - 15	60.0	32.0	239	6.2
T-33-6	90431	110	0 - 15	33.0	11.0	239	7.3
T-34-1	90699	78	0 - 15	58.3	4.4	126	6.3
T-34-2	90699	80	0 - 15	72.0	27.6	289	5.8
T-34-3	90699	82	0 - 15	26.0	7.0	205	6.8
T-34-4	90699	84	0 - 15	14.0	3.0	179	6.4
T-35-1	90862	20	0 - 15	14.0	1.4	111	6.4
T-35-2	90862	22	0 - 15	35.0	5.4	103	5.8
T-35-3	90862	24	0 - 15	81.0	15.8	299	6.0
T-35-4	90862	26	0 - 15	86.0	13.0	250	7.6
T-35-5	90862	28	0 - 15	11.0	1.6	116	7.6
T-35-6	90862	30	0 - 15	30.0	4.3	181	7.2

[z] T = transect; first number is the transect number; second number is the sample-point number within a transect.

Table A3.2. Soil-test phosphorus, extractable nitrate nitrogen (N), extractable potassium, and pH value for 0- to 15-cm layer soil samples from the M1 subbasin (Page 6 of 8).

Sample ID[z]	Lab lot no.	Lab no. within lot no.	Soil layer (cm)	Soil-test phosphorus ($mg\ kg^{-1}$)	Extractable Nitrate N ($mg\ kg^{-1}$)	Extractable potassium ($mg\ kg^{-1}$)	pH
T-35-7	90862	32	0 - 15	24.0	2.4	246	7.2
T-35-8	90862	34	0 - 15	32.0	3.0	178	7.8
T-35-9	90862	36	0 - 15	11.0	0.5	266	6.7
T-35-10	90862	38	0 - 15	21.0	2.2	123	7.8
T-36-1	90699	86	0 - 15	30.0	3.6	178	6.3
T-36-2	90699	88	0 - 15	59.3	8.2	108	6.3
T-36-3	90699	90	0 - 15	38.0	13.8	122	6.8
T-36-4	90699	92	0 - 15	72.0	7.3	457	7.1
T-37-1	90699	94	0 - 15	33.0	14.7	304	7.4
T-37-2	90699	96	0 - 15	57.0	19.6	214	5.8
T-37-3	90699	98	0 - 15	29.0	14.3	188	5.8
T-37-4	90699	100	0 - 15	19.0	9.7	180	5.9
T-37-5	90699	102	0 - 15	50.5	21.4	234	6.4
T-37-6	90699	104	0 - 15	30.0	17.0	224	6.7
T-38-1	90862	40	0 - 15	15.0	2.9	102	7.4
T-38-2	90699	106	0 - 15	21.0	3.7	154	6.2
T-38-3	90699	108	0 - 15	12.0	9.3	93	7.2
T-38-4	90699	110	0 - 15	16.0	3.1	246	6.2
T-38-5	90699	112	0 - 15	11.0	6.1	104	6.7
T-38-6	90699	114	0 - 15	2.5	1.1	115	6.0
T-38-7	90699	116	0 - 15	29.0	10.9	161	7.2
T-38-8	90699	118	0 - 15	11.0	4.0	137	5.9
T-39-1	90862	42	0 - 15	8.8	4.5	114	6.5
T-39-2	90862	44	0 - 15	21.0	21.8	102	6.4
T-39-3	90862	46	0 - 15	62.0	5.7	153	7.9
T-39-4	90862	48	0 - 15	63.0	9.9	141	7.8
T-39-5	90862	50	0 - 15	28.0	27.1	109	6.1
T-39-6	90862	52	0 - 15	20.0	30.8	150	5.9
T-39-7	90862	54	0 - 15	52.1	2.7	257	7.2
T-40-1	89667	48	0 - 15	18.0	0.5	137	7.5
T-40-2	89667	50	0 - 15	13.0	6.0	131	7.5
T-40-3	89667	52	0 - 15	13.0	7.8	216	6.2
T-40-4	89667	54	0 - 15	13.0	2.4	180	6.5
T-40-5	89667	56	0 - 15	28.0	15.7	342	6.4
T-40-6	89667	58	0 - 15	49.0	14.0	150	7.8
T-40-7	89667	60	0 - 15	15.0	1.5	233	7.9
T-40-8	89667	62	0 - 15	9.7	0.5	193	6.3
T-40-9	89667	64	0 - 15	6.0	11.3	88	6.7
T-40-10	89667	66	0 - 15	31.0	40.7	188	7.3
T-40-11	89667	68	0 - 15	9.7	14.7	106	6.7
T-40-12	89667	70	0 - 15	24.0	5.7	160	7.4
T-41-1	89667	72	0 - 15	15.0	3.8	116	6.0
T-41-2	89667	74	0 - 15	17.0	8.3	140	5.9
T-41-3	89667	76	0 - 15	8.1	5.2	133	6.2

[z] T = transect; first number is the transect number; second number is the sample-point number within a transect.

Table A3.2. Soil-test phosphorus, extractable nitrate nitrogen (N), extractable potassium, and pH value for 0- to 15-cm layer soil samples from the M1 subbasin (Page 7 of 8).

Sample ID[z]	Lab lot no.	Lab no. within lot no.	Soil layer (cm)	Soil-test phosphorus (mg kg^{-1})	Extractable Nitrate N (mg kg^{-1})	Extractable potassium (mg kg^{-1})	pH
T-41-4	89667	78	0 - 15	29.0	9.9	317	6.1
T-41-5	89667	80	0 - 15	18.0	4.8	109	7.7
T-41-6	89667	82	0 - 15	9.3	1.3	168	7.3
T-42-1	88637	78	0 - 15	18.0	5.0	177	7.4
T-42-2	88637	80	0 - 15	10.0	22.9	152	5.9
T-42-3	88637	82	0 - 15	11.0	9.1	168	5.8
T-42-4	88637	84	0 - 15	7.2	7.3	129	6.2
T-42-5	88637	86	0 - 15	26.0	19.7	223	5.5
T-42-6	88637	88	0 - 15	8.3	10.0	158	6.4
T-43-1	88637	90	0 - 15	88.0	11.9	589	6.9
T-43-2	88637	92	0 - 15	11.0	10.7	145	6.0
T-43-3	88637	94	0 - 15	12.0	14.1	159	5.9
T-43-4	88637	96	0 - 15	29.0	5.8	198	7.5
T-43-5	88637	98	0 - 15	49.0	2.8	143	7.7
T-44-1	90862	56	0 - 15	45.0	31.9	137	5.7
T-44-2	90862	58	0 - 15	60.0	9.3	128	5.7
T-44-3	90862	60	0 - 15	55.7	9.3	212	6.7
T-44-4	90862	62	0 - 15	23.0	7.2	131	6.0
T-44-5	90862	64	0 - 15	77.0	53.1	261	5.7
T-44-6	90862	66	0 - 15	49.0	1.9	219	7.0
T-44-7	90862	68	0 - 15	86.0	16.3	135	5.9
T-45-1	88637	100	0 - 15	47.0	5.8	273	6.7
T-45-2	88637	102	0 - 15	19.0	12.5	148	5.7
T-45-3	88637	104	0 - 15	8.6	1.6	150	6.2
T-45-4	88637	106	0 - 15	12.0	0.5	137	6.1
T-45-5	90862	70	0 - 15	12.0	2.0	120	6.2
T-45-6	90862	72	0 - 15	28.0	22.0	193	5.8
T-45-7	90862	74	0 - 15	28.0	0.5	274	6.3
T-46-1	90699	120	0 - 15	10.0	1.7	101	5.8
T-46-2	90699	122	0 - 15	29.0	6.0	103	6.5
T-46-3	90699	124	0 - 15	47.0	14.7	263	6.0
T-46-4	90699	126	0 - 15	15.0	6.5	96	6.2
T-46-5	90699	128	0 - 15	37.0	12.2	217	6.1
T-46-6	90699	130	0 - 15	54.7	27.0	459	6.3
T-46-7	90699	132	0 - 15	52.0	6.3	453	6.5
T-47-1	88637	108	0 - 15	9.6	2.3	141	6.5
T-47-2	88637	110	0 - 15	54.5	11.7	319	6.5
T-47-3	88637	112	0 - 15	16.0	3.4	276	6.6
T-47-4	88637	114	0 - 15	2.5	0.5	147	6.8
T-48-1	88637	116	0 - 15	14.0	3.5	163	6.8
T-48-2	88637	118	0 - 15	5.5	0.5	135	6.0
T-48-3	88637	120	0 - 15	2.5	0.5	153	6.3
T-48-4	88637	122	0 - 15	9.1	0.5	93	5.8
T-48-5	88637	124	0 - 15	11.0	0.5	140	5.8

[z] T = transect; first number is the transect number; second number is the sample-point number within a transect.

Table A3.2. Soil-test phosphorus, extractable nitrate nitrogen (N), extractable potassium, and pH value for 0- to 15-cm layer soil samples from the M1 subbasin (Page 8 of 8).

Sample ID[z,y]	Lab lot no.	Lab no. within lot no.	Soil layer (cm)	Soil-test phosphorus (mg kg^{-1})	Extractable Nitrate N (mg kg^{-1})	Extractable potassium (mg kg^{-1})	pH
T-48-6	88637	126	0 - 15	5.5	0.5	152	5.9
T-48-7(A)	88637	128	0 - 15	38.0	0.5	192	5.9
T-48-7(B)	88637	130	0 - 15	8.8	0.5	123	6.1
T-48-9	88637	132	0 - 15	5.1	0.5	139	6.2
T-49-1	89667	84	0 - 15	5.5	0.5	159	7.5
T-49-2	89667	86	0 - 15	2.5	0.5	148	6.7
T-49-3	89667	88	0 - 15	11.0	1.2	131	6.3
T-49-4	89667	90	0 - 15	17.0	0.5	121	6.2
T-49-5	89667	92	0 - 15	56.2	2.2	382	6.8
T-49-6	89667	94	0 - 15	22.0	4.1	216	7.0
T-49-7	89667	96	0 - 15	13.0	7.9	205	6.3
T-49-8	89667	98	0 - 15	42.0	4.5	148	7.7
T-49-9	89667	100	0 - 15	16.0	9.8	110	7.8
T-50-1	89667	102	0 - 15	9.0	2.6	141	6.5
T-50-2	89667	104	0 - 15	11.0	9.8	180	6.3
T-50-3	89667	106	0 - 15	25.0	1.4	197	7.5
T-50-4	89667	108	0 - 15	13.0	1.5	183	7.7
T-50-5	89667	110	0 - 15	10.0	0.5	252	7.4
T-50-6	89667	112	0 - 15	6.2	0.5	232	6.2
T-51-1	89667	114	0 - 15	358.0	1.9	489	7.2
T-51-2	89667	116	0 - 15	23.0	1.5	279	6.5
T-51-3	89667	118	0 - 15	138.0	0.5	551	7.7
T-52-1	90862	76	0 - 15	29.0	1.1	613	6.4
T-52-2	90862	78	0 - 15	37.0	2.8	188	7.9
T-52-3	90862	80	0 - 15	27.0	10.3	244	8.2
T-53-1	90862	82	0 - 15	7.2	0.5	191	6.6
T-53-2	90862	84	0 - 15	20.0	3.1	264	7.8
T-53-3	90862	86	0 - 15	8.2	2.5	276	7.1
T-53-4	90862	88	0 - 15	23.0	8.1	249	6.5
T-53-5	90862	90	0 - 15	6.0	1.1	261	6.3
T-53-6	90862	92	0 - 15	47.0	14.1	934	7.0
T-53-7	90862	94	0 - 15	9.2	0.5	239	6.4
T-53-8	90862	96	0 - 15	36.0	9.2	481	7.1
T-54-1	90862	98	0 - 15	11.0	0.5	272	6.9
T-54-2	90862	100	0 - 15	12.0	2.8	259	7.8
T-54-3	90862	102	0 - 15	9.6	3.6	295	7.7
T-54-4	90862	104	0 - 15	36.0	25.1	271	7.6
R1	90431	2	0 - 15	37.0	2.2	168	7.9
R2	90862	2	0 - 15	19.0	0.5	157	7.7
R3	90862	4	0 - 15	19.0	6.6	481	6.6
R4	90862	6	0 - 15	25.0	12.8	220	7.6
R5	90862	8	0 - 15	43.0	0.5	208	7.8
R6	90862	10	0 - 15	15.0	0.5	176	6.6
R7	90862	12	0 - 15	21.0	2.4	223	7.8
R8	90862	14	0 - 15	11.0	0.5	194	7.7

[z] T = transect; first number is the transect number; second number is the sample-point number within a transect.
[y] R = riparian land.

Table A3.3. Landscape and landuse information for each soil sampling site (Page 1 of 9).

Sample ID[z]	Landscape position[y]	Overall landscape position[y]	Slope aspect[x]	Slope curvature	Landuse type[w]	Manure intensity[v]
T-1-1	U	U	NW	Convex	P	T
T-1-2	U	U	S	Concave	P	N
T-1-3	U	U	W	Convex	A	N
T-1-4	M	M	S	Concave	A	N
T-1-5	M	L	NW	Convex	A	N
T-1-6	L	L	E	Concave	A	N
T-2-1	U	U	S/SW	Convex	P	Y
T-2-2	M	U	S	Concave	P	Y
T-2-3	R	R	SE	Concave	W	T
T-2-4	M	M	NE	Concave	A	Y
T-2-5	M	M	SW	Concave	A	Y
T-2-6	U	M	SW	Convex	A	Y
T-3-1	M	M	N / W	Convex	P	Y
T-3-2	L	M	N	Concave	P	Y
T-3-3	M	M	E	Concave	P	Y
T-4-1	U	M	SW	None	P	Y
T-4-2	L	L	SW	Concave	P	T
T-4-3	M	M	NE	None/Convex	A	Y
T-4-4	U	M	N	Convex	A	Y
T-4-5	L	M	NW	Concave	A	Y
T-4-6	U	M	N	Concave	A	Y
T-5-1	U	M	SW	Convex	P	Y
T-5-2	L	M	SW	Concave	P	Y
T-5-3	L	M	SW	Concave	P	T
T-5-4	U	M	SW	Convex	P	Y
T-5-5	U	M	SW	Convex	P	Y
T-5-6	M	M	NE	Concave	P	Y
T-5-7	L	M	NW	Concave	P	Y
T-6-1	R	R	E	Concave	A	T
T-6-2	M	M	SE	None	A	N
T-6-3	U	M	SW	Convex	A	N
T-6-4	U	M	SW	Concave	A	N
T-6-5	U	M	SW	Concave	A	N
T-6-6	U	M	E	Convex	A	Y
T-6-7	U	M	W	Convex	A	Y
T-6-8	U	M	NW	Convex	A	Y
T-6-9	U	M		Concave	A	Y
T-6-10	U	M	S	Convex	A	Y
T-7-1	U	U	SW	Concave to none	A	N
T-7-2	U	M	N	Concave	A	N

[z] T = transect; first number is the transect number; second number is the sample-point number within a transect.
[y] U = upper; M = mid; L = lower; D = depression.
[x] E = east; S = south; W = west; N = north.
[w] N = no manure; T = trace manure; Y = yes manure.
[v] A = annual crop; P = perennial crop; W = woodland.

Table A3.3. Landscape and landuse information for each soil sampling site (Page 2 of 9).

Sample ID[z]	Landscape position[y]	Overall landscape position[y]	Slope aspect[x]	Slope curvature	Landuse type[w]	Manure intensity[v]
T-7-3	M	M	SW	None	A	N
T-7-4	R	R	SE	Concave	P	T
T-8-1	R	R	SE	Concave	P	T
T-8-2	U	M	NE	Convex	P	T
T-8-3	L	L	SW	Concave	P	T
T-9-1	M	U	NE	None	A	Y
T-9-2	L	U	NE	Concave	A	Y
T-9-3	U	M	N	Convex	A	Y
T-9-4	M	M	NE	Concave	A	Y
T-9-5	L	M	NE	Concave	P	Y
T-9-6	L	M	N	None/Convex	W	T
T-9-7	U	M	NE	Convex	A	N
T-9-8	M	M	NE	Concave	A	N
T-9-9	M	M	N	Concave	A	N
T-9-10	U	M	NE	Convex	A	N
T-9-11	M	M	NE	Convex	A	N
T-9-12	R	M	N	Concave	A	N
T-9-13	M	M	N	Concave	A	N
T-9-14	R	R	N	Concave	P	N
T-9-15	M	L	NE	Concave	A	N
T-9-16	R	R	N	Concave	P	T
T-9-17	R	R	E	Concave	P	T
T-9-18	R	R	S	Concave	P	T
T-10-1	M	M	S	None	A	N
T-10-2	R	M	N	Concave	P	N
T-10-3	M	M	NE	Convex	A	N
T-11-1	U	U	N	Convex	P	Y
T-11-2	M	U	N	None/Concave	P	Y
T-11-3	M	U	N	Concave	P	Y
T-11-4	U	M	NE	Convex	P	Y
T-11-5	M	M	NE	Concave	P	Y
T-11-6	L	M	N	Concave	P	Y
T-12-1	U	U	NE	Convex	A	Y
T-12-2	M	U	NE	Concave	A	Y
T-12-3	M	U	NE	Concave	P	T
T-12-4	L	U	NE	Concave	P	T
T-12-5	L	U	NE	Concave	A	Y
T-13-1	U	U	NE	Convex	A	Y
T-13-2	M	U	NE	Convex	A	Y
T-13-3	L	U	NW	Concave	A	Y

[z] T = transect; first number is the transect number; second number is the sample-point number within a transect.
[y] U = upper; M = mid; L = lower; D = depression.
[x] E = east; S = south; W = west; N = north.
[w] N = no manure; T = trace manure; Y = yes manure.
[v] A = annual crop; P = perennial crop; W = woodland.

Table A3.3. Landscape and landuse information for each soil sampling site (Page 3 of 9).

Sample ID[z]	Landscape position[y]	Overall landscape position[y]	Slope aspect[x]	Slope curvature	Landuse type[w]	Manure intensity[v]
T-13-4	U	U	NE	Convex	A	Y
T-13-5	M	U	NE	Concave	A	Y
T-14-1	R	M	N	Concave	P	T
T-14-2	M	M	N	Convex	P	T
T-14-3	M	M	N	Convex	A	N
T-14-4	U	M	N	Convex	A	N
T-15-1	R	R	NE	Concave	P	T
T-15-2	L	L	N	Convex	P	T
T-15-3	L	L	N/NE	None	P	T
T-15-4	L	L	N	Concave	P	T
T-15-5	L	L	NE	Concave	P	T
T-15-6	M	L	NE	Concave	P	T
T-15-7	U	M	NE	Convex	P	T
T-16-1	L	L	SE	Concave	P	N
T-16-2	L	L	S	Concave	A	N
T-16-3	L	L	E	Convex	A	N
T-16-4	L	L	S	Concave	A	N
T-16-5	U	L	W	Concave	A	N
T-16-6	R	R	S	Concave	P	N
T-17-1	U	L	NE	Convex	A	Y
T-17-2	M	L	NE	Concave	A	Y
T-17-3	M	L	NE	Concave	A	Y
T-17-4	M	L	NE	Concave	A	Y
T-17-5	L	L	N	Concave	A	Y
T-17-6	R	R	S	Concave	P	T
T-18-1	U	L	NE	Convex	A	Y
T-18-2	R	R	S	Concave	P	T
T-18-3	M	M	SW	Convex	P	Y
T-18-4	U	L	SE	Convex	P	Y
T-18-5	U	M	SW	Concave	P	Y
T-18-6	U	M	SW	Convex	P	Y
T-18-7	M	M	SW	None/Concave	P	Y
T-18-8	U	M	SW	Convex	P	Y
T-19-1	R	R	S	Concave	P	T
T-19-2	L	R	NE	Convex	P	Y
T-19-3	R	R	S	Concave	P	T
T-19-4	R	R	SW	Convex	P	T
T-19-5	U	R	SW	Convex	P	Y
T-19-6	M	R	NW	Concave	P	Y
T-19-7	R	R	S	Concave	P	T

[z] T = transect; first number is the transect number; second number is the sample-point number within a transect.
[y] U = upper; M = mid; L = lower; D = depression.
[x] E = east; S = south; W = west; N = north.
[w] N = no manure; T = trace manure; Y = yes manure.
[v] A = annual crop; P = perennial crop; W = woodland.

Table A3.3. Landscape and landuse information for each soil sampling site (Page 4 of 9).

Sample ID[z]	Landscape position[y]	Overall landscape position[y]	Slope aspect[x]	Slope curvature	Landuse type[w]	Manure intensity[v]
T-19-8	M	R	SE	None	P	Y
T-19-9	U	L	SE	Convex	P	Y
T-19-10	M	L	SW	None/Concave	P	Y
T-19-11	R	R	S	Concave	P	T
T-20-1	U	L	SW	Convex	P	Y
T-20-2	L	L	SW	Concave	P	T
T-20-3	R	R	S	Concave	P	T
T-21-1	M	M	SE	Concave	A	Y
T-21-2	U	M	SW	Convex	A	Y
T-21-3	M	M	SW	Concave	A	Y
T-21-4	M	M	S	Concave	A	Y
T-21-5	U	M	S	Convex	A	Y
T-21-6	M	M	W	Concave	A	Y
T-21-7	R	R	S	Concave	W	N
T-22-1	R	R	S	Concave	P	N
T-22-2	M	M	NW	None	A	Y
T-22-3	U	M	W	Concave	A	Y
T-23-1	R	M	N	Concave	P	Y
T-23-2	M	M	NW	None	A	Y
T-23-3	M	M	NW	Concave	A	Y
T-23-4	M	M	NW	Concave	A	Y
T-23-5	U	M	NW	Convex	A	Y
T-23-6	L	M	SE	Concave	A	Y
T-23-7	R	R	E	Concave	W	T
T-24-1	R	R	E	Concave	W	T
T-24-2	M	R	SE	None	A	T
T-24-3	U	M	NE/S	Convex	A	Y
T-24-4	M	M	NW	Concave	A	Y
T-24-5	M	M	NW	Concave	A	Y
T-24-6	U	M	NW	Convex	A	Y
T-24-7	M	M	NW	Concave	A	Y
T-24-8	R	R	S	Concave	W	T
T-25-1	R	R	W	Concave	W	N
T-25-2	M	M	E	Concave	W	N
T-25-3	U	M	SW/S/SE	Convex	P	T
T-25-4	U	M	SE	Convex	P	T
T-25-5	U	M	S	Convex	P	T
T-25-6	M	M	S	Concave	P	T
T-25-7	U	U	SW	Convex	P	Y
T-25-8	U	U	SW	Concave	P	Y

[z] T = transect; first number is the transect number; second number is the sample-point number within a transect.
[y] U = upper; M = mid; L = lower; D = depression.
[x] E = east; S = south; W = west; N = north.
[w] N = no manure; T = trace manure; Y = yes manure.
[v] A = annual crop; P = perennial crop; W = woodland.

Table A3.3. Landscape and landuse information for each soil sampling site (Page 5 of 9).

Sample ID[z]	Landscape position[y]	Overall landscape position[y]	Slope aspect[x]	Slope curvature	Landuse type[w]	Manure intensity[v]
T-26-1	U	M	SE	Convex	A	Y
T-26-2	M	M	SE	Convex	A	Y
T-26-3	L	M	SE	Convex	A	Y
T-26-4	U	L	SE	Convex	P	Y
T-26-5	M	L	SE	Concave	P	Y
T-26-6	R	R	S	Concave	P	N
T-27-1	U	U	SW	Convex	P	N
T-27-2	M	U	S	Convex	P	N
T-27-3	L	U	SW	Concave	P	N
T-27-4	M	M	SE	Concave	W	N
T-27-5	M	M	SE	None	W	N
T-27-6	L	M	SE	Concave	W	N
T-27-7	U	M	SE	Convex	W	N
T-27-8	M	M	SE	None	W	N
T-27-9	R	L	S	Concave	W	N
T-27-10	U	L	S	Convex	W	N
T-27-11	M	L	S	Concave	W	N
T-27-12	R	R	S	Concave	W	N
T-27-13	L	R	E	Concave	P	N
T-27-14	L	R	SW	Concave	P	N
T-28-1	U	M	E	Concave	P	N
T-28-2	U	M	NE	Concave	P	N
T-28-3	U	M	E	Convex	P	N
T-28-4	L	M	SE	Concave	P	N
T-28-5	M	M	SE	Concave	P	N
T-28-6	R	L	SE	Concave	P	N
T-29-1	U	M	W	Convex	P	N
T-29-2	M	M	W	None	P	N
T-29-3	R	M	S	Concave	W	N
T-29-4	M	M	E	Convex	P	T
T-29-5	U	M	NE	Convex	A	Y
T-29-6	M	M	SW	Concave	A	Y
T-29-7	R	M	S/SE	Concave	P	Y
T-30-1	U	M	NE	Convex	A	Y
T-30-2	M	M	NE	None	A	Y
T-30-3	R	M	E	Concave	P	T
T-30-4	U	M	S	Convex	A	Y
T-31-1	U	M	E	Convex	P	T
T-31-2	M	M	E	None	P	T
T-31-3	L	M	S	Concave	P	T

[z] T = transect; first number is the transect number; second number is the sample-point number within a transect.
[y] U = upper; M = mid; L = lower; D = depression.
[x] E = east; S = south; W = west; N = north.
[w] N = no manure; T = trace manure; Y = yes manure.
[v] A = annual crop; P = perennial crop; W = woodland.

Table A3.3. Landscape and landuse information for each soil sampling site (Page 6 of 9).						
Sample ID[z]	Landscape position[y]	Overall landscape position[y]	Slope aspect[x]	Slope curvature	Landuse type[w]	Manure intensity[v]
T-32-1	U	M	W	Convex	P	T
T-32-2	M	M	W	Concave	P	T
T-32-3	M	M	W	None	P	T
T-32-4	R	M	S	Concave	P	T
T-33-1	L	L	E	Concave	A	Y
T-33-2	M	L	E	Concave	A	Y
T-33-3	U	L	NE/S	Convex	A	Y
T-33-4	U	L	SE	Convex	A	Y
T-33-5	M	L	SE	Concave	A	Y
T-33-6	R	L	SE	Concave	P	N
T-34-1	U	M	NE	Convex	A	Y
T-34-2	M	M	NE/E	None/Concave	A	Y
T-34-3	L	L	N	Concave	A	Y
T-34-4	L	L	E	Concave	P	N
T-35-1	U	U	NE	Convex	A	Y
T-35-2	M	U	NE	Convex	A	Y
T-35-3	M	U	N	Concave	A	T
T-35-4	R	M	N	Concave	A	Y
T-35-5	U	U	NE	Convex	A	Y
T-35-6	M	M	NE	Concave	A	Y
T-35-7	R	R	N	Concave	A	T
T-35-8	R	R	N	Concave	P	T
T-35-9	R	R	NW	Concave	W	T
T-35-10	R	R	N	Concave	P	T
T-36-1	L	U	N	Concave	A	Y
T-36-2	M	U	E	Concave	A	Y
T-36-3	M	U	E	Concave	A	N
T-36-4	U	U	E	Convex	A	N
T-37-1	R	L	E	Concave	P	N
T-37-2	M	L	NE	None	A	Y
T-37-3	U	L	NE	Convex	A	Y
T-37-4	U	L	S	Convex	A	Y
T-37-5	L	L	E	Concave	A	Y
T-37-6	R	R	E	Concave	W	N
T-38-1	L	M	SE	Concave	P	T
T-38-2	U	M	SE	Convex	P	T
T-38-3	L	M	E	Concave	P	T
T-38-4	U	M	NE	Convex	P	T
T-38-5	L	M	N	Concave	P	T
T-38-6	U	M	NE	Convex	P	T

[z] T = transect; first number is the transect number; second number is the sample-point number within a transect.
[y] U = upper; M = mid; L = lower; D = depression.
[x] E = east; S = south; W = west; N = north.
[w] N = no manure; T = trace manure; Y = yes manure.
[v] A = annual crop; P = perennial crop; W = woodland.

Table A3.3. Landscape and landuse information for each soil sampling site (Page 7 of 9).

Sample ID[z]	Landscape position[y]	Overall landscape position[y]	Slope aspect[x]	Slope curvature	Landuse type[w]	Manure intensity[v]
T-38-7	R	M	E	Concave	P	T
T-38-8	M	M	SW	Convex	P	T
T-39-1	U	M	NE	Convex	A	Y
T-39-2	M	M	NE	Concave	A	Y
T-39-3	M	M	NE	Concave	A	Y
T-39-4	L	M	E	Concave	A	Y
T-39-5	U	M	NE	Convex	A	Y
T-39-6	M	M	NE	None/Concave	A	Y
T-39-7	R	M	SE	Concave	P	T
T-40-1	U	U	SE	Convex	P	N
T-40-2	M	U	SE	Concave	A	N
T-40-3	L	U	S	Concave	A	N
T-40-4	U	U	SW	Convex	A	N
T-40-5	M	M	W	Concave	A	N
T-40-6	L	M	SW/S	Concave	A	N
T-40-7	L	L	S	Concave	A	N
T-40-8	U	M	SE	Convex	A	N
T-40-9	L	L	W	Concave	A	N
T-40-10	R	R	E	Concave	W	N
T-40-11	L	L	S	Concave	A	N
T-40-12	R	R	E	Concave	P	N
T-41-1	U	U	SW	Convex	A	N
T-41-2	M	U	SW	Concave	A	N
T-41-3	M	M	SW	None/Concave	A	N
T-41-4	L	M	SW	Concave	A	N
T-41-5	L	L	S	Concave	P	N
T-41-6	R	L	E	Concave/Convex	P	N
T-42-1	R	L	SE	Concave	P	N
T-42-2	M	M	E	Concave	A	N
T-42-3	U	M	E	Convex	A	N
T-42-4	U	M	E	Convex	A	N
T-42-5	M	M	S	Concave	A	N
T-42-6	U	M	SE	Convex	A	N
T-43-1	U	M	NE	Convex	A	N
T-43-2	U	M	NE	Convex	A	N
T-43-3	M	M	NE	None	A	N
T-43-4	L	M	E	Concave	A	N
T-43-5	L	M	SE	Concave	A	N
T-44-1	U	U	NE	Convex	A	N
T-44-2	M	U	NE	Concave	A	N

[z] T = transect; first number is the transect number; second number is the sample-point number within a transect.
[y] U = upper; M = mid; L = lower; D = depression.
[x] E = east; S = south; W = west; N = north.
[w] N = no manure; T = trace manure; Y = yes manure.
[v] A = annual crop; P = perennial crop; W = woodland.

Table A3.3. Landscape and landuse information for each soil sampling site (Page 8 of 9).

Sample ID[z]	Landscape position[y]	Overall landscape position[y]	Slope aspect[x]	Slope curvature	Landuse type[w]	Manure intensity[v]
T-44-3	L	M	NE	Concave	A	N
T-44-4	U	M	NE	Convex	A	N
T-44-5	M	M	NE	Concave	A	N
T-44-6	R	R	E	Concave	A	N
T-44-7	U	M	SW	Convex	A	N
T-45-1	L	M	SE	Concave	A	Y
T-45-2	M	M	SE	Concave	A	Y
T-45-3	U	U	E	Convex	A	Y
T-45-4	U	U	SE	Convex	A	Y
T-45-5	U	M	SE	Convex	A	Y
T-45-6	M	M	SE	None	A	Y
T-45-7	R	M	SE	Concave	P	N
T-46-1	U	U	NE	Convex	A	N
T-46-2	M	U	NE	Concave	A	N
T-46-3	M	U	NE	Concave	A	N
T-46-4	M	U	E	Convex	A	N
T-46-5	L	U	N	Concave	A	N
T-46-6	R	R	E	Concave	W	N
T-46-7	R	R	E	Concave	W	N
T-47-1	U	M	NE	Convex	P	N
T-47-2	M	M	NE	Concave	P	N
T-47-3	M	L	E	Concave	W	T
T-47-4	U	M	S	Convex	P	T
T-48-1	L	L	E	Concave	P	N
T-48-2	M	M	SE	Concave	P	N
T-48-3	U	M	SE	Convex	P	N
T-48-4	M	M	SE	Concave	P	N
T-48-5	M	M	SE	None	P	N
T-48-6	U	U	SE	Convex	P	N
T-48-7A	U	U	SE	Concave	P	N
T-48-7B	M	U	E	Concave	P	N
T-48-9	U	U	NE/SE	Convex	P	N
T-49-1	U	U	S	Convex	P	N
T-49-2	M	U	S	Concave	P	N
T-49-3	M	U	S	Concave	P	N
T-49-4	L	M	S	Concave	P	N
T-49-5	L	M	SE	Concave	P	N
T-49-6	M	M	S	Concave	A	N
T-49-7	M	M	SE	Concave	A	N
T-49-8	L	L	SE	Concave	A	N

[z] T = transect; first number is the transect number; second number is the sample-point number within a transect.
[y] U = upper; M = mid; L = lower; D = depression.
[x] E = east; S = south; W = west; N = north.
[w] N = no manure; T = trace manure; Y = yes manure.
[v] A = annual crop; P = perennial crop; W = woodland.

Table A3.3. Landscape and landuse information for each soil sampling site (Page 9 of 9).

Sample ID[z,y]	Landscape position[x]	Overall landscape position[x]	Slope aspect[w]	Slope curvature	Landuse type[v]	Manure intensity[u]
T-49-9	R	L	S	Concave	P	N
T-50-1	U	U	S	Convex	A	N
T-50-2	M	U	S	None/Concave	A	N
T-50-3	L	M	S	Concave	P	N
T-50-4	R	M	S	Concave	P	N
T-50-5	R	L	S	Concave	W	N
T-50-6	U	L	NW	Convex	W	N
T-51-1	U	U	S	Convex	P	N
T-51-2	M	U	S	Concave	P	N
T-51-3	R	M	S/SW	Concave	P	N
T-52-1	M	R	NW	Concave	W	T
T-52-2	R	R	NE	Concave	W	T
T-52-3	R	R	S	Concave	W	T
T-53-1	U	M	E	Convex	P	Y
T-53-2	M	M	E	Concave	P	Y
T-53-3	M	M	E	Concave	P	Y
T-53-4	M	M	N	Concave	P	Y
T-53-5	M	M	SE	Concave	P	Y
T-53-6	R	R	SE	Concave	P	T
T-53-7	M	M	NE	Convex	P	Y
T-53-8	R	R	E	Concave	W	T
T-54-1	U	M	E	Convex	P	Y
T-54-2	M	M	E	Concave	P	Y
T-54-3	L	M	E	Concave	P	Y
T-54-4	R	R	E	Concave	W	T
R1	R	R	S	Concave	W	N
R2	R	R	E	Concave	W	N
R3	R	R	S	Concave	W	N
R4	R	R	E	Concave	W	N
R5	R	R	E	Concave	W	N
R6	R	R	E	Convex	P	N
R7	R	R	N	Concave	P	T
R8	R	R	SE	Concave	P	T

[z] T = transect; first number is the transect number; second number is the sample-point number within a transect.
[y] R = riparian.
[x] U = upper; M = mid; L = lower; D = depression.
[w] E = east; S = south; W = west; N = north.
[v] N = no manure; T = trace manure; Y = yes manure.
[u] A = annual crop; P = perennial crop; W = woodland.

Table A3.4. Coordinate information of the soil sampling points. (Page 1 of 8)

Sample ID[z]	Latitude	Longitude	Northing	Easting
T-1-1	52.449575	-113.5418929	5814081.792	327265.697
T-1-2	52.449686	-113.5428616	5814096.453	327200.314
T-1-3	52.449829	-113.5443183	5814115.841	327101.901
T-1-4	52.449895	-113.5454954	5814125.998	327022.184
T-1-5	52.44988	-113.5472742	5814128.592	326901.268
T-1-6	52.449767	-113.5495865	5814121.569	326743.72
T-2-1	52.447917	-113.5416066	5813896.733	327278.66
T-2-2	52.447291	-113.54095	5813825.55	327320.825
T-2-3	52.446587	-113.540203	5813745.477	327368.828
T-2-4	52.446241	-113.5399863	5813706.483	327382.199
T-2-5	52.445635	-113.5385678	5813635.705	327476.215
T-2-6	52.445459	-113.5378932	5813614.522	327521.367
T-3-1	52.438597	-113.5321914	5812837.846	327882.052
T-3-2	52.438674	-113.5332656	5812848.969	327809.349
T-3-3	52.438747	-113.5356927	5812862.874	327644.687
T-4-1	52.43816	-113.5383511	5812803.944	327461.728
T-4-2	52.43781	-113.539044	5812766.677	327413.269
T-4-3	52.437562	-113.5396687	5812740.592	327369.844
T-4-4	52.437412	-113.5403789	5812725.608	327320.99
T-4-5	52.437131	-113.5413082	5812696.582	327256.734
T-4-6	52.435607	-113.542657	5812530.334	327159.1
T-5-1	52.432451	-113.5322691	5812154.576	327852.812
T-5-2	52.431994	-113.5326512	5812104.667	327825.059
T-5-3	52.430717	-113.5330749	5811963.67	327791.28
T-5-4	52.429818	-113.5331038	5811863.767	327785.81
T-5-5	52.42802	-113.5332332	5811664.132	327770.003
T-5-6	52.427484	-113.5335573	5811605.3	327745.882
T-5-7	52.426664	-113.533179	5811513.212	327768.4
T-6-1	52.421353	-113.5379162	5810933.915	327425.623
T-6-2	52.422296	-113.5375756	5811037.966	327452.463
T-6-3	52.423295	-113.5374605	5811148.783	327464.19
T-6-4	52.424271	-113.5379742	5811258.544	327433.079
T-6-5	52.426159	-113.5378996	5811468.317	327445.526
T-6-6	52.427583	-113.5376124	5811625.984	327470.612
T-6-7	52.428734	-113.5373885	5811753.444	327490.328
T-6-8	52.429452	-113.5374137	5811833.348	327491.419
T-6-9	52.43103	-113.5382349	5812010.788	327441.764
T-6-10	52.431897	-113.5377101	5812105.948	327480.823
T-7-1	52.42228	-113.5319403	5811022.746	327835.52
T-7-2	52.421486	-113.5329427	5810936.839	327764.276
T-7-3	52.420893	-113.5347526	5810875.211	327638.913
T-7-4	52.420494	-113.5355349	5810832.707	327584.169
T-8-1	52.420926	-113.5363986	5810882.808	327527.134
T-8-2	52.420403	-113.5369698	5810826.013	327486.257

[z] T = transect; first number is the transect number; second number is the sample-point number within a transect.

Table A3.4. Coordinate information of the soil sampling points. (Page 2 of 8)

Sample ID[z]	Latitude	Longitude	Northing	Easting
T-8-3	52.419466	-113.5376172	5810723.361	327438.581
T-9-1	52.407831	-113.5451903	5809447.63	326878.111
T-9-2	52.409311	-113.5442127	5809609.868	326950.391
T-9-3	52.410349	-113.5445526	5809726.111	326931.34
T-9-4	52.410796	-113.5444578	5809775.591	326939.537
T-9-5	52.411737	-113.5426598	5809875.929	327065.489
T-9-6	52.411983	-113.5407354	5809898.682	327197.314
T-9-7	52.412695	-113.5418923	5809980.625	327121.428
T-9-8	52.413203	-113.5414728	5810036.112	327151.941
T-9-9	52.413717	-113.5409529	5810092.027	327189.304
T-9-10	52.41398	-113.5401928	5810119.456	327242.019
T-9-11	52.41476	-113.5390531	5810203.471	327322.564
T-9-12	52.416175	-113.5373149	5810356.671	327446.283
T-9-13	52.417037	-113.5354326	5810448.035	327577.634
T-9-14	52.417615	-113.5343325	5810509.686	327654.688
T-9-15	52.418185	-113.5331287	5810570.201	327738.76
T-9-16	52.418951	-113.5325041	5810653.894	327784.214
T-9-17	52.419118	-113.532522	5810672.508	327783.648
T-9-18	52.419351	-113.5325183	5810698.409	327784.807
T-10-1	52.414542	-113.5320179	5810162.441	327800.089
T-10-2	52.414452	-113.5326927	5810154.041	327753.853
T-10-3	52.414442	-113.5336294	5810155.162	327690.121
T-11-1	52.406317	-113.5345961	5809253.945	327592.695
T-11-2	52.407769	-113.5346862	5809415.626	327592.231
T-11-3	52.409166	-113.5349414	5809571.585	327580.325
T-11-4	52.410153	-113.5348204	5809681.054	327592.404
T-11-5	52.410855	-113.5344214	5809758.166	327622.276
T-11-6	52.412069	-113.5344329	5809893.194	327626.229
T-12-1	52.405748	-113.5455017	5809216.741	326848.774
T-12-2	52.4061	-113.5439326	5809252.126	326956.868
T-12-3	52.406229	-113.5431912	5809264.697	327007.796
T-12-4	52.407593	-113.540452	5809409.824	327199.422
T-12-5	52.4079	-113.5398288	5809442.474	327243.005
T-13-1	52.405648	-113.5546509	5809227.579	326226.135
T-13-2	52.406239	-113.5543274	5809292.522	326250.46
T-13-3	52.406534	-113.554216	5809325.059	326259.196
T-13-4	52.407015	-113.553982	5809377.985	326277.001
T-13-5	52.409091	-113.5533534	5809607.33	326327.908
T-14-1	52.416006	-113.5516009	5810372.085	326474.243
T-14-2	52.414862	-113.5514762	5810244.57	326478.23
T-14-3	52.414096	-113.551192	5810158.707	326494.547
T-14-4	52.412818	-113.5495402	5810012.625	326601.851
T-15-1	52.422992	-113.5440756	5811130.904	327013.282
T-15-2	52.422712	-113.5439788	5811099.536	327018.767

[z] T = transect; first number is the transect number; second number is the sample-point number within a transect.

Table A3.4. Coordinate information of the soil sampling points. (Page 3 of 8)

Sample ID[z]	Latitude	Longitude	Northing	Easting
T-15-3	52.422076	-113.5443747	5811029.759	326989.361
T-15-4	52.421503	-113.5452476	5810968.13	326927.771
T-15-5	52.42081	-113.5465988	5810894.304	326833.191
T-15-6	52.420086	-113.5486864	5810818.798	326688.419
T-15-7	52.419862	-113.5494709	5810795.77	326634.203
T-16-1	52.423381	-113.5541649	5811198.364	326328.896
T-16-2	52.423971	-113.5534707	5811262.305	326378.41
T-16-3	52.424442	-113.5514915	5811309.928	326514.811
T-16-4	52.424769	-113.5502134	5811343.223	326602.983
T-16-5	52.42516	-113.5485366	5811382.681	326718.508
T-16-6	52.425407	-113.5471318	5811406.78	326814.976
T-17-1	52.427198	-113.5546895	5811624.085	326308.242
T-17-2	52.427534	-113.5534223	5811658.404	326395.704
T-17-3	52.428088	-113.5513608	5811715.059	326538.015
T-17-4	52.428608	-113.5498813	5811769.334	326640.627
T-17-5	52.428805	-113.5493811	5811790.041	326675.402
T-17-6	52.429036	-113.5481608	5811812.802	326759.258
T-18-1	52.427689	-113.5477348	5811661.99	326782.933
T-18-2	52.427913	-113.547443	5811686.2	326803.647
T-18-3	52.428243	-113.5470074	5811721.853	326834.552
T-18-4	52.428684	-113.5465091	5811769.699	326870.153
T-18-5	52.429482	-113.5468675	5811859.298	326848.919
T-18-6	52.430728	-113.5460581	5811995.918	326908.821
T-18-7	52.43164	-113.5453422	5812095.62	326961.056
T-18-8	52.433018	-113.5438348	5812245.248	327068.912
T-19-1	52.42938	-113.5495631	5811854.419	326665.287
T-19-2	52.429649	-113.5493597	5811883.844	326680.169
T-19-3	52.429844	-113.5490157	5811904.704	326704.317
T-19-4	52.429947	-113.5488863	5811915.847	326713.517
T-19-5	52.430513	-113.549399	5811980.018	326680.888
T-19-6	52.430916	-113.5500174	5812026.316	326640.436
T-19-7	52.431083	-113.5501319	5812045.162	326633.308
T-19-8	52.43153	-113.5510309	5812097.027	326573.957
T-19-9	52.432346	-113.5525581	5812191.435	326473.358
T-19-10	52.432084	-113.5536439	5812164.909	326398.526
T-19-11	52.432002	-113.5542452	5812157.235	326357.333
T-20-1	52.433593	-113.5525633	5812330.118	326477.904
T-20-2	52.432849	-113.5547415	5812252.617	326326.931
T-20-3	52.433159	-113.5539412	5812285.166	326382.545
T-21-1	52.435908	-113.543621	5812566.113	327094.76
T-21-2	52.436588	-113.544848	5812644.669	327014.032
T-21-3	52.436939	-113.5457115	5812685.769	326956.721
T-21-4	52.437076	-113.5469665	5812704.01	326871.965
T-21-5	52.43879	-113.5493224	5812900.26	326718.578

[z] T = transect; first number is the transect number; second number is the sample-point number within a transect.

Table A3.4. Coordinate information of the soil sampling points. (Page 4 of 8)

Sample ID[z]	Latitude	Longitude	Northing	Easting
T-21-6	52.438603	-113.5497313	5812880.446	326690.056
T-21-7	52.438911	-113.5500076	5812915.36	326672.487
T-22-1	52.44116	-113.554725	5813176.783	326360.739
T-22-2	52.440767	-113.5537402	5813130.714	326426.118
T-22-3	52.439927	-113.5522449	5813033.712	326524.433
T-23-1	52.444512	-113.5541085	5813548.054	326415.816
T-23-2	52.444139	-113.553088	5813504.123	326483.694
T-23-3	52.443485	-113.5505866	5813425.391	326651.1
T-23-4	52.443144	-113.5493858	5813384.59	326731.359
T-23-5	52.443007	-113.5489136	5813368.223	326762.909
T-23-6	52.441422	-113.5474383	5813188.429	326856.945
T-23-7	52.441384	-113.5469976	5813183.147	326886.744
T-24-1	52.443348	-113.5447294	5813396.117	327048.577
T-24-2	52.443556	-113.5448976	5813419.65	327037.962
T-24-3	52.443653	-113.5451621	5813431.07	327020.369
T-24-4	52.44499	-113.5477924	5813586.05	326846.877
T-24-5	52.445704	-113.5495358	5813669.63	326731.215
T-24-6	52.446041	-113.5502993	5813708.937	326680.659
T-24-7	52.446648	-113.5516194	5813779.605	326593.345
T-24-8	52.446822	-113.5523508	5813800.711	326544.331
T-25-1	52.451777	-113.5500956	5814346.309	326717.023
T-25-2	52.452187	-113.5497635	5814391.105	326741.196
T-25-3	52.45242	-113.5489903	5814415.161	326794.641
T-25-4	52.453349	-113.5472453	5814514.286	326916.838
T-25-5	52.453911	-113.5463571	5814574.654	326979.384
T-25-6	52.454242	-113.5457831	5814610.088	327019.677
T-25-7	52.454742	-113.544833	5814663.415	327086.183
T-25-8	52.455622	-113.54384	5814758.897	327157.09
T-26-1	52.455414	-113.554893	5814762.274	326405.396
T-26-2	52.454202	-113.5537545	5814624.76	326477.973
T-26-3	52.452889	-113.5525505	5814475.859	326554.608
T-26-4	52.452062	-113.5517683	5814382.016	326604.5
T-26-5	52.451475	-113.5514698	5814316.023	326622.473
T-26-6	52.451223	-113.5512907	5814287.57	326633.651
T-27-1	52.454743	-113.5658787	5814714.118	325656.439
T-27-2	52.454567	-113.56557	5814693.801	325676.715
T-27-3	52.454422	-113.5653539	5814677.155	325690.824
T-27-4	52.454119	-113.5648335	5814642.205	325724.981
T-27-5	52.453793	-113.5643293	5814604.736	325757.947
T-27-6	52.453525	-113.56392	5814573.946	325784.695
T-27-7	52.453322	-113.5635094	5814550.382	325811.789
T-27-8	52.453022	-113.5630248	5814515.852	325843.527
T-27-9	52.452749	-113.5625802	5814484.422	325872.655
T-27-10	52.452452	-113.5620372	5814450.086	325908.374

z T = transect; first number is the transect number; second number is the sample-point number within a transect.

Table A3.4. Coordinate information of the soil sampling points. (Page 5 of 8)

Sample ID[z]	Latitude	Longitude	Northing	Easting
T-27-11	52.45233	-113.5618295	5814436.019	325922.004
T-27-12	52.451708	-113.5605385	5814363.74	326007.261
T-27-13	52.450309	-113.5598329	5814206.468	326049.685
T-27-14	52.450286	-113.5582161	5814200.018	326159.443
T-28-1	52.447111	-113.5665412	5813867.018	325581.271
T-28-2	52.446925	-113.5640274	5813840.267	325751.342
T-28-3	52.445866	-113.5622907	5813718.315	325865.168
T-28-4	52.445123	-113.5612919	5813633.284	325930.105
T-28-5	52.444415	-113.5601982	5813551.918	326001.631
T-28-6	52.443736	-113.5589478	5813473.4	326083.922
T-29-1	52.441675	-113.5564737	5813238.257	326243.931
T-29-2	52.441582	-113.5570496	5813229.301	326204.429
T-29-3	52.441481	-113.557881	5813220.07	326147.533
T-29-4	52.441262	-113.5585699	5813197.375	326099.856
T-29-5	52.440904	-113.5593684	5813159.487	326044.182
T-29-6	52.438762	-113.5674908	5812940.88	325483.745
T-29-7	52.438268	-113.5691377	5812889.926	325369.868
T-30-1	52.436023	-113.5633508	5812626.304	325754.289
T-30-2	52.437051	-113.5621352	5812737.689	325840.962
T-30-3	52.437526	-113.561425	5812788.798	325891.102
T-30-4	52.437709	-113.5611969	5812808.599	325907.325
T-31-1	52.43901	-113.5580184	5812945.619	326128.465
T-31-2	52.439026	-113.5575521	5812946.276	326160.217
T-31-3	52.439139	-113.5572643	5812958.149	326180.221
T-32-1	52.43769	-113.5557835	5812793.454	326275.154
T-32-2	52.437693	-113.5562841	5812794.992	326241.144
T-32-3	52.437734	-113.5568367	5812800.88	326203.75
T-32-4	52.437758	-113.5572388	5812804.517	326176.517
T-33-1	52.428181	-113.5556673	5811735.748	326245.64
T-33-2	52.42754	-113.5586787	5811671.714	326038.412
T-33-3	52.426398	-113.5631702	5811555.544	325728.586
T-33-4	52.427195	-113.5671777	5811653.845	325459.31
T-33-5	52.424481	-113.562052	5811339.672	325797.04
T-33-6	52.423744	-113.5614705	5811256.314	325833.666
T-34-1	52.412759	-113.5655346	5810044.561	325514
T-34-2	52.414088	-113.5634048	5810187.209	325664.069
T-34-3	52.416508	-113.5600735	5810448.287	325900.126
T-34-4	52.417714	-113.5581141	5810577.679	326038.102
T-35-1	52.412397	-113.5766389	5810031.175	324757.474
T-35-2	52.413114	-113.5761639	5810109.755	324792.616
T-35-3	52.413872	-113.5756028	5810192.686	324833.776
T-35-4	52.415355	-113.5743291	5810354.512	324926.26
T-35-5	52.415216	-113.5734808	5810337	324983.391
T-35-6	52.41629	-113.5714468	5810451.507	325125.945

[z] T = transect; first number is the transect number; second number is the sample-point number within a transect.

Table A3.4. Coordinate information of the soil sampling points. (Page 6 of 8)

Sample ID[z]	Latitude	Longitude	Northing	Easting
T-35-7	52.417669	-113.5710783	5810603.963	325156.458
T-35-8	52.418783	-113.5710983	5810727.89	325159.507
T-35-9	52.419101	-113.5712761	5810763.683	325148.676
T-35-10	52.419296	-113.5714123	5810785.697	325140.188
T-36-1	52.413742	-113.5772917	5810182.324	324718.418
T-36-2	52.414258	-113.5791	5810244.092	324597.505
T-36-3	52.414097	-113.5803722	5810229.277	324510.359
T-36-4	52.413872	-113.5808972	5810205.532	324473.767
T-37-1	52.424072	-113.5641767	5811299.315	325650.985
T-37-2	52.423717	-113.5645964	5811260.851	325621.051
T-37-3	52.423505	-113.5648212	5811237.819	325604.932
T-37-4	52.423176	-113.5646156	5811200.737	325617.61
T-37-5	52.42161	-113.5637321	5811024.462	325671.494
T-37-6	52.420741	-113.5635814	5810927.464	325678.311
T-38-1	52.426969	-113.5727194	5811642.115	325081.703
T-38-2	52.427453	-113.5722139	5811694.713	325117.983
T-38-3	52.428419	-113.5703917	5811797.726	325245.673
T-38-4	52.428561	-113.57015	5811812.932	325262.664
T-38-5	52.428881	-113.5696611	5811847.334	325297.163
T-38-6	52.429444	-113.5687556	5811907.752	325360.941
T-38-7	52.429619	-113.5684389	5811926.447	325383.16
T-38-8	52.430067	-113.5677472	5811974.594	325431.949
T-39-1	52.426839	-113.5791028	5811643.131	324647.257
T-39-2	52.427833	-113.5774944	5811749.764	324760.537
T-39-3	52.428472	-113.5769083	5811819.401	324802.913
T-39-4	52.429	-113.5753833	5811874.419	324908.669
T-39-5	52.429469	-113.5752028	5811926.135	324922.797
T-39-6	52.429969	-113.5751333	5811981.568	324929.504
T-39-7	52.430058	-113.5749389	5811990.994	324943.07
T-40-1	52.454878	-113.5670028	5814731.844	325580.607
T-40-2	52.454724	-113.5682108	5814717.636	325497.932
T-40-3	52.454286	-113.5696455	5814672.397	325398.732
T-40-4	52.453353	-113.5671244	5814562.553	325566.318
T-40-5	52.453037	-113.5688503	5814531.583	325447.814
T-40-6	52.452262	-113.5709581	5814450.497	325301.547
T-40-7	52.450041	-113.5670555	5814194.083	325557.907
T-40-8	52.447374	-113.5674387	5813898.431	325521.328
T-40-9	52.445514	-113.5675647	5813691.899	325505.413
T-40-10	52.443754	-113.5676791	5813496.459	325490.682
T-40-11	52.442267	-113.5676076	5813330.928	325489.662
T-40-12	52.45511	-113.580392	5814790.06	324671.934
T-41-1	52.45484	-113.5807984	5814761.022	324643.253
T-41-2	52.453686	-113.5822603	5814636.245	324539.35
T-41-3	52.417669	-113.5710783	5810603.963	325156.458

[z] T = transect; first number is the transect number; second number is the sample-point number within a transect.

Table A3.4. Coordinate information of the soil sampling points. (Page 7 of 8)

Sample ID[z]	Latitude	Longitude	Northing	Easting
T-41-4	52.45299	-113.5832059	5814561.146	324472.34
T-41-5	52.450794	-113.5861059	5814323.997	324266.576
T-41-6	52.450408	-113.5864082	5814281.808	324244.5
T-42-1	52.443812	-113.5823527	5813538.457	324493.811
T-42-2	52.443777	-113.582869	5813535.82	324458.589
T-42-3	52.443621	-113.5835155	5813520.044	324414.037
T-42-4	52.444471	-113.5858757	5813620.305	324257.041
T-42-5	52.445295	-113.5870682	5813714.837	324179.292
T-42-6	52.445452	-113.587781	5813734.031	324131.483
T-43-1	52.434555	-113.5890314	5812525.307	324003.083
T-43-2	52.434848	-113.5882949	5812556.096	324054.308
T-43-3	52.435404	-113.5872574	5812615.398	324127.037
T-43-4	52.436112	-113.586115	5812691.348	324207.498
T-43-5	52.437162	-113.5840525	5812803.094	324351.851
T-44-1	52.426758	-113.5856444	5811650.02	324202.25
T-44-2	52.428075	-113.5849222	5811794.716	324256.584
T-44-3	52.430156	-113.5835528	5812022.797	324357.947
T-44-4	52.430678	-113.5829389	5812079.353	324401.751
T-44-5	52.430811	-113.5827556	5812093.697	324414.739
T-44-6	52.430919	-113.5826111	5812105.356	324424.99
T-44-7	52.431178	-113.58235	5812133.522	324443.767
T-45-1	52.421028	-113.5817796	5811003.436	324442.201
T-45-2	52.421661	-113.58297	5811076.72	324363.786
T-45-3	52.422037	-113.5841984	5811121.518	324281.767
T-45-4	52.423409	-113.586338	5811279.292	324141.768
T-45-5	52.420651	-113.5823532	5810962.907	324401.705
T-45-6	52.420405	-113.5822247	5810935.239	324409.464
T-45-7	52.420112	-113.5820843	5810902.315	324417.845
T-46-1	52.415878	-113.5877333	5810445.228	324016.915
T-46-2	52.41725	-113.5851333	5810591.469	324199.16
T-46-3	52.417914	-113.5837611	5810661.969	324295.101
T-46-4	52.418917	-113.58255	5810770.561	324381.432
T-46-5	52.419333	-113.5821583	5810815.869	324409.717
T-46-6	52.419417	-113.5821222	5810825.122	324412.506
T-46-7	52.419394	-113.58125	5810820.446	324471.715
T-47-1	52.444232	-113.5925148	5813609.9	323804.955
T-47-2	52.445299	-113.5933582	5813730.61	323751.905
T-47-3	52.446464	-113.5939832	5813861.686	323714.09
T-47-4	52.447312	-113.5958788	5813960.613	323588.678
T-48-1	52.448824	-113.5929738	5814121.66	323792.099
T-48-2	52.449183	-113.5936284	5814163.179	323749.056
T-48-3	52.449484	-113.594146	5814197.914	323715.091
T-48-4	52.45011	-113.5946387	5814268.729	323684.117
T-48-5	52.450959	-113.5956847	5814365.693	323616.443

[z] T = transect; first number is the transect number; second number is the sample-point number within a transect.

Table A3.4. Coordinate information of the soil sampling points. (Page 8 of 8)

Sample ID[z]	Latitude	Longitude	Northing	Easting
T-48-6	52.451664	-113.5966668	5814446.489	323552.537
T-48-7(A)	52.452797	-113.5980905	5814575.96	323460.344
T-48-7(B)	52.453937	-113.5997728	5814706.843	323350.616
T-48-9	52.454224	-113.6002622	5814739.955	323318.518
T-49-1	52.459162	-113.5916902	5815268.138	323920.57
T-49-2	52.458916	-113.5916984	5815240.802	323919.031
T-49-3	52.458619	-113.5917237	5815207.837	323916.127
T-49-4	52.457867	-113.5917194	5815124.202	323913.417
T-49-5	52.456051	-113.5913359	5814921.324	323932.222
T-49-6	52.455672	-113.591295	5814879.079	323933.488
T-49-7	52.454795	-113.5903383	5814779.223	323994.982
T-49-8	52.453358	-113.5884366	5814614.792	324118.446
T-49-9	52.451689	-113.5866809	5814424.922	324231.075
T-50-1	52.455398	-113.5771678	5814814.265	324892.112
T-50-2	52.454385	-113.5765753	5814700.18	324928.343
T-50-3	52.453507	-113.5746913	5814597.98	325052.853
T-50-4	52.452836	-113.5746988	5814523.381	325049.683
T-50-5	52.451838	-113.5745297	5814411.991	325057.215
T-50-6	52.451305	-113.5745784	5814352.838	325051.794
T-51-1	52.455716	-113.5582054	5814803.824	326181.56
T-51-2	52.454348	-113.5571959	5814649.269	326244.752
T-51-3	52.45255	-113.557903	5814451.028	326189.633
T-52-1	52.418217	-113.5342442	5810576.419	327663.04
T-52-2	52.418313	-113.5342983	5810587.224	327659.736
T-52-3	52.418433	-113.534425	5810600.87	327651.589
T-53-1	52.423669	-113.5773194	5811286.294	324755.913
T-53-2	52.423314	-113.576975	5811245.982	324777.918
T-53-3	52.422759	-113.5759051	5811181.671	324848.454
T-53-4	52.42244	-113.5750721	5811144.179	324903.82
T-53-5	52.421387	-113.5733435	5811022.895	325017.168
T-53-6	52.421112	-113.5727606	5810990.903	325055.708
T-53-7	52.420602	-113.5717121	5810931.652	325124.974
T-53-8	52.420828	-113.5715547	5810956.403	325136.57
T-54-1	52.425503	-113.5784139	5811492.894	324688.785
T-54-2	52.425572	-113.5833336	5811512.514	324354.617
T-54-3	52.425545	-113.5725537	5811483.362	325087.328
T-54-4	52.425533	-113.5713942	5811479.221	325166.104
R1	52.446004	-113.5527102	5813710.61	326516.696
R2	52.420086	-113.5762102	5810885.167	324817.112
R3	NA[x]	NA	NA	NA
R4	52.420074	-113.5743965	5810879.437	324940.375
R5	52.419605	-113.5721827	5810821.923	325089.032
R6	52.4197	-113.5718322	5810831.639	325113.238
R7	52.420109	-113.5710456	5810875.217	325168.337
R8	52.42063	-113.5708861	5810932.767	325181.243

[z] T = transect; first number is the transect number; second number is the sample-point number within a transect.
[y] R = riparian land.
[x] NA = not available.

Appendix 4. Statistical analysis of the M1 subbasin data.

by Emmanuel Mapfumo, Ph.D.

TABLE OF CONTENTS

SECTION 1: PHOSPHORUS DATA ANALYSIS FOR THE 0-5 CM DEPTH INTERVAL

Analysis of Variance for the Raw Phosphorus Data Using GLM Procedure

Examination of treatment effects. The phosphorus data taken in the 0-5 cm depth interval were examined. Combinations of land use type, amendment and slope position were numbered from 1-29 treatments and analyzed using a one-way analysis of variance with the Generalized Linear Models (GLM) procedure in SAS. Analysis of variance results indicated no treatment effects (F-value = 1.23; *P* = 0.1979) on the phosphorus levels. However, examination of residuals was conducted before adopting the results.

```
                                  The GLM Procedure
                               Class Level Information
Class        Levels  Values
treat            29  1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28
                     29

                            Number of observations    351


                                  The GLM Procedure
Dependent Variable: phosphorus
                                         Sum of
      Source                      DF        Squares     Mean Square    F Value    Pr > F
      Model                       28     61535.3023       2197.6894       1.23    0.1979
      Error                      322    574042.1751       1782.7397
      Corrected Total            350    635577.4774


                      R-Square     Coeff Var      Root MSE    phosp Mean
                      0.096818      92.42344      42.22250      45.68376


      Source                      DF    Type III SS     Mean Square    F Value    Pr > F
      treat                       28    61535.30232      2197.68937       1.23    0.1979
```

Detection of outliers. The univariate procedure was used to determine the presence/absence of outliers in the data set. An observation is an outlier if it falls more than 1.5 times the inter-quartile range (IQR) above the upper quartile or more than 1.5*IQR below the lower quartile. Thus, the outliers are defined using the upper and lower limits below;

Upper limit = Q_3 + 1.5 IQR
Lower limit = Q_1 - 1.5 IQR
Where: Q_1 and Q_3 are the lower and upper quartiles, respectively.

The PROC Univariate procedure was used in conjunction with the box plots to determine the lower and lower quartiles as well as the extreme points that would be deemed outliers. The following output comes from SAS analysis to determine the incidence of outliers. Thus, we only concentrate on the outliers that are above the upper quartile as opposed to those that are below the lower quartile since there were no negative values in the data set. This resulted in 16 observations detected as outliers. SAS marks by an O (O for outlier) a value between 1.5 and 3.0*IQR from the box and by an asterisk (*) a value even farther away. Thus, this data set contained outliers, extreme points that had a strong influence on the measures of variability in the data set. However, removal of outliers is only conducted if there is ample evidence that would justify this procedure. As a result, further analyses were conducted on the whole data set.

The UNIVARIATE Procedure
Variable: residuals

Moments

N	351	Sum Weights	351
Mean	0	Sum Observations	0
Std Deviation	40.4984012	Variance	1640.1205
Skewness	4.51007376	Kurtosis	35.4948412
Uncorrected SS	574042.175	Corrected SS	574042.175
Coeff Variation	.	Std Error Mean	2.16164474

Basic Statistical Measures

Location		Variability	
Mean	0.0000	Std Deviation	40.49840
Median	-5.6933	Variance	1640
Mode	-28.1889	Range	469.35714
		Interquartile Range	33.31111

Tests for Location: Mu0=0

Test	-Statistic-		-----p Value------	
Student's t	t	0	Pr > |t|	1.0000
Sign	M	-35	Pr >= |M|	0.0002
Signed Rank	S	-5881	Pr >= |S|	0.0018

Tests for Normality

Test	--Statistic---		-----p Value------	
Shapiro-Wilk	W	0.688986	Pr < W	<0.0001
Kolmogorov-Smirnov	D	0.14982	Pr > D	<0.0100
Cramer-von Mises	W-Sq	2.85741	Pr > W-Sq	<0.0050
Anderson-Darling	A-Sq	16.97885	Pr > A-Sq	<0.0050

Quantiles (Definition 5)

Quantile	Estimate
100% Max	402.70714
99%	175.35000
95%	57.35000
90%	34.02500
75% Q3	11.81111
50% Median	-5.69333
25% Q1	-21.50000
10%	-31.29286
5%	-40.32105
1%	-62.65000
0% Min	-66.65000

Extreme Observations

-----Lowest----		-----Highest-----	
Value	Obs	Value	Obs
-66.65	25	88.375	272
-65.65	16	175.350	158
-63.65	22	222.811	159
-62.65	26	268.679	123
-61.65	340	402.707	326

```
                      The UNIVARIATE Procedure
                          Variable:  residuals
                   Histogram                          #             Boxplot
   410+*                                              1                *
      .
      .
      .
      .
      .
      .
      .*                                              1                *
      .
      .*                                              1                *
      .
      .
   170+*                                              1                *
      .
      .
      .
      .**                                             5                0
      .***                                            7                0
      .***                                            9                |
      .*************                                 37                |
      .***************************                   79             +--+--+
      .**************************************       114             *-----*
      .**************************                    78             +-----+
      .****                                          12                |
   -70+**                                             6                |
       ----+----+----+----+----+----+----+---
       * may represent up to 3 counts
```

Test for normality of distribution of residuals. PROC INSIGHT and PROC GPLOT in SAS were used in making a plot of residuals against predicted values and to examine the pattern of residuals. The pattern of residuals gives an indication of whether or not the data follow a normal distribution as is required in all parametric analyses. The plot also helps determine whether or not the assumption of normality was violated such that we would determine if any transformation of data was required.

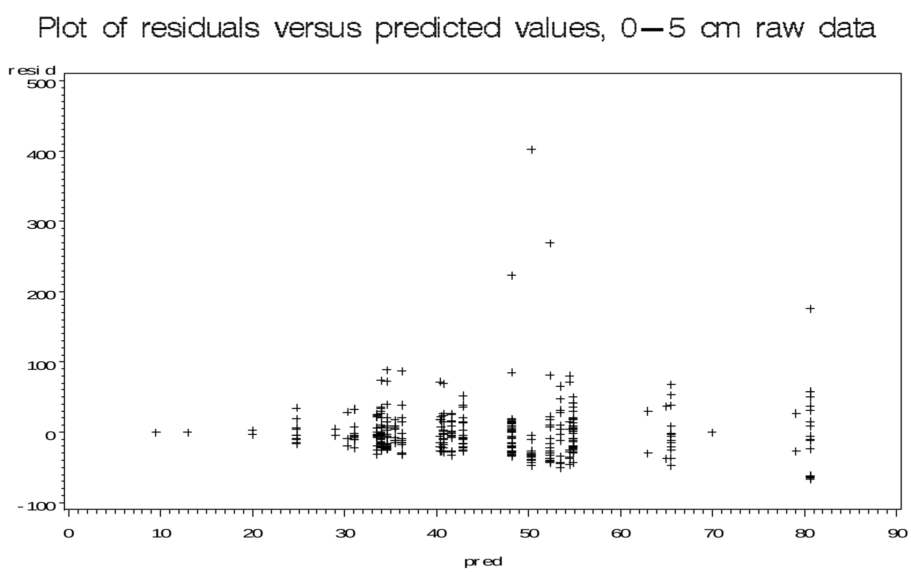

Fig. A4.1. Plot of residuals versus predicted values of phosphorus data.

The plot (Fig. A4.1) shows that the residuals are not evenly distributed below and above zero, and as predicted values increased the residuals became more spread out. This pattern indicates that the data are not normally distributed and a transformation of the data set would be required to normalize the data set. As a result, a logarithmic transformation was performed on the data set and the resulting lognormal data analyzed using the GLM procedure.

Analysis of Variance for Transformed Data Using GLM Procedure

The following SAS output shows the results of the analysis of variance of phosphorus data after a logarithmic ($\log_{10}$) transformation. This is a very powerful transformation that was adopted in order to attempt to normalize the data set. This was also essential to enable reasonable estimation of the covariance parameters.

Examination of treatment effects. The output from the GLM procedure below indicates that at least two treatments had significantly different levels of phosphorus (F = 2.22; ***P*** = 0.0005). This conclusion is contrary to the conclusion reached in the first analysis, which utilized the raw untransformed phosphorus data set.

```
                                        The GLM Procedure
                                     Class Level Information
Class        Levels  Values
treat            29  1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28
                     29

                                  Number of observations    351

                                        The GLM Procedure
Dependent Variable: transP
                                               Sum of
      Source                     DF           Squares     Mean Square    F Value    Pr > F
      Model                      28        6.29658451      0.22487802       2.22    0.0005
      Error                     322       32.67618182      0.10147883
      Corrected Total           350       38.97276633

                      R-Square     Coeff Var      Root MSE    transP Mean
                      0.161564      20.76577      0.318557       1.534051

      Source                     DF       Type I SS     Mean Square    F Value    Pr > F
      treat                      28      6.29658451      0.22487802       2.22    0.0005


      Source                     DF     Type III SS     Mean Square    F Value    Pr > F
      treat                      28      6.29658451      0.22487802       2.22    0.0005
```

Detection of outliers. The results of PROC Univariate box plot indicate that there were six outlier points in the data set, i.e. points marked by O and *. These data points were not removed from the whole data set because of lack of any clear reason to justify their removal. However, a closer look at the pattern of the distribution of residuals showed a pattern closer to a normal distribution than was the case with the raw data set.

The UNIVARIATE Procedure
Variable: resid

Moments

N	351	Sum Weights	351
Mean	0	Sum Observations	0
Std Deviation	0.30554954	Variance	0.09336052
Skewness	0.0023236	Kurtosis	1.52637028
Uncorrected SS	32.6761818	Corrected SS	32.6761818
Coeff Variation	.	Std Error Mean	0.01630903

Basic Statistical Measures

Location		Variability	
Mean	0.00000	Std Deviation	0.30555
Median	0.02413	Variance	0.09336
Mode	-0.27992	Range	2.49924
		Interquartile Range	0.38352

NOTE: The mode displayed is the smallest of 4 modes with a count of 3.

Tests for Location: Mu0=0

Test	-Statistic-		-----p Value------	
Student's t	t	0	Pr > |t|	1.0000
Sign	M	11	Pr >= |M|	0.2616
Signed Rank	S	534	Pr >= |S|	0.7785

Tests for Normality

Test	--Statistic---		-----p Value------	
Shapiro-Wilk	W	0.985359	Pr < W	0.0013
Kolmogorov-Smirnov	D	0.043341	Pr > D	0.1062
Cramer-von Mises	W-Sq	0.120081	Pr > W-Sq	0.0631
Anderson-Darling	A-Sq	0.78675	Pr > A-Sq	0.0425

Quantiles (Definition 5)

Quantile	Estimate
100% Max	1.3583912
99%	0.7063335
95%	0.4507563
90%	0.3461622
75% Q3	0.1954981
50% Median	0.0241275
25% Q1	-0.1880265
10%	-0.3883958
5%	-0.5038286
1%	-0.6760014
0% Min	-1.1408468

Extreme Observations

------Lowest------		------Highest-----	
Value	Obs	Value	Obs
-1.140847	301	0.671430	272
-1.028220	176	0.706334	24
-0.899767	298	0.852019	159
-0.676001	88	1.007030	123
-0.651178	90	1.358391	326

```
                         The UNIVARIATE Procedure
                             Variable:  resid
              Histogram                         #             Boxplot
  1.35+*                                        1                *
      .
      .
      .*                                        1                0
      .
  0.85+*                                        1                0
      .*                                        1                |
      .**                                       4                |
      .***                                      6                |
      .***                                      5                |
  0.35+****************                        31                |
      .****************                        32                |
      .**********************                  43             +-----+
      .********************************        63             *--+--*
      .********************                    39             |     |
 -0.15+*********************                   42             +-----+
      .**************                          28                |
      .***********                             21                |
      .********                                15                |
      .*****                                    9                |
 -0.65+***                                      6                |
      .
      .*                                        1                0
      .
      .*                                        1                0
 -1.15+*                                        1                0
       ----+----+----+----+----+----+--
       * may represent up to 2 counts
```

Examination of residuals. The plot of residuals against predicted values (Fig. A4.2) indicated the residuals were fairly evenly distributed below and above zero, thus the data had a pattern that was close to a normal distribution. This was also supported by the box plot, which indicated a distribution pattern close to a normal distribution.

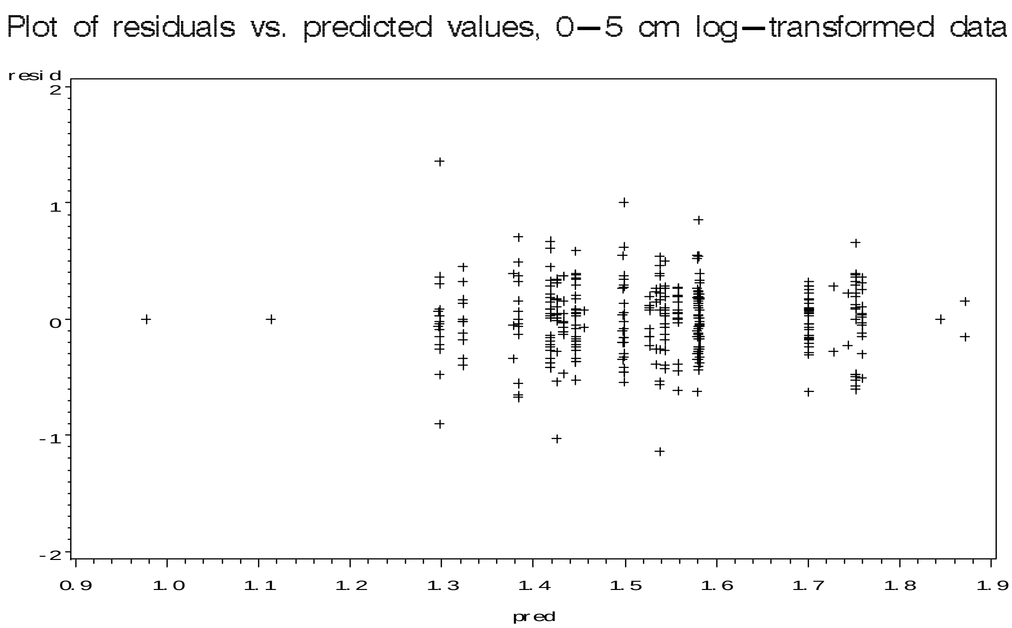

Fig. A4.2. Plot of residuals versus predicted values for the log-transformed data analysis.

Adjusting for Spatial Variability using MIXED Model Procedure

Estimating covariance parameters for log-transformed data. The following output shows estimates of the sill (σ^2) and the range (ρ) of the semi-variogram for data after logarithmic transformation, using the restricted maximum likelihood (REML) procedure in PROC MIXED. The Satterthwaite procedure was used to compute the denominator degrees of freedom so as to provide a more accurate F-test. This option is available in PROC MIXED.
After the transformation, the plot of residuals indicated that the errors were close to a normal distribution. Further, the estimation of the semi-variance makes sense only if the data set is normally distributed. After fitting the spherical, exponential and gaussian spatial correlation models, the results indicated that the highest Akaike's Information Criterion (AIC) and Schwarz's Bayesian Criterion (BIC) values, and the lowest –2REML Log Likelihood statistic were obtained for the gaussian spatial model, and this model was chosen as the best out of the three. Thus, the variance (σ^2) and range (ρ) estimates for this model were used in the adjustment of treatment effects.

```
                  The Mixed Procedure
                  Model Information
Data Set                     WORK.WATERSHD
Dependent Variable           logphosp
Covariance Structure         Spatial Gaussian
Subject Effect               Intercept
Estimation Method            REML
Residual Variance Method     Profile
Fixed Effects SE Method      Model-Based
Degrees of Freedom Method    Satterthwaite

                Class Level Information
   Class    Levels    Values
   treat        29    1 2 3 4 5 6 7 8 9 10 11 12 13
                      14 15 16 17 18 19 20 21 22 23
                      24 25 26 27 28 29

            Covariance Parameter Estimates
          Cov Parm     Subject      Estimate
          Variance     Intercept     0.02525
          SP(GAU)      Intercept      2.1964
          Residual                   0.07996


                    Fit Statistics

         -2 Res Log Likelihood           220.8
         AIC (smaller is better)         226.8
         AICC (smaller is better)        226.8
         BIC (smaller is better)         238.1

            Type 3 Tests of Fixed Effects
                  Num     Den
    Effect         DF      DF     F Value     Pr > F
    treat          28     309       1.44      0.0735
```

Using the covariance estimates to adjust for the treatment effects. The results indicate that the treatments had a significant effect on the phosphorus levels ($P < 0.001$). These results were obtained from the SAS Mixed model procedure used in conjunction with the PARMS statement with the estimated values of the sill (σ^2) and the range (ρ) of the semi-variogram. The Satterthwaite procedure was used to determine the denominator degrees of freedom so that a more accurate F-test could be conducted. The results indicate highly significant treatment effects on $\log_{10}$(phosphorus), contrary to the conclusions reached when no spatial adjustment was made. Without accounting for spatial variability, treatment effects were non-significant (P = 0.0735). Closer examination indicated significant main effects and interactions among position, type and manure.

```
        Estimating the covariance using REML, 0-5 cm for transformed data

                          The Mixed Procedure
                          Model Information
             Data Set                    WORK.WATERSHD
             Dependent Variable          logphosp
             Covariance Structure        Spatial Gaussian
             Subject Effect              Intercept
             Estimation Method           REML
             Residual Variance Method    None
             Fixed Effects SE Method     Model-Based
             Degrees of Freedom Method   Satterthwaite

                         Class Level Information
                Class    Levels    Values
                treat        29    1 2 3 4 5 6 7 8 9 10 11 12 13
                                   14 15 16 17 18 19 20 21 22 23
                                   24 25 26 27 28 29

                      Covariance Parameter Estimates
                     Cov Parm     Subject      Estimate
                     Variance     Intercept     0.02525
                     SP(GAU)      Intercept      2.1964

                      Type 3 Tests of Fixed Effects
                              Num     Den
                 Effect        DF      DF    F Value    Pr > F
                 treat         28     322     172121    <.0001
```

Estimates

Label	Estimate	Standard Error	DF	t Value	Pr > |t|
Manure+riparian vs Manure+upperslope	**-1.1742**	**0.006890**	**322**	**-170.42**	**<.0001**
No manure+riparian vs no manure+upperslope	**-0.6834**	**0.009696**	**322**	**-70.48**	**<.0001**
Manure+low vs manure+upperslope	**1.2797**	**0.007373**	**322**	**173.57**	**<.0001**
No Manure+low vs No manure+upperslope	**-0.4222**	**0.007942**	**322**	**-53.16**	**<.0001**
manure vs no manure	-7.3778	0.3334	322	-22.13	<.0001
heavy manure vs no manure	-3.7437	0.04026	322	-92.99	<.0001
annuals vs wooded	-11.6529	0.1893	322	-61.56	<.0001
perennials vs annuals	8.8717	0.09312	322	95.27	<.0001
perennials vs wooded	-26.4039	0.1767	322	-149.43	<.0001
Trace vs no manure	2.5323	0.06431	322	39.37	<.0001
grasses vs wooded	-38.0568	0.3492	322	-108.99	<.0001
upper vs others	-28.3012	0.2066	322	-136.96	<.0001
riparian vs others	-39.3974	0.2583	322	-152.52	<.0001
lower vs upper slope	-10.0217	0.07389	322	-135.63	<.0001

The above contrasts are not orthogonal. It is important to note that there were significant main effects and interaction effects among manure treatments and among vegetation types. Significant effects were observed among combinations of manure and position. From these results, we can see that low slope positions without manure had lower phosphorus levels than upper slope positions without manure. However, in manure treatments the phosphorus levels in low slope positions was greater than those in upper slope positions.

In situations where there are significant interaction effects we examine these effects instead of the main effects, since looking at the main effects could be misleading. Thus, the results we should concentrate on are those highlighted. The following figure helps to show where interaction effects exist (Fig. A4.3). For example, in the perennials without manure the levels of phosphorus increased between upper slope and riparian areas whereas the reverse was true for the perennials with trace manure. In the wooded areas, trace manure additions resulted in increased phosphorus in riparian areas compared to upper slope positions, whereas the reverse was true for wooded areas without manure.

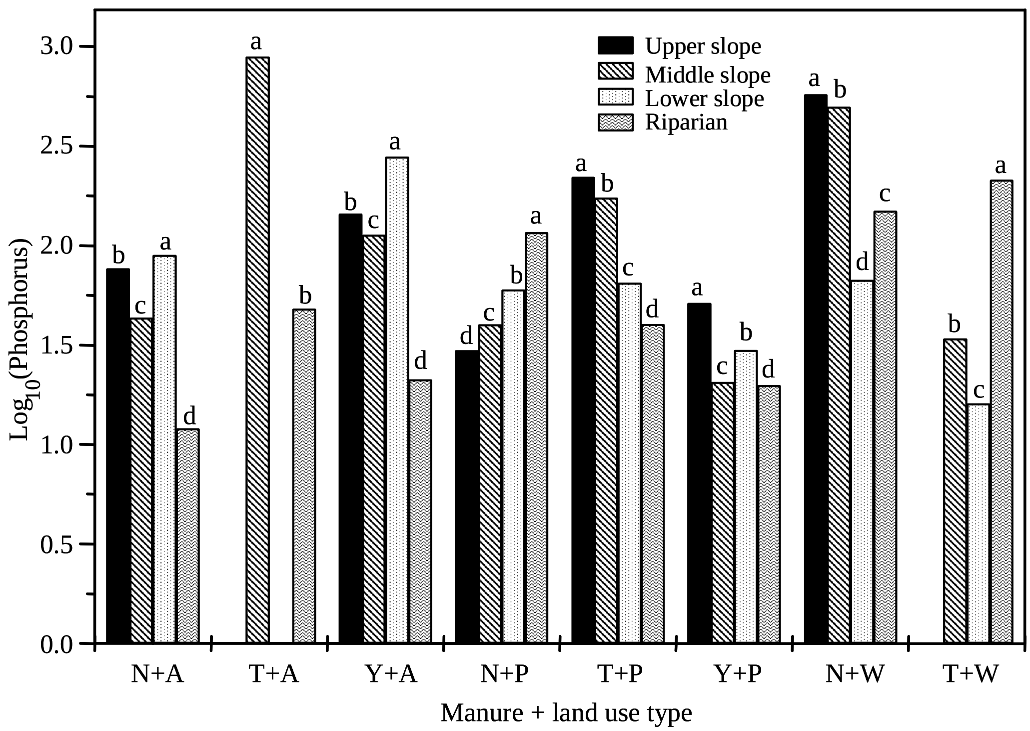

Fig. A4.3. Plot of log-transformed phosphorus levels for the 0-5 cm depth interval under different land use + manure, and slope positions. (For each manure + land use type combination, different letters indicate significant difference among slope positions at $P < 0.05$). Note: N = no manure, T = trace manure, Y = manure, A = annuals, P = perennials, W = wooded.

Analysis Using Simple PROC GLM With Both Overall Slope Position and Treatment

Two-factor analysis of variance using raw data. A simple analysis was conducted using PROC GLM with treatments and overall slope position as the two factors. The eight treatments were combinations of the manure application and land use type (referred to as mantype), and the four overall slope positions were upper, middle, lower and riparian slope positions as indicated in the class level information. The results indicate that the model accounted for a significant fraction of the variation (P = 0.0007). The analysis of variance table using type III sum of squares indicated that there was a significant two-way interaction between treatments and overall position.

The column graph (Fig. A4.4) below reflects the interaction effects. For the no manure + annual land use type, the phosphorus levels were smallest at upper slope positions and greatest in riparian areas. However, the reverse was true for the trace manure + annual land use type, with riparian areas having lower phosphorus levels than upper slope areas.

Note: This analysis used the raw data set, which had already been found to be not normally distributed. This violates the assumption of normality in parametric analyses and renders this analysis invalid.

```
                         Phosphorus analysis, two-way approach, 0-5 cm
                                       The GLM Procedure
                                   Class Level Information
                           Class         Levels    Values
                           mantype            8    1 2 3 4 5 6 7 8
                           ovpos              4    L M R U

                                 Number of observations    351
                                       The GLM Procedure
Dependent Variable: phosp
                                              Sum of
      Source                      DF         Squares     Mean Square    F Value    Pr > F
      Model                       26      96494.7737       3711.3374       2.23    0.0007
      Error                      324     539082.7038       1663.8355
      Corrected Total            350     635577.4774

                      R-Square     Coeff Var      Root MSE    phosp Mean
                      0.151822      89.28805      40.79014      45.68376

      Source                      DF     Type III SS     Mean Square    F Value    Pr > F
      mantype                      7     37289.88567      5327.12652       3.20    0.0027
      ovpos                        3      7132.23215      2377.41072       1.43    0.2342
      mantype*ovpos               16     60472.48300      3779.53019       2.27    0.0038
```

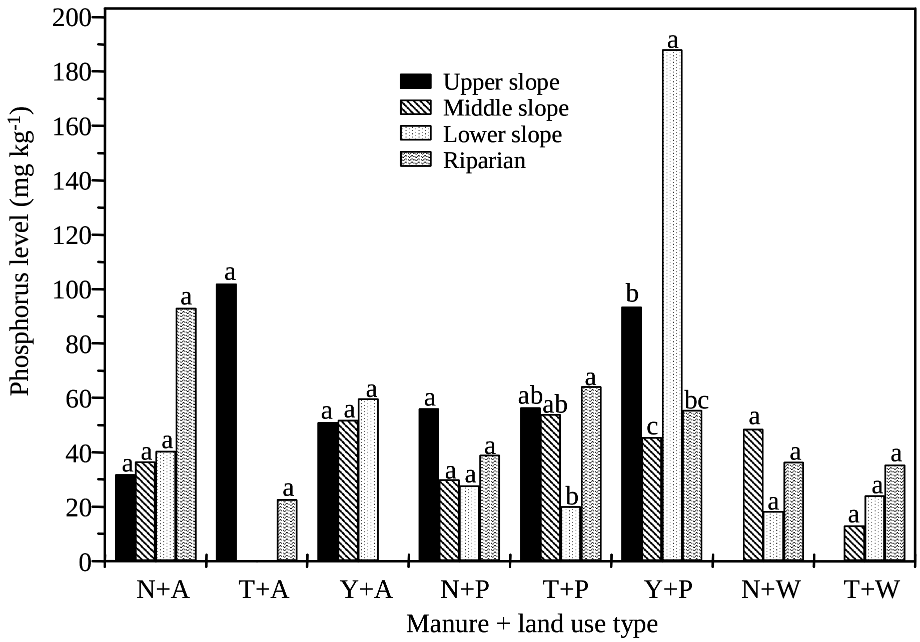

Fig. A4.4. Plot of phosphorus levels for the 0-5 cm depth interval under different land use + manure, and overall slope positions. For each manure + land use type, different letters indicate significant differences among overall slope positions at $P < 0.05$. Note: N = no manure, T = trace manure, Y = manure, A = annuals, P = perennials, W = wooded.

Two-factor analysis of variance using log-transformed data. Using the two-factor approach, with manure + land use type as one factor and overall slope position as another factor, a significant interaction effect was obtained. The F-value and probability from this analysis were very similar to the corresponding values obtained in the above analysis for raw data.

```
                     Phosphorus analysis, one-way approach, 0-5 cm
                                     The GLM Procedure
                                 Class Level Information
                           Class         Levels    Values
                           mantype            8    1 2 3 4 5 6 7 8
                           ovpos              4    L M R U
                               Number of observations    351

                                     The GLM Procedure
Dependent Variable: logp
                                            Sum of
      Source                      DF       Squares     Mean Square    F Value    Pr > F
      Model                       26    7.05780391      0.27145400       2.76    <.0001
      Error                      324   31.91496242      0.09850297
      Corrected Total            350   38.97276633

                     R-Square     Coeff Var      Root MSE    transP Mean
                      0.181096      20.45902      0.313852       1.534051

      Source                      DF   Type III SS     Mean Square    F Value    Pr > F
      mantype                      7    2.68677304      0.38382472       3.90    0.0004
      ovpos                        3    0.60341402      0.20113801       2.04    0.1079
      mantype*ovpos               16    4.04456314      0.25278520       2.57    0.0009
```

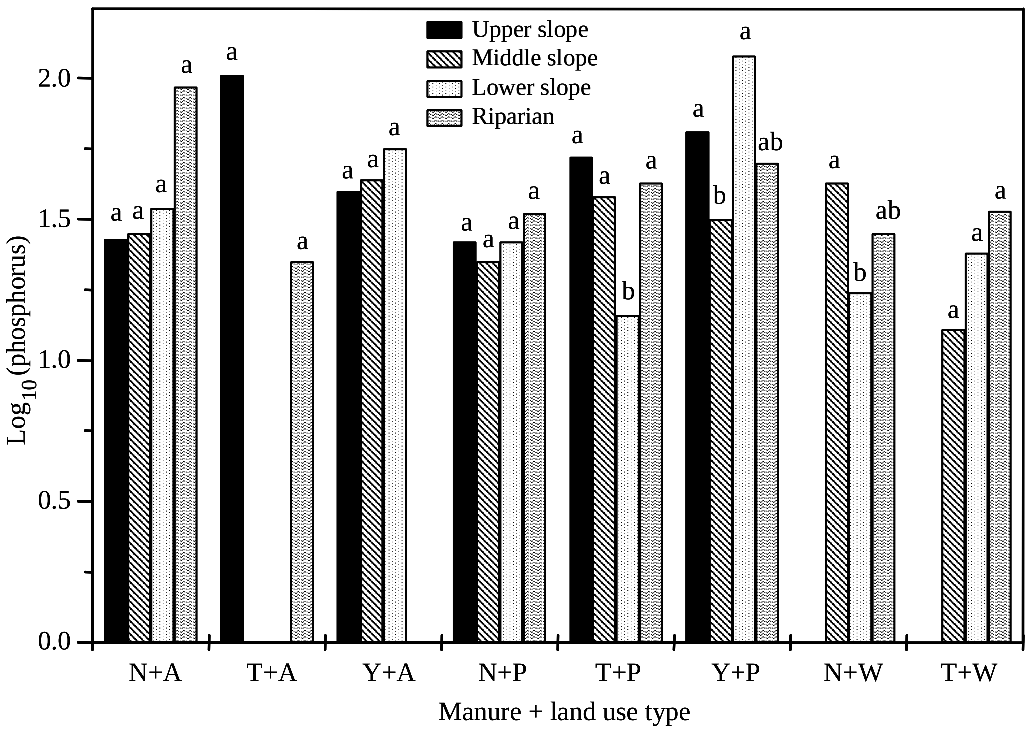

Fig. A4.5. Plot of $\log_{10}$ (phosphorus) for the 0-5 cm depth under different land use + manure, and overall slope positions. For each manure + land use type different letters indicate significant differences among slope positions at $P < 0.05$. Note: N = no manure, T = trace manure, Y = manure, A = annuals, P = perennials, W = wooded.

Power Analysis of Raw Data and Log-transformed Data

Power analysis and sample size estimation was conducted using SAS Proc IML (Interactive Matrix Language). The results presented are those for comparison of three manure treatments in future studies such as this one. The statistical power analysis characterizes the ability of a study to detect a meaningful effect size. It also determines the sample size required to provide a desired power for an effect of scientific interest. Traditionally statistical power is the probability $1-\beta$ of correctly rejecting the null hypothesis (H_o) when it is false.

The following power curves (Fig. A4.6) were obtained for comparing three manure treatments similar to those used in this M1 sub-basin study. Phosphorus means of the three treatments after logarithmic transformation were assumed to be equal to the population means (μ_1, μ_2, μ_3) and the overall standard deviation (σ), as well as the significance levels (0.10, 0.05 and 0.01) were used for the calculation of the statistical power for a given sample size. In general, many biologists and ecologists desire a statistical power of at least 85%. Thus, using the log-transformed data set the sample sizes required to detect meaningful differences would be approximately 50, 65 and 90, at significance levels of 0.10, 0.05 and 0.01, respectively.

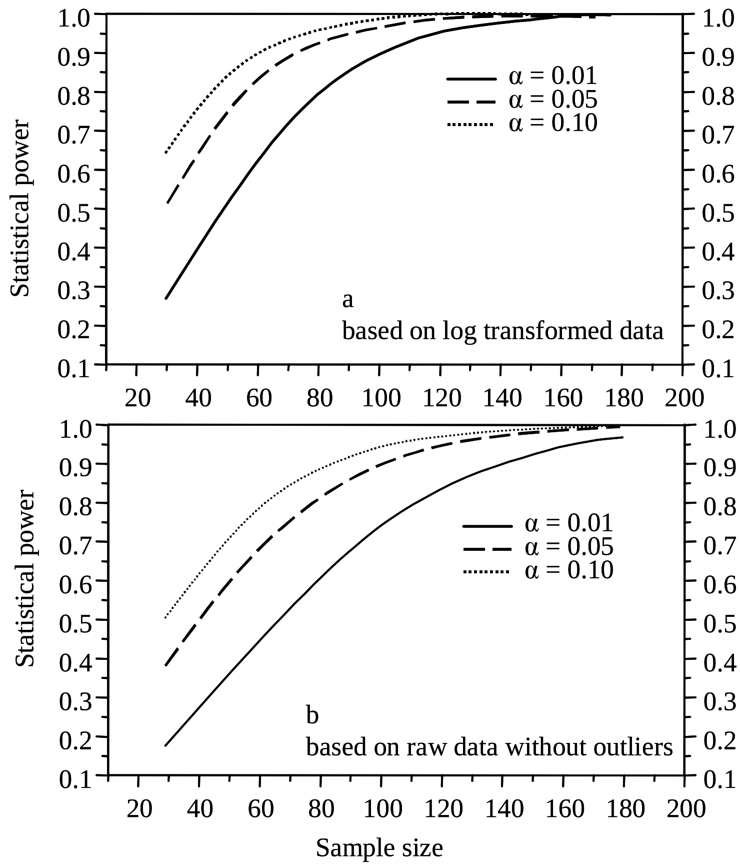

Fig. A4.6. Power and sample size curves for log-transformed and raw data set assuming three different significance levels.

Conclusions: Appropriate Analysis

The raw data set analyzed had several points that were outliers and the distribution of residuals indicated that the assumption of normality was violated. To improve the analysis, a logarithmic transformation was conducted and the resulting analysis of log-normal data indicated a distribution of residuals that was close to a normal distribution. This was important to ensure meaningful estimates of covariance parameters. The estimated covariance parameters were used to adjust for spatial correlation. The resulting analysis of variance after taking into account the spatial variability indicated highly significant treatment effects. Contrasts were performed to answer specific questions regarding differences among manure treatments, among slopes and among land use types. This log-transformed data analysis is the most appropriate analysis, because first, the data set was close to a normal distribution, and secondly treatment effects were evaluated after adjustment for spatial variability, and thirdly there were fewer outliers in the data set compared to the analysis in which raw data were used.

SECTION 2: PHOSPHORUS DATA ANALYSIS FOR THE 0-15 CM DEPTH INTERVAL

Analysis of Variance for the Raw Phosphorus Data Using GLM Procedure

Examination of treatment effects. The phosphorus data taken in the 0-15 cm depth interval were examined. Combinations of land use type, amendment and slope position were numbered from 1-29 treatments and analyzed using a one-way analysis of variance with the Generalized Linear Models (GLM) procedure in SAS. Analysis of variance results indicated no treatment effects (F-value = 1.06; $P = 0.3930$) on the phosphorus levels. However, examination of residuals was conducted before adopting the results.

```
                                        The GLM Procedure
                                     Class Level Information
Class        Levels  Values
treat            29  1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28
                     29
                                  Number of observations    353

Dependent Variable: phosp
                                         Sum of
      Source                     DF          Squares     Mean Square    F Value    Pr > F
      Model                      28       34723.8218       1240.1365       1.06    0.3930
      Error                     324      380833.5194       1175.4121
      Corrected Total           352      415557.3412

                      R-Square     Coeff Var      Root MSE    phosp Mean
                      0.083560      105.6956      34.28428      32.43683

      Source                     DF      Type III SS     Mean Square    F Value    Pr > F
      treat                      28      34723.82180      1240.13649       1.06    0.3930
```

Detection of outliers. The following output comes from SAS analysis to determine the incidence of outliers using PROC Univariate as described in Section 1 of this report. From the analysis 18 observations were detected as outliers. However, removal of outliers is only conducted if there is ample evidence that would justify this procedure. As a result, further analyses were conducted on the whole data set.

```
                                 The UNIVARIATE Procedure
                                        Variable:  resid
                                             Moments
                N                             353    Sum Weights                353
                Mean                            0    Sum Observations             0
                Std Deviation          32.8924521    Variance            1081.91341
                Skewness               4.76962861    Kurtosis            35.9802209
                Uncorrected SS         380833.519    Corrected SS        380833.519
                Coeff Variation                 .    Std Error Mean      1.75068858


                                   Basic Statistical Measures

                    Location                    Variability
                Mean       0.0000     Std Deviation            32.89245
                Median    -6.9727     Variance                     1082
                Mode     -22.5583     Range                   361.81090
                                      Interquartile Range      26.29482
            NOTE: The mode displayed is the smallest of 8 modes with a count of 3.

                                   Tests for Location: Mu0=0
                   Test           -Statistic-    -----p Value------
```

```
     Student's t    t         0    Pr > |t|    1.0000
     Sign           M       -45    Pr >= |M|   <.0001
     Signed Rank    S     -6609    Pr >= |S|   0.0004

                   Tests for Normality
Test                 --Statistic---    -----p Value------
Shapiro-Wilk         W     0.647004    Pr < W     <0.0001
Kolmogorov-Smirnov   D     0.146432    Pr > D     <0.0100
Cramer-von Mises     W-Sq  3.529835    Pr > W-Sq  <0.0050
Anderson-Darling     A-Sq  20.86036    Pr > A-Sq  <0.0050

                 Quantiles (Definition 5)
                 Quantile        Estimate
                 100% Max       319.92143
                 99%            167.56111
                 95%             40.73077
                 90%             28.59333
                 75% Q3           9.38649
                 50% Median      -6.97273
                 25% Q1         -16.90833
                 10%            -24.74615
                 5%             -31.81351
                 1%             -37.74615
                 0% Min         -41.88947

                   Extreme Observations
        ------Lowest-----        -----Highest-----
           Value      Obs           Value      Obs
        -41.8895      334         105.656      330
        -40.5895       22         167.561      161
        -38.0895      342         187.911      160
        -37.7462       47         233.100      123
        -36.0895       25         319.921      328

                 The UNIVARIATE Procedure
                     Variable:  resid
              Histogram                      #             Boxplot
310+*                                        1                *
   .
   .
   .
   .*                                        1                *
   .
   .*                                        1                *
   .*                                        1                *
   .
130+
   .*                                        1                *
   .
   .*                                        4                0
   .***                                      9                0
   .*********                               36                |
   .********************                    79             +--+--+
   .****************************************   160             *-----*
   .***************                         58                |
-50+*                                        2                |
    ----+----+----+----+----+----+----+----+
    * may represent up to 4 counts
```

Test for normality of distribution of residuals. PROC INSIGHT and PROC GPLOT in SAS were used in making a plot of residuals against predicted values and to examine the pattern of residuals (Fig. A4.7). The pattern of residuals gives an indication of whether or not the data follow a normal distribution, and also if any transformation of data would be required.

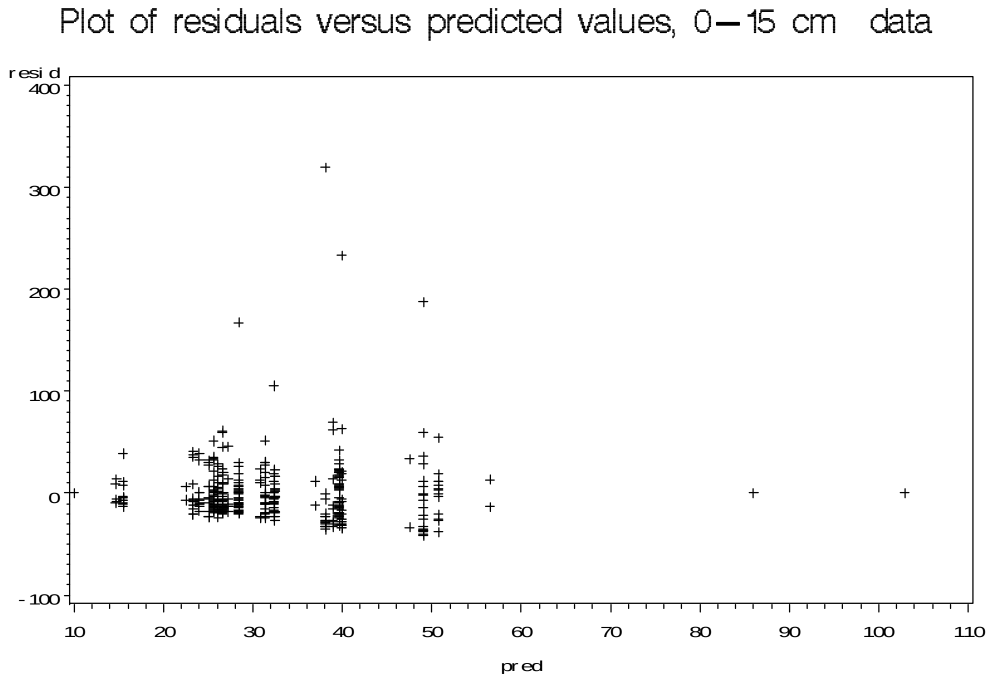

Fig. A4.7. Plot of residuals versus predicted values of phosphorus data for the 0-15 cm depth interval.

The plot shows that the residuals are not evenly distributed below and above zero, and as predicted values increased, the residuals became more spread out. This pattern indicates that the data are not normally distributed and a transformation of the data would be required to normalize the data set. As a result, a logarithmic transformation was performed on the data set and the resulting log-normal data analyzed using the GLM procedure.

Analysis of Variance for Transformed Data Using GLM Procedure

The following SAS output shows the results of the analysis of variance of phosphorus data for the 0-15 cm depth interval after a logarithmic (log_{10}) transformation. This is a very powerful transformation that was adopted in order to attempt to normalize the data set. This was also essential to enable reasonable estimation of the covariance parameters for use in adjusting for spatial variability of the data set when comparing treatments.

Examination of treatment effects. The output from the GLM procedure below indicates that at least two treatments had significantly different levels of phosphorus (F = 2.33; ***P*** = 0.0002). This conclusion is contrary to the conclusion reached in the first analysis, which utilized raw untransformed phosphorus data set.

```
         The GLM Procedure
                                           Class Level Information
Class          Levels  Values
treat              29  1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28
                       29
                                        Number of observations    353
```

```
                                       The GLM Procedure
Dependent Variable: transp
                                              Sum of
      Source                      DF         Squares     Mean Square    F Value    Pr > F
      Model                       28      8.01867141      0.28638112       2.33    0.0002
      Error                      324     39.79119393      0.12281233
      Corrected Total            352     47.80986533

                      R-Square     Coeff Var      Root MSE    transp Mean
                      0.167720      25.82811      0.350446       1.356839

      Source                      DF     Type III SS     Mean Square    F Value    Pr > F
      treat                       28      8.01867141      0.28638112       2.33    0.0002
```

Detection of outliers. The box plot indicates that there were three outlier points in the data set (i.e. points marked by O and *). These data points were not removed from the whole data set because of lack of any clear reason to justify their removal. However, a closer look at the pattern of the distribution of residuals showed a pattern closer to a normal distribution than was the case with the raw data set.

```
                           The UNIVARIATE Procedure
                                Variable:  resid
                                     Moments
                N                         353    Sum Weights                353
                Mean                        0    Sum Observations             0
                Std Deviation      0.33621892    Variance            0.11304316
                Skewness           0.28748194    Kurtosis            0.74345995
                Uncorrected SS     39.7911939    Corrected SS        39.7911939
                Coeff Variation             .    Std Error Mean      0.01789513

                           Basic Statistical Measures
                        Location                 Variability
                    Mean      0.00000     Std Deviation            0.33622
                    Median   -0.00000     Variance                 0.11304
                    Mode     -0.77833     Range                    2.34548
                                          Interquartile Range      0.45121
            NOTE: The mode displayed is the smallest of 7 modes with a count of 3.

                           Tests for Location: Mu0=0
                       Test           -Statistic-    -----p Value------
                       Student's t    t         0    Pr > |t|    1.0000
                       Sign           M      -0.5    Pr >= |M|   1.0000
                       Signed Rank    S    -515.5    Pr >= |S|   0.7886


                              Tests for Normality
                 Test                  --Statistic---    -----p Value------
                 Shapiro-Wilk          W      0.99147    Pr < W      0.0396
                 Kolmogorov-Smirnov    D     0.029978    Pr > D     >0.1500
                 Cramer-von Mises      W-Sq  0.044594    Pr > W-Sq  >0.2500
                 Anderson-Darling      A-Sq  0.352333    Pr > A-Sq  >0.2500

                             Quantiles (Definition 5)
                             Quantile       Estimate
                             100% Max       1.428400
                             99%            0.873616
                             95%            0.566460
                             90%            0.401548
                             75% Q3         0.203843
                             50% Median    -0.000000
                             25% Q1        -0.247366
                             10%           -0.402268
                             5%            -0.537733
                             1%            -0.778325
                             0% Min        -0.917079
```

```
                    Extreme Observations
            ------Lowest------        ------Highest-----
               Value      Obs            Value      Obs
           -0.917079      178         0.729120      330
           -0.778325      303         0.873616      160
           -0.778325      240         0.952653      161
           -0.778325       44         1.109615      123
           -0.730771       90         1.428400      328

                  The UNIVARIATE Procedure
                     Variable:  resid
Stem Leaf                                      #             Boxplot
  14 3                                          1                0
  13
  12
  11 1                                          1                0
  10
   9 5                                          1                0
   8 7                                          1                |
   7 3                                          1                |
   6 245667899                                  9                |
   5 113457888                                  9                |
   4 0000233335566678                          16                |
   3 000001122333346777888888999               27                |
   2 00000012334455555566777889                26             +-----+
   1 000111111122222333334444555555666778888888899   45       |     |
   0 0000112222333333444445555555666788899999  40             *--+--*
  -0 9999988888777777776666555555443333222100  40             |     |
  -1 99999766666655544444443322111100000       35             |     |
  -2 9987777766666666655444333322111           31             +-----+
  -3 99999877666554433333222111100000          32                |
  -4 7666555443222211000                       19                |
  -5 775442                                     6                |
  -6 65542                                      5                |
  -7 8883333                                    7                |
  -8                                                             |
  -9 2                                          1                |
     ----+----+----+----+----+----+----+----+----+
 Multiply Stem.Leaf by 10**-1
```

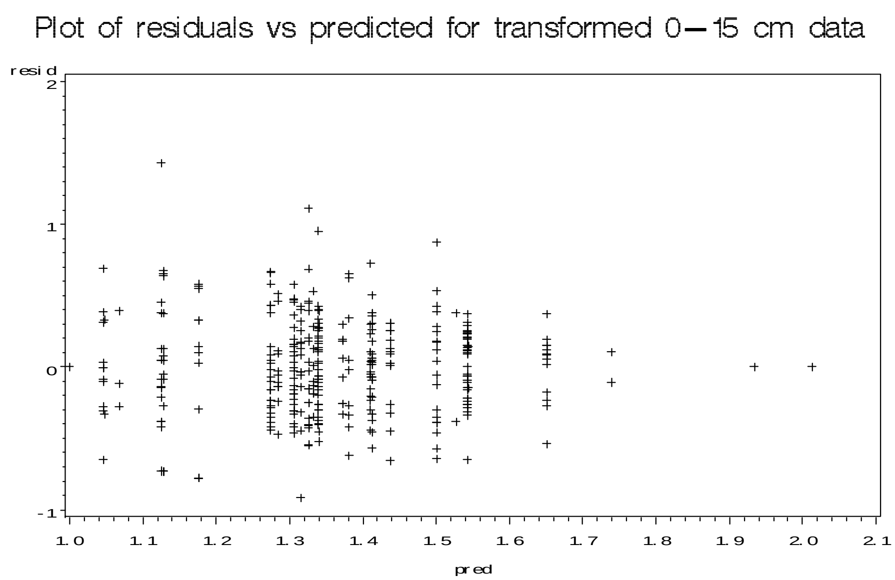

Fig. A4.8. Plot of residuals versus predicted values for the log-transformed data analysis.

Examination of residuals. The plot of residuals against predicted values (Fig. A4.8) indicated the residuals were fairly evenly distributed below and above zero, and thus the data had a pattern that was close to a normal distribution. This was also supported by the box plot, which indicated a distribution pattern close to a normal distribution.

Adjusting for Spatial Variability Using MIXED Model Procedure

Estimating covariance parameters for log-transformed data. The following output shows estimates of the sill (σ^2) and the range (ρ) of the semi-variogram for data after logarithmic transformation, using the restricted maximum likelihood (REML) procedure in PROC MIXED. The Satterthwaite procedure was used to compute the denominator degrees of freedom so as to provide a more accurate F-test. This option is available in PROC MIXED.

After the transformation, the plot of residuals indicated that the errors were close to a normal distribution. Further, the estimation of the semi-variance makes sense only if the data set is normally distributed. After fitting the spherical, exponential and gaussian spatial correlation models, the results indicated that the highest Akaike's Information Criterion (AIC) and Schwarz's Bayesian Criterion (BIC) values, and the lowest –2REML Log Likelihood statistic were obtained for the gaussian spatial model, and this model was chosen as the best out of the three. Thus, the variance (σ^2) and range (ρ) estimates for this model were used in the adjustment of treatment effects.

```
                  The Mixed Procedure
                  Model Information
Data Set                     WORK.WATERSHD
Dependent Variable           logphosp
Covariance Structure         Spatial Gaussian
Subject Effect               Intercept
Estimation Method            REML
Residual Variance Method     Profile
Fixed Effects SE Method      Model-Based
Degrees of Freedom Method    Satterthwaite

                Class Level Information
   Class    Levels    Values
   treat        29    1 2 3 4 5 6 7 8 9 10 11 12 13
                      14 15 16 17 18 19 20 21 22 23
                      24 25 26 27 28 29

          Covariance Parameters            3
          Columns in X                    30
          Columns in Z                     0
          Subjects                         1
          Max Obs Per Subject            353
          Observations Used              353
          Observations Not Used            0
          Total Observations             353

            Covariance Parameter Estimates
          Cov Parm     Subject      Estimate
          Variance     Intercept     0.03218
          SP(GAU)      Intercept      2.0525
          Residual                   0.09463

                  Fit Statistics
         -2 Res Log Likelihood          282.2
         AIC (smaller is better)        288.2
         AICC (smaller is better)       288.3
         BIC (smaller is better)        299.6
```

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
treat	28	311	1.88	0.0057

Using the covariance estimates to adjust for the treatment effects. The results indicate that the treatments had a significant effect on the phosphorus levels (*P* < 0.01). These results were obtained from the SAS Mixed model procedure used in conjunction with the PARMS statement with the estimated values of the sill (σ^2) and the range (ρ) of the semi-variogram. The Satterthwaite procedure was used to determine the denominator degrees of freedom so that a more accurate F-test could be conducted. The results indicate highly significant treatment effects on $\log_{10}$(phosphorus), contrary to the conclusions reached when no spatial adjustment was made. Without accounting for spatial variability, treatment effects were significant (*P* = 0.0057). Closer examination indicated significant main effects and interactions among position, type and manure.

The Mixed Procedure

Model Information

Data Set	WORK.WATERSHD
Dependent Variable	logphosp
Covariance Structure	Spatial Gaussian
Subject Effect	Intercept
Estimation Method	REML
Residual Variance Method	None
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Satterthwaite

Class Level Information

Class	Levels	Values
treat	29	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29

Dimensions

Covariance Parameters	2
Columns in X	30
Columns in Z	0
Subjects	1
Max Obs Per Subject	353
Observations Used	353
Observations Not Used	0
Total Observations	353

Parameter Search

CovP1	CovP2	Res Log Like	-2 Res Log Like
0.03218	2.0525	-279614.6885	559229.377

Covariance Parameter Estimates

Cov Parm	Subject	Estimate
Variance	Intercept	0.03218
SP(GAU)	Intercept	2.0525

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
treat	28	324	46179.8	<.0001

Estimates

Standard

Label	Estimate	Error	DF	t Value	Pr > |t|
Manure+riparian vs Manure+upperslope	**0.06139**	**0.01203**	**324**	**5.10**	**<.0001**
No manure+riparian vs no manure+upperslope	**-0.9821**	**0.01683**	**324**	**-58.36**	**<.0001**
Manure+low vs manure+upperslope	**0.6087**	**0.01296**	**324**	**46.97**	**<.0001**
No Manure+low vs No manure+upperslope	**-0.6162**	**0.01408**	**324**	**-43.77**	**<.0001**
manure vs no manure	22.7580	0.6211	324	36.64	<.0001
heavy manure vs no manure	0.6030	0.07443	324	8.10	<.0001
annuals vs wooded	-35.8604	0.3448	324	-104.00	<.0001
perennials vs annuals	15.4060	0.1790	324	86.07	<.0001
perennials vs wooded	-64.6009	0.3213	324	-201.08	<.0001
Trace vs no manure	6.7820	0.1209	324	56.10	<.0001
grasses vs wooded	-100.46	0.6313	324	-159.15	<.0001
upper vs others	-12.5547	0.3556	324	-35.31	<.0001
riparian vs others	-9.6532	0.4376	324	-22.06	<.0001
lower vs upper slope	-5.7417	0.1341	324	-42.80	<.0001

The above contrasts are not orthogonal. It is important to note that there were significant main effects and interactions among manure treatments and among vegetation types. Significant effects were observed among combinations of manure and position. From these results we can see that low slope positions without manure had lower phosphorus levels than upper slope positions without manure. However, in manure treatments the phosphorus levels in low slope positions was greater than those in upper slope positions.

The following graph shows where interaction effects exist (Fig. A4.9). For example, in the perennials without manure the levels of phosphorus increased between upper slope and riparian areas, whereas the reverse was true for the perennials with trace manure. In the wooded areas, trace manure additions resulted in increased phosphorus in riparian areas compared to upper slope positions, whereas the reverse was true for wooded areas without manure.

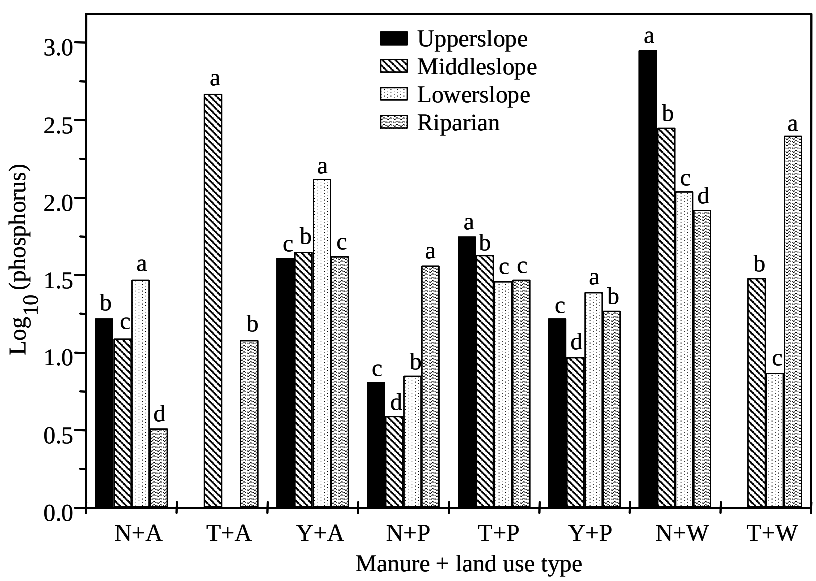

Fig. A4.9. Plot of log-transformed phosphorus levels for the 0-15 cm depth under different land use + manure, and slope positions. (For each manure + land use type combination, different letters indicate significant difference among slope positions at $P < 0.05$). Note: N = no manure, T = trace manure, Y = manure, A = annuals, P = perennials, W = wooded.

Conclusions: Appropriate Analysis

The raw 0-15 cm phosphorus data set analyzed had 18 points that were outliers and the distribution of residuals indicated that the assumption of normality was violated. A logarithmic transformation was conducted and the resulting analysis indicated a distribution of residuals that was close to a normal distribution. Without accounting for spatial variability the F-test indicated significant differences among treatments ($P = 0.0057$). The estimated covariance parameters were used to adjust for spatial correlation. The resulting analysis of variance after adjusting for spatial variability indicated highly significant treatment effects ($P < 0.0001$). In conclusion, the log-transformed data analysis is the most appropriate analysis, because first, the data set was close to a normal distribution, and secondly treatment effects were evaluated after adjustment for spatial variability, thirdly there were fewer outliers in the data set compared to the analysis in which raw data were used.