FIELD VALIDATION OF THE TEXAS PHOSPHORUS INDEX

TSSWCB Project 02-11

Final Report

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Executive Summary

Phosphorus (P) is an essential element in plant and animal nutrition. However, it also has been identified as an element that may serve a controlling function in the occurrence of eutrophication in fresh surface waterbodies. Eutrophication has been identified as one of the major causes of impaired water quality in the United States (USEPA, 1996). It restricts water use for fisheries, recreation, industry, and drinking due to the increased growth of undesirable algae, aquatic weeds and resulting oxygen shortages caused by their death and decomposition (Sharpley et al., 2000).

Although watershed scale studies are important to evaluate gross potential nutrient losses, research has clearly shown that field scale evaluations will be most critical for effective targeting of limited resources. Significant effort has been directed toward development of predictive tools which can be used to estimate potential nonpoint source losses of P. One example is a simple P index (PI) developed by the U.S. Department of Agriculture, Agricultural Research Service, as a field level screening tool to rank the vulnerability of fields as sources of P loss in runoff water (Lemunyon and Gilber, 1993). The PI currently used in Texas is patterned after this reference.

The objectives of this project were to field evaluate the PI model, make recommendations to improve the predictive potential of the PI model, and communicate to NRCS, TSSWCB, TCEQ, animal industry clientele, and citizens of Texas the findings of the demonstrations conducted through this project. Findings indicated that the best management practice for the producers is well managed pasture and hay fields. The highest amounts of runoff and erosion occurred in the tilled fields. The greatest erosion did not correlate to the highest amounts of P transported. Runoff P was best correlated to Mehlich-3 extractable P and Mg and there was no correlation between 200 mg kg^{-1} soil test P and runoff P concentrations.

We are recommending that the PI not be changed at this time to allow for the poultry project (TSSWCB Project 04-04) to be completed. These two projects in conjunction with a project being conducted by Daren Harmel, USDA/ARS in Riesel, Texas will be combined to formalize recommendations for the revision of the PI for Texas. These projects should be completed by December 2010. Based upon the results from these three projects, we will be able to make recommendations to improve the Texas PI. This in turn will help determine P land application rates using nutrient management plans, thus reducing the potential for P transport from fields where P sources of nutrients are applied and reducing the potential for P to enter surface waterbodies in concentrations high enough to contribute to P water quality issues.

Introduction

Phosphorus (P) is an essential element in plant and animal nutrition. However, it also has been identified as an element that may serve a controlling function in the occurrence of eutrophication in fresh surface water bodies. Eutrophication has been identified as one of the major causes of impaired water quality in the United States (USEPA, 1996). It restricts water use for fisheries, recreation, industry, and drinking due to the increased growth of undesirable algae, aquatic weeds and resulting oxygen shortages caused by their death and decomposition (Sharpley et al., 2000).

Although watershed scale studies are important to evaluate gross potential nutrient losses, research has clearly shown that field scale evaluations will be most critical for effective targeting of limited resources. Significant effort has been directed toward development of predictive tools which can be used to estimate potential nonpoint source losses of P. One example is a simple P index (PI) developed by the U.S. Department of Agriculture, Agricultural Research Service, as a field level screening tool to rank the vulnerability of fields as sources of P loss in runoff water (Lemunyon and Gilber, 1993). The PI currently used in Texas is patterned after this reference.

The PI is designed to provide a basic assessment of both source and transport factors (collectively referred to as site factors) controlling P loss in surface runoff. Source factors include soil test P level, inorganic and organic fertilizer phosphorus application rates and inorganic and organic fertilizer phosphorus methods of application. Transport factors include proximity of the nearest field application edge to a named stream or lake, runoff class and erosion potential. In Texas, the PI is a simple 8 x 5 matrix that combines site factors with a series of condition classes which identify Not Applicable, Very Low-Low, Medium, High and Very High levels of runoff potential. Site factors and condition classes are assigned weighted values based on relative importance. Utilizing field specific data, condition classes are assigned for each site factor and enable calculation of a numeric point value. Total index points for an individual site are then compared to a standard index to determine overall P runoff potential for the site. The state is divided into East and West Texas PI worksheets based upon the 25 inch rainfall line. The PI worksheets and Texas map are shown in Tables 1 and 2, Fig. 1 and the complete website for Texas NRCS Agronomy Note, Phosphorus Assessment Tool for Texas, is http://efotg.nrcs.usda.gov/references/public/TX/TXTechNote15_rev.pdf

Gburek et al. (1996) found that when the original PI was applied to a larger watershed in Pennsylvania, its field rankings did not accurately identify all areas with substantive impacts on stream water quality. Sharpley et al. (2000) reported that since the overall flow systems of upland watersheds are largely fixed in space, limited opportunity exists to control or manipulate the hydrology of these systems. Thus, the most realistic and likely most effective means for modification of potential P losses will be through management of the source terms of the PI.

TABLE 1. PHOSPHORUS INDEX WORKSHEET FOR EAST TEXAS

PHOSPHORUS INDEX WORKSHEET for East Texas

Client Name:			Crop:			
Planner:			Field(s):			
Rainfall:			Slope %:			
Location:			Runoff Curve No:		Soil Test Date:	
Site Characteristic (Weighting Factor)	0	[Weighting Factor Times the Column Factor] 1	2	4	8	Sub Total
Soil Test P Rating	N/A	Very Low – Low	Moderate	High	Very High	
(1.00)	[0]	[1.0]	[2.0]	[4.0]	[8.0]	
Fertilizer Phosphorus (P_2O_5) Application Rate	None Applied	1-40 lbs/ac P_2O_5	41-90 lbs/ac P_2O_5	91-150 lbs/ac P_2O_5	>150 lbs/ac P_2O_5	
(0.75)	[0]	[0.75]	[1.5]	[3.0]	[6.0]	
Organic Phosphorus (P_2O_5) Application Rate	None Applied	1-40 lbs/ac P_2O_5	41-90 lbs/ac P_2O_5	91-150 lbs/ac P_2O_5	>150 lbs/ac P_2O_5	
(0.75)	[0]	[0.75]	[1.5]	[3.0]	[6.0]	
Phosphorus Fertilizer Application Method and Timing	None Applied	Placed deeper than 2 in. or broadcast and incorporated within 48 hours*	Surface applied only during the period 12/1-2/15	Surface applied only during the period 6/16 – 4/15	Surface Applied 1/1 – 12/31	
(0.50)	[0]	[0.50]	[1.0]	[2.0]	[4.0]	
Organic Phosphorus source Application Method and Timing	None Applied	Placed deeper than 2 in. or broadcast and incorporated within 48 hours*	Surface applied only during the period 12/1-2/15	Surface applied only during the period 6/16 – 4/15	Surface Applied 1/1 – 12/31	
(0.50)	[0]	[0.50]	[1.0]	[2.0]	[4.0]	
Proximity of nearest field application area to named stream or lake	> 2000 feet	1000 – 1999 feet	500 – 999 feet	100 – 499 feet	< 100 feet	
(1.25)	[0]	[1.25]	[2.5]	[5.0]	[10.0]	
Runoff Class (Runoff Class Table 3)	Negligible	Low	Moderate	High	Very High	
(1.00)	[0]	[1.0]	[2.0]	[4.0]	[8.0]	
Soil Erosion (all sources)	Very Low <1 t/ac	Low 1-3 t/ac	Medium 3-5 t/ac	High 5-10 t/ac	Very High >10 t/ac	
(1.50)	[0]	[1.5]	[3.0]	[6.0]	[12.0]	
					Total Index Points:	

Phosphorus Index Classification – East Texas	
Index Points	Phosphorus Runoff Potential
< 12	Very Low - Low
12 – 22.75	Medium
23 - 32	High
> 32	Very High

*If using effluent with less than 2% solids (applied through a center pivot), the Organic Phosphorus Source Application and Timing, would be considered equivalent to "Placed deeper than 2 inches or broadcast and incorporated with 48 hours". If using effluent with 2% or more solids, not followed up with clear irrigation water, or not diluted to less than 2% solids, the Organic Phosphorus Source Application and Timing, would be considered as any other non-incorporated surface application.

TABLE 2. PHOSPHORUS INDEX WORKSHEET FOR WEST TEXAS

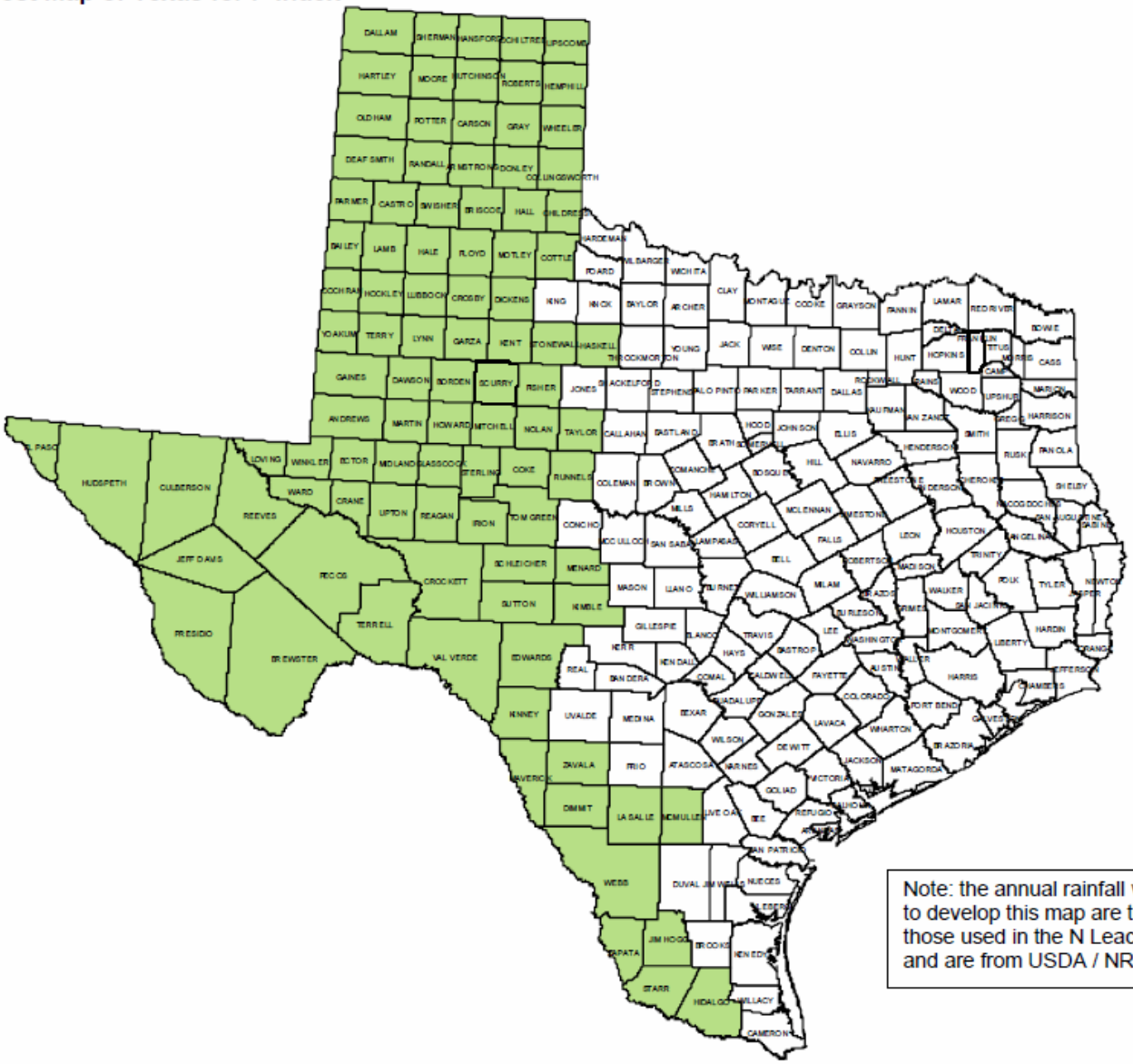
PHOSPHORUS INDEX WORKSHEET for West Texas

Client Name:			Crop:			
Planner:			Field(s):			
Rainfall:			Slope %:			
Location:			Runoff Curve No:		Soil Test Date:	
Site Characteristic (Weighting Factor)	[Weighting Factor Times the Column Factor] 0	1	2	4	8	Sub Total
Soil Test P Rating	N/A	Very Low – Low	Moderate	High	Very High	
(1.00)	[0]	[1.0]	[2.0]	[4.0]	[8.0]	
Fertilizer Phosphorus (P_2O_5) Application Rate	None Applied	1-40 lbs/ac P_2O_5	41-90 lbs/ac P_2O_5	91-150 lbs/ac P_2O_5	>150 lbs/ac P_2O_5	
(0.75)	[0]	[0.75]	[1.5]	[3.0]	[6.0]	
Organic Phosphorus (P_2O_5) Application Rate	None Applied	1-40 lbs/ac P_2O_5	41-90 lbs/ac P_2O_5	91-150 lbs/ac P_2O_5	>150 lbs/ac P_2O_5	
(0.75)	[0]	[0.75]	[1.5]	[3.0]	[6.0]	
Phosphorus Fertilizer Application Method and Timing	None Applied	Placed deeper than 2 in. or broadcast and incorporated within 48 hours*	Incorporated immediately before planting or green-up	Incorporated >4 months before planting, or surface applied < 4 months before planting	Surface applied >4 months before planting	
(0.50)	[0]	[0.50]	[1.0]	[2.0]	[4.0]	
Organic Phosphorus source Application Method and Timing	None Applied	Placed deeper than 2 in. or broadcast and incorporated within 48 hours*	Incorporated immediately before planting	Incorporated >4 months before planting or green-up, or surface applied < 4 months before planting or green-up	Surface applied >4 months before planting or green-up	
(0.50)	[0]	[0.50]	[1.0]	[2.0]	[4.0]	
Proximity of nearest field application area to named stream or lake	> 2000 feet	1000 – 1999 feet	500 – 999 feet	100 – 499 feet	< 100 feet	
(1.25)	[0]	[1.25]	[2.5]	[5.0]	[10.0]	
Runoff Class (Runoff Class Table 3)	Negligible	Low	Moderate	High	Very High	
(1.00)	[0]	[1.0]	[2.0]	[4.0]	[8.0]	
Soil Erosion (all sources)	Very Low <1 t/ac	Low 1-3 t/ac	Medium 3-5 t/ac	High 5-10 t/ac	Very High >10 t/ac	
(1.50)	[0]	[1.5]	[3.0]	[6.0]	[12.0]	
					Total Index Points:	

Phosphorus Index Classification – West Texas	
Index Points	Phosphorus Runoff Potential
< 15	Very Low - Low
15 – 24.75	Medium
25 - 35	High
> 35	Very High

* If using effluent with less than 2% solids (applied through a center pivot), the Organic Phosphorus Source Application and Timing, would be considered equivalent to "Placed deeper than 2 inches or broadcast and incorporated with 48 hours". If using effluent with 2% or more solids, not followed up with clear irrigation water, or not diluted to less than 2% solids, the Organic Phosphorus Source Application and Timing, would be considered as any other appropriate application category.

Figure 1 – East / West Map of Texas for P Index



Note: the annual rainfall values used to develop this map are the same as those used in the N Leaching Index and are from USDA / NRCS sources.

One key area of concern deals with the soil test P level source factor and its relationship to potential P loss. Research in Texas has shown that soil test P level can be highly dependent on several site factors including soil type, field history, P source, and soil test extractant. A first step in refining effective site classification strategies such as the PI is to evaluate the efficiency of the key soil test parameter, and its relationship to other source and transport variables.

Rainfall simulation has been used as a tool for predicting the effects of site specific characteristics on potential P loss. It is much easier and more cost effective than watershed scale studies. Most importantly, it offers an opportunity to verify the accuracy of less intensive methods, such as the PI, by examining the impacts of specific source and transport parameters on measured and predicted outcomes.

In theory, the PI provides a reasonably rapid approach for planners and land managers to identify sites with the greatest potential to contribute to nonpoint source pollution. In addition, it enables comparison of selected alternative management practices which can be used to reduce P losses. However, very limited research has been conducted to provide field validation of the effectiveness of the PI for predicting actual site vulnerability. Weighting factors for both source and transport factors, and vulnerability classifications largely have been intuitively defined. In addition, other soil and site factors may play important roles in controlling the potential for P loss under specific environmental conditions.

Field demonstrations for this project were conducted on sites within the Bosque and Leon Watersheds. Based on the results of this pilot project, additional demonstrations were recommended for the poultry areas of Texas to enable establishment of scientifically based economic and environmental P thresholds.

Materials and Methods

Demonstration sites were located mainly in the Bosque (waterbody segments 1226 and 1255) (Fig. 2) and Leon River (waterbody segment 1221) (Fig. 3) watersheds. These watersheds were selected because of the issues relating P runoff from dairies to P water quality issues within tributaries of the Leon River and tributaries and main channel of the Bosque River. Waterbody segment 1221 is listed as pathogen and total dissolved solids impaired, 1226 is listed as pathogens and chlorophyll *a* impaired, and 1255 segment is listed as pathogens, chloride, sulfate, total dissolved solids, ammonia-N, nitrite+nitrate-N, chlorophyll *a*, ortho-P and total-P impaired from non-point sources. All of the above segments were listed in the 2000 Texas Water Quality Inventory and 303(d) List as having potential sources of nutrients from agriculture. Demonstration sites were selected based on predetermined characteristics designed to facilitate the evaluation of specific input or related variables of the PI mainly from the three waterbody segments mentioned above. Eight sites were selected outside the area to be able to compare field runoff data to rainfall simulation data after all the projects are completed (estimated to be December 2010). The PI risk assessment was completed while in the field for all the field parameters and finalized based upon the soil test P rating and erosion potential. There are different P movement characteristics depending on P solubility that is related to pH, thus variable P potential movement from the field to the surface waterbody. We selected the approximate pH

separating non-calcareous soils and calcareous soils. Emphasis was placed on selection of soil series which represent the dominant series in the region and state. A total of 40 sites representing the dominant soil series used as manure application fields and commercial fertilizer application (site 1101) were evaluated over a two year period. The information from these demonstration sites should be used in assessing nutrient water quality issues in these three waterbody segments.

Soil parameters used in site selection were:

a) PI risk assessment: L, M, and VH.
b) Soil test P: L/M/H, >200 mg kg^{-1}.
c) pH: non-calcareous (pH < 7.5) soils and calcareous (pH = 7.5 or greater) soils within each of the PI/soil test P parameters.
d) Mineralogy, slope, leaching index, etc. will be documented for the PI.

For each field site, the PI was determined based on a thorough site evaluation conducted by Texas AgriLife Extension Service (Extension) and/or USDA-Natural Resources Conservation Service (NRCS) personnel. Each site was evaluated to determine the soil series by USDA-NRCS and/or Extension staff. In addition, soil samples were collected from each site at depth increments of 0 to 2, 2 to 6, and 0 to 6 inches for laboratory analyses of pH, EC, NO_3^--N, Ca, Mg, Na, K, P, S, and B. The analyses included the TAMU and Mehlich III methods for extractable P, TAMU extractable Ca, Mg, Na, K, and S for 2003 only, Mehlich III extractable Ca, Mg, Na, K, and S for 2004 and 2005, soil pH, nitrate-N, 2:1/water:soil salinity, hot water extractable B and soil solution soluble P (SSSP) on selected samples. The reason for the change from the TAMU extract to Mehlich III for extractable cations and S was because the Texas AgriLife Extension Service Soil Water and Forage Testing Laboratory (SWFTL) changed to Mehlich III in January 2004. The SSSP was based on a $CaCl_2$ soil extraction. This extraction was selected based upon previous research comparing the reproducibility of dilute salts, KCl and $CaCl_2$, at various concentrations and shaking times.

Rainfall simulations were conducted to estimate actual runoff P levels from field sites. Specific locations within each site were selected to best represent the characteristics and properties upon which the PI characterization was based. These included the soil series and related runoff and erosion potential classifications, slope, vegetative cover, proximity of edge of field to nearest waterbody, organic and inorganic nutrient application rates and timing of application.

The rainfall simulations were conducted using a Tlaloc 3000 rainfall simulator built by Joerns Inc. The simulator is based on the design of Miller (1987), and is an aluminum frame suspending a single low pressure, square pattern nozzle approximately 3 m above the soil surface. The simulator is capable of variable application rates up to 7.62 cm (3 in.) per hr. Based on this nozzle size and operating pressure, the actual application rate was 7.5 cm per hr. This rate is being used across the nation for the P Benchmark Soils Project on which Sam Feagley is a cooperator. The rate is equivalent to the 24 hr/25 yr storm event for Stephenville, Texas. Simulations were conducted on 1.5 m x 2 m plots. All rainfall simulation procedures were conducted in accordance with the Sera-17 National P Project guidelines for rainfall simulations.

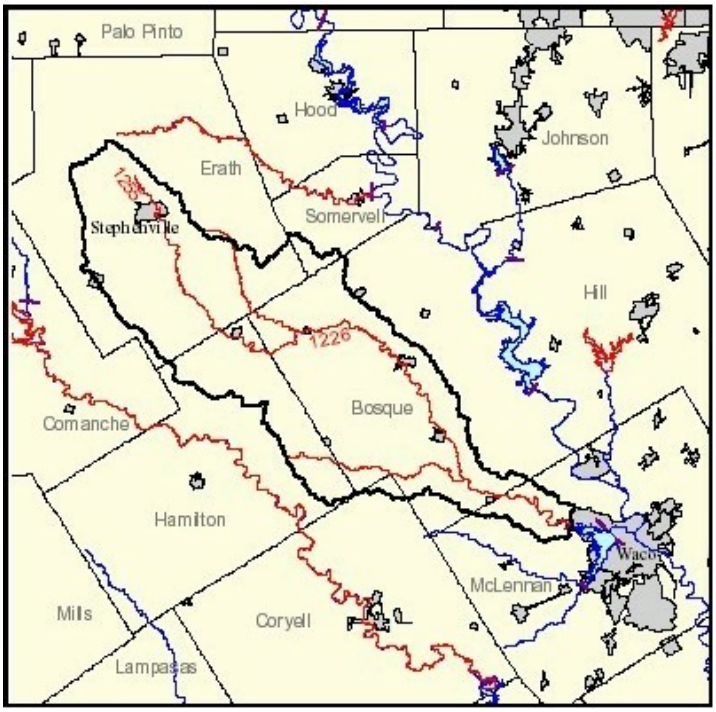


Figure 2. Map of the Upper North Bosque River waterbody segment (1255, Stephenville and north) and North Bosque River waterbody segment (1226, Stephenville and south to Lake Waco).

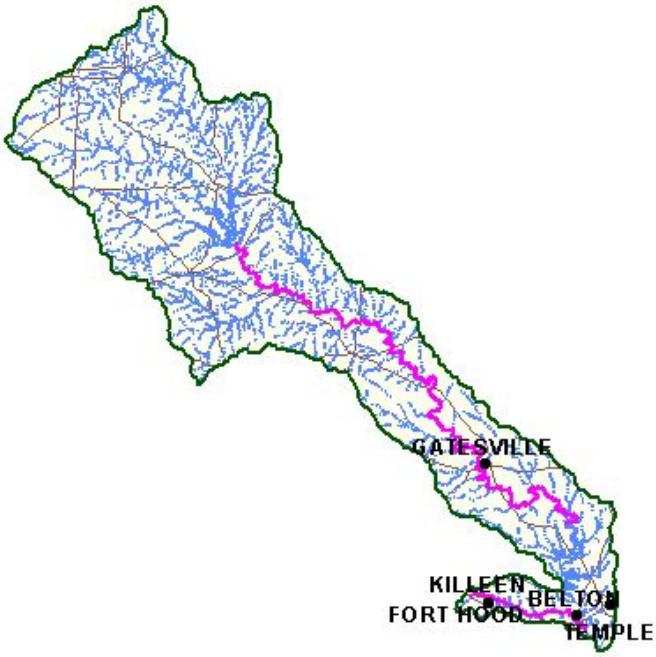


Figure 3. Leon River waterbody segment (1221, south from Lake Proctor to Lake Belton)

In 2003, a total of 3 rainfall simulations on three replicated sites were conducted at each of the 18 locations, providing three replications for statistical comparison. Runoff samples (1000 mL) were collected during each simulation at 2 intervals (15 and 30 minutes) after runoff was initiated. In 2004 and 2005, a total of 1 rainfall simulations were done on four sites at 22 locations. The multiple simulations on the same plots were discontinued because the runoff nutrient concentrations decreased with each rainfall simulation event, even after waiting for a week or more. It was determined that the soils were not coming back into equilibrium within in a week or more and it was not feasible to wait a week or more between each simulation. Thus, modifications were made to go to 4 plots and one simulation. During the simulations, timed sample collections were also changed to 5, 10, 15, 20, 25, and 30 minutes and a composite sample of 25 mL each sampling time. Total runoff volume was recorded each minute after runoff was initiated. Water samples were analyzed for pH, EC, NO_3^--N, Ca, Mg, Na, K, P, SO_4^{2-}, and B by the Texas AgriLife Extension Service SWFTL. Selected samples were analyzed for solution soluble P and suspended P.

A complementary component of the project was to more intensively evaluate correlations between soil test P in the target region by analyzing selected incoming client soil samples and samples from the rainfall simulation sites at the Texas AgriLife Extension SWFTL. Approximately 150 to 200 samples were selected for analysis per year. These samples were analyzed using the TAMU and Mehlich III methods for extractable P, soil pH, nitrate-N, and 2:1/water:soil salinity.

Selected Mehlich III and TAMU extracts were analyzed by colorimetric and ICP methods. This provided the needed insight into the influence of soluble organic P that will be required in order to establish rigid laboratory methodology and protocols. All other soil test parameters were determined using the established standard operating procedures of the SWFTL.

Data was analyzed utilizing standard statistical methods including regression, analysis of variance, and mean separation.

The objectives of this project were to 1) determine the effects of selected soil properties on measured and predicted P runoff; 2) compare and correlate different soil test and soil solution extractable P levels to runoff P; and 3) validate and/or modify the Texas Phosphorus Index as a predictive tool for classification of field sites relative to P loss potential.

Results and Discussion

General Information:

Information about the sites that were selected is given in Table 3. We were successful in selecting a wide range of soil characteristics among the sites as shown in Table 3. There were 5 samples with a very low-low PI rating, 23 with a medium, 8 with a high and 4 with a very high PI rating. There were 25 samples with <200 mg kg^{-1} Mehlich-3 soil test P (STP) and 15 with

Table 3. Selected information about selected sites.

Site	Soil Series	County	Soil Order	Management	Grazed	P Index Points	P Index Rating
0051	Ships Clay	Burleson	Vertisol	turf	no	12	Medium
0052	Ships Clay	Burleson	Vertisol	turf	no	12	Medium
0071	Heiden Clay	Falls	Vertisol	Corn/tilled	no	14	Medium
0072	Heiden Clay	Falls	Vertisol	Corn/tilled	no	19	Medium
0073	Houston Black	Falls	Vertisol	Corn/tilled	no	20	Medium
0074	Houston Black	Falls	Vertisol	pasture	no	13	Medium
0075	Houston Black	Falls	Vertisol	pasture	yes	11	Very Low - Low
0076	Heiden Clay	Falls	Vertisol	native prairie	no	5	Very Low - Low
0701	Bosque Loam	Comanche	Mollisol	sorghum/silage	no	23	High
0702	Brackett-Karnes	Comanche	Inceptisol	Pasture	yes	12	Medium
0901	Bolar Clay Loam	Comanche	Mollisol	Hay	no	20	Medium
0902	Denton silty clay loam	Comanche	Mollisol	Hay	no	18	Medium
1101	Patilo Nimrod Complex	Comanche	Alfisol	Water melon	no	12	Medium
1103	Nimrod fine sand	Comanche	Alfisol	Corn	no	14	Medium
1201	Pedernales loamy fine sand	Comanche	Alfisol	corn/silage	yes	26	High
1202	Lewisville clay loam	Comanche	Mollisol	corn/silage	yes	23	High
1401	Desan fine sand	Hamilton	Alfisol	Pasture	yes	11	Very Low - Low
1403	Minwells fine sandy loam	Hamilton	Alfisol	Pasture	yes	11	Very Low - Low
1502	Pidcoke gravelly clay loam	Hamilton	Mollisol	Pasture	yes	15	Medium
1503	Topsey clay loam	Hamilton	Mollisol	Corn/ tilled	yes	17	Medium
1701	Pidcoke gravelly clay loam	Hamilton	Mollisol	Hay	no	17	Medium
1702	Brackett-Maloterre	Hamilton	Inceptisol	Pasture	yes	17	Medium
F	Blanket clay loam, 1 to 3 %	Erath	Mollisol	Sorghum/ Bermuda	yes	35	Very High
G	Blanket clay loam, 1 to 3 %	Erath	Mollisol	Sorghum/ Bermuda	yes	17	Medium
H	Winthorst soil, 1 to 8%	Erath	Alfisol	Bermuda	yes	14	Medium
I	Krum silty clay, 1-5%	Hamilton	Mollisol	Bermuda	no	17	Medium
J	Real-Doss Complex 1-8%	Hamilton	Mollisol	Sorghum/ Bermuda	no	24	High
K	Winthorst soil, 1 to 8%	Erath	Alfisol	Bermuda	yes	8	Very Low - Low
L	Maloterre	Erath	Entisol	Mulch/ Sorghum	no	26	High
M	Bosque Clay Loam	Hamilton	Mollisol	Bermuda	no	24	High
N	Bosque Clay Loam	Hamilton	Mollisol	Bermuda	no	24	High
O	Nimrod fine sand	Comanche	Alfisol	Bermuda	yes	25	High
P	Nimrod-Arenosa-Patilo fine sands	Erath	Alfisol	Bermuda	yes	22	Medium
Q	Winthorst soil, 3-5%	Erath	Alfisol	Bare, Grazed rotational	yes	36	Very High
R	Winthorst fine sandy loam, 1-3%	Erath	Alfisol	Bermuda	no	16	Medium
S	Winthorst soil, 1-8%	Erath	Alfisol	Fallow/ bare	no	16	Medium
T	Winthorst soil, 1 to 8%	Erath	Alfisol	Bermuda	no	17	Medium
U	Bastrop fine sandy loam, 1-3%	Comanche	Alfisol	Mulch/ Corn	no	21	Medium
V	Sunev clay loam 3-5%	Comanche	Mollisol	Corn/ tilled	no	40	Very High
W	Purves-Bolar association	Comanche	Mollisol	Corn/ tilled	no	36	Very High

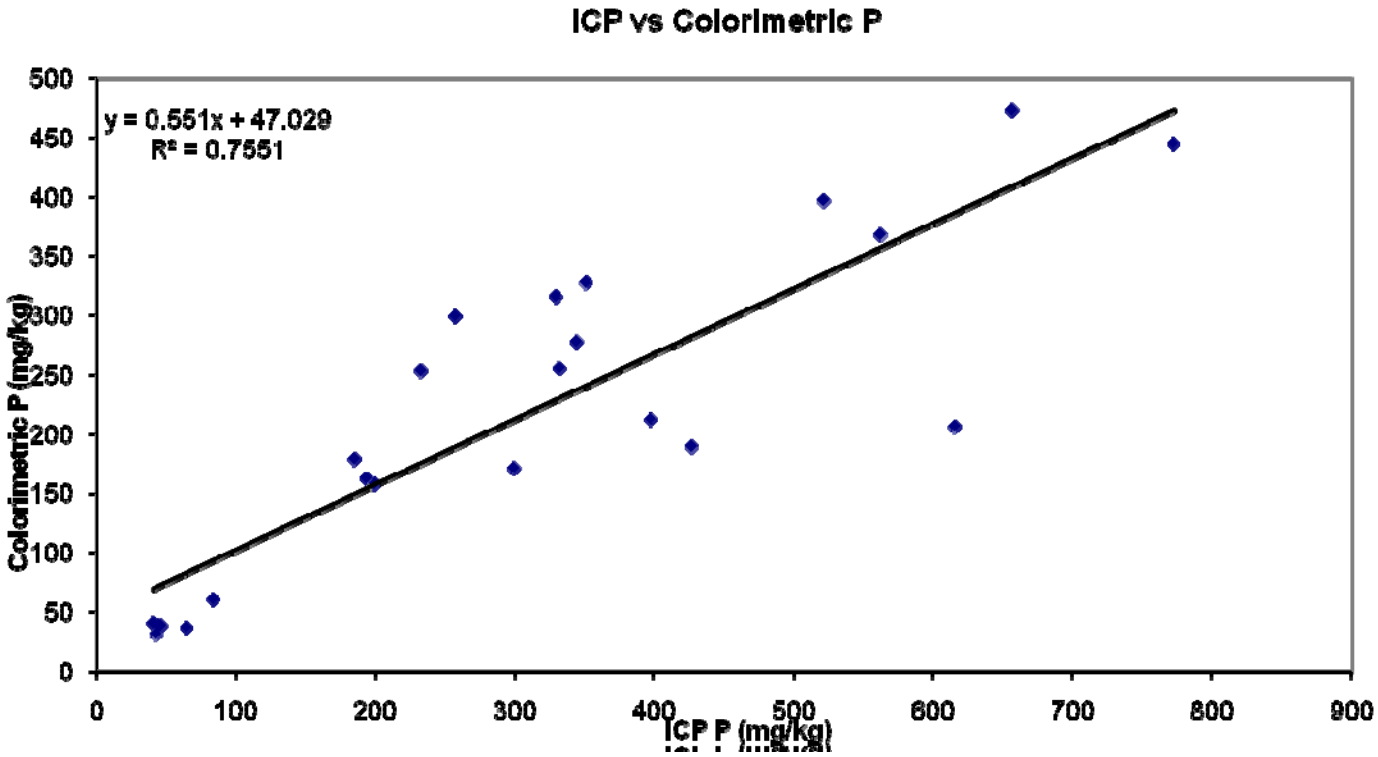


Figure 4. Comparison between colorimetric and ICP phosphorus methods of analyses.

≥200 mg kg^{-1} and there were 17 samples with pH values <7.5 and 23 with ≥7.5 pH values. There were 28 soil series representing 5 of the 10 Soil Orders that we have in Texas (Table 3).

In order to determine the appropriate method of analyses for the P, ICP and colorimetric methods of analyses were compared. Figure 4 contains the results for the average 0-6 inch samples collected in 2003. Based upon this data, for every 1 mg/kg of colorimetric P, there is about 2 mg/kg ICP P. The primary difference between the two is the colorimetric technique only analyzes the inorganic forms of P and the ICP analyzes all forms of P. The decision was made to use ICP analyzes only for the rest of the project.

At the time that this project was initiated, the Texas AgriLife Extension Service SWFTL was comparing the TAMU soil test extractant to the Mehlich-3 soil test extractant. The decision was made to convert to the Mehlich-3 soil test extractant due to the over extraction of P in calcareous soils and the under extraction of P in soils having pH values <5.5. Table 4 and Figure 5 contain data showing the comparison between the TAMU and Mehlich-3 soil test extractable P, K, Na, Ca, Mg, and S for 633 samples and extractable P for 161 samples, respectively in the Leon and Bosque River watersheds. The comparison of the TAMU extractable nutrients to the Mehlich-3 nutrients for the Leon and Bosque River watershed samples are very comparable except for Ca and Na (Table 4). The TAMU extractant extracts about 1.7 times more P than the Mehlich-3 extractant (Fig. 5).

Soil Samples:

All 0-6 inch soil samples were analyzed for pH, EC, NO_3-N, either TAMU or Mehlich-3 extractable K, Ca, Mg, S, and Na, and TAMU (2003 only) and Mehlich-3 extractable P, and selected samples were analyzed for B and $CaCl_2$ soluble P. For the 0-2 and 2-6 inch soil samples, pH and EC were not analyzed on the 2003 samples and NO_3-N and B were analyzed on selected samples for the entire project. The 0-6, 0-2 and 2-6 inch averages are given in Tables 5, 6, and 7. The 0-2 inch P and K concentrations were greater than the 0-6 and the 0-6 inch greater than the 2-6. For Ca, Mg, Na, and S the 0-6 and 2-6 inch samples were typically greater than the 0-2 inch samples. These relationships are primarily due to surface application of higher amounts of P and K than the other nutrients in manures.

It was found that the 0-6 inch sample can be estimated from the 0-2 and 2-6 inch data (Table 8) and the 0-2 and 2-6 inch can be estimated from the 0-6 inch samples (Table 8). Based upon the average and standard deviation for the individual plot 0-6 inch Mehlich-3 samples, the criteria for making the determination that the estimates were valid was 38.9%. Thus, for the 0-6 inch samples estimated from the 0-2 and 2-6 inch samples, 30 of the 40 sites met these criteria. For the 0-2 estimated from the 0-6 inch samples, 26 of the 40 sites met the criteria and for the 2-6 inch sample 29 of the 40 sites met the criteria. Thus, 65 to 75% of the time the 0-2 and 2-6 inch samples can be estimated from the 0-6 inch sample. This is a good comparison with other soil data such as data presented in a County Soil Survey prepared by NRCS and the Land Grant University that estimate that the soil data is approximately 75% accurate.

Runoff Samples:

The average concentrations of nutrients from the rainfall simulations runoff is listed in Table 9 and Appendix 1. Data in Table 9 are the averages for the four (numbered sites) or three (lettered sites) composite for each of the plots. Appendix 1 contains the average data for each timed sample. Sites 1103 and 1401 had infiltration and percolation rates greater than 7.5 cm hr^{-1}, our simulation rate. Thus, there will be no runoff data for these two sites and when the soil and runoff data are compared, the soil data for these two sites will not be included. Figures 6, 7, 8 and 9 are examples of the changes in runoff chemistry over the 30 minutes of monitoring the runoff. Most of the chemistry shows a slight decrease with time. This is expected since the soluble nutrients are being moved in the runoff. Thus, the concentrations should be greater with the early part of the runoff and decrease with time.

Table 4. Comparison of 633 samples analyzed through the Texas AgriLife Extension Service Soil, Water and Forage Testing Laboratory from 2003 to 2005 from the Leon and Bosque River Watersheds.

	TAMU Extractable					
	P	K	Na	Ca	Mg	S
	mg/kg					
medain	19	101	218	1066	125	29
average	45	247	242	3580	296	37
min	0	17	10	86	5	3
max	251	1768	575	42193	1344	503
number	633	633	633	633	633	633
	Mehlich-3 Extractable					
	Na	Mg	P	S	K	Ca
	mg/kg					
medain	121	102	31	19	96	801
average	134	251	50	27	236	1525
min	60	5	2	8	17	67
max	463	1277	248	469	1751	7476

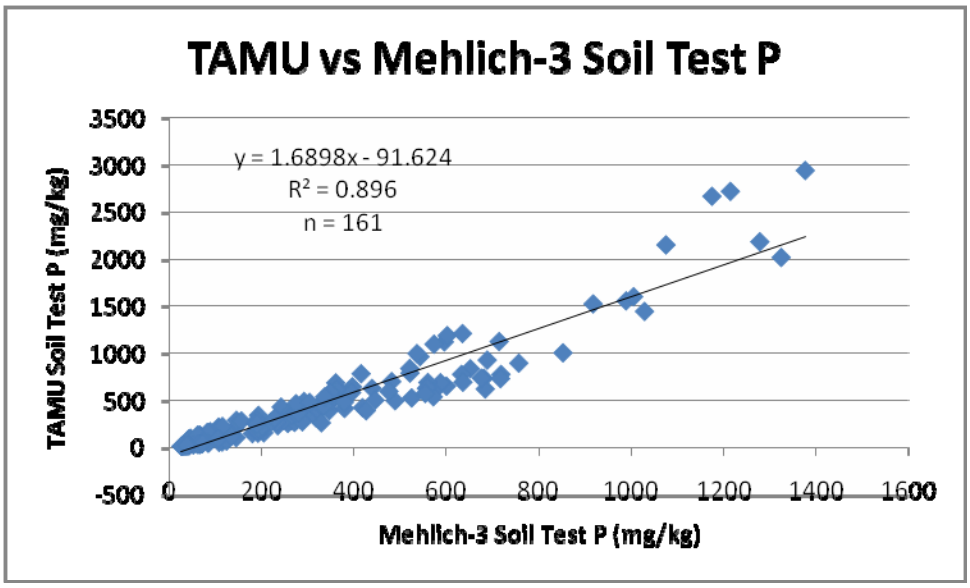


Figure 5. Comparison of 161 samples collected from 18 sites in 2003 from the Leon and Bosque River watersheds.

Table 5. Selected average soil chemical analyses for 0-6 inch depth.

			$CaCl_2$	Mehlich-3 Extractable†							
Site	pH	EC	P	P	K	Ca	Mg	S	Na	NO_3-N	B
		µmhos/cm	mg/kg								
51	7.51	729	2.48	49	289	7234	230	93	80	13.3	na‡
52	7.6	775	1.56	35	289	8165	264	92	91	10.2	na
71	8.16	445	na	14	248	17179	118	15	44	8.6	0.84
72	8.19	482	na	17	236	18674	170	19	81	9.3	1.15
73	7.82	467	na	32	354	16950	145	20	74	2.4	0.94
74	7.9	523	na	24	324	20019	157	29	124	3.6	1.21
75	7.75	565	na	15	266	19729	154	31	135	7.0	1.13
76	8.17	487	na	8	149	19703	161	34	140	2.8	1.16
701	7.98	471	1.63	44	143	9264	175	34	54	7.3	na
702	7.63	897	2.33	193	1529	5870	657	57	120	13.4	na
901	7.01	2036	3.96	321	1637	5652	989	228	258	4.7	na
902	6.94	2041	2.94	268	1359	6609	769	211	246	5.0	na
1101	7.12	358	0.29	40	188	1118	245	20	112	8.4	na
1103	6.59	109	0.18	20	168	6694	87	12	70	13.2	na
1201	7.65	680	1.79	218	603	1326	307	25	127	55.8	na
1202	7.65	566	0.27	57	453	9422	257	27	94	48.6	na
1401	5.14	142	0.81	29	54	243	20	17	83	5.1	na
1403	7.61	687	0.93	44	601	10462	324	53	92	6.2	na
1502	7.61	744	0.28	23	384	18511	262	25	91	11.8	na
1503	7.66	681	0.27	38	327	18173	333	27	112	15.2	na
1701	7.79	787	1.15	69	879	28680	455	76	149	37.6	na
1702	8.14	534	0.17	44	222	15270	249	40	116	7.9	na
				TAMU Extractable†							
F	6.92	857	7.93	657	1311	10742	780	135	321	10.7	2.08
G	6.97	1003	13.81	1607	2117	19318	1071	183	373	24.0	3.34
H	7.03	466	2.68	204	593	10892	800	77	339	10.5	0.67
I	7.1	651	9.97	846	772	198598	1314	203	312	18.2	1.84
J	6.78	539	2.94	26	750	6718	357	64	339	5.7	0.45
K	7.58	430	2.93	38	515	74907	355	81	277	4.4	0.37
L	7.8	538	10.52	614	1276	177199	1396	260	385	18.4	1.85
M	7.51	321	6.74	125	174	31753	351	106	280	9.1	0.35
N	7.51	326	7.86	160	303	35883	453	123	307	6.2	0.45
O	6.36	292	31.19	353	126	5077	145	73	253	13.3	0.55
P	6.33	284	28.33	457	153	9997	177	97	265	18.0	0.53
Q	4.86	318	2.81	20	173	2475	165	81	283	17.8	0.12
R	7.12	690	12.63	560	1064	13003	600	118	375	11.6	1.32
S	6.87	522	5.08	193	422	3945	257	74	281	12.1	0.55
T	6.83	517	15.03	440	250	7445	365	98	279	7.3	1.12

			$CaCl_2$	TAMU Extractable							
Site	pH	EC	P	P	K	Ca	Mg	S	Na	NO_3-N	B
		µmhos/cm	mg/kg								
U	5.52	328	1.15	21	111	1502	166	52	352	3.5	0.19
V	8.57	460	4.72	344	1589	73824	1022	127	491	6.1	0.64
W	8.1	547	6.51	544	1660	28833	878	113	473	18.6	1.17

†Average of four plots for Mehlich-3 data and three plots for TAMU data.

‡na = not analyzed.

Table 6. Selected average soil chemical analyses for 0-2 inch depth.

			$CaCl_2$	Mehlich-3 Extractable†							
Site	pH	EC	P	P	K	Ca	Mg	S	Na	NO_3-N	B
		µmhos/cm	mg/kg								
51	7.39	947	2.07	93	362	7382	312	107	68	na‡	na
52	7.49	890	1.58	45	323	8162	301	120	88	na	na
71	8.13	491	na†	44	291	14718	148	20	103	na	na
72	8.23	564	na	74	338	16152	196	26	139	na	na
73	7.89	526	na	178	529	14218	207	34	175	na	na
74	7.8	586	na	195	579	15763	338	37	258	na	na
75	7.71	647	na	119	459	15744	268	41	311	na	na
76	8.21	543	na	18	230	17288	197	34	423	na	na
701	7.82	512	1.76	55	176	9203	176	37	58	na	na
702	7.47	1057	2.96	365	1549	5638	867	80	103	na	na
901	7.06	1977	4.68	284	817	8780	471	244	206	na	na
902	6.87	2137	5.67	381	906	8155	501	297	200	na	na
1101	7.11	297	0.30	45	213	1116	238	16	106	na	na
1103	6.46	124	0.13	23	188	6383	92	12	78	16.2	na
1201	7.7	643	2.30	252	604	1339	347	25	114	na	na
1202	7.66	550	0.54	80	554	8879	281	28	93	na	na
1401	4.96	260	1.62	34	87	400	38	25	85	7.64	na
1403	7.37	754	1.33	69	705	9976	350	67	93	na	na
1502	7.61	729	0.33	41	444	17318	261	33	105	na	na
1503	7.79	687	0.32	63	320	17627	314	29	110	na	na
1701	7.55	615	2.83	149	952	26763	665	90	151	na	na
1702	7.97	598	0.23	18	123	19216	168	27	116	na	na
				TAMU Extractable†							
F	na	na	21.16	1421	1893	16008	1070	245	467	na	na
G	na	na	22.74	2606	2107	23022	1199	248	352	na	na
H	na	na	7.42	602	701	23238	978	118	331	na	na
I	na	na	17.15	1729	806	181664	1584	256	344	na	na
J	na	na	3.70	45	975	5952	415	75	341	na	na
K	na	na	4.74	89	613	40019	350	80	270	na	na
L	na	na	11.65	764	1400	163277	1428	257	401	na	na
M	na	na	13.99	213	249	22402	367	130	281	na	na
N	na	na	14.57	285	440	28424	522	142	286	na	na
O	na	na	49.63	527	183	9094	245	121	249	na	na
P	na	na	57.88	639	261	14049	299	165	287	na	na
Q	na	na	5.03	54	187	2440	167	111	308	na	na
R	na	na	16.16	771	1175	16652	750	150	358	na	na
S	na	na	9.82	315	546	4794	290	93	275	na	na

			$CaCl_2$	TAMU Extractable							
Site	pH	EC	P	P	K	Ca	Mg	S	Na	NO_3-N	B
		µmhos/cm	mg/kg								
T	na	na	25.83	1202	346	16748	777	220	322	na	na
U	na	na	2.25	35	133	1636	191	52	340	na	na
V	na	na	5.26	359	1458	69192	1016	116	442	na	na
W	na	na	7.59	626	1742	29014	900	118	448	na	na

†Average of four plots for Mehlich-3 data and three plots for TAMU data.

‡na = not analyzed.

Table 7. Selected average soil chemical analyses for 2-6 inch depth.

			$CaCl_2$	Mehlich-3 Extractable†							
Site	pH	EC	P	P	K	Ca	Mg	S	Na	NO_3-N	B
		µmhos/cm	mg/kg								
51	7.64	715	2.67	33	257	7236	195	70	79	na‡	na
52	7.65	823	1.39	28	267	8406	251	78	95	na	na
71	8.21	447	na†	24	252	16301	127	16	61	na	na
72	8.24	468	na	32	247	17057	176	20	95	na	na
73	7.86	433	na	67	410	16738	164	24	105	na	na
74	7.93	486	na	70	374	17905	204	33	173	na	na
75	7.75	539	na	40	308	18394	186	34	178	na	na
76	8.15	494	na	11	167	19566	177	35	215	na	na
701	8.08	455	1.79	41	118	8043	159	32	56	na	na
702	7.76	826	1.94	117	1553	6055	563	50	136	na	na
901	7.26	1907	3.43	235	1359	6558	716	198	254	na	na
902	6.68	2270	8.80	547	696	8974	427	375	181	na	na
1101	6.93	327	0.26	34	174	1113	256	20	117	na	na
1103	6.53	93	0.15	16	131	7207	80	9	68	13.1	na
1201	7.62	753	1.67	171	556	945	245	21	127	na	na
1202	7.62	577	0.18	42	392	9587	243	25	95	na	na
1401	5.54	104	0.46	26	41	215	10	11	86	4.5	na
1403	7.62	607	0.57	33	547	10480	417	45	92	na	na
1502	7.74	678	0.22	17	366	19627	261	24	86	na	na
1503	7.7	706	0.33	27	350	18298	334	29	113	na	na
1701	7.94	676	0.75	33	829	30101	370	61	144	na	na
1702	8.22	425	0.11	29	176	17336	204	32	115	na	na
				TAMU Extractable†							
F	na	na	5.52	402	1237	10384	732	108	315	na	na
G	na	na	9.99	1101	2129	16711	978	155	357	na	na
H	na	na	2.03	62	571	6690	752	57	346	na	na
I	na	na	7.50	594	705	211207	1264	183	321	na	na
J	na	na	2.59	19	595	6804	331	58	323	na	na
K	na	na	2.45	24	521	86413	357	80	305	na	na
L	na	na	9.21	558	1308	180209	1384	257	497	na	na
M	na	na	4.28	87	150	33491	336	84	290	na	na
N	na	na	5.02	113	240	41426	440	109	318	na	na
O	na	na	24.91	267	84	5147	106	56	243	na	na
P	na	na	18.47	354	124	7605	131	71	272	na	na
Q	na	na	2.70	12	170	2523	164	76	288	na	na
R	na	na	9.94	463	1031	11849	544	105	414	na	na
S	na	na	3.27	129	377	3341	248	58	293	na	na
T	na	na	9.72	229	220	5055	259	67	273	na	na

			$CaCl_2$	TAMU Extractable							
Site	pH	EC	P	P	K	Ca	Mg	S	Na	NO_3-N	B
		µmhos/cm	mg/kg								
U	na	na	0.79	16	110	1544	156	51	340	na	na
V	na	na	2.95	257	1499	72430	973	119	491	na	na
W	na	na	6.37	492	1560	28043	844	110	480	na	na

†Average of four plots for Mehlich-3 data and three plots for TAMU data.
‡na = not analyzed.

Table 8. Estimation of the Mehlich-3 soil test P using the 0-2 and 2-6 inch samples to estimate the 0-6 inch and the 0-6 inch sample to estimate the 0-2 and 2-6 inch samples.

Site	Actual Meh-3 P	0-6 Calculated From 0-2 and 2-6 inch P	% Diff	Actual Meh-3 P 0-2 inch	0-2 Calculated From 0-6 inch	% Diff	Actual Meh-3 P 2-6 inch	2-6 Calculated From 0-6 inch	% Diff
0051	49	53	7.76%	93	80.85	13.06%	33	35.53	7.65%
0052	35	34	3.97%	45	57.75	28.33%	28	25.38	9.38%
0071	14	31	118.57%	44	23.10	47.50%	24	10.15	57.71%
0072	17	46	169.76%	74	28.05	62.09%	32	12.33	61.48%
0073	32	104	223.84%	178	52.80	70.34%	67	23.20	65.37%
0074	24	111	363.54%	195	39.60	79.69%	70	17.40	75.14%
0075	15	66	340.47%	119	24.75	79.20%	40	10.88	72.81%
0076	8	13	66.38%	18	13.20	26.67%	11	5.80	47.27%
0701	44	46	3.68%	55	72.60	32.00%	41	31.90	22.20%
0702	193	199	3.03%	365	318.45	12.75%	117	139.93	19.59%
0901	321	251	21.75%	284	529.65	86.50%	235	232.73	0.97%
0902	268	492	83.66%	381	442.20	16.06%	547	194.30	64.48%
1101	40	38	5.92%	45	66.00	46.67%	34	29.00	14.71%
1201	218	198	9.30%	252	359.70	42.74%	171	158.05	7.57%
1202	57	55	4.32%	80	94.05	17.56%	42	41.33	1.61%
1403	44	45	2.00%	69	72.60	5.22%	33	31.90	3.33%
1502	23	25	8.35%	41	37.95	7.44%	17	16.68	1.91%
1503	38	39	2.32%	63	62.70	0.48%	27	27.55	2.04%
1701	69	71	3.30%	149	113.85	23.59%	33	50.03	51.59%
1702	44	25	42.34%	18	72.60	303.33%	29	31.90	10.00%
F	657	738	12.37%	1421	1084.05	23.71%	402	476.33	18.49%
G	1607	1598	0.58%	2606	2651.55	1.75%	1101	1165.08	5.82%
H	204	240	17.75%	602	336.60	44.09%	62	147.90	138.55%

Site	Actual Meh-3 P	0-6 Calculated From 0-2 and 2-6 inch P	% Diff	Actual Meh-3 P 0-2 inch	0-2 Calculated From 0-6 inch	% Diff	Actual Meh-3 P 2-6 inch	2-6 Calculated From 0-6 inch	% Diff
I	846	969	14.49%	1729	1395.90	19.27%	594	613.35	3.26%
J	26	28	6.08%	45	42.90	4.67%	19	18.85	0.79%
K	38	45	19.61%	89	62.70	29.55%	24	27.55	14.79%
L	614	626	1.95%	764	1013.10	32.60%	558	445.15	20.22%
M	125	129	2.86%	213	206.25	3.17%	87	90.63	4.17%
N	160	170	6.10%	285	264.00	7.37%	113	116.00	2.65%
O	353	353	0.06%	527	582.45	10.52%	267	255.93	4.15%
P	457	448	1.96%	639	754.05	18.00%	354	331.33	6.41%
Q	20	26	29.30%	54	33.00	38.89%	12	14.50	20.83%
R	560	565	0.83%	771	924.00	19.84%	463	406.00	12.31%
S	193	190	1.36%	315	318.45	1.10%	129	139.93	8.47%
T	440	550	25.02%	1202	726.00	39.60%	229	319.00	39.30%
U	21	22	6.05%	35	34.65	1.00%	16	15.23	4.84%
V	344	291	15.51%	359	567.60	58.11%	257	249.40	2.96%
W	544	536	1.43%	626	897.60	43.39%	492	394.40	19.84%

Table 9. Selected chemical data for the composite runoff samples.

SITE	pH	EC	NO_3-N	B	Na	Mg	P	S	K	Ca	Mn	Fe	Cu	Zn
		µmhos/cm	mg/L											
51	7.44	61	0.49	0.02	8.46	0.34	0.22	3.19	2.46	2.62	0.00	0.08	0.00	0.00
52	7.36	70	0.56	0.02	8.51	0.43	0.20	3.52	2.77	3.85	0.00	0.08	0.00	0.00
71	7.34	72	0.52	0.04	7.89	0.52	0.14	4.13	2.60	5.48	0.00	0.07	0.01	0.00
72	7.31	80	0.55	0.05	8.62	0.62	0.13	5.20	2.65	6.42	0.00	0.09	0.01	0.00
73	7.28	68	0.54	0.05	7.25	0.62	0.08	5.97	2.60	6.76	0.00	0.10	0.02	0.00
74	7.84	70	1.58	0.08	11.13	0.79	0.42	6.48	2.54	50.49	0.07	0.09	0.02	0.01
75	8.26	68	3.80	0.08	14.80	0.87	0.63	6.94	2.81	99.75	0.11	0.08	0.02	0.01
76	8.77	71	5.43	0.08	18.80	1.01	0.86	7.60	3.10	145.56	0.15	0.05	0.02	0.01
701	9.21	80	5.61	0.08	19.86	1.16	1.17	6.38	3.14	185.30	0.22	0.04	0.02	0.01
702	9.11	93	4.45	0.06	17.86	1.14	0.98	5.49	2.92	192.73	0.17	0.02	0.02	0.01
901	9.04	105	2.20	0.05	15.62	1.17	0.89	4.13	2.66	197.83	0.17	0.02	0.02	0.01
902	8.95	115	0.49	0.05	14.47	1.20	0.82	2.98	2.46	197.65	0.15	0.02	0.02	0.01
1101	8.72	127	0.49	0.05	17.47	1.27	0.66	4.14	2.57	214.08	0.10	0.00	0.02	0.00
1201	8.65	138	0.85	0.57	19.88	1.33	0.79	5.68	3.17	222.70	0.10	0.01	0.03	0.00
1202	8.58	145	1.42	0.59	23.35	1.39	1.01	7.90	3.85	234.10	0.09	0.01	0.03	0.00
1403	8.54	151	2.10	0.98	27.11	1.51	1.15	11.05	4.86	245.18	0.09	0.02	0.03	0.01
1502	8.58	155	2.30	0.99	26.12	1.54	1.32	11.51	5.32	260.40	0.08	0.02	0.03	0.01
1503	8.39	144	2.12	0.50	24.79	1.35	1.44	10.18	5.20	201.10	0.06	0.03	0.03	0.02
1701	8.20	137	1.69	0.49	21.58	1.08	1.44	7.80	4.70	134.01	0.05	0.04	0.04	0.03
1702	8.00	133	1.10	0.12	17.54	0.84	1.60	4.52	4.33	78.40	0.03	0.05	0.03	0.03
F	8.23	98	1.48	0.10	4.74	5.85	3.58	0.83	17.64	44.15	1.00	0.83	0.06	0.17
G	8.00	80	0.76	0.08	4.23	4.05	2.53	0.46	13.31	28.83	0.59	0.66	0.06	0.14
H	7.79	78	0.63	0.06	4.09	3.21	2.07	0.41	12.57	21.57	0.38	0.57	0.05	0.13
I	7.64	73	0.56	0.05	4.10	2.39	1.55	0.39	11.59	13.71	0.19	0.47	0.05	0.11

SITE	pH	EC	NO_3-N	B	Na	Mg	P	S	K	Ca	Mn	Fe	Cu	Zn
		µmhos/cm	mg/L											
J	7.57	103	1.48	0.08	7.83	2.65	2.55	1.58	13.41	11.81	0.11	0.33	0.06	0.07
K	7.50	109	2.08	0.11	11.59	2.89	3.18	1.96	12.60	10.70	0.06	0.21	0.08	0.05
L	7.29	111	2.40	0.15	15.59	2.98	3.55	2.12	11.82	9.58	0.03	0.13	0.10	0.04
M	7.42	99	1.76	0.15	12.51	2.84	2.68	1.37	9.13	15.97	0.03	0.11	0.07	0.04
N	7.39	109	1.55	0.21	9.42	3.37	2.37	1.25	7.55	24.20	0.04	0.08	0.06	0.04
O	7.42	129	1.36	0.24	6.13	3.86	2.15	1.28	6.36	29.48	0.04	0.07	0.04	0.03
P	6.98	134	1.43	0.25	6.13	4.42	1.51	0.92	7.22	25.13	0.22	0.07	0.04	0.03
Q	6.75	124	1.44	0.20	6.13	3.54	0.76	0.54	6.13	16.33	0.28	0.07	0.02	0.02
R	6.51	107	1.37	0.17	6.13	3.61	0.32	0.56	9.67	13.82	0.43	0.13	0.08	0.02
S	6.72	128	1.05	0.15	5.34	4.05	1.22	1.78	10.60	18.85	0.32	0.18	0.09	0.03
T	6.91	152	0.56	0.14	5.38	4.91	1.86	2.44	13.55	24.57	0.29	0.20	0.10	0.04
U	7.01	172	0.48	0.12	5.96	4.74	2.22	2.50	11.29	25.93	0.16	0.17	0.03	0.03
V	7.60	136	1.42	0.09	8.61	5.08	2.66	1.61	12.00	126.02	0.26	0.23	0.03	0.06
W	8.31	107	1.88	0.08	10.26	5.45	3.14	1.23	13.02	204.69	0.36	0.30	0.03	0.08

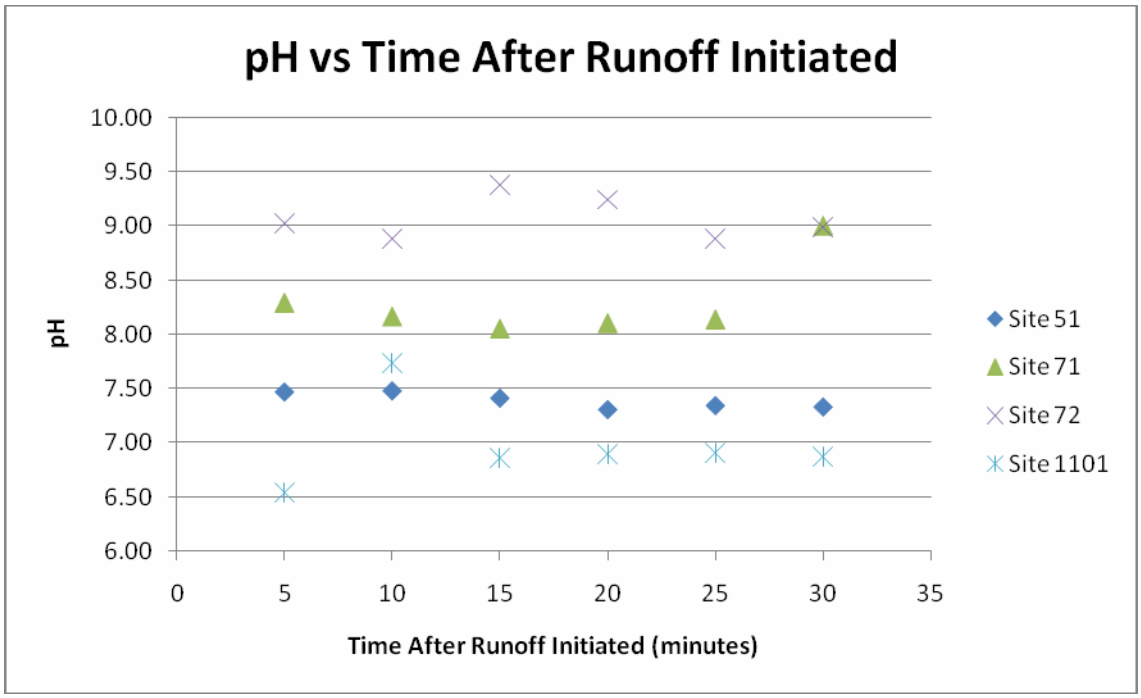


Figure 6. pH vs. time after runoff initiated for selected sites.

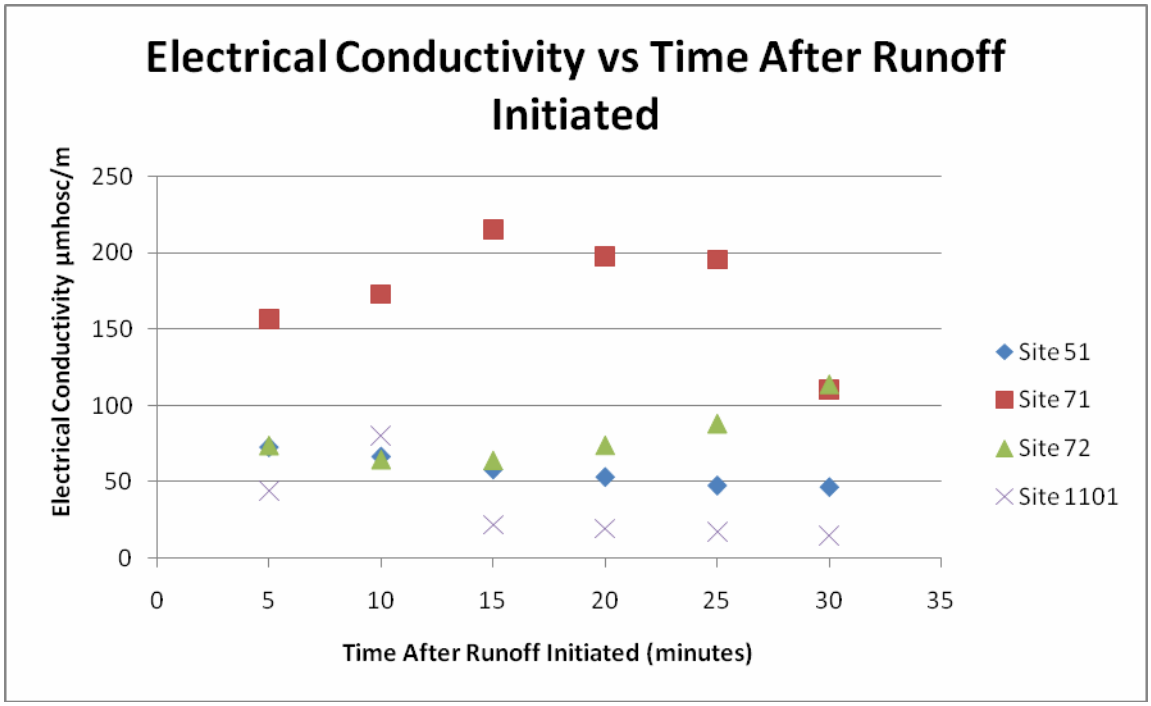


Figure 7. Electrical conductivity vs. time after runoff for selected sites.

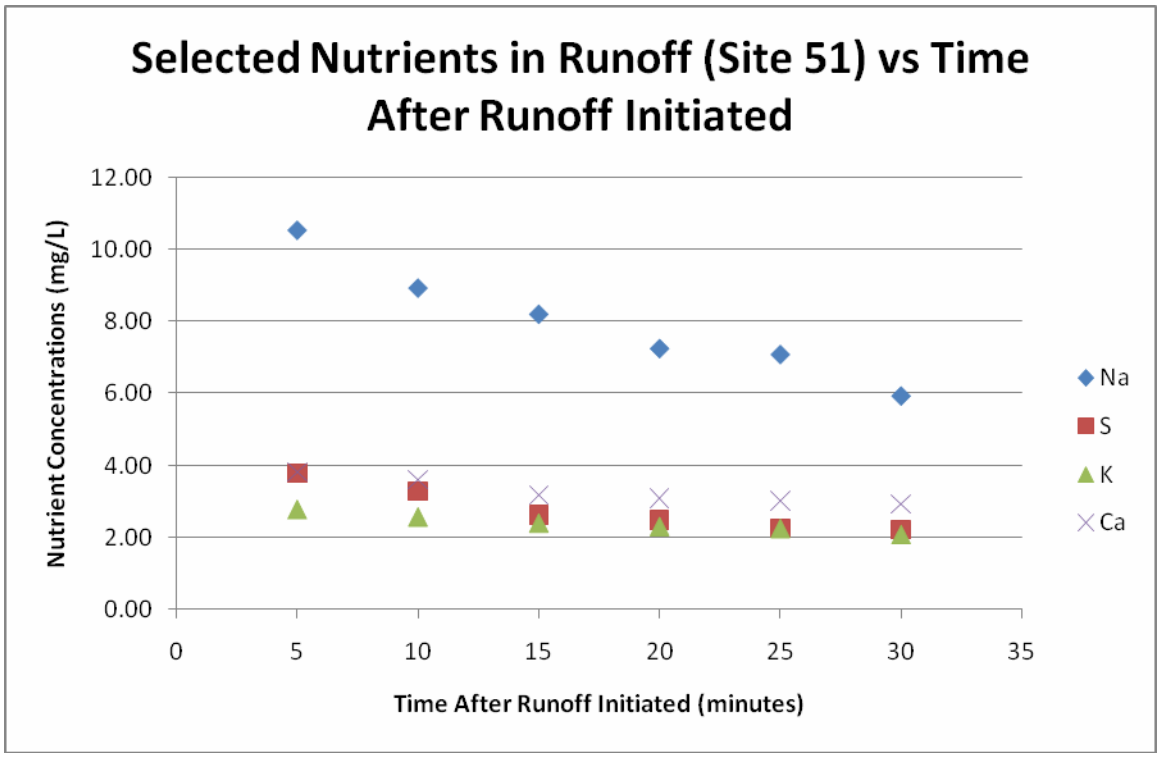


Figure 8. Selected nutrients in the runoff from site 51 vs. time after runoff initiated to illustrate chemical changes as runoff event progresses.

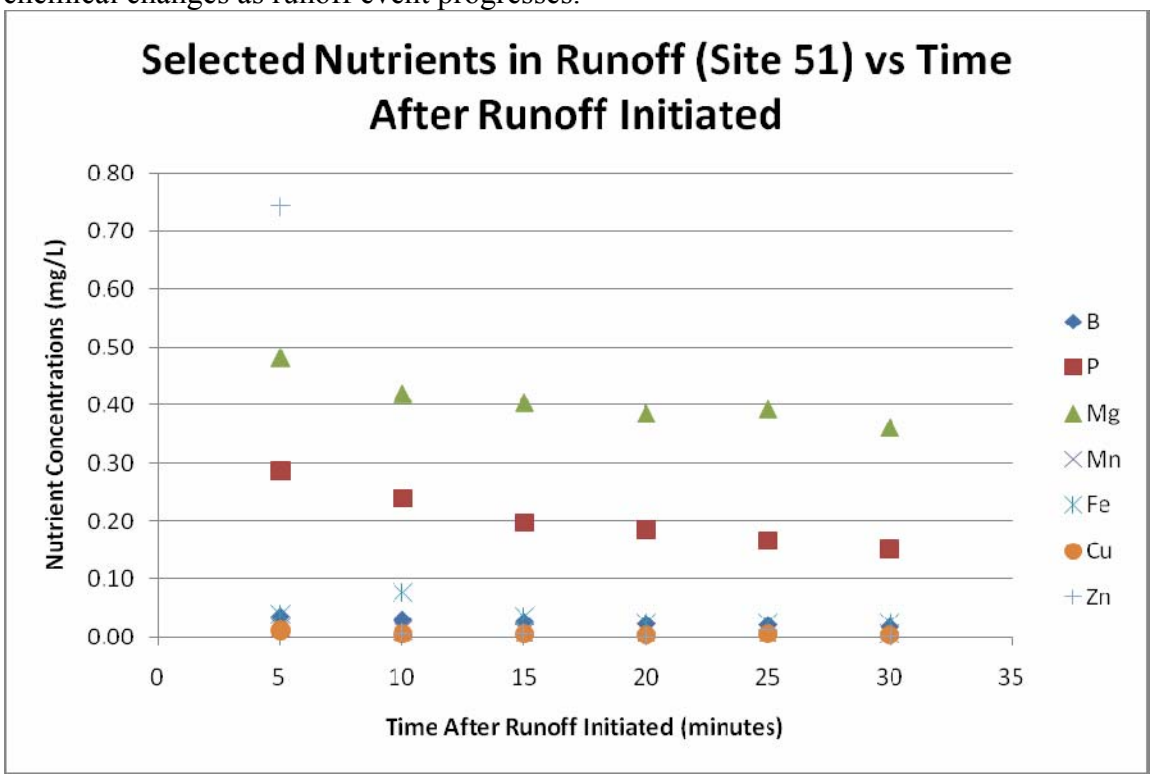


Figure 9. Selected nutrients in the runoff from site 51 vs. time after runoff initiated to illustrate chemical changes as runoff event progresses.

Comparison of runoff and soil data to PI:

The runoff P and soil chemical data were compared. The best correlations were between the Mehlich-3 P and Mg with the runoff P. This data is shown in Figures 10 and 11. The R^2 was highest for the 0-6 and 2-6 inch samples compared to the 0-2 inch samples. The relationship between the PI index points and the runoff P is shown in Figure 12. The R^2 was 0.2. Based upon the analysis conducted with only the lettered sites, if Mehlich-3 Mg is added to the PI, then the r^2 can be improved from 0.37 to 0.63 (Jacoby, 2005; Harstad, 2005).

Extension Outreach:

The information that was obtained from the project has been delivered to various county, agency, state, and national meetings. The county programs were given in Erath, Comanche and Hopkins counties. Agency presentations were given to TSSWCB, NRCS, TCEQ and City of Waco. Presentations were made for state stakeholder meetings and four presentations were made at the American Society of Agronomy/Soil Science Society of America/Crop Science Society of America national and international meetings. The number of meetings per year and the total number of individuals reached is given in Table 10.

Summary and Recommendations:

This demonstration project was carried out to field test and evaluate the Texas Phosphorus Assessment Tool, Phosphorus Index (PI). The PI is a tool used to determine the potential for P to be transported from the field to a surface waterbody based upon the best science at the time when it was proposed (Lemunyon and Gilber, 1993). However, there was no field validation of the model anywhere in the U.S.. Thus, this project was developed to field test the model and determine if modifications can be made to field verify the model. This project is one of the first funded to field test the PI and one of the few that has been funded to field evaluate the PI. The PI is used in conjunction with the NRCS Nutrient Management Practice Standard, Code 590, to make P rate recommendations for land application of P sources of nutrients. It is required when organic sources of nutrients are land applied and suggested when inorganic sources are used when following Code 590.

Based upon the field data for runoff amounts and erosion, the best management practice for the producers is well managed pasture followed by hay. The highest amounts of runoff and erosion occurred in the tilled fields. Assuming that 1 mg L^{-1} is the limit for agriculture runoff as it is for some waste water treatment plants across the U.S., does this runoff concentration relate to the TCEQ 200 ppm (mg kg^{-1})? If lines were drawn at 200 mg kg^{-1} STP and 1 mg L^{-1} P in the runoff in Figure 10, it is clear that there are numerous STP concentrations over 200 that yielded less than 1 mgL^{-1} and there are numerous STP concentrations below 200 that yielded greater than 1 mgL^{-1} . Thus, as has been stated many times by Texas AgriLife Extension and Research personnel, there is no relationship between the 200 mg kg^{-1} STP and the potential for P in runoff. Mehlich-3 extractable P and Mg were best correlated to runoff P with the 0-6 inch and 2-6 inch samples being better correlated than the 0-2 inch soil sample. Because we were able to estimate the 0-2 and 2-6 inch P concentration with 65 to 75% accuracy and the 0-6 inch samples correlated better to the runoff P concentration, we recommend that the 0-2 and 2-6 inch soil

sampling requirement be discontinued and all soil samples be collected at the 0-6 inch depth only. This will also reduce the potential for mistakes in calculating the nutrient requirements from the 0-2 and 2-6 inch soil sample as must be done to estimate the 0-6 inch recommendation.

We are recommending that the PI not be changed at this time to allow for the poultry project (TSSWCB Project 04-04) to be completed. These two projects in conjunction with a project being conducted by Daren Harmel, USDA/ARS in Riesel will be combined to formalize recommendations for the revision of the PI for Texas. These projects should be completed by December 2010. Based upon the results from these three projects, we will be able to make recommendations to improve the Texas PI. This in turn will help determine P land application rates using nutrient management plans, thus reducing the potential for P transport from fields where P sources of nutrients are applied and reducing the potential for P to enter surface waterbodies in concentrations high enough to contribute to P water quality issues.

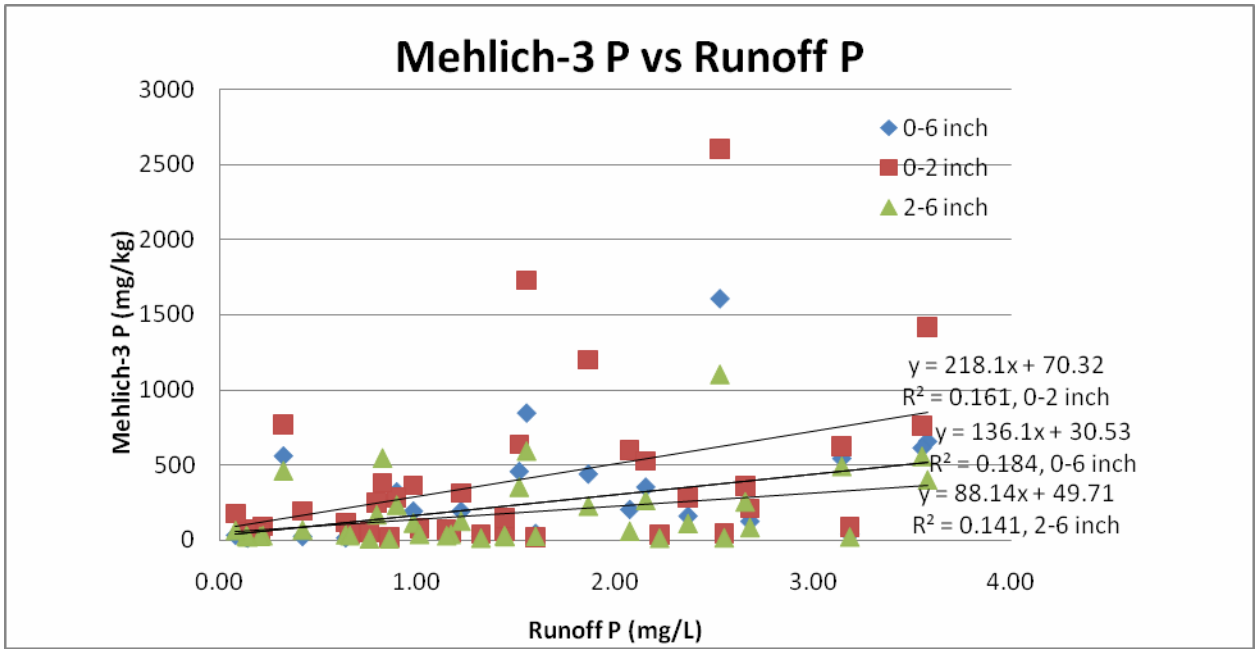


Figure 10. Mehlich-3 P correlation to runoff P for the 0-2, 2-6, and 0-6 inch soil samples for all sites.

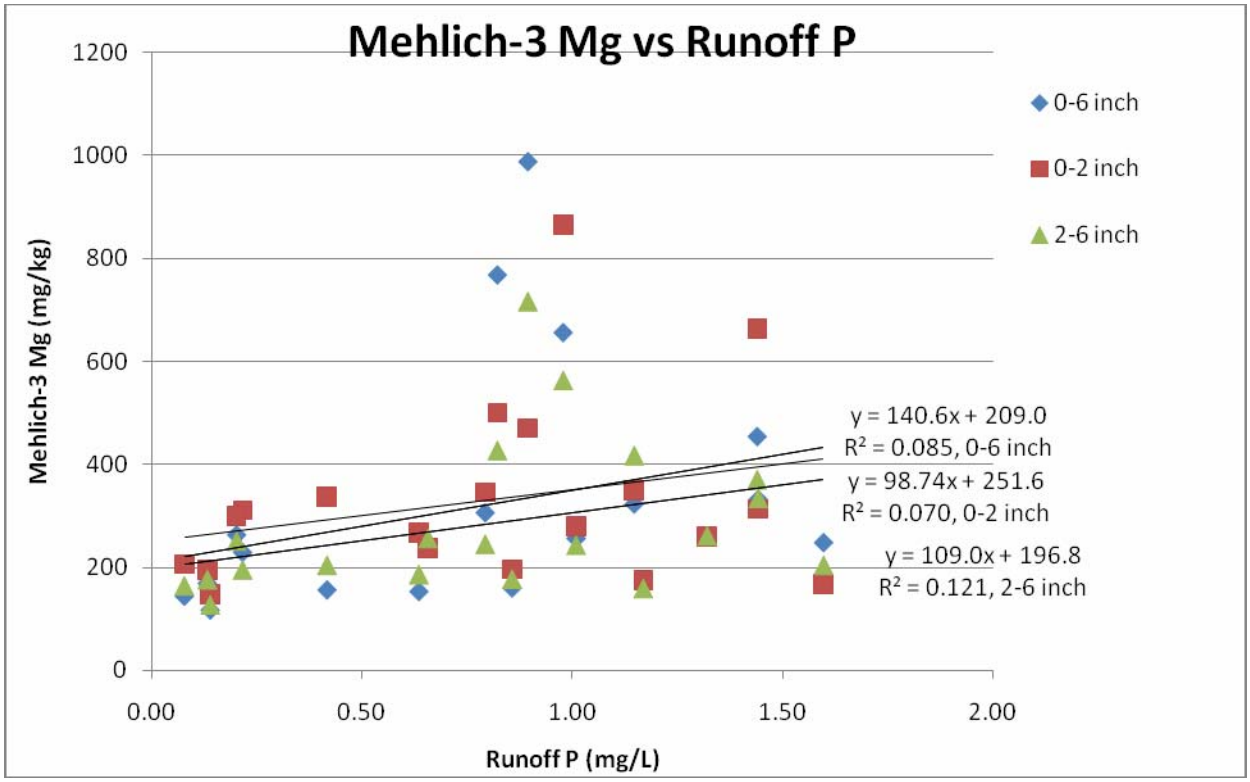


Figure 11. Mehlich-3 P correlation to runoff P for the 0-2, 2-6, and 0-6 inch soil samples for all sites.

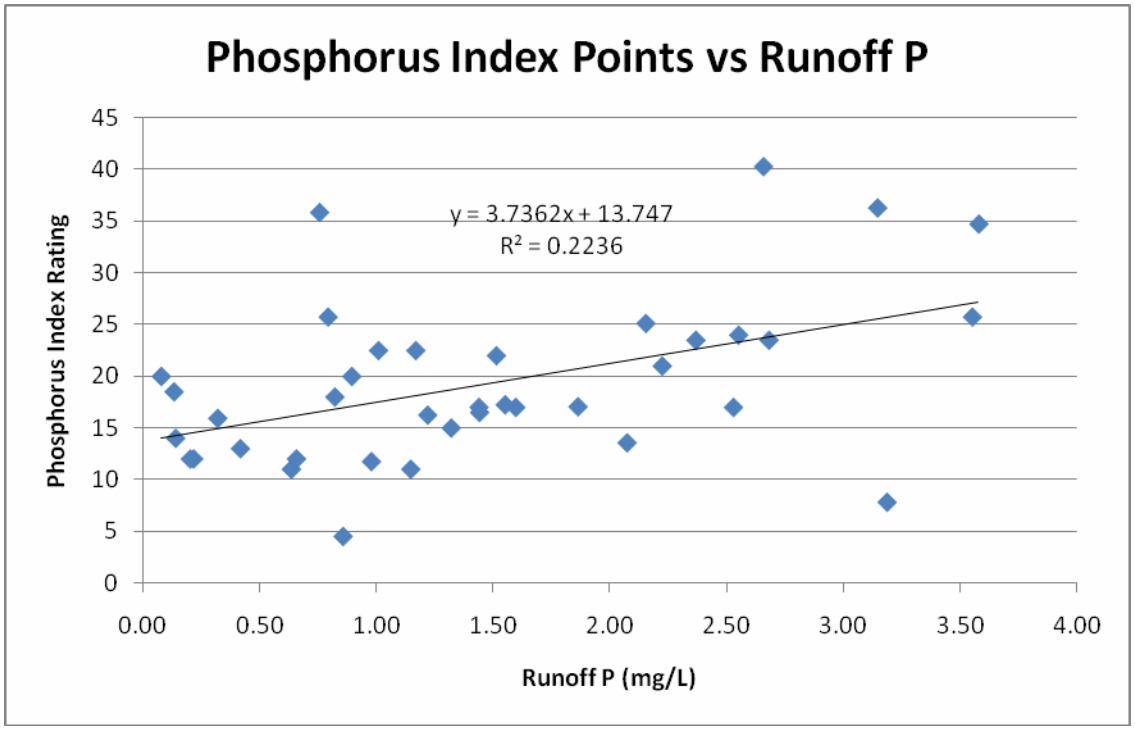


Figure 12. Phosphorus index points calculated from the Phosphorus Index vs. runoff P from all sites.

Table 10. Extension outreach of information obtained from this project.

Year	Dates	Total Number of Individuals
2003	3/27, 9/25, 10/28	190
2004	1/27, 2/2, 2/6, 2/23, 3/25, 4/19, 6/1-4, 10/6	339
2005	1/25, 1/27, 10/5, 11/1, 11/2, 12/15, 12/20	205
2006	4/27, 4/28, 10/31	102
2007	2/19, 2/27, 10/30	164

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Appendix 1

Runoff Chemistry
Averages for four plots (numbered) or three plots (lettered)

Site	Time	pH	EC	NO_3-N	B	Na	Mg	P	S	K	Ca	Mn	Fe	Cu	Zn
	minutes		µmhos/cm	mg/kg											
51	5	7.47	73	na†	0.04	10.53	0.48	0.29	3.79	2.78	3.82	0.017	0.039	0.011	0.744
51	10	7.48	67	na	0.03	8.93	0.42	0.24	3.28	2.57	3.60	0.013	0.077	0.006	0.008
51	15	7.42	58	na	0.03	8.21	0.40	0.20	2.62	2.40	3.17	0.009	0.036	0.005	0.007
51	20	7.31	54	na	0.02	7.26	0.39	0.18	2.49	2.30	3.08	0.008	0.024	0.004	0.001
51	25	7.35	48	na	0.02	7.10	0.39	0.17	2.24	2.24	3.02	0.007	0.025	0.005	0.013
51	30	7.33	47	na	0.02	5.95	0.36	0.15	2.22	2.08	2.93	0.006	0.024	0.004	0.002
51	c	7.44	61	0.49	0.02	8.46	0.34	0.22	3.19	2.46	2.62	0.002	0.082	0.004	0.001
52	5	7.13	87	na	0.05	7.71	0.79	0.13	5.53	3.32	9.10	0.020	0.036	0.013	0.024
52	10	7.22	72	na	0.04	6.35	0.66	0.10	5.73	2.82	7.70	0.015	0.027	0.012	0.024
52	15	7.20	63	na	0.04	6.05	0.64	0.08	4.83	2.59	7.18	0.014	0.029	0.012	0.010
52	20	7.25	56	na	0.04	5.70	0.59	0.08	4.22	2.37	6.51	0.013	0.025	0.013	0.007
52	25	7.26	50	na	0.05	5.74	0.60	0.07	4.79	2.15	5.90	0.008	0.022	0.015	0.002
52	30	7.29	48	na	0.05	5.58	0.53	0.06	4.46	2.03	5.81	0.008	0.029	0.015	0.003
52	c	7.28	68	0.54	0.05	7.25	0.62	0.08	5.97	2.60	6.76	0.002	0.103	0.017	0.001
71	5	8.30	157	na	0.12	23.58	1.73	1.48	7.85	3.41	254.33	0.386	0.149	0.023	0.053
71	10	8.17	173	na	0.11	23.45	1.73	1.48	7.95	3.52	252.13	0.400	0.142	0.024	0.070
71	15	8.06	216	na	0.11	22.59	1.76	1.62	7.57	3.56	250.80	0.411	0.159	0.027	0.066
71	20	8.11	198	na	0.11	21.37	2.24	1.97	7.42	3.80	376.33	0.552	0.184	0.024	0.060
71	25	8.14	196	na	0.09	19.10	1.66	1.40	6.02	3.26	216.00	0.344	0.229	0.025	0.059
71	30	9.00	111	na	0.08	16.89	1.61	1.37	5.39	3.25	230.23	0.347	0.180	0.023	0.048
71	c	9.21	80	5.61	0.08	19.86	1.16	1.17	6.38	3.14	185.30	0.222	0.044	0.020	0.014
72	5	9.03	74	na	0.08	18.02	2.03	1.45	4.08	2.90	305.15	0.249	0.234	0.018	0.048
72	10	8.89	65	na	0.07	19.05	1.92	1.21	5.08	2.88	331.55	0.239	0.093	0.014	0.053
72	15	9.39	64	na	0.06	18.63	2.01	1.50	5.25	2.97	322.78	0.262	0.209	0.018	0.043
72	20	9.25	74	na	0.06	17.88	2.17	1.57	5.05	3.05	311.05	0.282	0.294	0.021	0.054

Site	Time	pH	EC	NO_3-N	B	Na	Mg	P	S	K	Ca	Mn	Fe	Cu	Zn
	minutes		µmhos/cm	mg/kg											
72	25	8.89	88	na	0.06	18.33	2.15	1.67	5.37	3.10	345.93	0.305	0.206	0.017	0.038
72	30	9.00	114	na	0.05	15.55	1.93	1.35	4.64	2.88	312.03	0.276	0.177	0.017	0.036
72	c	8.72	127	0.49	0.05	17.47	1.27	0.66	4.14	2.57	214.08	0.098	0.003	0.024	0.005
73	5	8.13	164	na	1.21	23.73	2.04	1.95	8.71	4.86	349.10	0.268	0.292	0.057	0.068
73	10	8.31	166	na	1.08	27.36	2.14	1.84	12.59	5.69	416.43	0.269	0.162	0.053	0.042
73	15	8.60	174	na	1.03	30.43	2.49	2.30	15.01	6.88	459.45	0.320	0.171	0.029	0.042
73	20	8.17	226	na	0.97	28.11	2.39	2.13	14.03	7.04	435.93	0.302	0.202	0.051	0.051
73	25	7.81	268	na	0.95	25.36	2.21	1.89	12.34	6.38	388.58	0.242	0.218	0.056	0.042
73	30	8.76	131	na	0.90	23.48	2.19	1.77	11.35	6.48	390.40	0.224	0.205	0.055	0.049
73	c	8.58	155	2.30	0.99	26.12	1.54	1.32	11.51	5.32	260.40	0.084	0.018	0.032	0.012
74	5	7.79	119	na	0.15	19.81	0.70	2.17	4.18	4.74	9.46	0.025	0.096	0.043	0.050
74	10	7.79	104	na	0.14	17.98	0.71	1.99	3.51	4.39	8.35	0.021	0.083	0.041	0.047
74	15	7.27	84	na	0.13	17.00	0.71	1.89	3.15	4.18	7.50	0.018	0.078	0.039	0.038
74	20	7.30	106	na	0.12	16.04	0.71	1.78	2.78	3.92	7.30	0.017	0.070	0.038	0.036
74	25	7.42	107	na	0.11	15.26	0.72	1.68	2.48	3.74	7.07	0.016	0.069	0.037	0.033
74	30	7.72	140	na	0.11	14.30	0.71	1.60	2.24	3.57	6.95	0.016	0.069	0.035	0.036
74	c	7.85	131	1.21	0.12	17.26	0.71	1.90	3.24	4.28	8.47	0.021	0.060	0.036	0.037
75	5	7.37	83	na	0.12	22.48	0.79	1.58	7.82	4.75	18.14	0.038	0.224	0.033	0.062
75	10	7.76	78	na	0.11	21.22	0.74	1.47	6.92	4.51	15.66	0.033	0.201	0.032	0.051
75	15	8.05	116	na	0.10	19.58	0.69	1.33	5.73	4.17	13.24	0.028	0.187	0.033	0.074
75	20	8.16	132	na	0.09	17.77	0.67	1.24	5.03	3.92	12.75	0.026	0.177	0.030	0.051
75	25	8.09	113	na	0.06	12.36	0.49	0.87	3.23	3.04	9.47	0.020	0.132	0.023	0.032
75	30	7.61	173	na	0.08	16.23	0.67	1.10	4.08	3.57	12.14	0.027	0.175	0.030	0.042
75	c	7.90	130	0.97	0.10	20.57	0.71	1.38	6.09	4.39	14.93	0.032	0.114	0.035	0.050
76	5	7.76	183	na	0.13	34.51	0.86	0.41	9.37	2.55	48.01	0.041	0.257	0.033	0.044
76	10	8.28	176	na	0.12	32.75	0.78	0.36	8.35	2.46	39.56	0.033	0.230	0.031	0.043

Site	Time	pH	EC	NO_3-N	B	Na	Mg	P	S	K	Ca	Mn	Fe	Cu	Zn
	minutes		µmhos/cm	mg/kg											
76	15	8.60	165	na	0.11	30.73	0.72	0.31	7.68	2.39	33.38	0.028	0.198	0.031	0.043
76	20	8.71	137	na	0.10	29.10	0.71	0.29	6.94	2.31	32.25	0.026	0.192	0.029	0.045
76	25	8.73	117	na	0.09	27.88	0.71	0.29	6.40	2.30	32.11	0.027	0.192	0.029	0.042
76	30	8.86	141	na	0.09	26.06	0.69	0.27	5.80	2.23	30.77	0.026	0.186	0.028	0.045
76	c	8.96	123	0.25	0.11	31.42	0.71	0.34	7.84	2.55	35.89	0.036	0.151	0.032	0.059
701	5	8.49	65	na	0.04	5.22	2.49	0.66	5.57	5.09	58.20	0.335	0.309	0.025	0.035
701	10	8.52	56	na	0.03	4.61	2.16	0.55	6.74	4.32	46.90	0.257	0.285	0.022	0.020
701	15	8.53	54	na	0.03	4.82	2.08	0.49	5.70	3.95	44.89	0.235	0.282	0.022	0.023
701	20	8.57	51	na	0.03	4.64	1.97	0.48	5.54	3.70	43.22	0.225	0.251	0.022	0.024
701	25	8.57	50	na	0.03	5.06	1.96	0.47	6.31	3.44	42.11	0.221	0.258	0.021	0.025
701	30	8.60	48	na	0.03	5.05	2.21	0.55	5.68	3.87	51.54	0.250	0.218	0.022	0.021
701	c	8.46	59	0.60	0.05	7.03	2.84	0.99	6.90	8.16	33.99	0.196	0.161	0.024	0.054
702	5	7.72	191	na	0.10	12.86	5.26	2.79	8.35	17.49	11.88	0.070	0.103	0.036	0.038
702	10	7.73	171	na	0.09	11.67	4.69	2.63	8.00	14.92	10.79	0.070	0.081	0.034	0.027
702	15	7.73	146	na	0.09	10.36	4.32	2.54	7.76	13.08	9.94	0.069	0.076	0.032	0.027
702	20	7.73	126	na	0.09	10.04	4.25	2.55	8.07	12.12	9.56	0.061	0.073	0.031	0.023
702	25	7.72	120	na	0.09	9.74	4.10	2.46	6.99	11.03	9.38	0.059	0.072	0.031	0.020
702	30	7.72	110	na	0.09	11.88	4.80	2.69	7.77	15.39	11.15	0.072	0.066	0.034	0.030
702	c	7.68	149	2.08	0.10	26.54	9.83	2.38	13.39	17.09	22.77	0.057	0.063	0.038	0.030
901	5	7.59	344	na	0.21	18.05	4.71	3.71	8.89	50.75	17.31	0.027	0.115	0.080	0.069
901	10	7.59	361	na	0.20	18.46	5.18	4.34	9.79	52.44	21.56	0.043	0.124	0.075	0.077
901	15	7.55	342	na	0.19	17.30	5.14	4.17	9.03	46.14	22.60	0.033	0.120	0.074	0.070
901	20	7.52	278	na	0.18	14.50	4.38	3.93	7.62	38.52	17.88	0.030	0.119	0.072	0.063
901	25	7.51	244	na	0.18	12.90	4.04	3.78	7.28	32.68	15.76	0.028	0.117	0.068	0.051
901	30	7.47	222	na	0.18	12.07	3.84	3.58	6.48	28.56	16.23	0.029	0.126	0.066	0.048
901	c	7.37	337	3.78	0.17	16.39	4.70	3.83	8.27	39.22	17.15	0.058	0.113	0.060	0.072

Site	Time	pH	EC	NO_3-N	B	Na	Mg	P	S	K	Ca	Mn	Fe	Cu	Zn
	minutes		µmhos/cm	mg/kg											
902	5	7.88	234	na	0.13	19.57	5.70	2.70	9.44	24.02	11.21	0.103	0.111	0.037	0.044
902	10	7.97	181	na	0.12	15.89	4.76	2.59	6.84	18.61	9.74	0.087	0.097	0.032	0.037
902	15	8.01	153	na	0.11	13.70	4.08	2.47	5.99	15.34	8.18	0.071	0.088	0.031	0.037
902	20	7.98	132	na	0.10	12.36	3.66	2.36	5.46	13.20	7.42	0.064	0.083	0.030	0.040
902	25	7.94	116	na	0.09	11.33	3.40	2.24	4.25	11.57	6.82	0.061	0.077	0.029	0.035
902	30	7.94	106	na	0.09	10.63	3.25	2.17	3.86	10.55	6.48	0.054	0.072	0.029	0.035
902	c	7.84	171	2.83	0.12	16.31	4.66	2.81	7.03	23.24	11.10	0.056	0.084	0.047	0.034
1101	5	6.53	44	na	na	6.29	14.12	1.11	2.33	9.28	46.45	3.186	0.995	0.033	0.094
1101	10	7.74	80	1.03	0.16	10.44	4.57	1.77	2.67	8.68	67.35	0.403	0.273	0.043	0.051
1101	15	6.86	22	na	na	4.54	10.44	0.92	1.00	7.11	34.16	2.342	0.879	0.030	0.061
1101	20	6.89	19	na	na	4.45	10.13	0.89	0.94	6.67	34.04	2.353	0.780	0.029	0.058
1101	25	6.90	17	na	na	4.05	8.36	0.78	0.81	5.63	27.95	2.020	0.825	0.029	0.054
1101	30	6.87	14	na	na	3.63	6.68	0.64	0.61	4.46	22.50	1.602	0.596	0.026	0.038
1101	c	6.84	20	0.80	na	4.55	8.16	0.70	0.84	5.43	28.21	1.638	0.111	0.015	0.023
1201	5	9.51	169	na	0.06	7.08	7.71	1.62	1.57	18.60	21.25	0.127	0.336	0.029	0.059
1201	10	9.53	135	na	0.06	4.95	6.35	1.60	1.28	15.54	18.36	0.153	0.405	0.029	0.065
1201	15	9.51	108	na	0.06	5.22	5.24	1.73	0.84	12.75	13.95	0.148	0.402	0.028	0.059
1201	20	9.45	85	na	0.05	4.52	4.38	1.59	0.83	9.76	11.79	0.136	0.378	0.026	0.054
1201	25	9.48	68	na	0.04	3.47	3.83	1.59	0.77	8.13	9.33	0.144	0.436	0.024	0.053
1201	30	9.50	59	na	0.04	3.12	3.96	1.69	0.79	6.47	9.47	0.186	0.517	0.026	0.064
1201	c	9.40	101	1.70	0.05	4.52	5.11	1.64	1.08	11.39	12.07	0.137	0.258	0.020	0.054
1202	5	8.11	90	na	0.07	5.63	4.47	1.52	2.73	10.76	157.63	0.554	0.284	0.026	0.055
1202	10	8.10	76	na	0.06	5.53	4.15	1.32	2.14	9.32	151.03	0.535	0.308	0.024	0.054
1202	15	8.27	72	na	0.06	4.38	4.10	1.06	2.16	9.66	159.00	0.556	0.258	0.021	0.049
1202	20	8.29	64	na	0.05	4.56	3.80	1.16	1.78	8.26	147.70	0.523	0.255	0.020	0.049
1202	25	8.36	65	na	0.05	4.01	3.72	0.97	1.62	7.86	149.03	0.520	0.232	0.025	0.044

Site	Time	pH	EC	NO_3-N	B	Na	Mg	P	S	K	Ca	Mn	Fe	Cu	Zn
	minutes		µmhos/cm	mg/kg											
1202	30	8.49	60	na	0.05	4.69	3.75	1.07	1.88	8.64	155.38	0.532	0.223	0.019	0.045
1202	c	8.38	74	1.21	0.05	5.22	3.65	1.04	2.15	8.66	140.30	0.483	0.089	0.018	0.037
1403	5	6.89	120	na	na	2.70	1.72	1.25	na	16.17	7.89	0.027	0.044	0.012	0.020
1403	10	6.97	96	na	na	2.08	1.45	1.12	na	12.37	6.63	0.020	0.037	0.010	0.018
1403	15	7.16	84	na	na	1.73	1.28	0.98	na	10.54	5.84	0.017	0.037	0.008	0.019
1403	20	7.19	74	na	na	na	1.17	0.86	na	9.22	5.30	0.015	0.027	0.007	0.014
1403	25	7.23	67	na	na	na	1.13	0.79	na	8.03	5.07	0.014	0.026	0.007	0.014
1403	30	7.22	62	na	na	na	1.04	0.71	na	7.22	4.76	0.013	0.027	0.007	0.014
1403	c	7.20	89	0.20	na	2.01	1.34	0.97	na	11.06	6.30	0.019	0.037	0.010	0.027
1502	5	8.03	66	na	0.06	7.55	1.30	0.66	0.97	4.90	15.65	0.048	0.138	0.029	0.029
1502	10	8.06	64	na	0.06	7.53	1.27	0.63	0.84	4.64	15.14	0.046	0.124	0.028	0.021
1502	15	8.10	62	na	0.06	7.47	1.24	0.60	0.77	4.42	14.63	0.044	0.116	0.027	0.022
1502	20	8.11	60	na	0.06	7.20	1.22	0.57	0.70	4.23	14.86	0.045	0.121	0.026	0.024
1502	25	8.12	59	na	0.06	7.07	1.19	0.53	0.63	4.05	14.54	0.044	0.111	0.026	0.020
1502	30	8.14	58	na	0.06	7.14	1.17	0.51	0.60	3.90	14.31	0.042	0.115	0.025	0.020
1502	c	8.08	65	0.44	0.06	7.59	1.22	0.58	0.77	4.52	14.74	0.042	0.099	0.026	0.023
1503	5	7.65	395	na	0.12	19.62	4.76	1.43	12.86	4.05	212.40	0.174	0.335	0.029	0.034
1503	10	7.71	364	na	0.11	18.77	4.33	1.32	11.42	3.72	182.13	0.144	0.327	0.027	0.029
1503	15	7.77	315	na	0.11	17.79	4.01	1.27	10.15	3.54	164.48	0.130	0.345	0.027	0.026
1503	20	7.78	300	na	0.11	16.99	3.79	1.23	9.16	3.44	154.73	0.124	0.351	0.027	0.028
1503	25	7.83	279	na	0.11	16.24	3.66	1.22	8.56	3.31	153.00	0.126	0.373	0.027	0.028
1503	30	7.83	265	na	0.10	15.65	3.54	1.20	8.06	3.24	149.45	0.126	0.334	0.027	0.028
1503	c	7.72	321	14.58	0.11	18.15	3.77	1.20	9.88	3.63	158.40	0.123	0.147	0.025	0.023
1701	5	7.65	186	na	na	8.78	4.83	1.56	3.54	17.48	25.93	0.033	0.109	0.017	0.002
1701	10	7.69	186	na	na	7.85	4.90	1.42	3.15	16.80	23.83	0.022	0.083	0.015	0.001
1701	15	7.76	166	na	na	7.21	4.41	1.37	2.80	15.31	22.94	0.020	0.076	0.015	0.051

Site	Time	pH	EC	NO_3-N	B	Na	Mg	P	S	K	Ca	Mn	Fe	Cu	Zn
	minutes		µmhos/cm	mg/kg											
1701	20	7.81	148	na	na	6.18	3.91	1.30	2.38	13.58	21.06	0.018	0.077	0.014	0.006
1701	25	7.84	138	na	na	5.97	3.73	1.29	2.22	12.76	21.10	0.017	0.074	0.014	0.006
1701	30	7.68	69	0.84	0.18	11.21	4.66	1.97	2.60	8.80	69.26	0.380	0.270	0.049	0.055
1701	c	7.81	163	8.87	na	7.33	4.31	1.38	2.79	15.17	22.98	0.021	0.071	0.014	0.001
1702	5	7.00	99	na	0.16	132.07	4.38	1.70	4.09	10.59	14.18	0.076	0.315	0.351	0.156
1702	10	7.01	84	na	0.15	136.38	4.13	1.49	3.31	9.28	11.14	0.067	0.303	0.354	0.108
1702	15	7.10	72	na	0.20	137.35	3.93	1.34	2.69	8.55	9.44	0.065	0.296	0.357	0.110
1702	20	7.12	62	na	0.14	138.43	3.81	1.20	2.22	7.93	8.45	0.064	0.295	0.357	0.109
1702	25	7.16	55	na	0.14	137.13	3.67	1.09	1.87	7.42	7.73	0.064	0.290	0.355	0.108
1702	30	7.24	51	na	0.14	137.13	3.64	1.02	1.66	7.13	7.18	0.062	0.310	0.356	0.108
1702	c	7.49	78	na	0.13	137.05	4.01	1.37	2.87	8.85	10.62	0.067	0.304	0.358	0.109
F	15	8.29	85	na	0.10	4.35	5.84	3.60	0.73	16.80	43.20	1.020	0.829	0.061	0.165
F	30	8.58	71	na	0.09	4.12	5.01	3.10	0.50	13.53	37.82	0.871	0.782	0.057	0.151
F	c	8.23	66	na	0.08	4.09	4.82	2.99	0.51	12.65	36.61	0.836	0.762	0.056	0.147
G	15	na	64	na	0.05	3.92	2.28	1.47	0.28	11.78	12.77	0.172	0.474	0.043	0.127
G	30	na	50	na	0.05	3.88	2.12	1.35	0.22	10.53	12.03	0.162	0.442	0.041	0.084
G	c	7.64	91	1.99	0.10	4.73	5.73	3.49	0.82	16.87	43.27	0.979	0.832	0.061	0.163
H	15	7.25	98	1.48	0.10	4.74	5.85	3.58	0.83	17.64	44.15	1.000	0.835	0.063	0.165
H	30	7.37	103	0.66	0.09	4.42	5.19	3.14	0.84	18.19	36.23	0.838	0.791	0.057	0.140
H	c	7.29	103	0.46	0.09	4.19	4.83	2.86	0.79	18.14	32.31	0.762	0.739	0.050	0.124
I	15	7.47	99	na	0.09	4.17	4.57	2.59	0.76	17.99	28.69	0.713	0.727	0.046	0.112
I	30	7.39	81	na	0.08	3.94	4.11	2.33	0.52	14.69	26.30	0.664	0.644	0.043	0.103
I	c	7.42	74	na	0.09	4.20	3.80	2.13	0.46	13.39	24.14	0.607	0.620	0.042	0.098
J	15	6.48	72	na	0.09	4.06	3.68	2.04	0.48	12.82	23.24	0.582	0.608	0.041	0.103
J	30	6.33	93	4.53	0.10	4.44	4.23	2.34	0.87	16.73	26.37	0.642	0.679	0.043	0.113
J	c	6.51	102	2.84	0.09	4.32	4.63	2.60	0.98	18.57	29.15	0.714	0.719	0.046	0.121

Site	Time	pH	EC	NO_3-N	B	Na	Mg	P	S	K	Ca	Mn	Fe	Cu	Zn
	minutes		µmhos/cm	mg/kg											
K	15	6.94	106	2.09	0.09	4.43	4.79	2.72	1.02	19.28	30.34	0.742	0.749	0.049	0.117
K	30	6.80	72	0.87	0.08	4.16	5.72	3.21	0.54	15.95	36.99	1.155	0.768	0.052	0.159
K	c	7.01	60	0.58	0.08	4.07	6.00	3.35	0.42	14.51	38.76	1.314	0.785	0.054	0.181
L	15	9.14	57	na	0.08	4.07	5.96	3.39	0.41	13.92	38.07	1.361	0.769	0.053	0.184
L	30	9.24	56	na	0.07	4.03	5.18	2.98	0.35	11.89	33.11	1.172	0.747	0.052	0.157
L	c	9.12	51	na	0.07	3.96	5.10	3.01	0.35	11.44	33.24	1.154	0.718	0.051	0.146
M	15	7.17	47	na	0.08	4.10	5.28	3.12	0.30	11.93	34.60	1.192	0.723	0.053	0.156
M	30	7.30	56	1.11	0.08	4.24	6.25	3.58	0.40	14.62	40.52	1.427	0.741	0.056	0.177
M	c	7.24	64	0.75	0.08	4.30	6.49	3.64	0.42	15.59	41.42	1.472	0.792	0.057	0.188
N	15	7.66	71	0.58	0.07	4.21	6.14	3.39	0.40	14.57	38.73	1.394	0.745	0.053	0.193
N	30	7.69	68	0.31	0.06	4.06	3.74	2.18	0.30	11.93	22.63	0.676	0.624	0.047	0.182
N	c	7.67	69	0.24	0.06	4.02	2.69	1.69	0.31	11.72	15.60	0.337	0.529	0.044	0.151
O	15	7.13	64	na	0.05	3.92	2.28	1.47	0.28	11.78	12.77	0.172	0.474	0.043	0.127
O	30	7.07	59	na	0.05	3.88	2.12	1.35	0.22	10.53	12.03	0.162	0.442	0.041	0.084
O	c	7.17	54	na	0.05	3.93	2.03	1.26	0.19	9.37	11.64	0.156	0.422	0.039	0.081
P	15	6.89	50	na	0.05	3.93	2.01	1.24	0.19	9.02	11.62	0.154	0.422	0.039	0.072
P	30	6.88	59	0.95	0.05	3.97	2.20	1.38	0.25	10.08	12.70	0.171	0.441	0.041	0.092
P	c	6.98	67	0.72	0.05	4.00	2.32	1.48	0.33	11.16	13.37	0.180	0.462	0.043	0.101
Q	15	6.96	73	0.56	0.05	4.10	2.39	1.55	0.39	11.59	13.71	0.186	0.470	0.046	0.113
Q	30	7.01	75	0.36	0.06	4.14	3.11	2.26	0.43	13.75	22.87	0.268	0.557	0.050	0.138
Q	c	7.07	73	0.24	0.06	4.16	3.45	2.53	0.36	13.16	27.44	0.310	0.678	0.053	0.148
R	15	7.31	73	na	0.06	4.11	3.49	2.59	0.32	12.58	28.58	0.315	0.713	0.053	0.172
R	30	7.47	66	na	0.05	3.93	2.75	1.97	0.24	9.79	21.18	0.231	0.639	0.046	0.127
R	c	7.34	61	na	0.04	3.95	2.28	1.61	0.20	8.69	16.75	0.180	0.509	0.043	0.430
S	15	7.74	57	na	0.05	3.94	2.10	1.46	0.18	8.26	14.97	0.158	0.466	0.042	0.393
S	30	7.80	68	1.09	0.05	4.15	2.65	1.90	0.23	10.23	20.39	0.219	0.541	0.047	0.414

Site	Time	pH	EC	NO_3-N	B	Na	Mg	P	S	K	Ca	Mn	Fe	Cu	Zn
	minutes		µmhos/cm	mg/kg											
S	c	7.80	77	0.75	0.06	4.08	3.03	2.18	0.28	11.36	24.11	0.259	0.615	0.050	0.130
T	15	7.64	83	0.59	0.06	4.09	3.28	2.38	0.30	11.93	26.54	0.288	0.694	0.053	0.140
T	30	7.70	79	0.34	0.06	4.16	3.03	1.96	0.32	12.06	22.54	0.253	0.731	0.049	0.117
T	c	7.70	73	0.27	0.06	4.09	2.83	1.68	0.28	11.59	19.90	0.235	0.734	0.047	0.081
U	15	6.97	71	na	0.05	4.01	2.71	1.50	0.29	11.53	18.39	0.222	0.720	0.047	0.074
U	30	6.99	64	na	0.05	3.88	2.20	1.16	0.20	8.94	14.35	0.172	0.615	0.043	0.062
U	c	7.04	60	na	0.04	3.94	1.95	1.02	0.18	8.08	12.31	0.144	0.544	0.042	0.056
V	15	9.67	56	na	0.04	3.92	1.96	1.06	0.16	7.70	13.03	0.156	0.521	0.041	0.057
V	30	9.68	67	1.25	0.05	3.91	2.43	1.35	0.24	9.92	16.72	0.201	0.631	0.045	0.070
V	c	9.59	74	0.86	0.05	3.86	2.77	1.52	0.29	11.00	19.33	0.235	0.706	0.047	0.078
W	15	8.96	80	0.66	0.05	4.00	2.87	1.55	0.29	11.62	19.50	0.233	0.749	0.048	0.079
W	30	9.06	111	0.36	0.08	7.08	2.91	2.54	1.51	12.60	14.87	0.138	0.487	0.059	0.058
W	c	9.07	125	0.25	0.11	10.70	3.00	3.22	1.95	12.51	11.73	0.071	0.291	0.075	0.043

†na = not analyzed