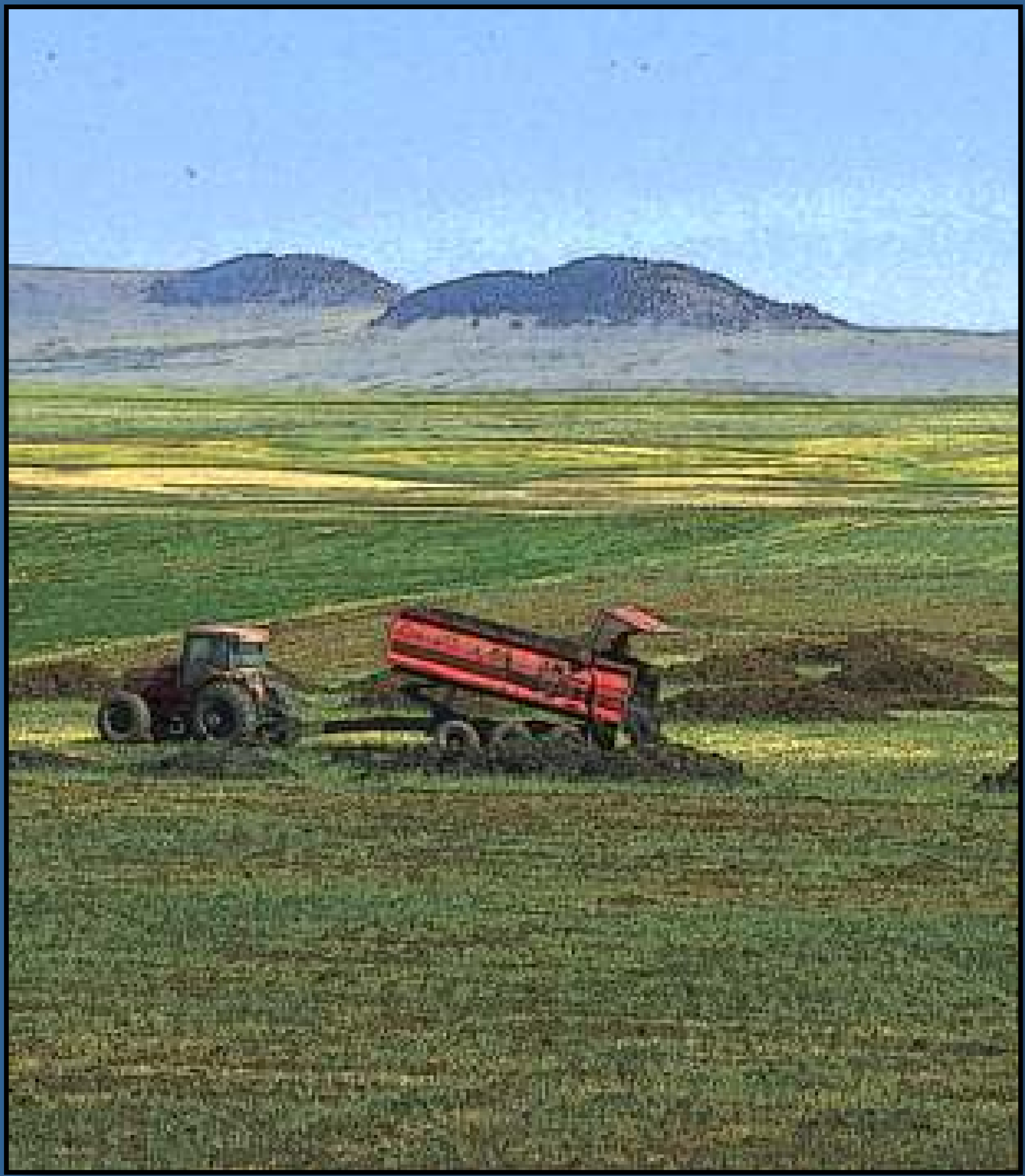

Volume 4:

Nitrogen Loss in Surface Runoff

Assessment of Environmental Sustainability in Alberta's Agricultural Watersheds Project

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Nitrogen Loss in Surface Runoff

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2008

Citation
Casson, J.P., Olson, B.M., Little, J.L., and Nolan, S.C. 2008. Assessment of Environmental Sustainability in Alberta's Agricultural Watersheds Project. Volume 4: Nitrogen loss in surface runoff. Alberta Agriculture and Rural Development, Lethbridge, Alberta, Canada. 71 pp.

Published by
Water Resources Branch
Alberta Agriculture and Rural Development
Lethbridge, Alberta, Canada

Printed in Canada

Copies of this report are available from
Water Resources Branch
Alberta Agriculture and Rural Development
Agriculture Centre
100, 5401 - 1 Avenue South,
Lethbridge, Alberta
Canada, T1J 4V6
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ABSTRACT

Agricultural sources of nutrients are associated with the eutrophication of surface waters in Alberta and elsewhere. Eutrophication is the excessive growth of aquatic plants and algae due to the enrichment of surface waters with nutrients, and this can degrade water quality for domestic, industrial, and recreational uses. Phosphorus (P) and nitrogen (N) from agricultural land are major non-point sources nutrients of particular concern. The application of commercial fertilizers, livestock manure, and increase water erosion contribute to nutrient loss. The ability to predict the amount of nutrient loss in runoff water from soil characteristics would be a useful tool for determining potential risk to nutrient losses in Alberta. Although some work has been carried out for P in Alberta, there are limited field-scale data for determining soil N and runoff N relationships in the province. The purpose of this 3-yr study was to determine the field-scale relationship between soil nitrate N and runoff total N and nitrate N from field-sized catchments or “microwatersheds” under spring snowmelt and summer rainfall conditions in Alberta.

Eight field-scale micro watersheds (2 to 248 ha) throughout Alberta were selected for the study. One site was ungrazed grassland, five sites were cultivated, non-manured crop fields, and two sites were manured crop fields. The sites were instrumented with circular flumes and automated water samplers and runoff was monitored for a 3-yr period. Soils were sampled from three incremental layers (0 to 2.5 cm, 2.5 to 5 cm and 5 to 15 cm) each spring and fall using a stratified landform-based approach. Soil samples were analyzed for extractable nitrate N content and the results were calculated for the 0- to 2.5-cm, 0- to 5-cm, and 0- to 15-cm soil layers. Water samples were analyzed for nitrate N, ammonia N, and total N concentrations.

Moderate to high application rates of manure caused higher nitrate N levels in the soil. The seasonal mean nitrate N content in the surface 15 cm of soil ranged from 2 to 74 mg kg^{-1} among the sites. The manured sites tended to have higher nitrate N content and the grassland site had the least amount of nitrate N. Spring runoff, which was mainly from snowmelt, accounted for the majority of runoff at nearly all of the sites, overall, snowmelt runoff accounted for 90% of the runoff. The seasonal nitrate N flow-weighted mean concentration (FWMC) ranged from below detection limit to 43.4 mg L^{-1}, and the seasonal total N FWMC ranged from 0.43 to 106 mg L^{-1} among the sites. Concentrations of total N exported from the microwatersheds exceeded the in-stream Alberta water quality guideline of 1 mg L^{-1} total N at all sites. Significant linear relationships were found between extractable nitrate N in soil and total N in runoff ($r^2 = 0.65$ to 0.72), and between extractable nitrate N in soil and nitrate N in runoff ($r^2 = 0.62$ to 0.69). There was no relationship between soil nitrate N and runoff ammonia N. The relationships were driven by one point from one of the manured sites (from a single rainfall event in 2005), and when this point was removed, the relationships were considerably weaker ($r^2 = 0.28$ to 0.44). Therefore, the relationships are not particularly strong and soil extractable nitrate N is a weak predictor of nitrate N or total N in edge-of-field runoff water.

ACKNOWLEDGEMENTS

We wish to thank Rod Bennett, Frank Hecker, Andrea Kalischuk, Brent Paterson, Andy Jedrych, Callie Volf, and Gerald Ontkean. Thanks to Lawrence Schinkel, Murray Peters, Ward Henry, Syd Abday, Wayne Jamieson, Francine Forrest, Debbie Werk, Keith Adamson, Paul Graveland, Andrea Kalischuk, Janelle Villeneuve for assistance with runoff sampling; and to Tom Goddard, Brandon Green, Doug Keyes, Roger Andreiuk, Doug Penney, Wayne Pettapiece, Bob MacMillan, Emmanuel Mapfumo, Deb Werk, Germar Lohstraeter, Kerrianne Koehler-Munro, Craig Sprout, Mark Nelson, Wiebe Buruma, Bonnie Clease, Dave Hyland, Roger Skretting, Paul Maloff, Heather Kolberg, and Dave Coutts for assistance with soil sampling design, method development, and data collection. Thanks also to Enviro-Test Laboratories (now ALS Laboratory Group) and Norwest Labs (now part of Bodycote Testing Group) for sample analysis. In addition, this project would not be possible without the cooperation of the producers, landowners, and the municipalities. Partial funding for this study came from the Agricultural Funding Consortium, with contributions from the Alberta Livestock Industry Development Fund, the Alberta Crop Industry Development Fund, and the Alberta Agricultural Research Institute.

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INTRODUCTION

Nitrogen (N) is a key nutrient input for optimum crop production in intensive agricultural systems, and most agricultural systems are deficient in N and will respond significantly to added N (Delgado 2002; Eickhout et al. 2006). Nitrogen is often applied to crop land through the use of commercial fertilizers and livestock manures. Nitrogen can also be increased in soil through the use of legumes in crop rotations. At the beginning of this century, 49.5 million Mg of N fertilizer was used worldwide (Baligar et al. 2001). Being one of the most dynamic and mobile elements, N is difficult to manage for crop production (Delgado 2002). The recovery of N fertilizer is about 50% on average, and the excess accumulates in soil or is lost (Delgado 2002; Eickhout et al. 2006).

Nitrogen fertilizer is susceptible to losses through volatilization, denitrification, leaching, surface runoff, and wind erosion (Delgado 2002). The loss of N to surface water, with sufficient phosphorus (P), can cause or accelerate eutrophication (Chambers et al. 2001; Eickhout et al. 2006). High nitrate N levels in drinking water can have human health implications (Chambers et al. 2001). Nitrogen enters lakes and streams with sediment and as dissolved organic and inorganic forms (Follett and Delgado 2002). Eutrophication is the excessive growth of aquatic plants and algae due to the enrichment of surface waters with nutrients, which in turn cause oxygen depletion, taste and odour problems, loss of biodiversity, and loss of aesthetic and recreational value (Carpenter et al. 1998; Follett and Delgado 2002). Even though N and P are associated with accelerated eutrophication, P has received the most attention (Sharpley et al. 1987). In water bodies, P tends to be the more limiting nutrient. Sharpley et al. (1987) suggested that N is less limiting because of N exchange between the atmosphere and water bodies and fixation of atmospheric N by blue-green algae.

Nutrient additions that cause eutrophication have been identified as “one of the most significant forms of river pollution” by the United Nations (UNESCO 2002) and one of most common causes of impairment in fresh waters in the United States (US EPA 1998). Contamination of ground and surface water by N is also a growing concern in Canada (Chambers et al. 2001; De Jong et al. 2007). Eickhout et al. (2006) predicted that losses of N to air and water will continue to increase well into the twenty-second century, particularly in developing countries, because of increased human population, increased food consumption, a shift to more meat-based diets, increased in the arable land base, and more intensive agricultural systems.

Nitrogen loss through runoff has been studied by many researchers looking at the effects of land cover and management (Burnwell et al. 1975; Douglas et al. 1998; Schilling and Spooner 2006), manure application (Eghball and Gilley 1999; Harmel et al. 2006; Miller et al. 2006), commercial fertilizers (Gascho et al. 1998), soil type (Harmel et al. 2006), hydrology (Zheng et al. 2006), and tillage methods (Römkens et al. 1973; Masand 1992). Though nitrate N can be lost through surface runoff, larger amounts are generally lost through sub-surface flow (Hubbard and Sheridan 1983; Alberts and Spomer 1985; Hubbard et al. 1991; Lowrance 1992).

Harmel et al. (2006) summarized N and P load data (expressed as kg ha^{-1}) from 40 peer reviewed papers. They reported that annual N loads exhibited no relationship with field size, but dissolved N was significantly related to application rate. However, particulate and total N were not related to application rate. They also reported that, on average, particulate N losses contributed three times as much as dissolved forms. They found a weak, significant direct relationship between annual P load and soil-test phosphorus (STP), but there was no mention of a relationship or lack of a relationship between annual N load and soil N. Particulate N loads were highest with conventional tillage compared to conservation or zero-tillage. Dissolved N losses were higher with zero tillage, and N loads were lower from pasture and rangeland compared to cultivated land. Even though conservation tillage had a clear effect on nutrient load loss, there was no clear tendency regarding effects on nutrient loads by other conservation practices such as waterways, terraces, riparian buffers, and filter strips.

Export coefficients of N, P, and suspended solids for southern Alberta were reviewed by Jeje (2006). For non-intensive agriculture land, total N export coefficients ranged from 0.63 to 9.8 kg ha^{-1} yr^{-1}; whereas, export coefficients ranged from 0.1 to 14.9 kg ha^{-1} yr^{-1} for intensive agricultural land.

The amount of N lost in surface runoff is usually small compared to N fertilizer inputs to cropping systems. In an 8-year monitoring project of 20 watersheds, Sharpley et al. (1987) found that 3 to 9% of N fertilizer inputs were lost in surface runoff. They also reported that on average 64% of total N lost in runoff was in particulate form. Crop rotation watersheds lost 2.3 times more N compared to unfertilized native grassland.

Understanding relationships between nutrients near the soil surface and the loss of nutrients in runoff water and the factors that influence these relationships is useful in making predictions, assessing risk, and evaluating management practices. Relationships between soil P and runoff P has been reported by several researchers (Sharpley et al. 1977, 1978; Daniel et al. 1994; Pote et al. 1996; Torbert et al. 2002; Little et al. 2007). Similar type relationships have not been reported in the literature for N. A few researchers have shown some relationship between soil N and runoff N. Gilley et al. (2007), in a small-plot rainfall simulation study, reported that by reducing the nitrate N content in the top 5 cm of soil from 9.49 to 2.52 mg kg^{-1}, the amount of nitrate N in runoff was reduced from 2.29 to 0.60 mg L^{-1}. Miller et al. (2006) found a significant positive relationship between ammonium N in soil and ammonium N in runoff from a manure rate application study. Perhaps the dynamic nature of N in soil, and the fact P has received more attention, may be reasons why quantitative relationships between soil and runoff N are not readily available.

From 1999 to 2006, the Alberta Soil Phosphorus Limits Project was carried out to develop recommendations for P limits for agricultural land in Alberta (Paterson et al. 2006). The project included literature reviews, laboratory studies, and field studies. One of the field studies was a 3-yr study where eight, small, agricultural watersheds in Alberta were monitored for soil nutrients and nutrient loss in edge-of-field runoff water. The main focus of the study was to develop a relationship between soil-test phosphorus (STP) and P in the runoff water. Little et al. (2006, 2007) reported a linear relationship between soil and runoff P. In addition to the P data, N in the soil and runoff water was also measured, but the results were not reported. The purpose of this report is to summarize the N data from the Alberta Soil Phosphorus Limits Project watershed study. The main objective of this study was to determine the field-scale relationship between soil nitrate N and runoff total N and nitrate N from field-sized catchments or “microwatersheds” under spring snowmelt and summer rainfall conditions in Alberta.

MATERIALS AND METHODS

Site Description

Site descriptions have previously been provided by Little et al. (2006, 2007). Eight field-scale microwatershed sites were selected in areas with high agricultural intensity, high runoff potential, good drainage, uniform management, no farmyard or non-agricultural influences, and good access (Figure 1). The sites included one ungrazed grassland site (STV) west of Stavely; five cultivated, non-manured sites near Crowfoot Creek (CFT), Grande Prairie Creek (GPC), Renwick Creek (REN), Threehills Creek (THC), and Wabash Creek (WAB); and two cultivated, manured sites near Ponoka (PON) and Lower Little Bow River (LLB).

The sites represented a range of precipitation and runoff potential within the agricultural area of Alberta (Table 1). Management characteristics of the cultivated sites were typical for Alberta and ranged from no-till at the CFT and THC sites, to reduced tillage at the REN site, and conventional tillage at the WAB, GPC, LLB, and PON sites. The CFT, LLB, and GPC sites had ultiple, but similarly managed fields. The PON site received high rates of cattle manure,

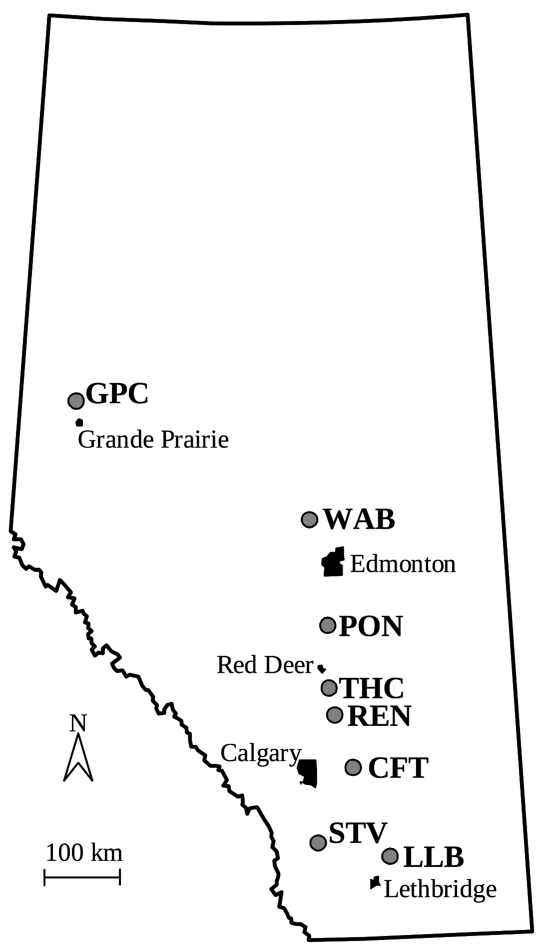

Figure 1. Microwatershed sites within the agricultural regions of Alberta.

whereas the LLB site received moderate rates of cattle manure. The STV site had not been grazed by cattle for at least 15 yr prior to the start of the study and had minimal cattle grazing on the site since 1949 (Little et al. 2007).

Table 1. Characteristics and management information of the fields closest to the drainage outlet at the eight microwatershed sites (Little et al. 2007).

Site	Area (ha)	Mean slope (%)	Annual precipitation [z] (mm)	Est. annual runoff potential [y] (mm)	Management [x]
			Ungrazed grassland site		
STV	2	8	500-550	113	GL
			Non-manured sites		
CFT	248	1	350-400	12	NT
GPC	62	2	450-500	77	CT
REN	26	2	400-450	18	RT
THC	51	4	450-500	35	NT
WAB	33	1	500-550	26	CT
			Manured sites		
LLB [w,v]	88	1	350-400	14	CT
PON [v]	30	2	500-550	36	CT

[z] Chetner and Agroclimatic Atlas Working Group (2003).
[y] Jedrych et al. (2002).
[x] GL = grassland, CT = conventional tillage, RT = reduced tillage, NT = no tillage before seeding.
[w] Irrigated.
[v] LLB site cattle manure applied every 3 yr, PON site cattle manure applied one to two times per year.

Digital elevation models (DEMs) derived from photogrammetry at each site was used to identify microwatershed boundaries, contributing areas, and areas where flow and deposition were likely to occur. The ln (α/tanβ) topographic or wetness index was determined, where α is the upslope contributing area and β is the local slope (Quinn et al. 1995).

All the soils at the sites were classified as Chernozems, either in the Dark Brown, Black, or Dark Gray Great Group (Table 2). The surface soil texture was similar among the sites, with more clay at the GPC site. Organic matter content ranged from 43 g kg^{-1} at the WAB site to 140g kg^{-1} at the STV site. Soil pH ranged from 5.7 at the REN site to 7.7 at the LLB site.

Site	Soil class [z]	Landform type [y]	Slope (%)	Lower [x] (%)	Mid [x] (%)	Upper [x] (%)	Texture (surface/subsurface) [w]	Organic matter [w] (g kg^{-1})	Clay [w] (g kg^{-1})	pH [w]
					Ungrazed grassland site					
STV	O.BLC	M1h	6 – 25	33	34	33	L / CL	140	140	6.5
					Non-manured sites					
CFT	O.DBC	U1h	1 – 4	9	55	36	L / SiL	53	210	6.4
GPC	SZ.DGC	U1h-M1l	1 – 4	17	65	17	CL / C	75	290	6.0
REN	O.BLC	M1m	1 – 8	32	52	15	L / SL	66	150	5.7
THC	O.BLC	M1m	0 – 6	24	49	26	L / L	100	230	6.0
WAB	O.DGC	U1h	1 – 4	7	73	20	L / CL	43	200	5.9
					Manured sites					
LLB	O.DBC	U1l	1 – 2	30	59	11	L / CL	45	260	7.7
PON	E.BLC	H1l	0 – 5	25	58	17	L / CL	96	120	6.5

Table 2. Summary of surface soil and landform characteristics in the microwatersheds (Little et al. 2006, 2007).

[z] Classification symbols follow Canadian System of Soil Classification: O = Orthic; SZ = Solonetzic; E = Eluviated; DB = Dark Brown; BL = Black; DG = Dark Gray; C = Chernozem.
[y] Landform symbols follow the AGRASID convention: U = undulating; M = rolling; H = hummocky; l = low relief; m = moderate relief; h = high relief (relative for each landform).
[x] Proportion of microwatershed in each landscape position.
[w] Measured at the mid landform position.

Soil Sampling and Analysis

Soil sampling. Soil sampling details have previously been reported by Little et al. (2006, 2007) and Nolan et al. (2007). Soil sampling was stratified by landform position at each site. A minimum of six, three-point transects were selected on the classified DEM at each site according to landform position (upper, mid, and lower). Additional points were identified according to wetness index and proximity to outlet to ensure that extractable nitrate N was measured where flow and deposition were most likely to occur. The number of sampling points ranged from 22 to 48, with the exception of the STV site, which had three sampling points. A Differential Global Positioning System, accurate to less than 1 m, was used to identify sampling points for repeat sampling.

The frame-excavation method was used to obtain representative portions of fertilizer bands or manure and soil (Little et al. 2006, 2007; Nolan et al. 2007). Soil samples were excavated from the 0- to 2.5-cm, 2.5- to 5-cm, and 5- to 15-cm layers. One frame per sampling point was used for non-manured fields and two frames per sampling point were used at the manured sites and at the ungrazed grassland site (STV). The excavated soil in each layer was well mixed in the field, and a 500-g subsample was shipped in coolers with ice packs to the laboratory.

Fall sampling was carried out after the landowners had completed crop harvesting, fertilization, manure application, and tillage in order to characterize nitrate N levels for spring runoff events. To characterize the nitrate N levels for the summer runoff events, a subsample of points in runoff contributing areas identified by a high wetness index were sampled after seeding and fertilizing had been completed. These points represented 20% of the points that were sampled in the fall (n = 5 to 10). All sites were sampled each spring, except for the STV site where no fertilizer was applied.

Quality control. For quality control, two duplicate samples from the three soil layers were submitted for each site with the fall samples. These samples were designated as sampling points 50 and 51. One duplicate sample from the three soil layers were submitted for each site with the spring samples and was designated as sample point 50. During the 3-yr study, 201 of the batch soil samples were submitted with check samples (samples 50 and 51). Of these, one value was missing and comparisons could not be made, leaving 200 comparisons. The number of samples that were analyzed with checks represented about 8% of the total number (2,469) of soil samples analyzed in the study. In addition to the check samples sent to the private laboratories, check sample were analyzed by the Alberta Agriculture and Rural Development (ARD) Laboratory, either in Edmonton (fall 2002 sample set) or in Lethbridge (fall 2003 and fall 2004 sample sets). Check samples were not analyzed in the ARD Laboratories with the spring sample sets. A total of 137 check samples were analyzed by the ARD laboratories.

A large volume (20 to 25 L) of soil from the 0- to 15-cm layer was collected at each site during the summer of 2002. These samples were air-dried, ground, and mixed well and used as reference samples for quality control. Three subsamples of the reference sample were submitted with each season of site samples, and these were designated as sample site 52, soil layers 0 to 2.5 cm, 2.5 to 5 cm, and 5 to 15 cm. The reference sample for each site came from the same bulk sample collected from the 0- to 15-cm layer; and therefore, were used as three replicates, even though they were identified as three different soil layers. Three private laboratories were used during the study. Reference samples from each site were analyzed three times at Lab 2, six times at Lab 1, and nine times at Lab 3. The exception was the STV site reference sample, which was analyzed three times at all three labs.

Extractable nitrate nitrogen. Soil samples were dried and ground to pass through a 2-mm sieve, and analyzed for extractable nitrate N content. The first laboratory (Lab 1) analyzed the samples collected in the fall of 2002 and the spring of 2003. Samples from the fall of 2003 were analyzed by Lab 2, and the samples collected in the spring of 2004, fall of 2004, and spring of 2005 were analyzed by Lab 3. Labs 2 and 3 were the same company but different locations. Nitrate N was extracted using the modified Kelowna method (Ashworth and Mrazek 1995) at Lab 1, and the potassium chloride extraction method (Maynard and Kalra 1993) was used at Labs 2 and 3. Nitrate N in the extracts were determined by spectroscopy.

Site Instrumentation

Flumes. The CFT, GPC, LLB, THC, REN, WAB sites were instrumented with circular flumes (Samani et al. 1991) as previously described by Little et al (2006, 2007). Briefly, the flumes consisted of a 0.273-m internal diameter (ID) high-density polyethylene (HDPE) pipe installed vertically inside a 0.9-m ID HDPE horizontal pipe. The lengths of the horizontal and vertical pipes were 3 m and 2.1 m, respectively. The vertical column was located 0.9 m from the inlet of the flume and was slotted with 10, 8-mm ID holes spaced at 10-mm intervals. Due to site restrictions, the circular flume at the LLB site was shortened to 1.83 m in length, while the CFT site had a smaller version of the circular flume (0.61-m ID by 1.83-m long). The PON site was initially instrumented with a 0.61-m H-flume, which was replaced with a circular flume in June 2003. The STV site was bordered on the down-slope edge with a trough, which directed runoff water into a 0.15-m trapezoidal flume.

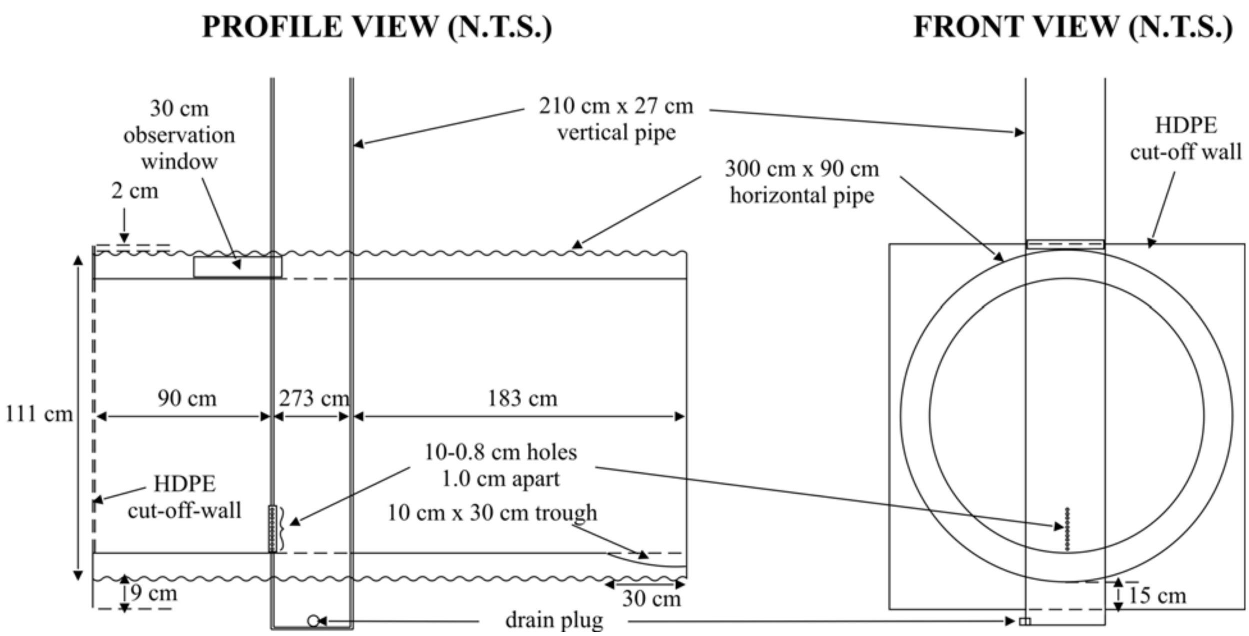

Figure 2. Profile and front view of a typical circular flume.

Other instrumentation. Each site was equipped with a float potentiometer placed within the vertical column to measure head (or stage). Staff gauges were mounted on the exterior of the vertical column for manual flow measurements during site visits. Sites were also equipped with Lakewood TP10K5 thermistors and Davis tipping bucket rain gauges, which were replaced with Texas tipping bucket rain gauges in May 2004. Sites were powered with two, 15-W solar panels, and rechargeable 12-V batteries. A second float potentiometer and Lakewood datalogger were installed at most sites in 2004 for backup collection of flow data.

Each site was equipped with ROM Communications Microcom units, except for the STV site. These units were integrated dataloggers with analog cellular communications technology that allowed real-time monitoring of site conditions. The units were programmed to monitor head, temperature, precipitation, and battery voltage every 30 s. When detected, flow or precipitation were recorded in the datalogger and reported on the website every 15 min and alarms were sent via pagers and emails to team members. A technician and a continuously-monitored meteorological station were permanently on-site at the STV site. This site was equipped with a Lakewood Ultralogger and a float potentiometer to record head.

Water samples were taken by ISCO 6700 automated water sampling devices (Tededyne Isco Inc., Lincoln, Nebraska, United States), equipped with 24, 1-L ProPaks™ and disposable polyethylene inserts. The ISCO samplers were programmed to take a 150-mL sample every 15 minutes for a total volume of 900 mL or six samples per bottle. Changes in head were used to trigger the ISCO via a ROM Communications Microcom unit whenever flow volumes reached the minimum criteria set for each microwatershed site.

A natural gas company constructed an earth road through the REN site in January 2004 that bisected the natural runoff pattern. In May 2004, two culverts were installed under the new road at low points to allow runoff to move through the microwatershed to the flume. Unfortunately, the road affected the 2004 runoff due to increased erosion at the site and because some of the runoff flowed over the county road northeast of the flume before entering the rear of the flume. A vertical pipe was installed on the edge of the road culvert in August 2004 to divert runoff from the road directly into the culvert.

Water Sampling and Analysis

Water samples were collected daily during runoff events and then immediately transported in coolers to the nearest Envirotest Laboratory location in Calgary, Edmonton, or Grande Prairie. Within a 24-h period of continuous sampling, 16 water samples in ProPaks™ were collected. Each sample was analyzed for P, which was the main focus of the study (Little et al. 2006, 2007). For N in the water samples, the first, middle, and last samples of the daily ProPaks™ samples were analyzed within 48 h for nitrate N and nitrite N, within 28 d for ammonia N and total Kjeldahl N, and within 7 d for total suspended solids and total dissolved solids. Blanks filled with deionized water, as well as a prepared standards of known N concentrations, were submitted to the lab with each batch of samples as part of a quality assurance/quality control program.

Data Analysis

Flow measurements. Prior to head (or stage) data being converted to flows, values were corrected for the offset or zero value of the flume. The flumes were then calibrated using the Water Ware software program developed by Samani et al. (1991). The resulting calibrations were then plotted in TableCurve 2D, version 3 (Jandel Scientific Software 1994), to fit an appropriate curve to the data. Once a curve was selected and applied to the heads, a correction factor was applied to account for the slope of the flume and for any inactive head in the flume.

Flows in the 0.9-m circular flumes were best described by the following power function.

$$y = 0.0702\ x^{2.093} \qquad (1)$$

Where:
y = flow (L s^{-1})
x = head (cm)

Flows in the 0.61-m circular flume at the CFT site were described by the following power function.

$$y = 0.0000673\,x^{2.072} \tag{2}$$

Runoff nitrogen calculations. To calculate flow-weighted mean concentrations (FWMCs), water flow data were linearly interpolated to 1-minute intervals using Proc Expand in SAS (Statistical Software Institute Inc. 2003) (Little 2006, 2007). The area under the curve was then integrated to estimate total daily flow volumes using a SAS area macro. The mean daily concentration data were then matched to the total daily volumes and loads were calculated for matching values by multiplying flow and concentration data. Seasonal FWMCs were then calculated by dividing the total load for all events by the total flow volume for all events during the season.

Missing flows were accounted for using three methods depending on the period of time for which data were missing (Little 2006, 2007). If the time period for which the flow data were missing was less than 1 d, flows were linearly interpolated with missing head values supplemented by manual field measurements, where possible. If the time period was greater than 1 d, FWMCs were calculated for days with flow, and mean daily concentrations (not flow-weighted) were used for days without flow. The daily averages were then averaged for the whole event to determine the concentration. If no flow data were available, mean concentrations of the parameters were used.

Statistical analysis. Analyses of the soil and water samples were completed using SAS version 9.1 (SAS Institute Inc. 2003). The Univariate procedure was used to test the distribution of the data, and the Means and Summary procedures were used to generate descriptive statistics. The REG procedure was used to relate measures of soil nitrate N to runoff N fractions. The General Linear Model(GLM) procedure and Tukey test were used to determined significant differences among the three laboratories using the data for the reference soil samples. The GLM procedure and Tukey test were also used to determine significant differences among the upper, mid, and lower slope positions for soil nitrate N at each watershed site. A significance level of 0.05 was used throughout this study.

RESULTS AND DISCUSSION

Soil Nitrate Nitrogen

Quality control results. The mean nitrate N values obtained for the reference samples (sample 52) from Labs 1 and 3 were not significantly different for any of the sites (Table 3). Mean values from Lab 2 were significantly lower at the CFT and GPC sites, and significantly higher at the LLB site compared to the other two labs. The Lab 2 mean for the REN site was significantly lower than the Lab 3 mean, but not significantly different from the Lab 1 mean. There were no significant differences among the three labs at the PON, STV, THC, and WAB sites. Because of few significant differences and only three reference samples were analyzed at Lab 2, no attempt was made to standardize the batch sample values to one laboratory.

Table 3. Extractable nitrate N means for the reference soil samples.

Site	Lab 1[z] n=6	Lab 2[y] n=3	Lab 3[x] n=9
	------------------------------	(mg kg^{-1})	------------------------------
CFT[w]	8.9a	5.4b	8.8a
GPC	20.6a	12.6b	20.3a
LLB	8.6b	13.9a	8.7b
PON	55.0a	77.9a	86.0a
REN	3.9ab	1.9b	5.2a
STV[v]	1.6a	1.1a	3.3a
THC	6.7a	1.8a	5.5a
WAB	8.8a	7.4a	8.8a

[z] Fall 2002 and spring 2003 samples analyzed.
[y] Fall 2003 samples analyzed.
[x] Spring 2004, fall 2004, and spring 2005 samples analyzed.
[w] Means within the same row followed by the same letter do not differ significantly (P<0.05).
[v] n=3 for all three labs for the STV site.

There were 120 (60%) check sample values that were within ±20% of the corresponding batch sample values. Thirty-seven (19%) check sample values were less than 80% of the corresponding batch sample values, and 43 (22%) check samples were greater than 120% of the corresponding batch sample values. Eighty-three (42%) check sample values were within ±10% of the batch sample values, and 58 (29%) check sample values were within ±5% of the batch sample values.

Generally, the duplicate values agreed well with the batch samples, even though 40% of the checks values were not within ±20% of the batch sample values (Figure 3). Many of these discrepancies were due to low values and a small difference between the batch sample and check sample resulted in either a small or large ratio. There were five samples for which the check and batch samples had particularly high discrepancies (Table 4).

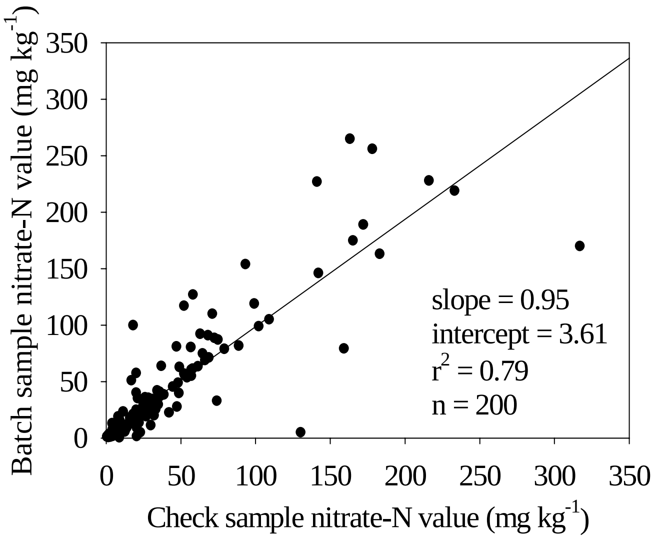

Figure 3. Extractable nitrate N values for the batch soil samples compared to the check samples. Perfect agreement between the batch and check samples would have resulted in all the points falling on a 1-to-1 line.

Table 4. Nitrate N content of five batch samples compared to the corresponding check sample values.

Site	Year	Season	Sample point number	Soil layer (cm)	Sample Nitrate N (mg kg^{-1})	Check nitrate N (mg kg^{-1})	Check:Sample ratio	ARD Lab nitrate N (mg kg^{-1})
GPC	2003	Fall	12	0-2.5	5.1	22.8	4.5	26
GPC	2003	Fall	12	2.5-5	1.5	20.4	12.0	11
GPC	2003	Fall	12	5-15	0.5	8.7	17.4	10
PON	2002	Fall	18	0-2.5	5	130	26.0	20
PON	2003	Spring	6	2.5-5	100	18	0.18	na[z]

[z] Not analyzed.

The three samples from the GPC were from the three soil layers collected at the same time in the fall of 2003 (Table 4). The check values were much higher than the batch sample values, and the ARD Lab values were much closer to the check values. These samples were analyzed by Lab 2, and fall 2003 was the only time this lab was used to analyze soil samples. However, the other sample point (#7) at the GPC site and the other seven sites had good agreement between batch and check samples. It is unknown why the check samples did not agree very well with the batch samples from sample point #12 at the GPC site in the fall of 2003. Perhaps samples were switched or mislabeled.

The PON site was heavily manured. The low values of 5 mg kg^{-1} for the batch sample in fall 2002 and 18 mg kg^{-1} for the check sample in spring 2003 was not generally expected. The ARD

Lab value in fall 2002 was not useful (Table 4). A total of 252 batch soil samples from the PON site were analyzed, and the values ranged from 1.8 to 325 mg kg^{-1}. Because of the range and distribution of the data, the discrepancies between the PON site batch and check samples, shown in Table 4, could not be explained by identifying one or the other as outliers.

The option is no longer available to re-analyze soil samples. Therefore, based on the checks sample results, no adjustments were made to the main data set.

Soil nitrate nitrogen content. The seasonal mean values of extractable nitrate N ranged from 3.3 to 196 mg kg^{-1} in the 0- to 2.5-cm layer (Table 5), 2.4 to 177 mg kg^{-1} in the 0- to 5-cm layer (Table 6), and 1.6 to 163 mg kg^{-1} in the 0- to 15-cm layer (Table 7). The STV site had the lowest nitrate N content and the PON site had the highest nitrate N content. The soil at the LLB site contained about one-third the amount of nitrate N compared to the PON site. The five non-manured cultivated sites had soil nitrate N intermediate between the STV and LLB sites. In the 0- to 15-cm layer, for example, the 3-yr mean values were 3.2 mg kg^{-1} for the STV site, 37 mg kg^{-1} for the LLB site, 116 mg kg^{-1} for the PON site, and a range of 12 to 19 mg kg^{-1} for the five non-manured, cultivated sites (CFT, GPC, REN, THC, WAB). It would appear that manure application increased the soil nitrate N content at the LLB and PON sites.

The extractable nitrate N results among the sites followed the same pattern reported for soil-test P (STP) by Little et al. (2007). For example, in 2002, the mean STP in the 0- to 15-cm layer was 3 mg kg^{-1} at the STV site, 269 mg kg^{-1} at the LLB site, 512 mg kg^{-1} at the PON site, and 20 to 35 mg kg^{-1} at the five non-manured, cultivated sites (Little et al. 2007). The relative differences among the grassland, non-manured, and manured sites were not as great for nitrate N compared to STP. This difference between the two nutrients may be due to loss processes, such as leaching, volatilization, and denitrification, which may affect nitrate N concentrations.

Agronomically, most of the sites were low in extractable nitrate N. Sampling soil to the 60-cm depth is preferred when making N fertilizer recommendations; however, samples were taken only to the 15-cm depth in this study. Adjustment factors can be used to convert values to a 0- to 60-cm basis. An adjustment factor of 1.84 was used for the seven non-irrigated sites, and a adjustment factor of 3.03 was used for the LLB irrigated site (Soil Test Technical Advisory Group 1988). The values in Table 7 were first converted to kg ha^{-1}, using soil bulk density values, which were measured at each site in the fall of 2004 except for the GPC site. Soil bulk density values used were 600 kg m^{-3} for the STV site, 900 kg m^{-3} for the THC and PON sites, 1000 kg m^{-3} for the REN site, and 1100 kg m^{-3} for the CFT, WAB, and LLB sites (unpublished data). The bulk density at the GPC was assumed to be 1000 kg m^{-3}. Using nitrate N values determined for the fall season in 2002, 2003, and 2004, N fertilizer requirements were estimated for silage barley production (McKenzie et al. 2000). Recommendations ranged from 56 to 140 kg ha^{-1} N fertilizer for the non-manured, cultivated sites. About 56 to 78 kg ha^{-1} could be applied at the LLB site, and 67 kg ha^{-1} N fertilizer at the PON site, but only in 2004 (i.e., for the 2005 crop year). These N fertilizer recommendations are crude estimates, and were meant to only to give an indication of the level of N deficiency at the sites. Obtaining soil samples to the 60-cm depth, as well as taking into account actual soil moisture conditions, target crop, and economic factors, would provide more realistic recommendations.

The Agricultural Operation Practices Act (AOPA) regulates the application of livestock manure on agricultural land in Alberta using soil N limits (Province of Alberta 2005). The N limit for the LLB site is 270 kg ha^{-1} nitrate N in the top 60 cm of soil, and the limit for the PON site is 225 kg ha^{-1} nitrate N. Based on the approach to estimate the amount of nitrate N on a 0- to 60-cm layer basis, as described in the previous paragraph, the LLB site remained below the AOPA limit; whereas, the PON site was most likely above the AOPA limit in 2002 and 2003, but below the limit in 2004.

Generally, for the non-manure crop sites the nitrate N content was higher in the spring compared to the previous fall (Table 7). Soil sampling in the spring was carried out after all spring field operations had been completed including seeding. Therefore, enough time may have allowed nitrate N to accumulate through mineralization. On average, the nitrate N content in the 0- to 15-cm layer was higher in the spring compared to the fall by 3.3 times at the CFT site, 1.8 times at the GPC site, 2.7 times at the REN site, 1.2 times at the THC site, and 3.7 times at the WAB site. This was also true for the LLB site, but not for the PON site. On average, the nitrate N content in the spring was 30% lower than in the fall at the latter site.

Table 5. Mean extractable nitrate N values in the 0- to 2.5-cm soil layer at each microwatershed site.

Site	Fall 2002	Spring 2003	Fall 2003	Spring 2004	Fall 2004	Spring 2005
	mg kg^{-1}					
			Ungrazed grassland site			
STV	4.1	ns[z]	3.3	ns	7.2	ns
			Non-manured sites			
CFT	11	48	13	33	24	100
GPC	32	76	36	35	6.8	11
REN	11	17	5.0	39	14	46
THC	7.0	14	7.1	13	57	11
WAB	13	39	9.0	42	5.8	34
			Manured sites			
LLB	43	43	23	63	31	61
PON	52	53	182	115	84	196

[z] Not sampled.

There was no consistent variation in nitrate N content with soil depth. Overall, there was a general trend for less nitrate N concentrations in the 0- to 15-cm soil layer compared to the 0- to 2.5-cm and 0- to 5-cm soil layers. The average nitrate N content among all the sites was 33 mg kg^{-1} in the 0- to 2.5-cm and 0- to 5-cm layers and 31 mg kg^{-1} in the 0- to 15-cm layer. This indicates that nitrate N was generally distributed uniformly throughout the 15-cm soil layer. On a per site basis during the 3-yr period, there were significant differences only at the CFT and GPC sites, where the nitrate N content in the 0- to 15-cm layer was significantly lower (data not shown). However, there were significant differences among the three soil layers for one or more sample seasons for each site. For example, at the GPC site in spring 2003, there was significantly less nitrate N in the 0- to 15-cm layer (30 mg kg^{-1}) compared to either the 0- to 2.5-cm (76 mg kg^{-1}) or 0- to 5-cm (58 mg kg^{-1}) layers. Usually when there were significant differences among the soil layers, the nitrate N was lowest in the 0- to 15-cm layer. Nolan et al. (2007) reported that STP concentration at these sites was generally less in the 0- to 15-cm layer compared to the to 0- to 2.5-cm layer.

Table 6. Mean extractable nitrate N values in the 0- to 5-cm soil layer at each microwatershed site.

Site	Fall 2002	Spring 2003	Fall 2003	Spring 2004	Fall 2004	Spring 2005
	------------	------------	------------ mg kg^{-1}	------------	------------	------------
			Ungrazed grassland site			
STV	3.4	ns[z]	2.4	ns	6.6	ns
			Non-manured sites			
CFT	11	56	14	40	25	91
GPC	31	58	33	28	7.3	35
REN	11	21	5.3	46	13	45
THC	7.0	15	7.7	13	48	12
WAB	14	37	9.1	39	7.6	32
			Manured sites			
LLB	42	35	28	59	32	66
PON	85	49	177	84	78	177

[z] Not sampled.

Table 7. Mean extractable nitrate N values in the 0- to 15-cm soil layer at each microwatershed site.

Site	Fall 2002	Spring 2003	Fall 2003	Spring 2004	Fall 2004	Spring 2005
	------------	------------	------------ mg kg^{-1}	------------	------------	------------
			Ungrazed grassland site			
STV	2.4	ns[z]	1.6	ns	5.5	ns
			Non-manured sites			
CFT	12	41	12	42	17	51
GPC	19	30	21	17	6.5	33
REN	11	13	4.8	34	12	29
THC	5.5	12	7.5	28	32	15
WAB	14	40	9.4	40	11	49
			Manured sites			
LLB	34	27	35	74	31	56
PON	163	59	144	58	67	134

[z] Not sampled.

There were few significant differences among the upper, mid, and lower landform positions for nitrate N contact in the 0- to 15-cm soil layer. Because of the reduced sample sites in the spring, landform positions were only compared in the fall. In the fall of 2002, the lower slope had less nitrate N than the upper slope at the LLB site; whereas, the opposite was true at the THC site (Figure 4). Nitrate N content was significantly less in the lower landform position compared to the mid landform position at the CFT site in 2003, and nitrate N content was significantly less in the upper landform position compared to the mid and lower landform positions at the PON site in 2004 (data not shown). There were no significant differences among the landform positions at the other sites in 2003 and 2004.

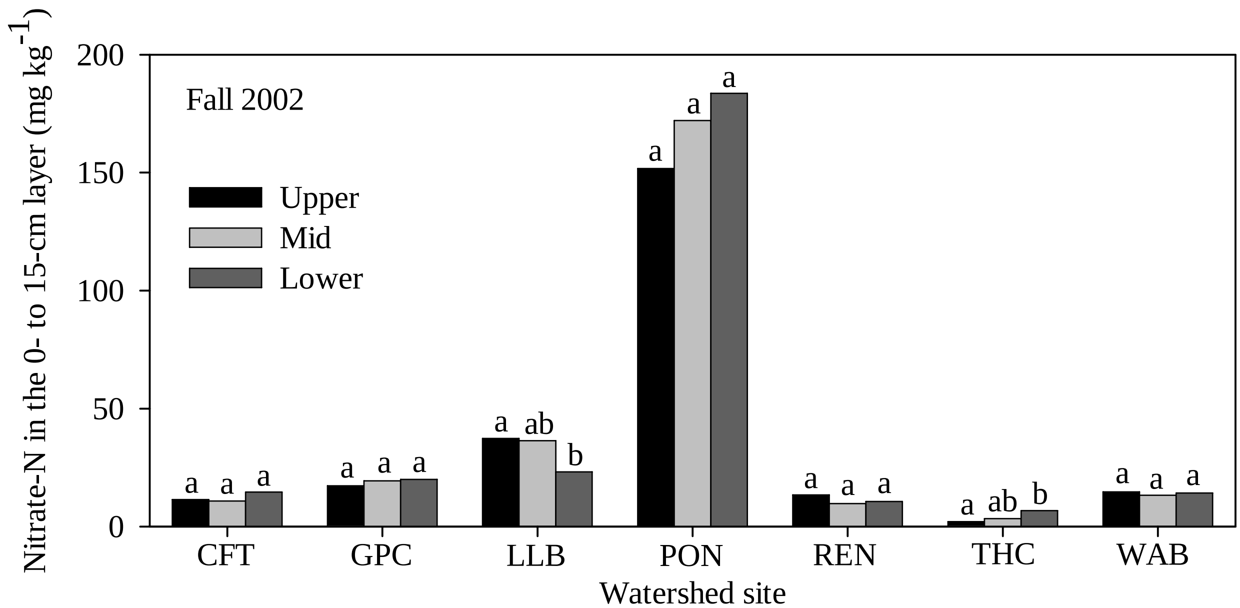

Figure 4. Mean extractable nitrate N in soil at the upper, mid, and lower landform positions at the study sites in the fall of 2002. Within each site, bars with the same letter are not significantly different at $P \leq 0.05$.

Runoff Water

Hydrographs. Spring runoff occurred at all sites in 2003, at all sites except the LLB and PON sites in 2004, and at all sites except the two southernmost sites (LLB and STV) in 2005 (Table 8). Winter precipitation in 2003 ranged from more than 20% below normal at the STV and LLB sites to more than 70% above normal at the GPC, PON, and THC sites. In 2004, winter precipitation was well below normal at most sites and about normal for the THC and WAB sites. Winter precipitation in 2005 was near normal at most sites, except for the LLB site (45% below) and the THC site (50% above) (Table 9). Spring runoff started as early as mid-February in 2004 and as late as early April in 2003, starting at the southernmost sites and moving progressively north. Spring runoff was continuous at most sites in 2003, but had two or three phases at most sites in 2004 and 2005 due to intervening cold periods.

Table 8. Hydrological characteristics of the spring and summer runoff events.

Site	Duration of runoff (days)	Start of runoff	Mean flow ($m^3 s^{-1}$)	Total flow volume (m^3)	Runoff depth (mm)	Number of samples	Duration of runoff (days)	Number of events	Mean flow ($m^3 s^{-1}$)	Total flow volume (m^3)	Runoff depth (mm)	Number of samples
	Spring 2003						Summer 2003					
	Ungrazed grassland site											
STV	4	14-Mar	0.0009	406	20.3	4						
	Non-manured sites											
CFT	12	14-Mar	0.0760	59 320	23.9	41						
GPC	13	13-Apr	0.0530	25 858[z]	41.7	44						
REN	12	22-Mar	0.0140	4 655[y]	17.9	35	1	1	na[x]	na	na	2
THC	10	23-Mar	0.0060	6 503	12.8	29						
WAB	9	11-Apr	0.0070	4 517	13.7	22						
	Manured sites											
LLB	7	15-Mar	0.0025	1 140	1.3	25	24	12	0.0027	1 828	2.1	52
PON	12	7-Apr	0.0025	2 044	6.8	31						
	Spring 2004						Summer 2004					
	Ungrazed grassland site											
STV	1	18-Mar	$3x10^{-6}$	0.23	0.01	2						
	Non-manured sites											
CFT	13	9-Mar	0.0910	89 019	35.9	38						
GPC	6	3-Apr	0.0070	5 139	8.3	17	19	5	0.0101	12 766	20.6	51
REN	13	25-Feb	0.0080	9 708	37.3	40	4	3	0.0023	124	0.5	6
THC	18	12-Mar	0.0060	7 457	14.6	54						
WAB	4	3-Apr	0.0085	2 321	7.0	12						
	Manured sites											
LLB	12	22-Feb	$6x10^{-5}$	253	0.02	32	12	9	0.0012	548	0.6	33
PON						0	2	2	0.0010	143	0.5	5
	Spring 2005						Summer 2005					
	Ungrazed, grassland site											
STV						0	3	2	na	na	na	2
	Non-manured sites											
CFT	22	26-Feb	0.0056	9 740	3.9	54						
GPC	18	8-Mar	0.0310	37 934	61.2	48						
REN	13	1-Mar	0.0029	6 882	26.4	30	7	5	0.0054	772	3.0	13
THC	14	4-Mar	0.0085	10 640	20.9	42	2	2	0.0013	98	0.2	6
WAB	16	5-Mar	0.0070	6 025	18.2	38						
	Manured sites											
LLB						0	19	7	0.0122	11 238	6.1	36
PON	15	7-Mar	0.0204	21 521	71.7	46	1	1	0.0022	40	0.1	1

[z] Includes data up until 23 Apr 2003, though flow continued after this date.
[y] Includes data up until 30 Mar 2003, though flow continued after this date.
[x] Not available.

Table 9. Precipitation differences from 30-yr normal (1971 to 2000) data for each microwatershed site.

Site	Winter difference from normal precipitation (%)[z]			Summer difference from normal precipitation (%)		
	2003	2004	2005	2003	2004	2005
				Ungrazed grassland site		
STV	-38	-61	-14	-42	74	88
				Non-manured sites		
CFT	14	-21	-6	-30	-17	35
GPC	91	-5	-1	-44	77	-11
REN	8	-44	-9	-55	-5	19
THC	73	11	50	-59	23	5
WAB	64	3	-7	-47	47	-6
				Manured sites		
LLB	-23	-42	-45	-75	-1	74
PON	86	-43	-3	-48	-28	-16

[z] Positive values are percent greater than the 30-yr normals and negative values are percent less than the 30-yr normals for each site. Data were provided by Environment Canada (2005).

Total and mean flow volumes for the spring runoff period were least at the STV site for all 3 yr, while the greatest total volumes were observed at the CFT site in 2004, the REN site in 2004, and the GPC site in 2005. The four northernmost sites (THC, PON, WAB, and GPC) had their greatest flow volumes in 2005, while the two southernmost sites (LLB and STV) had their greatest flow volumes in 2003. Nearly all sites had their lowest flow volumes in 2004, except for the CFT site, and the STV site, which had no spring runoff in 2005, and the REN site, which was disturbed by the construction of a natural gas well. However, measurements at the REN site in 2004 were likely overestimated due to water entering the rear of the flume following road construction within the site. Flows were underestimated at the REN site in 2003 due to the washout of the wooden drop box surrounding the flume. Datalogger failure resulted in missing or underestimation of spring flows at the GPC site in 2003 and the STV site in 2005.

The lack of spring runoff at the PON site in 2004 was due to a combination of lower precipitation levels in the winter of 2004 and deep tillage in the fall of 2003 that increased snowmelt infiltration. Deep tillage involved ripping the soil in the low lying areas of the field to 46-cm depths using a Paraplow, followed by deep cultivation to a 15-cm depth that left the soil surface very rough. At the LLB site in 2004, flows were minimal and were generated exclusively by a snowdrift along the plywood berm at the edge of the field. It is unlikely that any runoff would have been generated without the berm, which was installed with the site instrumentation. No runoff was observed at the LLB site in the spring of 2005 due to lack of snow cover. Much of the snow at the LLB site likely sublimated in all 3 yr due to the low snowfall levels and the rapid temperature increases due to the Chinook winds that are prevalent in the region.

Although winter precipitation was below normal at the STV site in all 3 yr, the low runoff volumes were surprising given the steepness of the site. In comparison with grazed watersheds near the site, this site produced 10% or less of the runoff produced from the grazed watersheds

(Mapfumo et al. 2002), even though this site had more snow accumulation than the grazed sites. The increased snow accumulation was attributed to the abundant litter cover, which was more heterogeneous and five to seven and a half times greater in mass than at the grazed sites (W. Willms, Agriculture and Agri-Food Canada, personal communications). The litter cover may have also increased infiltration; however, it is unlikely that it would account for that much of the observed decrease.

Runoff volumes were very high at the GPC and PON sites in 2005, due to above average snowfall and a rapid melt. Unfortunately, the peaks of the hydrograph were missed from these sites due to the binding of the float potentiometer within the vertical pipe at high flows. Therefore, the total flow volumes were underestimated at both of these sites in the spring of 2005. Reports from the local newspaper suggest that the runoff observed at the GPC site caused local flooding (Daily Herald Tribune – March 11, 2005) and field observations indicated that the water depth at the site was at least 1 m deep. The rapid temperature change was likely responsible for the large volumes as precipitation levels were around normal at both sites in 2005.

Summer events were much less common than spring events, occurring at only two sites in 2003, four sites in 2004, and five sites in 2005. Summer precipitation was below normal at all sites in 2003, but was above average at the northernmost sites (GPC, WAB, THC) and at the STV site in 2004, and at the southernmost sites in 2005 (LLB, STV, CFT, REN) (Table 9). Only the PON site had below average summer precipitation in all 3 yr.

Most runoff events at the LLB site were of short duration (less than 12 h), had low flow rates, and were generated as a result of irrigation with a center-pivot sprinkler system. Although the size of the irrigation events was relatively small, they generated the majority of runoff in 2003 and 2004. In addition, summer runoff volumes at the LLB site were greater than the volume of spring snowmelt runoff in all 3 yr. Irrigation accounted for 57% of the runoff in 2003, 68% of the runoff in 2004, but only 8% of the runoff in 2005. Summer rainfall runoff was very high in 2005 when two, greater than 1-in-100 yr, rainfall events were recorded in the LLB region. More than 250 mm of rain was recorded in June compared with the 30-yr normal value of 53 mm, with another 137 mm recorded in September compared with the 30-yr normal value of 38.3 mm. These two events from June 5 to 9 and September 10 to 14 accounted for 85% of the runoff volume at the LLB site in 2005.

Summer events accounted for 71% of the total runoff at the GPC site in 2004; however, at the remainder of the sites, summer runoff was relatively minor, ranging from 0.18% at the PON site in 2005 to 10% at the REN site in 2005. Two sites (CFT and WAB) generated no summer runoff. Overall, summer events accounted for slightly less than 10% of all runoff during the 3-yr study. The relatively minor contribution of summer precipitation events to the P exported by overland flow compared to spring runoff is typical of cold climates in the western Canadian prairies. Nicholaichuk (1967) estimated that 80% of the runoff from two small watersheds in Saskatchewan was generated by spring snowmelt. In Alberta, total yearly runoff from small agricultural watersheds tends to be dominated by snowmelt (Gill et al. 1998; Wuite and Chanasyk 2003; Ontkean et al. 2005). For the majority of the microwatersheds, spring snowmelt runoff was still the predominant contributor to runoff.

Spring runoff nitrogen concentrations. The nitrate N FWMCs of the non-manured sites ranged from 0.60 mg L^{-1} at the REN site to 1.47 mg L^{-1} at the WAB site in 2003, 0.75 mg L^{-1} at the CFT to 10.6 mg L^{-1} at the WAB site in 2004, and 0.04 mg L^{-1} at the CFT to 3.08 mg L^{-1} at the WAB site in 2005 (Table 10). The spring runoff nitrate N FWMCs from the STV site in 2003 and 2004 were much lower than nitrate N FWMCs from the non-manured sites, due to the much smaller volumes of runoff from this highly vegetated grassland site.

Levels of nitrate N FWMC were greatest (18.5 mg L^{-1}) at the LLB site in the spring of 2003 following the manure application in the fall of 2002. In contrast, the heavily manured PON site nitrate N FWMC value was two orders of magnitude lower than at the LLB site and lower than at the non-manured CFT, GPC, REN, THC, and WAB sites in 2003 (Table 10). No manure was applied to the LLB site in the fall of 2003, and the 2004 spring runoff nitrate N FWMC was an order of magnitude lower than in the previous year at this site because the runoff was generated from a snowdrift along the fence line at this site in February 2004; and therefore, the runoff was diluted and not due to a true field runoff event. In 2004, there was no spring runoff at the PON site. In 2005, the nitrate N FWMC value at the PON site was higher than in 2003. However, the nitrate N FWMC for PON in 2005 (2.96 mg L^{-1}) was lower than at the non-manured WAB site (3.08 mg L^{-1}).

The spring runoff total N FWMC of the non-manured sites ranged from 2.96 mg L^{-1} at the GPC site to 6.40 mg L^{-1} at the THC site in 2003, 2.32 mg L^{-1} at the CFT to 13.4 mg L^{-1} at the WAB site in 2004, and 2.64 mg L^{-1} at the CFT to 6.43 mg L^{-1} at the WAB site in 2005 (Table 10). The spring runoff total N FWMCs at the STV site were higher in 2003 than in 2004, and they were lower than the runoff values from the non-manured sites in both years.

The LLB site had manure applied to the portion of the microwatershed nearest the outlet in the spring of 2002, which allowed greater opportunity for N to be adsorbed by soil and mixed with the subsurface soil by intensive tillage following spring manure application and fall harvest. As such, the total N FWMCs values in 2003 spring runoff at the LLB site were an order of magnitude lower than at the PON site (Table 10). Spring runoff total N FWMCS were higher in 2003 than in 2004 at the LLB site and higher in 2003 than in 2005 at the PON site.

The total N FWMC at the heavily manured PON site was extremely high in the spring of 2003, with some individual total N values exceeding 100 mg L^{-1}. Total suspended solids (TSS) concentrations were also elevated (data not shown) and accumulation of sediment in the flume was observed during field visits, indicating that selective sampling of sediment from the H-flume may have been an issue at the PON site. The replacement of the H-flume in the spring of 2003 mitigated these concerns. Given the high total N FWMC and the poor incorporation following the recent manure application, it is likely that the soil nitrate N was overwhelmed by the N content of the manure and was not representative of soil N conditions. Individual values at the PON site in the spring of 2003 were as high as 178.1 mg L^{-1}, with a FWMC of 105.9 mg L^{-1} total N (Table 10). These extremely high values can be attributed to the application of manure close to freeze up in the fall of 2002. The manure was very poorly incorporated and visible on the

Table 10. Minima, maxima, and flow-weighted mean concentrations (FWMC) of nitrate N and total N from all sites.

Site	Nitrate N						Total N					
	Min. (mg L^{-1})	Max. (mg L^{-1})	FWMC (mg L^{-1})	Min. (mg L^{-1})	Max. (mg L^{-1})	FWMC (mg L^{-1})	Min. (mg L^{-1})	Max. (mg L^{-1})	FWMC (mg L^{-1})	Min. (mg L^{-1})	Max. (mg L^{-1})	FWMC (mg L^{-1})
	----- Spring 2003 -----			----- Summer 2003 -----			----- Spring 2003 -----			----- Summer 2003 -----		
	Ungrazed grassland site											
STV	0.01	0.26	0.04				1.28	3.13	2.39			
	Non-manured sites											
CFT	0.15	3.28	1.28				1.59	8.54	3.66			
GPC	<DL[z]	3.13	1.10				1.55	5.57	2.95			
REN[y]	0.10	1.34	0.60	11.0	15.4	13.2	1.95	12.1	4.71	14.4	19.1	16.8
THC	0.31	4.75	1.05				2.66	11.7	6.40			
WAB	0.98	2.43	1.47				2.73	11.3	4.69			
	Manured sites											
LLB	0.09	34.7	18.5	0.03	22.8	2.58	6.00	43.9	26.6	3.16	29.9	7.59
PON	<DL[z]	8.39	0.41				4.80	178.1	105.9			
	----- Spring 2004 -----			----- Summer 2004 -----			----- Spring 2004 -----			----- Summer 2004 -----		
	Ungrazed grassland site											
STV	<DL[z]	<DL[z]	<DL[z]				0.43	0.43	0.43			
	Non-manured sites											
CFT	<DL[z]	1.80	0.75				0.47	4.85	2.32			
GPC	0.01	12.3	3.34	0.01	16.3	4.75	0.15	17.0	4.95	0.65	19.9	6.90
REN[y]	0.26	2.04	1.01	1.92	7.78	5.19	2.3	57.5	6.45	2.90	17.3	11.1
THC	0.68	6.41	1.76				2.38	15.8	5.18			
WAB	10.1	15.0	10.6				12.7	18.8	13.4			
	Manured sites											
LLB	0.19	10.8	1.15	0.05	129.8	5.08	2.40	18.1	3.80	0.46	140.2	8.03
PON				14.1	32.9	19.3				20.3	42.3	26.9
	----- Spring 2005 -----			----- Summer 2005 -----			----- Spring 2005 -----			----- Summer 2005 -----		
	Ungrazed grassland site											
STV				<DL[z]	<DL[z]	<DL[z]				0.63	0.93	0.78
	Non-manured sites											
CFT	<DL[z]	0.77	0.04				0.53	5.78	2.64			
GPC	<DL[z]	0.90	0.14				0.85	6.34	2.78			
REN[y]	0.16	1.69	0.32	0.03	4.38	1.15	2.08	6.94	4.16	1.05	28.0	5.63
THC	0.33	9.59	1.67	0.21	7.99	0.75	3.67	18.8	5.49	2.65	13.1	4.35
WAB	0.18	10.8	3.08				2.50	14.9	6.43			
	Manured sites											
LLB				<DL[z]	36.3	24.8				2.18	49.1	32.0
PON	0.48	18.1	2.96	43.4	43.4	43.4	6.7	34.1	11.9	50.7	50.7	50.7

[z] Below laboratory detection limits.
[y] Site contaminated by gas well access road construction prior to runoff in the spring of 2004.

surface at the time of soil sampling; and therefore, the 2003 spring runoff nitrate N and total N FWMCs from PON were deemed as outliers.

Ratios of nitrate N:total N in snowmelt runoff varied widely at the non-manured sites, ranging from 0.01 at the CFT site in 2003 to 0.79 at the WAB site in 2004 (Table 11). There was a narrower range of nitrate N:total N in rainfall runoff at the non-manured sites, ranging from 0.17 at the THC site in 2005 to 0.79 at the REN site in 2003 (Table 11). Ammonia N made up 21% (at THC site in snowmelt 2003) or less of the total N at the non-manured sites, regardless of runoff type (Table 11). Ratios of nitrate N:total N and ammonia N:total N were low at the STV site, regardless of year and runoff type (Table 11).

Table 11. Ratios of nitrate N flow-weighted mean concentration (FWMC) to total N FWMC by runoff type. Ratios of ammonia N FWMC to total N FWMC are in parentheses.

Site	Snowmelt 2003	Rainfall 2003	Snowmelt 2004	Rainfall 2004	Snowmelt 2005	Rainfall 2005
			Ungrazed grassland site			
STV	0.02 (0.18)		0.00^z (0.06)			0.00 (0.03)
			Non-manured sites			
CFT	0.35 (0.10)		0.33 (0.15)		0.01 (0.01)	
GPC	0.37 (0.03)		$0.68 (0.03)^y$	0.69 (0.00)	0.05 (0.07)	
REN	0.13 (0.19)	0.79 (0.02)	$0.16 (0.08)^x$	$0.47 (0.02)^x$	0.08 (0.11)	0.21 (0.03)
THC	0.16 (0.21)		0.34 (0.07)		0.30 (0.03)	0.17 (0.00)
WAB	0.31 (0.03)		0.79 (0.03)		0.48 (0.03)	
			Manured sites			
LLB	$0.70 (0.03)^y$	$0.34 (0.02)^w$	0.30 (0.17)	$0.63 (0.00)^w$		$0.78 (0.00)^w$
PON	0.00 (0.52)			0.72 (0.00)	0.25 (0.30)	0.86 (0.00)

^{z} A zero indicates no detectable nitrate N or ammonia N.
^{y} Includes spring runoff plus additional snowmelt events.
^{x} Site contaminated by gas well access road construction prior to runoff in the spring of 2004.
^{w} Includes irrigation events.

Ratios of nitrate N: total N in snowmelt runoff varied widely at the manured sites, ranging from 0 at the PON site in 2003 to 0.70 at the LLB site in 2003 (Table 11). There was a narrower range of nitrate N: total N in rainfall runoff at the non-manured sites, ranging from 0.34 at the LLB site in 2003 to 0.86 at the PON site in 2005. Ammonia N tended to be low in snowmelt and rainfall/irrigation runoff at the LLB site, but it made up 52% of the runoff total N in snowmelt 2003 and 30% of the runoff total N in snowmelt 2005 at the PON site.

Summer runoff nitrogen concentrations. At the non-manured sites, nitrate N FWMCs ranged from 0.75 mg L^{-1} at the THC site in 2003 to 13.2 mg L^{-1} at the REN site in 2003 (Table 10). Summer nitrate N FWMCs at the non-manured sites were generally lower than the spring FWMCs (Table 10). The only summer event at the STV event resulted in nitrate N FWMCs below the laboratory detection limit. Summer nitrate N FWMCs at the manured sites ranged from 2.58 mg L^{-1} at the LLB site in 2003 to 43.4 mg L^{-1} at the PON site in 2005. Comparisons between spring and summer events were difficult to make at the manured sites because only the LLB site in 2003 and PON in 2005 had spring snowmelt runoff and summer runoff (spring 2004 at the LLB site was omitted because of diluted runoff from the fence line snowdrift as described previously). In 2003, the spring nitrate N FWMC was higher than the summer nitrate N FMWC at the LLB site, but in 2005 the summer nitrate N FWMC was higher than the spring nitrate N FWMC at the PON site.

The total N FWMCs were higher in summer runoff at the non-manured sites than in spring runoff (except at the THC site in 2005) with values ranging from 4.35 mg L^{-1} at the THC site in 2005 to 16.8 mg L^{-1} at the REN site in 2003 (Table 10). The only summer event at the STV event resulted in total N FWMCs an order of magnitude below the non-manured site values (Table 10).

The summer total N FWMCs ranged from 7.59 mg L^{-1} at the LLB site in 2003 to 50.7 mg L^{-1} at the PON site in 2005 (Table 10). At the LLB site, the summer total N FWMC was lower than during spring runoff in 2003 and higher in summer than in spring 2004 (due to the diluted runoff being generated from the snowdrift along the fence line as described previously). The summer total N FWMC was higher than the spring total N FWMC at the PON site in 2005 (Table 10).

Regardless of how runoff was generated, concentrations of total N exported from the microwatersheds exceeded the in-stream Alberta water quality guideline of 1 mg L^{-1} total N for the protection of aquatic life (Alberta Environment 1999). It should be noted that this guideline was developed for third- and fourth-order streams, which are much larger than our ephemeral first-order streams and may not be directly applicable to field scales. Even runoff from the ungrazed native prairie site exceeded the 1 mg L^{-1} total N guideline in spring 2003 (Table 10). As such, it appears that applying the 1 mg L^{-1} total N water quality objective to field scales may not be appropriate.

Relating Nitrogen Concentrations in Soil and Runoff

Results from spring and summer runoff events were included for analysis of the relationship between mean soil nitrate N and runoff nitrate N and total N FWMCs. Seasonal flow-weighted averages were calculated by summing the loads from all spring or summer events and dividing by the flow during that period. Spring snowmelt runoff results were related to the soil sampling results from the previous fall, while summer runoff events were related to the soil sampling results from the spring of the same year. The 2004 and 2005 data from the REN site were excluded since comparison of the results with those measured in 2003 indicated that the gas well access road construction in spring 2004 caused abnormally high concentrations of TP in the spring and summer runoff (Little et al. 2006). Data from spring snowmelt in 2004 at the LLB site were also excluded as runoff was generated exclusively from a snow bank at the edge of the field and would not have occurred without the berm constructed to direct runoff into the flume. Results from the spring runoff in 2003 at the PON site were also excluded due to the recent application of manure that was poorly incorporated due to the frozen soil conditions and the selective sampling of sediment by the ISCO due to sediment accumulation in the H-flume.

Significant linear relationships were found between nitrate N in soil and nitrate N (r^2 = 0.62 to 0.69) and total N (r^2 = 0.65 to 0.72) FWMCs in spring and summer runoff for all three soil layers (Figure 5a-f). Differences among the three soil layers were minimal, and this reflects the similarity of nitrate N content among the soil layers. Coefficients of determination improved slightly in the 0- to 5-cm soil layer compared with the 0- to 2.5-cm and 0- to 15-cm soil layers. There were no relationships between soil nitrate N and runoff ammonia N (Figure 5g-i).

Although previous studies have found that surface runoff interacts with only a very shallow depth of soil (Sharpley et al. 1978; Sharpley 1985), the relationships developed in our study had similar predictive ability among the soil layers for nitrate N and total N in runoff (Figure 5a-f). Statistical comparisons of the relationships indicated that the slopes and intercepts of the relationships for all three layers were not significantly different. It was anticipated that soil nitrate N from shallower sampling depths may have a stronger relationship with runoff N because the majority of runoff occurred during spring snowmelt when frozen soil restricts infiltration and minimizes the interaction between runoff and soils. However, given that soil nitrate N values among all three layers were similar in our study, it was not surprising they predicted runoff N equally well.

Except for one point from the PON site, the soil nitrate N mean values used in the relationships were within a relatively narrow range from 2 to 74 mg kg^{-1}. The one point from the PON site drives the relationship (Figure 5a-f). This point represented the rainfall runoff event that occurred at the PON site in 2005, and when this data point was removed, the coefficients of determination declined from 0.62 to 0.69 to 0.28 to 0.35 for nitrate N FWMC relationships and from 0.65 to 0.72 to 0.36 to 0.44 for total N FWMC relationships. Even though the relationships were still significant (*P* values of 0.0003 to 0.0070), soil nitrate N explained 44% or less of the variation in runoff N FWMC. The moderately manured LLB site behaved more like a non-manured sites in respect to how much soil nitrate N was lost to runoff, and this is in contrast to findings for STP and runoff P from these same microwatershed sites (Little et al. 2007; Little et al. 2006). They found strong relationships between STP and runoff P ($r^2 \geq 0.87$), with clear distinctions among the heavily manure PON site, the moderately manured LLB site, and the other six sites.

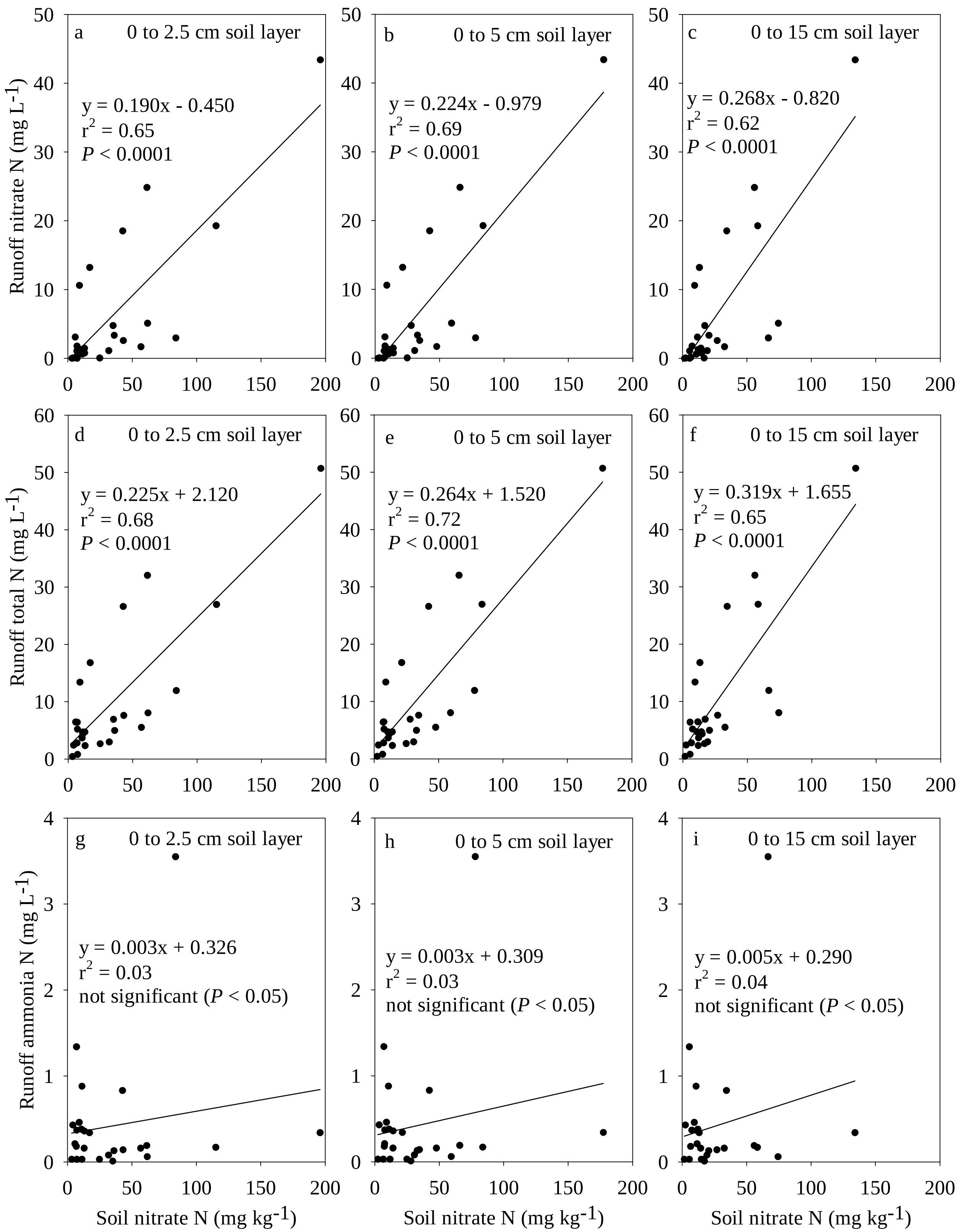

Figure 5. Relationships between nitrate N in soil and N in runoff.

CONCLUSIONS

Moderate to high application rates of manure caused higher nitrate N levels in the soil. The nitrate N content in the surface 15-cm of soil ranged from 5 to 51 mg kg^{-1} at the five cultivated, non-manured sites, 27 to 74 mg kg^{-1} at the two manured sites, and 2 to 6 mg kg^{-1} at the grassland site. The five cultivated non-manured sites and the manured site at LLB contained nitrate N less than optimum agronomic levels and crops would likely respond to added N fertilizer. There were few differences among the 0- to 2.5-cm, 0- to 5-cm, and 0- to 15-cm soil layers, suggesting that nitrate N tended to be evenly distributed in the top 15 cm of soil. There were also few significant differences among the upper, mid, and lower landform positions at the sites.

Spring runoff accounted for the majority of runoff at nearly all of the sites, except for the irrigated LLB site and the GPC site in 2004. Snowmelt runoff accounted for 90% of the runoff volume from the eight sites during the 3 yr of the study.

The seasonal nitrate N FWMC ranged from below detection limit of 0.04 mg L^{-1} at the grassland site, from 0.04 to 13.2 mg L^{-1} among the five cultivated, non-manured sites, and from 0.41 to 43.4 mg L^{-1} for the two manured sites. The seasonal total N FWMC ranged from 0.43 to 2.39 mg L^{-1} at the grassland site, from 2.32 to 17.3 mg L^{-1} among the five cultivated, non-manured sites, and from 3.80 to 106 mg L^{-1} for the two manured sites. Concentrations of total N exported from the microwatersheds exceeded the in-stream Alberta water quality guideline for the protection of aquatic life of 1 mg L^{-1} total N at all sites.

Linear relationships were found between extractable nitrate N in soil and total N in runoff and between extractable nitrate N in soil and nitrate N in runoff. There was no relationship between soil nitrate N and runoff ammonia N. The relationships among the three soil layers were similar, and this reflects the similar nitrate N concentrations among the soil layers. Therefore, nitrate N content in the three soil layers predicted nitrate N and total N concentrations in runoff water equally well. Coefficients of determination among the three soil layers ranged from 0.62 to 0.69 for nitrate N in runoff and from 0.65 to 0.72 for total N in runoff. These linear relationships were driven by one point from the heavily manured PON site. When this point was removed, coefficients of determination decreased to a range from 0.28 to 0.35 for the nitrate N in runoff and to a range from 0.36 to 0.44 for total N in runoff. Therefore, the relationships are not particularly strong and soil extractable nitrate N is a weak predictor of nitrate N or total N in edge-of-field runoff water.

REFERENCES

Alberta Environment. 1999. Surface water quality guidelines for use in Alberta. Publication T/483. Alberta Environment, Edmonton, Alberta, Canada. 20 pp.

Alberts, E.E. and Spomer, R.G. 1985. Dissolved nitrogen and phosphorus in runoff from watersheds in conservation and conventional tillage. J. Soil Water Conserv. **40**: 153-157.

Ashworth, J. and Mrazek, K. 1995. "Modified Kelowna" test for available phosphorus and potassium in soil. Commun. Soil Sci. Plant Anal. **26**: 731-739.

Baligar, V.C., Fageria, N.K., and He, Z.L. 2001. Nutrient use efficiency in plants. Commun. Soil Sci. Plant Anal. **32**: 921-950.

Burnwell, R.E., Timmons, D.R., and Holt, R.F. 1975. Nutrient transport in surface runoff as influenced by soil cover and seasonal periods. Soil Sci. Soc. Am. Proc. **39**: 523-528.

Carpenter, S.R., Caraco, N.F., Correll, D.L., Howarth, R.W., Sharpley, A.N., and Smith, V.H. 1998. Nonpoint pollution of surface waters with phosphorus and nitrogen. Ecol. Applic. **8**: 559-568.

Chambers, P.A., Guy, M., Roberts, E.S., Charlton, M.N., Kent, R., Gagnon, C., Grove, G., and Foster, N. 2001. Nutrients and their impact on the Canadian environment. Agriculture and Agri-Food Canada, Environment Canada, Fisheries and Oceans Canada, Health Canada, and Natural Resources Canada. 241 pp.

Chetner, S. and Agroclimatic Atlas Working Group. 2003. Agroclimatic atlas of Alberta: 1971-2000. Agdex 071-1, Alberta Agriculture, Food and Rural Development, Edmonton, Alberta, Canada. 97 pp.

Daniel, T.C., Sharpley, A.N., Edwards, D.R., Wedepohl, R., and Lemunyon, J.L. 1994. Minimizing surface water eutrophication from agriculture by phosphorus management. J. Soil Water Conserv. **49**: 30-38 (supplement).

De Jong, R., Yang, J.Y., Drury, C.F., Huffman, E.C., Kirkwood, V., and Yang, X.M. 2007. The indicator of risk of water contamination by nitrate-nitrogen. Can. J. Soil Sci. **87**: 179-188.

Delgado, J.A. 2002. Quantifying the loss mechanisms of nitrogen. J. Soil Water Conserv. **57**: 389-398.

Douglas, Jr., C.L., King, K.A., and Zuzel, J.F. 1998. Nitrogen and phosphorus in surface and sediment from a wheat-pea rotation in northeastern Oregon. J. Environ. Qual. **27**: 1170-1177.

Eghball B. and Gilley J.E. 1999. Phosphorus and nitrogen in runoff following beef cattle manure or compost application. J. Environ. Qual. **28**: 1201-1210.

Eickhout, B., Bouwman, A.F., and van Zeijts, H. 2006. The role of nitrogen in world food production and environmental sustainability. Agric. Ecosyst. Environ. **116**: 4-14.

Environment Canada. 2005. Climate normals and averages. [Online] Available at http://www.climate.weatheroffice.ec.gc.ca/climate_normals/stnselect_e.html (Accessed December 2005).

Follett, R.F. and Delgado, J.A. 2002. Nitrogen fate and transport in agricultural systems. J. Soil and Water Conserv. **57**: 402-408.

Gascho, G.J., Wauchope, R.D., Davis, J.G., Truman, C.C., Dowler, C.C., Hook, J.E., Sumner, H.R., and Johnson, A.W. 1998. Nitrate-nitrogen, soluble, and bioavailable phosphorus runoff from simulated rainfall after fertilizer application. Soil Sci. Soc. Am. J. **62**: 1711-1718.

Gill, S.I., Naeth, M.A., Chanasyk, D.S., and Baron, V.S. 1998. Runoff and sediment yield from snowmelt and rainfall as influenced by forage type and grazing intensity. Can. J. Soil Sci. **78**: 699-706.

Gilley, J.E., Eghball, B., and Marx, D.B. 2007. Nitrogen and phosphorus concentrations of runoff as affected by moldboard plowing. Trans. ASABE **50**: 1543-1548.

Harmel, D., Potter, S., Casebolt P., Reckhow, K., Green, C., and Haney, R. 2006. Compilation of measured nutrient load data for agricultural land uses in the United States. J. Am. Water Res. Assoc. **42**: 1163-1178.

Hubbard, R.K., Leonard, R.A., and Johnson, A.W. 1991. Nitrate transport on a coastal plain soil underlain by plinthite. Trans ASAE **34**: 802-808.

Hubbard, R.K. and Sheridan, J.M. 1983. Water and nitrate losses from a small upland coastal plain watershed. J. Environ. Qual. **12**: 291-295.

Jandel Scientific Software. 1994. TableCurve 2D v. 3. AISN Software Inc.

Jedrych, A.T., Martin, T.C., and Vanderwel, D.S. 2002. Runoff map of Alberta at the AGRASID soil polygon scale. Pages 159-163 *in* Proceedings of the Alberta Soil Science Workshop, Lethbridge, Alberta, Canada. February 19-20, 2002.

Jeje, Y. 2006. Export coefficients for total phosphorus, total nitrogen, and total suspended solids in the southern Alberta region. Alberta Environment, Edmonton, Alberta, Canada. 22 pp.

Little, J.L., Nolan, S.C., and Casson, J.P. 2006. Relationships between soil-test phosphorus and runoff phosphorus in small Alberta watersheds. 150 pp. *In* Alberta Soil Phosphorus Limits Project. Volume 2: Field-scale losses and soil limits. Alberta Agriculture, Food and Rural Development, Lethbridge, Alberta, Canada.

Little, J.L., Nolan, S.C., Casson, J.P., and Olson, B.M. 2007. Relationship between soil and runoff phosphorus in small Alberta watersheds. J. Environ. Qual. **36**: 1289-1300.

Lowrance, R. 1992. Nitrogen outputs from a field-size agricultural watershed. J. Environ. Qual. **21**: 602-607.

Mapfumo, E., Willms, W.D., and Chanasyk, D.S. 2002. Water quality of surface runoff from grazed fescue grassland watersheds in Alberta. Water Qual. Res. J. Canada. **37**: 543-562.

Masand, S.S. 1992. Effect of soil tillage methods and nitrogen levels on nitrogen loss in runoff. Indian J. Hill Farming **5**: 151-153.

Maynard, D.G. and Kalra, Y.P. 1993. Nitrate and exchangeable ammonium nitrogen. Pages 25-38 *in* M.R. Carter (ed.). Soil sampling and methods of analysis. Canadian Society of Soil Science. CRC Press, Inc., Boca Raton, Florida, United States.

McKenzie, R.H., DeMulder, J., and Solberg, E. 2000. Optimizing barley silage production in Alberta. Agdex 114/540-1. Alberta Agriculture, Food and Rural Development, Edmonton, Alberta, Canada. 4 pp.

Miller, J.J., Olson, E.C.S., Chanasyk, D.S., Beasley, B.W., Larney, F.J., and Olson, B.M. 2006. Phosphorus and nitrogen in rainfall simulation runoff after fresh and composted beef cattle manure. J. Environ. Qual. **35**: 1279-1290.

Nicholaichuk, W. 1967. Comparative watershed studies in southern Saskatchewan. Trans. ASAE. **10**: 502-504.

Nolan, S.C., Little, J.L., Casson, J.P., Hecker. F.J., and Olson, B.M. 2007. Field-scale variation of soil phosphorus within small Alberta watersheds. J. Soil Water Conserv. **62**: 414-422.

Ontkean, G.R., Chanasyk, D.S., and Bennett, D.R. 2005. Snowmelt and growing season phosphorus flux in an agricultural watershed in south-central Alberta, Canada. Water Qual. Res. J. Can. **40**: 402-417.

Paterson, B.A., Olson, B.M., and Bennett, D.R. 2006. Alberta soil phosphorus limits project. Volume 1: Summary and recommendations. Alberta Agriculture, Food and Rural Development, Lethbridge, Alberta, Canada. 82 pp.

Pote, D.H., Daniel, T.C., Sharpley, A.N., Moore, Jr., P.A., Edwards, D.R., and Nichols, D.J. 1996. Relating extractable soil phosphorus to phosphorus losses in runoff. Soil Sci. Soc. Am. J. **60**: 855-859.

Province of Alberta. 2005. Agricultural operations practices act and regulations. Alberta Queen's Printer, Edmonton, Alberta, Canada.

Quinn, P.F., Beven, K.J., and Lamb, R. 1995. The ln(a/tanβ) Index: How to calculate it and how to use it within the topmodel framework. Hydrological Processes **9**: 161-182.

Romkens, M.J.M., Nelson, D.W., and Mannering, J.V. 1973. Nitrogen and phosphorus composition of surface runoff as affected by tillage method. J. Environ. Qual. **2**: 292-295.

Samani, Z., Jorat, S., and Yousaf, M. 1991. Hydraulic characteristics of circular flume. J. Irrig. and Drain. Eng. **117**: 558-566.

SAS Institute Inc. 2002. The SAS® System for Windows™, release 9.1. SAS Institute Inc., Cary, North Carolina, United States.

Schilling, K.E. and Spooner, J. 2006. Effects of watershed-scale land use change on stream nitrate concentrations. J. Environ. Qual. **35**: 2132-2145.

Sharpley, A.N. 1985. Depth of surface soil-runoff interaction as affected by rainfall, soil slope, and management. Soil Sci. Soc. Am. J. **49**: 1010-1015.

Sharpley, A.N., Smith, S.J., and Naney, J.W. 1987. Environmental impact of agricultural nitrogen and phosphorus use. J. Agric. Food Chem. **35**: 812-817.

Sharpley, A.N., Syers, J.K., and Tillman, R.W. 1978. An improved soil-sampling procedure for the prediction of dissolved inorganic phosphate concentrations in surface runoff from pastures. J. Environ. Qual. **7**: 455-456.

Sharpley, A.N., Tillman, R.W., and Syers, J.K. 1977. Use of laboratory extraction data to predict losses of dissolved inorganic phosphate in surface runoff and tile drainage. J. Environ. Qual. **6**: 33-36.

Soil Test Technical Advisory Group. 1988. Soil test recommendations for Alberta technical manual. Alberta Agriculture, Edmonton, Alberta, Canada.

Torbert, H.A., Daniel, T.C., Lemunyon, J.L., and Jones, R.M. 2002. Relationship of soil test phosphorus and sampling depth to runoff phosphorus in calcareous and noncalcareous soils. J. Environ. Qual. **31**: 1380-1387.

United Nations Educational Scientific and Cultural Organization (UNESCO). 2002. UN World water development report: Water for people, water for life. [Online] Available at http://www.unesco.org/water/wwap/wwdr/table_contents.shtml. (Accessed January 10, 2006).

United States Environmental Protection Agency (US EPA). 1998. National Water Quality Inventory: 1998 Report to Congress. EPA #: 841-R00001. Washington, DC., United States.

Wuite, J.J. and Chanasyk, D.S. 2003. Evaluation of two beneficial management practices to improve water quality. Alberta Agricultural Research Institute Project No. 990054. 199 pp.

Zheng, F.-L., Huang, C.-H., and Norton L.D. 2006. Effects of near-surface hydraulic gradients on nitrate and phosphorus losses in surface runoff. J. Environ. Qual. **33**: 2174-2182.

Appendix 1. Descriptive statistics for the soil extractable nitrate N data for the eight microwatersheds.

Table A1.1 Descriptive statistics for the soil extractable nitrate N data for the Crowfoot Creek (CFT) watershed.

Soil layer (cm)	Mean ($mg\ kg^{-1}$)	Min. ($mg\ kg^{-1}$)	Max. ($mg\ kg^{-1}$)	Range ($mg\ kg^{-1}$)	SD[z] ($mg\ kg^{-1}$)	SE[yz] ($mg\ kg^{-1}$)	CV[z] (%)	N[y]
				Fall 2002				
0 to 2.5	10.8	3.6	31.0	27.4	6.0	0.9	56	48
0 to 5	11.0	4.4	35.1	30.7	6.2	0.9	56	48
0 to 15	12.1	3.5	44.8	41.2	9.4	1.4	78	48
				Spring 2003				
0 to 2.5	48.1	6.0	124.0	118.0	42.0	13.3	87	10
0 to 5	55.5	6.0	118.5	112.5	42.5	13.4	76	10
0 to 15	41.3	10.0	68.8	58.8	17.6	5.6	43	10
				Fall 2003				
0 to 2.5	13.0	2.2	31.1	28.9	6.4	0.9	49	48
0 to 5	14.2	4.3	27.2	22.8	6.0	0.9	42	48
0 to 15	11.9	4.1	22.5	18.3	4.9	0.7	41	48
				Spring 2004				
0 to 2.5	33.0	9.2	71.0	61.8	23.5	7.4	71	10
0 to 5	39.5	11.1	69.5	58.4	18.5	5.8	47	10
0 to 15	42.0	14.8	62.9	48.1	16.1	5.1	38	10
				Fall 2004				
0 to 2.5	24.8	4.8	81.8	77.0	16.1	2.3	65	48
0 to 5	24.9	10.0	68.6	58.6	11.2	1.6	45	48
0 to 15	16.8	6.2	50.2	44.0	8.1	1.2	48	48
				Spring 2005				
0 to 2.5	99.7	28.0	230.0	202.0	56.5	17.9	57	10
0 to 5	91.4	30.0	190.0	160.0	44.0	13.9	48	10
0 to 15	51.1	20.0	114.7	94.7	25.4	8.0	50	10

[z] SD = standard deviation; SE = standard error; CV = coefficient of variation; N = number of observations.

Table A1.2. Descriptive statistics for the soil extractable nitrate N data for the Grande Prairie Creek (GPC) watershed.

Soil layer (cm)	Mean (mg kg^{-1})	Min. (mg kg^{-1})	Max. (mg kg^{-1})	Range (mg kg^{-1})	SD^{z} (mg kg^{-1})	SE^{z} (mg kg^{-1})	CV^{z} (%)	N^{y}
				Fall 2002				
0 to 2.5	31.8	0.5	61.0	60.5	17.9	3.8	56	22
0 to 5	30.7	0.5	65.2	64.7	16.3	3.5	53	22
0 to 15	19.2	0.5	50.1	49.6	10.6	2.3	55	22
				Spring 2003				
0 to 2.5	76.3	40.0	139.0	99.0	39.9	16.3	52	6
0 to 5	57.8	29.0	94.5	65.5	25.9	10.6	45	6
0 to 15	30.1	15.0	48.8	33.8	12.8	5.2	43	6
				Fall 2003				
0 to 2.5	36.0	0.2	122.0	121.8	30.2	5.7	84	28
0 to 5	32.8	0.2	100.6	100.4	25.1	4.7	77	28
0 to 15	20.6	0.2	57.3	57.1	14.6	2.8	71	28
				Spring 2004				
0 to 2.5	35.1	3.4	58.2	54.8	20.5	9.2	58	5
0 to 5	28.0	2.4	41.8	39.4	15.4	6.9	55	5
0 to 15	17.3	1.6	22.9	21.3	9.1	4.1	53	5
				Fall 2004				
0 to 2.5	6.8	2.0	50.4	48.4	10.4	2.0	153	28
0 to 5	7.3	1.8	44.5	42.7	9.2	1.7	126	28
0 to 15	6.5	1.5	25.8	24.2	5.7	1.1	88	28
				Spring 2005				
0 to 2.5	35.6	11.0	69.0	58.0	24.1	10.8	68	5
0 to 5	34.8	17.0	69.5	52.5	21.1	9.4	61	5
0 to 15	33.3	21.0	44.8	23.8	11.0	4.9	33	5

^{z} SD = standard deviation; SE = standard error; CV = coefficient of variation; N = number of observations.

Table A1.3. Descriptive statistics for the soil extractable nitrate N data for the Lower Little Bow River (LLB) watershed.

Soil layer (cm)	Mean (mg kg^{-1})	Min. (mg kg^{-1})	Max. (mg kg^{-1})	Range (mg kg^{-1})	SD[z] (mg kg^{-1})	SE[z] (mg kg^{-1})	CV[z] (%)	N[y]
				Fall 2002				
0 to 2.5	42.6	9.3	101.0	91.7	19.0	2.8	45	45
0 to 5	42.3	8.8	97.5	88.7	18.4	2.7	43	45
0 to 15	34.3	10.8	75.3	64.5	14.2	2.1	41	45
				Spring 2003				
0 to 2.5	43.1	8.0	91.0	83.0	26.5	8.8	61	9
0 to 5	34.6	9.0	72.5	63.5	19.1	6.4	55	9
0 to 15	26.9	5.7	56.8	51.2	15.6	5.2	58	9
				Fall 2003				
0 to 2.5	22.7	9.2	46.1	36.9	7.4	1.1	32	45
0 to 5	27.9	9.3	59.7	50.4	9.5	1.4	34	45
0 to 15	35.4	7.0	76.7	69.8	14.1	2.1	40	45
				Spring 2004				
0 to 2.5	61.9	20.2	90.4	70.2	21.4	7.1	34	9
0 to 5	59.3	19.0	85.7	66.7	18.9	6.3	32	9
0 to 15	74.4	32.1	97.9	65.8	19.8	6.6	27	9
				Fall 2004				
0 to 2.5	30.9	8.0	98.3	90.3	20.7	3.1	67	45
0 to 5	32.1	7.4	95.3	87.9	21.9	3.3	68	45
0 to 15	30.6	5.6	121.7	116.0	24.5	3.7	80	45
				Spring 2005				
0 to 2.5	61.4	18.0	125.0	107.0	40.3	13.4	66	9
0 to 5	65.9	14.0	150.5	136.5	48.0	16.0	73	9
0 to 15	55.8	8.0	118.8	110.8	41.3	13.8	74	9

[z] SD = standard deviation; SE = standard error; CV = coefficient of variation; N = number of observations.

Table A1.4. Descriptive statistics for the soil extractable nitrate N data for the Ponoka (PON) watershed.

Soil layer (cm)	Mean (mg kg^{-1})	Min. (mg kg^{-1})	Max. (mg kg^{-1})	Range (mg kg^{-1})	SD^{z} (mg kg^{-1})	SE^{z} (mg kg^{-1})	CV^{z} (%)	N^{y}
				Fall 2002				
0 to 2.5	52.5	1.8	217.0	215.2	59.1	12.6	113	22
0 to 5	85.5	5.8	199.5	193.7	52.6	11.2	61	22
0 to 15	163.5	36.2	261.8	225.6	63.0	13.4	39	22
				Spring 2003				
0 to 2.5	52.5	25.0	110.0	85.0	30.3	12.4	58	6
0 to 5	49.2	21.0	88.5	67.5	27.5	11.2	56	6
0 to 15	58.9	24.3	99.5	75.2	26.9	11.0	46	6
				Fall 2003				
0 to 2.5	182.3	52.9	314.0	261.1	70.4	15.0	39	22
0 to 5	176.5	46.6	307.5	260.9	73.2	15.6	41	22
0 to 15	144.3	35.9	287.2	251.2	73.2	15.6	51	22
				Spring 2004				
0 to 2.5	115.0	55.0	184.0	129.0	59.2	24.2	51	6
0 to 5	83.7	44.3	121.6	77.3	35.6	14.5	43	6
0 to 15	58.3	31.2	81.8	50.6	21.7	8.9	37	6
				Fall 2004				
0 to 2.5	83.8	33.6	216.0	182.4	48.8	10.4	58	22
0 to 5	77.9	39.5	175.0	135.5	37.3	8.0	48	22
0 to 15	66.6	39.6	101.9	62.2	17.2	3.7	26	22
				Spring 2005				
0 to 2.5	196.0	116.0	316.0	200.0	69.7	28.4	36	6
0 to 5	177.3	100.0	263.0	163.0	58.4	23.9	33	6
0 to 15	134.0	64.0	171.8	107.8	40.1	16.4	30	6

^{z} SD = standard deviation; SE = standard error; CV = coefficient of variation; N = number of observations.

Table A1.5. Descriptive statistics for the soil extractable nitrate N data for the Renwick Creek (REN) watershed.

Soil layer (cm)	Mean (mg kg^{-1})	Min. (mg kg^{-1})	Max. (mg kg^{-1})	Range (mg kg^{-1})	SD[z] (mg kg^{-1})	SE[yz] (mg kg^{-1})	CV[z] (%)	N[y]
				Fall 2002				
0 to 2.5	11.2	2.5	73.9	71.4	14.6	2.8	130	28
0 to 5	10.5	3.0	68.8	65.7	13.9	2.6	132	28
0 to 15	10.8	2.0	51.1	49.1	12.3	2.3	114	28
				Spring 2003				
0 to 2.5	17.0	12.0	22.0	10.0	3.9	1.6	23	6
0 to 5	21.3	15.0	28.0	13.0	4.5	1.8	21	6
0 to 15	13.1	9.7	16.7	7.0	2.9	1.2	22	6
				Fall 2003				
0 to 2.5	5.0	0.5	25.5	25.0	4.9	0.9	98	27
0 to 5	5.3	1.8	23.8	22.0	4.4	0.9	83	27
0 to 15	4.8	1.8	23.1	21.3	4.1	0.8	86	27
				Spring 2004				
0 to 2.5	39.0	25.8	53.8	28.0	12.5	5.1	32	6
0 to 5	46.0	32.9	72.4	39.5	14.6	6.0	32	6
0 to 15	34.2	20.9	55.7	34.8	11.9	4.9	35	6
				Fall 2004				
0 to 2.5	14.4	4.3	33.7	29.4	8.0	1.5	56	28
0 to 5	13.4	3.6	35.6	32.0	8.1	1.5	61	28
0 to 15	12.1	3.0	71.3	68.3	14.5	2.7	119	28
				Spring 2005				
0 to 2.5	45.8	28.0	69.0	41.0	14.5	5.9	32	6
0 to 5	44.6	37.5	53.0	15.5	6.2	2.5	14	6
0 to 15	29.2	23.2	39.2	16.0	5.4	2.2	18	6

[z] SD = standard deviation; SE = standard error; CV = coefficient of variation; N = number of observations.

Table A1.6. Descriptive statistics for the soil extractable nitrate N data for the Stavely (STV) watershed.

Soil layer (cm)	Mean (mg kg^{-1})	Min. (mg kg^{-1})	Max. (mg kg^{-1})	Range (mg kg^{-1})	SD[z] (mg kg^{-1})	SE[z] (mg kg^{-1})	CV[z] (%)	N[y]
				Fall 2002				
0 to 2.5	4.1	3.8	4.3	0.5	0.3	0.1	6	3
0 to 5	3.4	2.9	3.8	0.9	0.5	0.3	14	3
0 to 15	2.4	1.8	3.1	1.4	0.7	0.4	29	3
				Spring 2003				
0 to 2.5	ns[y]	ns	ns	ns	ns	ns	ns	ns
0 to 5	ns	ns	ns	ns	ns	ns	ns	ns
0 to 15	ns	ns	ns	ns	ns	ns	ns	ns
				Fall 2003				
0 to 2.5	3.3	1.4	6.5	5.1	2.8	1.6	86	3
0 to 5	2.3	1.4	3.8	2.5	1.3	0.8	56	3
0 to 15	1.6	1.3	2.1	0.8	0.4	0.2	26	3
				Spring 2004				
0 to 2.5	ns	ns	ns	ns	ns	ns	ns	ns
0 to 5	ns	ns	ns	ns	ns	ns	ns	ns
0 to 15	ns	ns	ns	ns	ns	ns	ns	ns
				Fall 2004				
0 to 2.5	7.2	4.2	9.4	5.2	2.7	1.6	37	3
0 to 5	6.6	4.5	8.1	3.6	1.9	1.1	28	3
0 to 15	5.5	4.0	6.3	2.2	1.3	0.7	23	3
				Spring 2005				
0 to 2.5	ns	ns	ns	ns	ns	ns	ns	ns
0 to 5	ns	ns	ns	ns	ns	ns	ns	ns
0 to 15	ns	ns	ns	ns	ns	ns	ns	ns

[z] SD = standard deviation; SE = standard error; CV = coefficient of variation; N = number of observations.
[y] Not sampled.

Table A1.7. Descriptive statistics for the soil extractable nitrate N data for the Threehills Creek (THC) watershed.

Soil layer (cm)	Mean (mg kg^{-1})	Min. (mg kg^{-1})	Max. (mg kg^{-1})	Range (mg kg^{-1})	SD^{z} (mg kg^{-1})	SE^{z} (mg kg^{-1})	CV^{z} (%)	N^{y}
				Fall 2002				
0 to 2.5	7.0	1.9	29.2	27.3	6.1	1.2	87	27
0 to 5	7.0	1.9	27.8	25.9	5.9	1.1	84	27
0 to 15	5.5	1.1	32.3	31.1	6.2	1.2	113	27
				Spring 2003				
0 to 2.5	13.5	6.0	24.0	18.0	6.4	2.6	48	6
0 to 5	15.0	7.5	24.0	16.5	5.6	2.3	37	6
0 to 15	12.4	7.2	17.5	10.3	3.4	1.4	28	6
				Fall 2003				
0 to 2.5	7.1	3.6	18.5	14.9	2.9	0.6	40	27
0 to 5	7.7	3.8	21.6	17.8	3.3	0.6	43	27
0 to 15	7.5	2.4	24.7	22.2	4.0	0.8	53	27
				Spring 2004				
0 to 2.5	12.8	8.4	17.0	8.6	3.5	1.4	27	6
0 to 5	13.2	9.5	17.7	8.2	3.3	1.4	25	6
0 to 15	27.7	18.8	48.8	30.1	10.6	4.3	38	6
				Fall 2004				
0 to 2.5	56.7	18.0	99.7	81.7	21.0	4.0	37	27
0 to 5	47.7	16.1	82.0	65.8	16.6	3.2	35	27
0 to 15	32.6	12.0	59.9	47.9	11.4	2.2	35	27
				Spring 2005				
0 to 2.5	11.2	5.0	22.0	17.0	5.9	2.4	53	6
0 to 5	11.8	7.5	21.0	13.5	4.8	2.0	41	6
0 to 15	14.8	10.5	27.0	16.5	6.2	2.5	42	6

^{z} SD = standard deviation; SE = standard error; CV = coefficient of variation; N = number of observations.

Table A1.8. Descriptive statistics for the soil extractable nitrate N data for the Wabash Creek (WAB) watershed.

Soil layer (cm)	Mean ($mg\ kg^{-1}$)	Min. ($mg\ kg^{-1}$)	Max. ($mg\ kg^{-1}$)	Range ($mg\ kg^{-1}$)	SD[z] ($mg\ kg^{-1}$)	SE[z] ($mg\ kg^{-1}$)	CV[z] (%)	N[y]
				Fall 2002				
0 to 2.5	12.9	2.7	56.7	54.0	12.4	2.4	97	27
0 to 5	14.1	2.7	71.5	68.8	15.3	2.9	108	27
0 to 15	14.3	3.5	66.6	63.1	14.8	2.8	103	27
				Spring 2003				
0 to 2.5	38.3	22.0	63.0	41.0	14.5	5.9	38	6
0 to 5	36.7	27.0	56.0	29.0	11.0	4.5	30	6
0 to 15	40.3	23.7	76.0	52.3	21.5	8.8	53	6
				Fall 2003				
0 to 2.5	9.0	4.1	28.2	24.1	4.8	0.9	53	27
0 to 5	9.1	4.3	27.3	22.9	4.5	0.9	50	27
0 to 15	9.4	5.2	24.0	18.8	4.4	0.8	46	27
				Spring 2004				
0 to 2.5	41.8	15.0	79.6	64.6	29.0	11.8	69	6
0 to 5	39.3	19.2	70.9	51.7	22.1	9.0	56	6
0 to 15	39.9	20.2	65.8	45.6	17.6	7.2	44	6
				Fall 2004				
0 to 2.5	5.8	2.4	28.6	26.2	5.0	1.0	87	27
0 to 5	7.6	3.7	48.9	45.2	8.5	1.6	113	27
0 to 15	11.5	5.1	49.2	44.1	9.2	1.8	80	27
				Spring 2005				
0 to 2.5	34.0	10.0	85.0	75.0	27.6	11.3	81	6
0 to 5	31.6	12.0	72.0	60.0	21.9	8.9	69	6
0 to 15	49.3	22.0	89.3	67.3	24.9	10.2	50	6

[z] SD = standard deviation; SE = standard error; CV = coefficient of variation; N = number of observations.

Appendix 2. Extractable soil nitrate N data for the reference samples (i.e., Sample 52) from the eight microwatersheds.

Site	Year	Season	Laboratory[z]	0- to 2.5-cm soil layer[y]	2.5- to 5-cm soil layer[y]	5- to 15-cm soil layer[y]
				-------------------------	mg kg^{-1}	-------------------------
CFT	2002	fall	Edmonton	7.9	7.9	8.1
CFT	2003	spring	Edmonton	10.0	9.0	10.0
CFT	2003	fall	Calgary	5.6	5.3	5.3
CFT	2004	spring	Saskatoon	7.0	6.6	6.6
CFT	2004	fall	Saskatoon	11.2	11.6	11.0
CFT	2005	spring	Saskatoon	8.6	8.4	8.4
GPC	2002	fall	Edmonton	20.5	20.9	21.1
GPC	2003	spring	Edmonton	20.0	20.0	21.0
GPC	2003	fall	Calgary	13.6	11.7	12.4
GPC	2004	spring	Saskatoon	17.4	18.6	17.2
GPC	2004	fall	Saskatoon	20.8	21.2	21.2
GPC	2005	spring	Saskatoon	22.8	22.6	21.2
LLB	2002	fall	Edmonton	8.5	7.5	7.4
LLB	2003	spring	Edmonton	10.0	9.0	9.0
LLB	2003	fall	Calgary	13.4	13.9	14.3
LLB	2004	spring	Saskatoon	9.8	7.2	6.8
LLB	2004	fall	Saskatoon	10.2	10.2	9.6
LLB	2005	spring	Saskatoon	9.0	8.3	8.3
PON	2002	fall	Edmonton	34.0	33.0	30.0
PON	2003	spring	Edmonton	86.0	72.0	75.0
PON	2003	fall	Calgary	77.2	85.5	71.1
PON	2004	spring	Saskatoon	54.2	58.8	58.2
PON	2004	fall	Saskatoon	94.2	95.4	94.6
PON	2005	spring	Saskatoon	110.0	106.0	103.0
REN	2002	fall	Edmonton	3.3	3.4	3.4
REN	2003	spring	Edmonton	3.0	4.0	6.0
REN	2003	fall	Calgary	2.0	1.9	1.9
REN	2004	spring	Saskatoon	3.2	3.2	3.0
REN	2004	fall	Saskatoon	7.7	7.3	7.7
REN	2005	spring	Saskatoon	5.2	5.4	5.2
STV	2002	fall	Edmonton	2.0	1.2	1.5
STV	2003	fall	Calgary	0.2	2.0	1.2
STV	2004	fall	Saskatoon	3.8	3.0	3.0
THC	2002	fall	Edmonton	3.4	2.8	3.0
THC	2003	spring	Edmonton	4.0	6.0	21.0
THC	2003	fall	Calgary	1.4	2.4	1.5
THC	2004	spring	Saskatoon	2.6	2.4	2.8
THC	2004	fall	Saskatoon	13.3	9.7	9.3
THC	2005	spring	Saskatoon	3.4	3.2	3.4
WAB	2002	fall	Edmonton	7.8	7.7	8.0
WAB	2003	spring	Edmonton	10.0	9.0	10.0
WAB	2003	fall	Calgary	8.8	7.1	6.3
WAB	2004	spring	Saskatoon	6.2	6.6	6.4
WAB	2004	fall	Saskatoon	10.0	9.8	10.2
WAB	2005	spring	Saskatoon	10.2	10.0	10.0

[z] Norwest Lab in Edmonton, Enviro-Test Lab in Calgary, Enviro-Test Lab in Saskatoon.
[y] For submission purposes to the labs, three samples were designated as three different soil layers, but actually came from the same 0- to 15-cm layer for each reference sample.

Appendix 3. Extractable soil nitrate N data for the check samples and the corresponding batch samples.

Table A3.1. Extractable soil nitrate N data for the check samples and the corresponding batch samples for the Crowfoot Creek (CFT) watershed.

Site	Year	Season	Check sample number	Corresponding sample site number	Laboratory[z]	Soil layer	Check sample NO_3-N	Sample NO_3-N	ARD Lab[y] NO_3-N	Check/ sample ratio
						cm	----------	mg kg^{-1}	----------	
CFT	2002	fall	50	18	Edmonton	0 to 2.5	19.5	20.6	23.0	0.95
CFT	2002	fall	50	18	Edmonton	2.5 to 5	15.9	13.0	19.0	1.22
CFT	2002	fall	50	18	Edmonton	5 to 15	15.7	13.1	16.0	1.20
CFT	2002	fall	51	17	Edmonton	0 to 2.5	8.9	8.0	11.0	1.11
CFT	2002	fall	51	17	Edmonton	2.5 to 5	5.6	4.9	9.0	1.14
CFT	2002	fall	51	17	Edmonton	5 to 15	5.2	4.1	7.0	1.27
CFT	2003	spring	50	10	Edmonton	0 to 2.5	26.0	27.0	na[x]	0.96
CFT	2003	spring	50	10	Edmonton	2.5 to 5	57.0	55.0	na	1.04
CFT	2003	spring	50	10	Edmonton	5 to 15	20.0	20.0	na	1.00
CFT	2003	fall	50	2	Calgary	0 to 2.5	23.0	22.1	37.8	1.04
CFT	2003	fall	50	2	Calgary	2.5 to 5	15.8	17.9	27.7	0.88
CFT	2003	fall	50	2	Calgary	5 to 15	8.2	10.9	11.5	0.75
CFT	2003	fall	51	19	Calgary	0 to 2.5	28.1	29.2	48.9	0.96
CFT	2003	fall	51	19	Calgary	2.5 to 5	20.2	23.6	40.8	0.86
CFT	2003	fall	51	19	Calgary	5 to 15	11.4	11.9	20.3	0.96
CFT	2004	spring	50	4	Saskatoon	0 to 2.5	13.8	9.2	na	1.50
CFT	2004	spring	50	4	Saskatoon	2.5 to 5	68.6	71.2	na	0.96
CFT	2004	spring	50	4	Saskatoon	5 to 15	57.8	61.4	na	0.94
CFT	2004	fall	50	30	Saskatoon	0 to 2.5	23.2	23.2	32.5	1.00
CFT	2004	fall	50	30	Saskatoon	2.5 to 5	13.2	11.6	61.9	1.14
CFT	2004	fall	50	30	Saskatoon	5 to 15	9.6	8.6	117.9	1.12
CFT	2004	fall	51	32	Saskatoon	0 to 2.5	88.6	81.8	6.2	1.08
CFT	2004	fall	51	32	Saskatoon	2.5 to 5	52.6	55.4	9.4	0.95
CFT	2004	fall	51	32	Saskatoon	5 to 15	35.6	41.0	20.9	0.87
CFT	2005	spring	50	4	Saskatoon	0 to 2.5	99.0	119.0	na	0.83
CFT	2005	spring	50	4	Saskatoon	2.5 to 5	68.4	91.0	na	0.75
CFT	2005	spring	50	4	Saskatoon	5 to 15	33.8	42.0	na	0.80

[z] Norwest Lab in Edmonton, Enviro-Test Lab in Calgary, Enviro-Test Lab in Saskatoon.
[y] Alberta Agriculture and Rural Development (ARD) laboratory (ARD Edmonton lab in 2002, ARD Lethbridge lab in 2003 and 2004).
[x] Not analyzed.

Table A3.2. Extractable soil nitrate N data for the check samples and the corresponding batch samples for the Grande Prairie Creek (GPC) watershed.

Site	Year	Season	Check sample number	Corresponding sample site number	Laboratory[z]	Soil layer	Check sample NO_3-N	Sample NO_3-N	ARD Lab[y] NO_3-N	Check/ sample ratio
						cm	---------- mg kg^{-1}	----------		
GPC	2002	fall	50	24	Edmonton	0 to 2.5	25.5	24.5	24.0	1.04
GPC	2002	fall	50	24	Edmonton	2.5 to 5	33.0	25.5	28.0	1.29
GPC	2002	fall	50	24	Edmonton	5 to 15	10.1	10.2	9.0	0.99
GPC	2002	fall	51	11	Edmonton	0 to 2.5	19.4	20.2	18.0	0.96
GPC	2002	fall	51	11	Edmonton	2.5 to 5	24.8	20.9	20.0	1.19
GPC	2002	fall	51	11	Edmonton	5 to 15	9.5	9.1	9.0	1.04
GPC	2003	spring	50	1	Edmonton	0 to 2.5	48.0	49.0	na[x]	0.98
GPC	2003	spring	50	1	Edmonton	2.5 to 5	25.0	26.0	na	0.96
GPC	2003	spring	50	1	Edmonton	5 to 15	12.0	7.0	na	1.71
GPC	2003	fall	50	7	Calgary	0 to 2.5	32.6	28.9	42.5	1.13
GPC	2003	fall	50	7	Calgary	2.5 to 5	38.6	38.4	52.8	1.01
GPC	2003	fall	50	7	Calgary	5 to 15	21.1	13.4	34.2	1.57
GPC	2003	fall	51	12	Calgary	0 to 2.5	22.8	5.1	26.0	4.47
GPC	2003	fall	51	12	Calgary	2.5 to 5	20.4	1.7	10.8	12.00
GPC	2003	fall	51	12	Calgary	5 to 15	8.7	0.5	9.8	17.40
GPC	2004	spring	50	1	Saskatoon	0 to 2.5	29.0	31.6	na	0.92
GPC	2004	spring	50	1	Saskatoon	2.5 to 5	29.0	31.6	na	0.92
GPC	2004	spring	50	1	Saskatoon	5 to 15	16.4	18.6	na	0.88
GPC	2004	fall	50	18	Saskatoon	0 to 2.5	2.4	2.4	2.4	1.00
GPC	2004	fall	50	18	Saskatoon	2.5 to 5	2.6	4.0	3.3	0.65
GPC	2004	fall	50	18	Saskatoon	5 to 15	4.0	4.4	3.1	0.91
GPC	2004	fall	51	7	Saskatoon	0 to 2.5	2.2	3.0	2.7	0.73
GPC	2004	fall	51	7	Saskatoon	2.5 to 5	2.4	2.4	2.4	1.00
GPC	2004	fall	51	7	Saskatoon	5 to 15	2.0	2.0	1.8	1.00
GPC	2005	spring	50	4	Saskatoon	0 to 2.5	31.8	20.2	na	0.64
GPC	2005	spring	50	4	Saskatoon	2.5 to 5	22.4	13.6	na	0.61
GPC	2005	spring	50	4	Saskatoon	5 to 15	41.6	22.6	na	0.54

[z] Norwest Lab in Edmonton, Enviro-Test Lab in Calgary, Enviro-Test Lab in Saskatoon.
[y] Alberta Agriculture and Rural Development (ARD) laboratory (ARD Edmonton lab in 2002, ARD Lethbridge lab in 2003 and 2004).
[x] Not analyzed.

Table A3.3. Extractable soil nitrate N data for the check samples and the corresponding batch samples for the Lower Little Bow River (LLB) watershed.

Site	Year	Season	Check sample number	Corresponding sample site number	Laboratory[z]	Soil layer	Check sample NO_3-N	Sample NO_3-N	ARD Lab[y] NO_3-N	Check/ sample ratio
						cm	----------	mg kg^{-1}	----------	
LLB	2002	fall	50	15	Edmonton	0 to 2.5	30.8	34.4	21.0	0.90
LLB	2002	fall	50	15	Edmonton	2.5 to 5	38.4	38.4	21.0	1.00
LLB	2002	fall	50	15	Edmonton	5 to 15	24.8	28.9	15.0	0.86
LLB	2002	fall	51	27	Edmonton	0 to 2.5	32.9	33.1	19.0	0.99
LLB	2002	fall	51	27	Edmonton	2.5 to 5	33.5	33.1	23.0	1.01
LLB	2002	fall	51	27	Edmonton	5 to 15	29.0	28.2	18.0	1.03
LLB	2003	spring	50	3	Edmonton	0 to 2.5	26.0	27.0	na[x]	0.96
LLB	2003	spring	50	3	Edmonton	2.5 to 5	22.0	22.0	na	1.00
LLB	2003	spring	50	3	Edmonton	5 to 15	26.0	28.0	na	0.93
LLB	2003	fall	50	18	Calgary	0 to 2.5	26.7	19.2	14.6	1.39
LLB	2003	fall	50	18	Calgary	2.5 to 5	28.1	35.5	13.6	0.79
LLB	2003	fall	50	18	Calgary	5 to 15	26.7	30.9	13.1	0.86
LLB	2003	fall	51	6	Calgary	0 to 2.5	11.6	10.2	3.3	1.14
LLB	2003	fall	51	6	Calgary	2.5 to 5	11.2	8.5	2.8	1.32
LLB	2003	fall	51	6	Calgary	5 to 15	8.5	5.8	2.2	1.47
LLB	2004	spring	50	8	Saskatoon	0 to 2.5	72.4	88.6	na	0.82
LLB	2004	spring	50	8	Saskatoon	2.5 to 5	61.4	63.4	na	0.97
LLB	2004	spring	50	8	Saskatoon	5 to 15	74.8	87.2	na	0.86
LLB	2004	fall	50	31	Saskatoon	0 to 2.5	27.6	25.8	21.3	1.07
LLB	2004	fall	50	31	Saskatoon	2.5 to 5	22.0	20.6	17.9	1.07
LLB	2004	fall	50	31	Saskatoon	5 to 15	17.4	17.2	7.0	1.01
LLB	2004	fall	51	32	Saskatoon	0 to 2.5	13.8	11.0	8.4	1.25
LLB	2004	fall	51	32	Saskatoon	2.5 to 5	10.8	8.4	5.8	1.29
LLB	2004	fall	51	32	Saskatoon	5 to 15	6.4	4.0	3.1	1.60
LLB	2005	spring	50	3	Saskatoon	0 to 2.5	102.0	99.0	na	1.03
LLB	2005	spring	50	3	Saskatoon	2.5 to 5	109.0	105.0	na	1.04
LLB	2005	spring	50	3	Saskatoon	5 to 15	78.8	79.0	na	1.00

[z] Norwest Lab in Edmonton, Enviro-Test Lab in Calgary, Enviro-Test Lab in Saskatoon.
[y] Alberta Agriculture and Rural Development (ARD) laboratory (ARD Edmonton lab in 2002, ARD Lethbridge lab in 2003 and 2004).
[x] Not analyzed.

Table A3.4. Extractable soil nitrate N data for the check samples and the corresponding batch samples for the Ponoka (PON) watershed.

Site	Year	Season	Check sample number	Corresponding sample site number	Laboratory[z]	Soil layer	Check sample NO_3-N	Sample NO_3-N	ARD Lab[y] NO_3-N	Check/ sample ratio
						cm	----------	mg kg^{-1}	----------	
PON	2002	fall	50	8	Edmonton	0 to 2.5	74.0	33.0	76.0	2.24
PON	2002	fall	50	8	Edmonton	2.5 to 5	172.0	189.0	169.0	0.91
PON	2002	fall	50	8	Edmonton	5 to 15	178.0	256.0	214.0	0.70
PON	2002	fall	51	18	Edmonton	0 to 2.5	130.0	5.0	20.0	26.00
PON	2002	fall	51	18	Edmonton	2.5 to 5	52.0	117.0	94.0	0.44
PON	2002	fall	51	18	Edmonton	5 to 15	58.0	127.0	120.0	0.46
PON	2003	spring	50	6	Edmonton	0 to 2.5	52.0	57.0	na[x]	0.91
PON	2003	spring	50	6	Edmonton	2.5 to 5	18.0	100.0	na	0.18
PON	2003	spring	50	6	Edmonton	5 to 15	71.0	110.0	na	0.65
PON	2003	fall	50	18	Calgary	0 to 2.5	163.0	265.0	179.0	0.62
PON	2003	fall	50	18	Calgary	2.5 to 5	141.0	227.0	167.2	0.62
PON	2003	fall	50	18	Calgary	5 to 15	93.2	154.0	115.0	0.61
PON	2003	fall	51	5	Calgary	0 to 2.5	317.0	170.0	322.6	1.86
PON	2003	fall	51	5	Calgary	2.5 to 5	183.0	163.0	264.0	1.12
PON	2003	fall	51	5	Calgary	5 to 15	159.0	79.2	157.2	2.01
PON	2004	spring	50	3	Saskatoon	0 to 2.5	165.0	175.0	na	0.94
PON	2004	spring	50	3	Saskatoon	2.5 to 5	56.8	60.6	na	0.94
PON	2004	spring	50	3	Saskatoon	5 to 15	36.8	63.8	na	0.58
PON	2004	fall	50	15	Saskatoon	0 to 2.5	62.8	92.2	108.1	0.68
PON	2004	fall	50	15	Saskatoon	2.5 to 5	56.6	80.4	99.3	0.70
PON	2004	fall	50	15	Saskatoon	5 to 15	64.4	75.0	90.5	0.86
PON	2004	fall	51	9	Saskatoon	0 to 2.5	20.0	57.6	45.1	0.35
PON	2004	fall	51	9	Saskatoon	2.5 to 5	38.2	38.6	54.5	0.99
PON	2004	fall	51	9	Saskatoon	5 to 15	49.0	62.8	68.4	0.78
PON	2005	spring	50	15	Saskatoon	0 to 2.5	216.0	228.0	na	1.06
PON	2005	spring	50	15	Saskatoon	2.5 to 5	233.0	219.0	na	0.94
PON	2005	spring	50	15	Saskatoon	5 to 15	142.0	146.0	na	1.03

[z] Norwest Lab in Edmonton, Enviro-Test Lab in Calgary, Enviro-Test Lab in Saskatoon.
[y] Alberta Agriculture and Rural Development (ARD) laboratory (ARD Edmonton lab in 2002, ARD Lethbridge lab in 2003 and 2004).
[x] Not analyzed.

Table A3.5. Extractable soil nitrate N data for the check samples and the corresponding batch samples for the Renwick Creek (REN) watershed.

Site	Year	Season	Check sample number	Corresponding sample site number	Laboratory[z]	Soil layer	Check sample NO_3-N	Sample NO_3-N	ARD Lab[y] NO_3-N	Check/ sample ratio
						cm	---------- mg kg^{-1} ----------			
REN	2002	fall	50	3	Edmonton	0 to 2.5	10.1	9.9	10.0	1.02
REN	2002	fall	50	3	Edmonton	2.5 to 5	11.4	10.0	10.0	1.14
REN	2002	fall	50	3	Edmonton	5 to 15	27.0	27.5	26.0	0.98
REN	2002	fall	51	14	Edmonton	0 to 2.5	5.0	5.6	8.0	0.89
REN	2002	fall	51	14	Edmonton	2.5 to 5	3.7	3.2	4.0	1.16
REN	2002	fall	51	14	Edmonton	5 to 15	1.8	2.8	2.0	0.64
REN	2003	spring	50	27	Edmonton	0 to 2.5	16.0	17.0	na[x]	0.94
REN	2003	spring	50	27	Edmonton	2.5 to 5	18.0	21.0	na	0.86
REN	2003	spring	50	27	Edmonton	5 to 15	5.0	5.0	na	1.00
REN	2003	fall	50	9	Calgary	0 to 2.5	3.9	na	3.6	
REN	2003	fall	50	9	Calgary	2.5 to 5	6.5	6.0	8.0	1.08
REN	2003	fall	50	9	Calgary	5 to 15	9.7	8.8	10.2	1.10
REN	2003	fall	51	20	Calgary	0 to 2.5	2.2	1.0	1.8	2.20
REN	2003	fall	51	20	Calgary	2.5 to 5	4.3	2.9	4.2	1.48
REN	2003	fall	51	20	Calgary	5 to 15	5.8	4.4	6.3	1.32
REN	2004	spring	50	3	Saskatoon	0 to 2.5	54.0	53.8	na	1.00
REN	2004	spring	50	3	Saskatoon	2.5 to 5	44.6	45.6	na	0.98
REN	2004	spring	50	3	Saskatoon	5 to 15	24.2	22.8	na	1.06
REN	2004	fall	50	26	Saskatoon	0 to 2.5	9.7	4.3	5.7	2.26
REN	2004	fall	50	26	Saskatoon	2.5 to 5	7.0	3.0	4.0	2.33
REN	2004	fall	50	26	Saskatoon	5 to 15	5.7	2.7	2.1	2.11
REN	2004	fall	51	24	Saskatoon	0 to 2.5	12.7	6.7	7.0	1.90
REN	2004	fall	51	24	Saskatoon	2.5 to 5	12.3	5.7	6.9	2.16
REN	2004	fall	51	24	Saskatoon	5 to 15	8.7	4.0	4.2	2.18
REN	2005	spring	50	3	Saskatoon	0 to 2.5	66.2	69.0	na	0.96
REN	2005	spring	50	3	Saskatoon	2.5 to 5	36.4	37.0	na	0.98
REN	2005	spring	50	3	Saskatoon	5 to 15	17.4	18.0	na	0.97

[z] Norwest Lab in Edmonton, Enviro-Test Lab in Calgary, Enviro-Test Lab in Saskatoon.
[y] Alberta Agriculture and Rural Development (ARD) laboratory (ARD Edmonton lab in 2002, ARD Lethbridge lab in 2003 and 2004).
[x] Not analyzed.

Table A3.6. Extractable soil nitrate N data for the check samples and the corresponding batch samples for the Stavley (STV) watershed.

Site	Year	Season	Check sample number	Corresponding sample site number	Laboratory[z]	Soil layer	Check sample NO_3-N	Sample NO_3-N	ARD Lab[y] NO_3-N	Check/ sample ratio
						cm	----------	mg kg^{-1}	----------	
STV	2002	fall	50	1	Edmonton	0 to 2.5	3.3	4.1	2.0	0.80
STV	2002	fall	50	1	Edmonton	2.5 to 5	2.0	3.6	BDL[x]	0.56
STV	2002	fall	50	1	Edmonton	5 to 15	1.4	2.8	BDL	0.50
STV	2002	fall	51	3	Edmonton	0 to 2.5	3.8	3.8	2.0	1.00
STV	2002	fall	51	3	Edmonton	2.5 to 5	3.5	2.0	2.0	1.75
STV	2002	fall	51	3	Edmonton	5 to 15	3.0	1.2	2.0	2.50
STV	2003	fall	50	1	Calgary	0 to 2.5	4.3	1.9	2.1	2.26
STV	2003	fall	50	1	Calgary	2.5 to 5	1.4	0.9	1.6	1.56
STV	2003	fall	50	1	Calgary	5 to 15	0.5	1.2	1.5	0.42
STV	2004	fall	50	1	Saskatoon	0 to 2.5	8.6	8.0	4.5	1.08
STV	2004	fall	50	1	Saskatoon	2.5 to 5	6.4	6.4	4.8	1.00
STV	2004	fall	50	1	Saskatoon	5 to 15	5.2	5.8	3.9	0.90

[z] Norwest Lab in Edmonton, Enviro-Test Lab in Calgary, Enviro-Test Lab in Saskatoon.
[y] Alberta Agriculture and Rural Development (ARD) laboratory (ARD Edmonton lab in 2002, ARD Lethbridge lab in 2003 and 2004).
[y] Below detection limit.

Table A3.7. Extractable soil nitrate N data for the check samples and the corresponding batch samples for the Threehills Creek (THC) watershed.

Site	Year	Season	Check sample number	Corresponding sample site number	Laboratory[z]	Soil layer	Check sample NO_3-N	Sample NO_3-N	ARD Lab[y] NO_3-N	Check/ sample ratio
						cm	----------	mg kg^{-1}	----------	
THC	2002	fall	50	6	Edmonton	0 to 2.5	4.3	5.4	8.0	0.80
THC	2002	fall	50	6	Edmonton	2.5 to 5	4.0	4.8	7.0	0.83
THC	2002	fall	50	6	Edmonton	5 to 15	2.8	3.4	7.0	0.82
THC	2002	fall	51	18	Edmonton	0 to 2.5	4.8	5.4	8.0	0.89
THC	2002	fall	51	18	Edmonton	2.5 to 5	4.4	4.5	8.0	0.98
THC	2002	fall	51	18	Edmonton	5 to 15	1.3	2.2	4.0	0.59
THC	2003	spring	50	6	Edmonton	0 to 2.5	9.0	16.0	na[x]	0.56
THC	2003	spring	50	6	Edmonton	2.5 to 5	8.0	19.0	na	0.42
THC	2003	spring	50	6	Edmonton	5 to 15	4.0	13.0	na	0.31
THC	2003	fall	50	16	Calgary	0 to 2.5	7.5	8.8	8.7	0.85
THC	2003	fall	50	16	Calgary	2.5 to 5	8.8	7.8	9.9	1.13
THC	2003	fall	50	16	Calgary	5 to 15	6.8	7.7	8.7	0.88
THC	2003	fall	51	11	Calgary	0 to 2.5	3.7	4.8	4.8	0.77
THC	2003	fall	51	11	Calgary	2.5 to 5	4.1	7.3	6.3	0.56
THC	2003	fall	51	11	Calgary	5 to 15	6.0	5.8	6.9	1.03
THC	2004	spring	50	4	Saskatoon	0 to 2.5	17.4	17.0	na	1.02
THC	2004	spring	50	4	Saskatoon	2.5 to 5	16.4	16.0	na	1.03
THC	2004	spring	50	4	Saskatoon	5 to 15	34.8	29.6	na	1.18
THC	2004	fall	50	24	Saskatoon	0 to 2.5	47.3	27.7	37.1	1.71
THC	2004	fall	50	24	Saskatoon	2.5 to 5	11.3	23.3	16.2	0.48
THC	2004	fall	50	24	Saskatoon	5 to 15	29.7	11.3	8.8	2.63
THC	2004	fall	51	11	Saskatoon	0 to 2.5	16.7	51.0	17.0	0.33
THC	2004	fall	51	11	Saskatoon	2.5 to 5	28.7	30.7	13.2	0.93
THC	2004	fall	51	11	Saskatoon	5 to 15	22.7	18.7	6.3	1.21
THC	2005	spring	50	1	Saskatoon	0 to 2.5	8.6	10.0	na	0.86
THC	2005	spring	50	1	Saskatoon	2.5 to 5	6.2	8.0	na	0.78
THC	2005	spring	50	1	Saskatoon	5 to 15	26.0	36.0	na	0.72

[z] Norwest Lab in Edmonton, Enviro-Test Lab in Calgary, Enviro-Test Lab in Saskatoon.
[y] Alberta Agriculture and Rural Development (ARD) laboratory (ARD Edmonton lab in 2002, ARD Lethbridge lab in 2003 and 2004).
[x] Not analyzed.

Table A3.8. Extractable soil nitrate N data for the check samples and the corresponding batch samples for the Wabash Creek (WAB) watershed.

Site	Year	Season	Check sample number	Corresponding sample site number	Laboratory[z]	Soil layer	Check sample NO_3-N	Sample NO_3-N	ARD Lab[y] NO_3-N	Check/ sample ratio
						cm	---------- mg kg^{-1}	----------		
WAB	2002	fall	50	22	Edmonton	0 to 2.5	6.2	6.0	5.0	1.03
WAB	2002	fall	50	22	Edmonton	2.5 to 5	5.7	5.5	4.0	1.04
WAB	2002	fall	50	22	Edmonton	5 to 15	5.4	5.2	5.0	1.04
WAB	2002	fall	51	10	Edmonton	0 to 2.5	9.4	11.9	8.0	0.79
WAB	2002	fall	51	10	Edmonton	2.5 to 5	8.7	8.5	6.0	1.02
WAB	2002	fall	51	10	Edmonton	5 to 15	9.9	10.1	10.0	0.98
WAB	2003	spring	50	1	Edmonton	0 to 2.5	32.0	30.0	na[x]	1.07
WAB	2003	spring	50	1	Edmonton	2.5 to 5	31.0	30.0	na	1.03
WAB	2003	spring	50	1	Edmonton	5 to 15	20.0	25.0	na	0.80
WAB	2003	fall	50	24	Calgary	0 to 2.5	5.8	4.8	7.4	1.21
WAB	2003	fall	50	24	Calgary	2.5 to 5	5.4	5.8	8.2	0.93
WAB	2003	fall	50	24	Calgary	5 to 15	5.4	5.3	10.9	1.02
WAB	2003	fall	51	11	Calgary	0 to 2.5	8.8	10.7	12.0	0.82
WAB	2003	fall	51	11	Calgary	2.5 to 5	9.9	9.7	10.7	1.02
WAB	2003	fall	51	11	Calgary	5 to 15	9.2	13.1	16.4	0.70
WAB	2004	spring	50	6	Saskatoon	0 to 2.5	20.6	20.4	na	1.01
WAB	2004	spring	50	6	Saskatoon	2.5 to 5	21.0	22.0	na	0.95
WAB	2004	spring	50	6	Saskatoon	5 to 15	30.2	33.2	na	0.91
WAB	2004	fall	50	3	Saskatoon	0 to 2.5	10.4	11.0	6.6	0.95
WAB	2004	fall	50	3	Saskatoon	2.5 to 5	18.2	14.8	11.9	1.23
WAB	2004	fall	50	3	Saskatoon	5 to 15	48.6	39.8	18.3	1.22
WAB	2004	fall	51	13	Saskatoon	0 to 2.5	9.0	6.6	2.6	1.36
WAB	2004	fall	51	13	Saskatoon	2.5 to 5	7.6	6.6	5.5	1.15
WAB	2004	fall	51	13	Saskatoon	5 to 15	20.4	9.0	7.2	2.27
WAB	2005	spring	50	3	Saskatoon	0 to 2.5	20.2	40.2	na	1.99
WAB	2005	spring	50	3	Saskatoon	2.5 to 5	21.4	35.2	na	1.64
WAB	2005	spring	50	3	Saskatoon	5 to 15	47.2	81.0	na	1.72

[z] Norwest Lab in Edmonton, Enviro-Test Lab in Calgary, Enviro-Test Lab in Saskatoon.
[y] Alberta Agriculture and Rural Development (ARD) laboratory (ARD Edmonton lab in 2002, ARD Lethbridge lab in 2003 and 2004).
[x] Not analyzed.

Appendix 4. Extractable soil nitrate N data for the eight microwatersheds from 2002 to 2005.

Table A4.1. Extractable soil nitrate N data for the Crowfoot Creek (CFT) watershed.

Sample site	Landform position[z]	Fall 2002 0 to 2.5 cm	Fall 2002 2.5 to 5 cm	Fall 2002 5 to 15 cm	Fall 2003 0 to 2.5 cm	Fall 2003 2.5 to 5 cm	Fall 2003 5 to 15 cm	Fall 2004 0 to 2.5 cm	Fall 2004 2.5 to 5 cm	Fall 2004 5 to 15 cm
		--------- mg kg^{-1} ---------			--------- mg kg^{-1} ---------			--------- mg kg^{-1} ---------		
1	L	7.9	4.0	4.8	3.9	5.8	4.4	11.3	8.7	4.3
2	D	14.7	8.9	11.5	22.1	17.9	10.9	32.0	16.0	7.3
3	D	12.1	10.7	11.6	3.9	5.3	3.9	16.7	16.3	7.3
4	L	8.7	6.7	5.1	8.8	8.3	3.9	43.7	28.0	14.3
5	D	10.8	13.4	5.7	6.0	11.9	9.9	53.3	29.0	11.7
6	L	7.4	7.8	8.0	12.9	14.8	8.5	26.3	18.3	10.3
7	L	22.6	20.1	40.6	10.9	6.8	8.5	48.7	26.0	26.0
8	M	23.2	16.5	20.1	10.5	10.5	7.8	15.0	11.7	7.7
9	M	11.3	11.4	20.7	12.2	15.0	14.5	20.0	16.3	9.7
10	L	5.6	11.4	6.2	6.8	5.8	4.6	22.3	13.0	8.7
11	M	10.0	7.8	4.8	14.3	27.4	22.8	41.8	44.4	15.8
12	M	4.8	5.3	2.8	16.5	33.5	16.0	11.0	29.8	10.0
13	M	3.6	5.2	3.1	13.4	21.9	13.4	10.4	33.4	10.8
14	M	6.3	4.5	3.3	12.1	13.1	8.3	29.3	17.0	8.3
15	U	14.7	10.6	17.8	25.0	20.6	13.9	25.0	11.3	9.7
16	M	5.9	6.0	6.2	2.2	7.0	6.8	20.0	14.7	6.7
17	U	8.0	4.9	4.1	11.1	9.9	6.1	14.3	7.4	4.6
18	M	20.6	13.0	13.1	8.7	10.7	9.0	30.6	13.6	8.8
19	U	7.0	5.5	5.6	29.2	23.6	11.9	26.4	18.6	10.2
20	M	31.0	39.2	49.6	24.3	30.1	5.6	23.0	13.8	11.4
21	M	7.9	8.5	14.7	11.9	21.6	16.5	15.0	37.0	16.0
22	M	13.2	16.7	18.6	14.3	26.7	18.5	8.6	37.2	13.6
23	U	22.6	14.4	14.2	12.4	13.8	7.7	34.6	22.8	9.0
24	M	7.1	9.3	6.3	10.9	9.0	10.0	19.0	12.2	6.2
25	L	4.6	4.9	7.0	4.6	4.1	4.9	15.6	12.2	6.6
26	L	15.7	16.0	20.2	13.8	14.3	6.3	53.2	25.0	11.4
27	U	9.9	11.5	6.0	10.2	15.3	15.3	4.8	25.0	10.0
28	M	11.3	10.5	6.1	16.8	25.3	16.5	10.8	37.8	18.8
29	M	6.3	7.3	4.0	6.0	14.5	10.0	6.6	23.6	10.0
30	U	10.9	9.5	7.5	31.1	10.5	4.4	23.2	11.6	8.6
31	M	11.7	10.0	9.5	13.4	10.2	3.7	36.0	18.6	10.2
32	L	19.8	23.9	16.8	11.4	11.2	7.1	81.8	55.4	41.0
33	U	7.0	13.3	6.7	7.1	16.0	11.7	10.8	29.8	13.6
34	M	7.1	8.5	10.0	13.8	22.8	14.8	15.8	34.8	10.6
35	L	4.6	5.8	6.0	8.3	23.3	25.8	8.8	26.0	10.8
36	M	6.3	7.6	6.9	9.7	13.1	15.8	7.2	23.8	12.2
37	M	8.1	9.0	12.4	11.1	22.3	18.4	6.4	40.2	16.2
38	M	3.9	6.6	5.2	14.1	18.7	15.5	13.0	46.8	18.8
39	M	7.1	7.2	7.6	21.4	30.4	18.2	10.6	48.0	16.8
40	D	9.2	10.9	8.5	6.1	10.5	11.4	23.4	45.8	14.8
41	U	8.3	10.6	33.5	18.9	8.0	10.5	40.2	22.8	17.0
42	L	7.0	6.8	6.5	11.9	4.1	11.4	28.8	18.6	13.2
43	L	15.9	16.8	13.8	17.9	18.5	7.5	49.2	52.6	37.0
44	L	8.3	6.0	4.1	11.7	11.7	2.9	24.0	11.6	6.6
45	L	10.2	13.9	13.3	23.0	16.7	4.8	26.2	16.2	11.6
46	M	5.7	8.2	9.9	9.4	22.6	17.9	8.4	21.8	10.0
47	L	13.5	22.0	57.7	13.4	11.6	6.0	50.4	30.6	21.6
48	L	20.9	31.3	25.4	14.5	17.0	8.2	37.0	29.4	14.2

Table A4.1. Extractable soil nitrate N data for the Crowfoot Creek (CFT) watershed. (continued)

		Spring 2003			Spring 2004			Spring 2005		
Sample site	Landform position[z]	0 to 2.5 cm	2.5 to 5 cm	5 to 15 cm	0 to 2.5 cm	2.5 to 5 cm	5 to 15 cm	0 to 2.5 cm	2.5 to 5 cm	5 to 15 cm
		--------- mg kg^{-1} ---------			--------- mg kg^{-1} ---------			--------- mg kg^{-1} ---------		
1	L	8.0	20.0	36.0	35.8	50.4	41.8	34.0	82.0	28.0
2	D	24.0	48.0	31.0	9.6	31.6	12.4	83.0	68.0	18.0
3	D	15.0	20.0	47.0	61.2	42.4	48.4	111.0	103.0	15.0
4	L	47.0	121.0	38.0	9.2	71.2	61.4	119.0	91.0	42.0
5	D	74.0	103.0	35.0	31.4	64.0	55.4	67.0	45.0	37.0
6	L	124.0	108.0	31.0	15.2	41.4	55.0	97.0	131.0	26.0
7	L	45.0	22.0	48.0	71.0	68.0	59.6	116.0	90.0	32.0
10	L	27.0	55.0	20.0	11.0	11.2	16.6	112.0	39.0	19.0
43	L	111.0	126.0	44.0	60.6	58.2	42.4	230.0	150.0	77.0
44	L	6.0	6.0	12.0	25.4	21.2	40.0	28.0	32.0	15.0

[z] D = depression; L = lower slope; M = mid slope; U = upper slope.

Table A4.2. Extractable soil nitrate N data for the Grande Prairie Creek (GPC) watershed.

Sample site	Landform position[z]	Fall 2002			Fall 2003			Fall 2004		
		0 to 2.5 cm	2.5 to 5 cm	5 to 15 cm	0 to 2.5 cm	2.5 to 5 cm	5 to 15 cm	0 to 2.5 cm	2.5 to 5 cm	5 to 15 cm
		--------- mg kg^{-1} ---------			--------- mg kg^{-1} ---------			--------- mg kg^{-1} ---------		
1	L	19.3	24.2	10.3	26.0	12.1	3.1	3.0	2.4	5.4
4	M	1.5	0.5	0.5	0.2	0.2	0.2	2.4	2.2	1.8
5	M	33.6	39.0	24.8	26.0	37.7	28.4	3.4	12.0	7.4
6	M	10.7	22.6	17.2	7.3	11.9	9.2	3.0	10.0	12.0
7	M	38.8	32.3	8.7	28.9	38.4	13.4	3.0	2.4	2.0
9	L	51.5	40.5	14.6	0.9	0.2	0.2	2.8	1.6	1.2
10	M	42.8	29.3	6.6	29.8	33.3	20.7	2.8	4.0	2.6
11	M	20.2	20.9	9.1	21.1	19.0	19.0	2.2	2.6	2.4
12	M	0.5	0.5	0.5	5.1	1.7	0.5	2.0	1.6	1.6
13	M	40.3	25.8	10.6	35.7	21.8	4.3	6.8	7.8	6.6
15	L	53.2	56.1	11.9	26.5	12.9	6.1	3.0	2.6	4.8
16	L	47.2	29.6	8.1	61.5	66.1	21.9	2.4	3.2	4.4
17	L	31.2	26.3	9.8	122.0	56.1	35.4	2.8	2.4	3.0
18	M	58.7	53.3	25.3	32.1	24.8	12.4	2.4	4.0	4.4
21	U	39.5	31.5	9.3	28.2	34.9	25.5	5.8	6.0	6.8
22	M	49.5	27.1	8.5	41.5	32.5	19.0	2.8	6.4	4.6
23	U	24.6	27.6	14.9	20.2	20.7	12.6	2.6	10.6	9.4
24	U	24.5	25.5	10.2	30.4	36.4	14.6	4.2	9.4	6.6
26	M	24.7	31.1	27.5	46.1	43.2	17.9	26.0	25.8	14.4
27	M	61.0	69.4	42.5	90.8	55.9	26.2	50.4	38.6	16.4
28	M	11.9	11.2	9.5	40.1	32.3	15.5	4.6	3.8	3.0
30	M	15.2	28.0	16.5	28.2	29.8	13.9	2.0	6.2	6.4
31	M	ns[y]	ns	ns	17.2	13.6	8.3	4.0	6.6	4.8
32	D	ns	ns	ns	3.2	1.4	0.2	3.4	3.4	2.2
33	U	ns	ns	ns	29.8	13.6	6.3	3.2	6.0	4.2
34	U	ns	ns	ns	61.4	62.7	21.8	13.2	16.8	13.2
35	M	ns	ns	ns	113.0	88.2	35.7	23.8	17.0	14.8
36	M	ns	ns	ns	35.2	25.0	12.4	2.4	3.0	4.2
		Spring 2003			**Spring 2004**			**Spring 2005**		
		0 to 2.5 cm	2.5 to 5 cm	5 to 15 cm	0 to 2.5 cm	2.5 to 5 cm	5 to 15 cm	0 to 2.5 cm	2.5 to 5 cm	5 to 15 cm
		--------- mg kg^{-1} ---------			--------- mg kg^{-1} ---------			--------- mg kg^{-1} ---------		
1	L	49.0	26.0	7.0	31.6	31.6	18.6	52.0	23.0	17.0
4	M	40.0	18.0	8.0	3.4	1.4	1.2	20.0	14.0	23.0
6	M	45.0	39.0	27.0	ns[y]	ns	ns	ns	ns	ns
9	L	139.0	50.0	26.0	58.2	25.4	12.8	26.0	35.0	52.0
12	M	108.0	51.0	18.0	46.4	28.0	15.2	11.0	28.0	40.0

[z] D = depression; L = lower slope; M = mid slope; U = upper slope.
[y] not sampled.

Table A4.3. Extractable soil nitrate N data for the Lower Little Bow River (LLB) watershed.

		Fall 2002			Fall 2003			Fall 2004		
Sample site	Landform position[z]	0 to 2.5 cm	2.5 to 5 cm	5 to 15 cm	0 to 2.5 cm	2.5 to 5 cm	5 to 15 cm	0 to 2.5 cm	2.5 to 5 cm	5 to 15 cm
		--------- mg kg^{-1} ---------			--------- mg kg^{-1} ---------			--------- mg kg^{-1} ---------		
1	L	18.8	17.6	8.0	11.6	15.3	23.0	40.0	54.7	68.7
2	L	28.6	25.5	22.8	15.1	27.2	21.9	22.0	20.7	22.7
3	M	52.6	49.9	40.4	15.5	35.0	35.4	72.0	76.7	60.3
4	L	33.9	40.1	17.5	19.4	17.5	29.8	38.7	43.0	38.0
5	L	40.6	40.6	31.7	13.4	19.9	22.1	98.3	92.3	69.3
6	L	22.1	11.2	7.9	10.2	8.5	5.8	15.7	9.7	6.7
7	M	80.0	84.0	54.7	26.0	31.5	29.2	48.7	47.0	55.0
8	M	45.4	31.9	24.2	9.2	11.2	16.2	74.0	84.0	143.0
9	M	23.6	37.9	38.3	21.3	27.4	41.7	25.3	25.3	14.7
10	U	35.2	66.2	32.3	20.2	26.9	48.1	49.0	45.3	26.3
11	M	50.4	45.8	32.3	29.4	26.4	29.8	11.3	13.3	10.7
12	M	47.0	55.2	53.5	12.8	28.7	57.8	52.3	53.0	36.7
13	M	63.7	61.1	38.1	32.0	55.4	66.6	61.3	59.3	48.7
14	D	51.9	37.4	27.9	21.9	32.6	48.1	58.3	63.3	51.7
15	M	34.4	38.4	28.9	27.2	31.6	33.8	12.7	10.0	4.2
16	U	64.0	61.9	39.9	23.8	44.2	38.9	35.6	39.2	35.4
17	M	72.5	71.2	47.2	13.6	23.8	34.5	28.6	56.2	45.0
18	U	54.4	49.8	32.1	19.2	35.5	30.9	17.6	17.4	19.6
19	U	35.1	42.4	31.1	15.0	19.6	19.7	17.8	17.0	14.0
20	L	26.2	26.5	19.6	16.0	24.7	29.6	26.8	26.4	20.4
21	L	37.5	30.6	20.3	28.1	41.5	43.7	14.6	14.0	20.0
22	U	101.0	94.0	64.2	30.8	35.2	51.7	46.0	51.0	59.4
23	M	82.0	83.0	54.7	27.4	46.1	39.8	57.0	93.2	67.2
24	M	9.3	8.3	56.0	29.2	51.7	65.8	49.6	53.6	58.6
25	M	59.7	35.1	0.5	27.7	66.8	91.5	30.6	39.2	44.6
26	L	45.4	41.2	28.7	32.5	39.6	67.3	25.4	33.4	39.0
27	U	33.1	33.1	28.2	23.3	28.2	28.1	8.0	6.8	4.8
28	M	18.7	25.7	20.1	31.5	45.1	39.8	9.4	8.4	6.8
29	U	37.5	43.1	26.0	22.3	23.0	33.2	18.6	20.2	16.0
30	M	35.1	38.3	25.9	33.3	33.3	33.5	8.2	15.0	14.0
31	M	45.8	35.4	20.3	15.6	31.8	48.8	25.8	20.6	17.2
32	M	24.2	29.9	24.7	27.4	32.6	56.8	11.0	8.4	4.0
33	M	23.5	31.2	34.5	17.7	31.5	32.0	22.0	21.0	14.2
34	U	22.8	22.7	24.4	24.5	42.5	40.6	17.6	22.4	12.6
35	M	24.8	25.7	27.6	21.6	31.6	44.9	12.6	20.2	10.2
36	U	39.6	45.8	23.2	24.0	30.8	31.1	21.0	22.6	11.8
37	M	71.2	76.5	56.0	17.3	29.6	76.2	40.4	49.0	45.6
38	U	44.7	54.2	43.1	26.4	38.3	40.0	26.2	24.2	17.6
39	M	36.1	39.7	29.4	18.7	29.9	39.6	23.0	21.8	15.4
40	M	24.2	27.9	26.0	18.7	23.3	20.2	8.2	8.0	5.8
41	U	51.4	53.4	32.2	25.0	51.7	50.8	24.0	19.6	10.2
42	M	29.5	34.4	25.1	24.7	41.3	28.4	13.4	11.2	7.2
43	M	42.6	43.6	29.0	46.1	73.4	68.0	47.4	47.2	44.4
44	U	57.7	18.5	6.0	27.7	27.9	17.7	12.6	5.2	4.0
45	M	40.3	20.6	7.2	27.5	21.3	12.2	10.8	7.0	4.8

Table A4.3. Extractable soil nitrate N data for the Lower Little Bow River (LLB) watershed. (continued)

Sample site	Landform position[z]	Spring 2003			Spring 2004			Spring 2005		
		0 to 2.5 cm	2.5 to 5 cm	5 to 15 cm	0 to 2.5 cm	2.5 to 5 cm	5 to 15 cm	0 to 2.5 cm	2.5 to 5 cm	5 to 15 cm
		--------- mg kg^{-1} ---------			--------- mg kg^{-1} ---------			--------- mg kg^{-1} ---------		
1	L	21.0	14.0	12.0	54.0	52.6	102.0	67.0	99.0	107.0
2	L	75.0	34.0	30.0	49.2	55.2	86.2	80.0	74.0	36.0
3	M	27.0	22.0	28.0	61.0	56.6	105.0	99.0	105.0	79.0
4	L	48.0	20.0	18.0	90.4	81.0	104.0	24.0	19.0	9.0
6	L	8.0	10.0	4.0	70.0	53.8	53.2	18.0	10.0	5.0
7	M	30.0	39.0	42.0	69.0	73.8	75.6	125.0	176.0	103.0
8	M	52.0	18.0	8.0	88.6	63.4	87.2	93.0	106.0	71.0
20	L	36.0	24.0	17.0	20.2	17.8	38.6	24.0	22.0	23.0
21	L	91.0	54.0	49.0	55.0	56.6	85.4	23.0	22.0	24.0

[z] D = depression; L = lower slope; M = mid slope; U = upper slope.

Table A4.4. Extractable soil nitrate N data for the Ponoka (PON) watershed.

Sample site	Landform position[z]	Fall 2002 0 to 2.5 cm	Fall 2002 2.5 to 5 cm	Fall 2002 5 to 15 cm	Fall 2003 0 to 2.5 cm	Fall 2003 2.5 to 5 cm	Fall 2003 5 to 15 cm	Fall 2004 0 to 2.5 cm	Fall 2004 2.5 to 5 cm	Fall 2004 5 to 15 cm
		--------- mg kg^{-1} ---------			--------- mg kg^{-1} ---------			--------- mg kg^{-1} ---------		
1	D	6.9	6.3	51.0	130.0	95.0	60.5	51.8	59.2	52.8
2	L	33.0	116.0	180.0	145.0	120.0	128.0	167.0	111.0	46.2
3	L	47.0	157.0	212.0	142.0	120.0	62.6	151.0	120.0	66.0
4	M	3.7	8.0	183.0	309.0	288.0	243.0	56.8	45.8	50.6
5	U	51.0	110.0	236.0	170.0	163.0	79.2	43.4	35.6	43.0
6	M	1.8	120.0	318.0	230.0	305.0	297.0	33.6	49.2	85.4
7	M	170.0	229.0	282.0	144.0	121.0	87.7	132.0	104.0	93.8
8	L	33.0	189.0	256.0	148.0	120.0	64.6	83.4	78.4	76.0
9	U	60.0	77.0	21.0	202.0	178.0	117.0	57.6	38.6	62.8
10	U	217.0	150.0	301.0	155.0	124.0	48.5	77.2	88.8	50.2
11	M	133.0	209.0	220.0	147.0	136.0	86.5	38.0	99.6	98.6
12	L	5.3	176.0	213.0	255.0	205.0	135.0	61.2	60.2	62.4
13	M	19.6	129.0	218.0	100.0	57.6	98.3	111.0	86.6	59.6
14	M	10.6	78.0	210.0	214.0	207.0	162.0	46.2	47.8	59.0
15	L	27.0	146.0	325.0	314.0	301.0	192.0	92.2	80.4	75.0
16	M	9.2	12.9	80.0	266.0	291.0	254.0	122.0	76.8	58.0
17	U	114.0	163.0	175.0	52.9	40.3	30.6	53.2	53.6	44.8
18	U	5.0	117.0	127.0	265.0	227.0	154.0	42.4	41.0	50.6
19	M	57.0	167.0	226.0	176.0	212.0	108.0	108.0	76.0	55.6
20	U	20.7	98.0	210.0	173.0	176.0	116.0	39.6	39.8	39.6
21	L	24.5	73.0	210.0	67.3	76.0	34.7	216.0	134.0	52.8
22	M	105.0	75.0	201.0	205.0	193.0	262.0	59.8	59.4	59.0

Sample site	Landform position[z]	Spring 2003 0 to 2.5 cm	Spring 2003 2.5 to 5 cm	Spring 2003 5 to 15 cm	Spring 2004 0 to 2.5 cm	Spring 2004 2.5 to 5 cm	Spring 2004 5 to 15 cm	Spring 2005 0 to 2.5 cm	Spring 2005 2.5 to 5 cm	Spring 2005 5 to 15 cm
		--------- mg kg^{-1} ---------			--------- mg kg^{-1} ---------			--------- mg kg^{-1} ---------		
1	D	32.0	42.0	42.0	142.0	69.8	66.0	116.0	84.0	46.0
2	L	44.0	17.0	75.0	56.4	32.2	24.6	316.0	210.0	123.0
3	L	25.0	17.0	26.0	175.0	60.6	63.8	174.0	133.0	104.0
6	M	57.0	100.0	110.0	77.6	54.2	39.0	152.0	138.0	121.0
15	L	110.0	67.0	73.0	184.0	59.2	45.0	228.0	219.0	146.0
21	L	47.0	32.0	57.0	55.0	38.4	35.2	190.0	168.0	134.0

[z] D = depression; L = lower slope; M = mid slope; U = upper slope.

Table A4.5. Extractable soil nitrate N data for the Renrick Creek (REN) watershed.

Sample site	Landform position[z]	Fall 2002			Fall 2003			Fall 2004		
		0 to 2.5 cm	2.5 to 5 cm	5 to 15 cm	0 to 2.5 cm	2.5 to 5 cm	5 to 15 cm	0 to 2.5 cm	2.5 to 5 cm	5 to 15 cm
		--------- mg kg^{-1} ---------			--------- mg kg^{-1} ---------			--------- mg kg^{-1} ---------		
1	M	9.3	9.2	39.3	6.0	5.1	4.3	24.7	16.7	9.3
2	L	31.7	12.3	7.0	6.5	2.6	2.9	28.3	43.0	56.0
3	L	9.9	10.0	27.5	13.4	12.4	8.0	33.7	19.0	12.0
4	L	8.2	4.3	1.9	6.8	4.6	2.9	19.0	13.0	7.0
5	L	3.8	3.2	1.3	4.9	3.2	2.2	9.0	11.3	5.3
6	L	4.0	2.8	1.7	3.2	2.6	1.9	25.3	41.3	90.3
7	M	4.3	3.3	2.0	3.4	7.0	2.9	11.7	12.0	5.7
8	L	7.2	5.0	2.6	3.1	4.4	2.7	26.3	19.0	8.7
9	L	13.2	14.0	7.7	ns[y]	6.0	8.8	21.3	13.0	8.7
10	L	5.3	4.0	2.8	2.0	4.4	4.8	8.0	6.0	5.0
11	L	6.0	4.9	3.5	2.4	3.1	3.1	7.7	5.3	4.0
12	D	7.0	6.8	4.4	4.6	6.5	3.4	16.7	14.7	10.3
13	M	6.3	5.0	4.1	4.4	4.6	2.4	10.3	9.7	6.7
14	U	5.6	3.2	2.8	4.8	4.1	2.4	9.7	10.0	6.3
15	M	10.7	4.3	2.7	3.7	2.7	2.0	18.3	8.0	6.0
16	U	5.9	3.0	13.5	2.0	1.5	1.9	14.3	11.0	10.3
17	M	8.2	6.0	3.1	4.8	3.7	2.2	16.0	14.3	8.0
18	U	4.7	5.0	5.5	2.4	2.7	2.2	14.3	11.3	3.7
19	M	9.3	11.9	14.8	0.5	3.9	6.5	4.7	5.0	4.0
20	U	38.5	47.6	55.2	1.0	2.9	4.4	9.7	9.0	5.3
21	M	4.8	4.9	11.7	3.1	4.4	4.1	5.0	3.7	2.7
22	U	2.5	3.6	1.6	1.4	2.2	2.7	8.0	9.7	4.7
23	M	4.7	4.5	2.3	2.4	8.8	5.8	5.0	4.3	3.7
24	U	4.1	3.1	1.6	2.7	6.0	3.9	6.7	5.7	4.0
25	L	12.5	9.6	12.3	7.5	8.5	3.7	9.3	8.7	4.3
26	M	5.2	11.2	20.0	8.2	10.7	8.2	4.3	3.0	2.7
27	L	73.9	63.7	29.9	25.5	22.1	22.8	19.0	11.3	20.7
28	U	7.4	8.8	24.9	3.7	8.8	7.3	15.7	9.7	6.0
		Spring 2003			Spring 2004			Spring 2005		
		0 to 2.5 cm	2.5 to 5 cm	5 to 15 cm	0 to 2.5 cm	2.5 to 5 cm	5 to 15 cm	0 to 2.5 cm	2.5 to 5 cm	5 to 15 cm
		--------- mg kg^{-1} ---------			--------- mg kg^{-1} ---------			--------- mg kg^{-1} ---------		
1	M	20.0	29.0	10.0	45.4	51.0	32.6	51.0	47.0	17.0
3	L	22.0	34.0	11.0	53.8	45.6	22.8	69.0	37.0	18.0
4	L	13.0	28.0	12.0	31.4	40.6	13.4	47.0	48.0	19.0
5	L	18.0	24.0	9.0	26.8	47.2	27.2	47.0	36.0	14.0
6	L	12.0	18.0	7.0	25.8	40.0	26.0	33.0	42.0	40.0
27	L	17.0	21.0	5.0	50.6	94.2	47.4	28.0	50.0	21.0

[z] D = depression; L = lower slope; M = mid slope; U = upper slope.
[y] not analyzed.

Table A4.6. Extractable soil nitrate N data for the Stavely (STV) watershed.[z]										
		Fall 2002			Fall 2003			Fall 2004		
Sample site	Landform position[y]	0 to 2.5 cm	2.5 to 5 cm	5 to 15 cm	0 to 2.5 cm	2.5 to 5 cm	5 to 15 cm	0 to 2.5 cm	2.5 to 5 cm	5 to 15 cm
		--------- mg kg^{-1} ---------			--------- mg kg^{-1} ---------			--------- mg kg^{-1} ---------		
1	U	4.1	3.6	2.8	1.9	0.9	1.2	8.0	6.4	5.8
2	M	4.3	2.8	1.7	6.5	1.2	1.2	9.4	6.8	5.2
3	L	3.8	2.0	1.2	1.4	2.2	1.4	4.2	4.8	3.8

[z] The STV site was not sampled in the spring of 2003, 2004, and 2005.
[y] D = depression; L = lower slope; M = mid slope; U = upper slope.

Table A4.7. Extractable soil nitrate N data for the Threehills Creek (THC) watershed.

Sample site	Landform position[z]	Fall 2002			Fall 2003			Fall 2004		
		0 to 2.5 cm	2.5 to 5 cm	5 to 15 cm	0 to 2.5 cm	2.5 to 5 cm	5 to 15 cm	0 to 2.5 cm	2.5 to 5 cm	5 to 15 cm
		--------- mg kg^{-1} ---------			--------- mg kg^{-1} ---------			--------- mg kg^{-1} ---------		
1	D	29.2	26.5	34.5	18.5	24.7	26.2	96.3	67.7	45.0
3	L	10.8	11.0	5.4	7.7	9.2	8.2	50.0	34.3	24.0
4	L	7.1	8.6	6.9	5.8	6.5	6.3	73.0	46.7	29.7
6	L	5.4	4.8	3.4	6.8	11.2	8.5	79.0	36.7	30.0
7	L	23.0	22.7	8.6	9.4	9.9	9.5	80.7	62.3	29.3
8	L	7.1	12.8	12.3	7.3	8.3	9.2	51.7	39.7	28.7
9	L	2.5	2.3	2.2	4.1	6.6	5.8	69.3	45.7	34.3
10	M	4.4	5.8	2.9	10.0	10.9	9.5	74.3	48.7	33.7
11	M	4.9	4.2	2.9	4.8	7.3	5.8	51.0	30.7	18.7
12	L	6.1	7.5	2.8	7.3	9.2	8.5	99.7	58.7	50.3
13	M	2.2	1.7	1.1	8.2	8.3	4.6	51.3	31.7	22.3
14	U	3.8	3.8	2.1	4.6	3.7	3.7	54.0	43.0	17.3
15	M	9.3	7.1	3.3	5.1	6.1	8.2	68.0	46.0	24.3
16	U	3.5	1.4	0.5	8.8	7.8	7.7	63.0	31.3	20.0
17	M	2.2	2.6	1.3	5.8	6.0	6.6	40.0	28.0	17.0
18	U	5.4	4.5	2.2	6.5	6.8	9.9	54.0	39.7	30.3
19	M	5.0	11.6	8.2	5.1	3.9	1.4	18.0	14.3	10.0
20	U	3.7	1.8	0.5	3.6	4.1	2.6	30.3	27.7	13.7
21	M	7.2	4.5	1.6	9.0	8.7	6.8	54.0	40.7	27.7
22	M	11.9	3.3	1.1	7.0	6.1	6.0	49.3	40.3	28.7
23	M	3.3	5.3	3.0	4.4	7.7	5.3	29.3	23.0	17.3
24	U	1.9	2.7	2.0	7.3	7.0	4.9	27.7	23.3	11.3
25	L	8.0	9.0	4.0	9.5	13.4	9.9	59.7	37.7	30.7
26	L	6.5	6.4	6.0	7.0	6.6	4.6	34.0	25.0	17.3
27	M	3.6	2.8	0.5	7.3	9.9	8.7	85.7	58.7	26.7
28	M	5.2	3.8	1.7	6.5	8.0	5.6	38.3	30.3	20.0
29	L	5.5	10.5	5.6	4.8	7.0	6.6	49.3	34.7	17.7
		Spring 2003			Spring 2004			Spring 2005		
		0 to 2.5 cm	2.5 to 5 cm	5 to 15 cm	0 to 2.5 cm	2.5 to 5 cm	5 to 15 cm	0 to 2.5 cm	2.5 to 5 cm	5 to 15 cm
		--------- mg kg^{-1} ---------			--------- mg kg^{-1} ---------			--------- mg kg^{-1} ---------		
1	D	15.0	17.0	10.0	15.4	20.0	64.4	10.0	8.0	36.0
3	L	12.0	13.0	12.0	13.8	13.4	31.4	13.0	12.0	13.0
4	L	8.0	17.0	20.0	17.0	16.0	29.6	22.0	20.0	11.0
6	L	16.0	19.0	13.0	8.4	10.6	23.4	8.0	11.0	11.0
8	L	6.0	9.0	7.0	13.2	11.0	31.6	9.0	14.0	10.0
26	L	24.0	24.0	5.0	8.8	11.4	29.6	5.0	10.0	17.0

[z] D = depression; L = lower slope; M = mid slope; U = upper slope.

Table A4.8. Extractable soil nitrate N data for the Wabash Creek (THC) watershed.

Sample site	Landform position[z]	Fall 2002 0 to 2.5 cm	Fall 2002 2.5 to 5 cm	Fall 2002 5 to 15 cm	Fall 2003 0 to 2.5 cm	Fall 2003 2.5 to 5 cm	Fall 2003 5 to 15 cm	Fall 2004 0 to 2.5 cm	Fall 2004 2.5 to 5 cm	Fall 2004 5 to 15 cm
		--------- mg kg^{-1} ---------			--------- mg kg^{-1} ---------			--------- mg kg^{-1} ---------		
1	L	10.0	14.0	11.9	7.3	6.8	5.1	3.4	5.6	26.4
2	D	26.7	29.1	27.9	28.2	26.4	22.3	28.6	69.2	49.4
3	L	20.1	16.1	10.5	14.5	12.2	23.1	11.0	14.8	39.8
4	L	6.3	9.0	8.1	17.5	16.8	12.6	7.6	7.2	8.8
5	L	6.2	7.8	9.1	10.4	7.7	13.3	4.0	8.0	13.2
6	M	17.7	20.3	15.2	6.6	8.3	5.4	2.4	5.0	10.0
7	L	8.5	6.7	8.4	6.3	7.5	10.5	3.0	6.2	9.6
8	M	7.4	8.0	6.3	9.9	8.5	12.6	4.8	4.8	9.6
9	M	4.9	4.6	4.9	6.6	8.3	13.1	4.0	3.6	5.8
10	M	11.9	8.5	10.1	8.2	7.3	11.9	3.8	3.8	6.2
11	M	27.3	35.5	36.0	10.7	9.7	13.1	3.4	6.8	15.4
12	M	56.7	86.4	64.1	7.0	4.9	6.8	3.8	8.8	23.4
13	M	8.1	11.5	7.1	7.8	11.9	6.3	6.6	6.6	9.0
14	L	14.9	15.1	10.2	9.0	9.5	7.1	2.6	8.4	16.4
15	M	6.0	5.6	5.6	8.8	11.1	8.5	7.0	6.4	9.2
16	M	4.1	4.4	4.0	8.8	10.9	8.3	4.6	6.6	8.2
17	M	5.1	4.8	6.4	8.8	9.2	7.3	4.4	6.4	9.0
18	U	8.5	13.7	23.0	6.0	6.3	6.6	6.0	10.4	8.2
19	M	2.7	2.8	3.9	8.0	8.0	5.6	3.4	7.2	9.8
20	U	8.3	5.8	6.1	8.8	7.7	8.3	9.8	14.0	11.0
21	M	5.9	5.5	4.5	5.1	5.3	6.8	5.2	7.0	8.6
22	U	6.0	5.5	5.2	8.3	11.2	8.2	4.4	5.4	13.2
23	M	6.5	5.4	10.5	4.9	5.6	6.5	5.6	7.4	8.2
24	U	15.9	27.6	31.0	4.8	5.8	5.3	4.4	6.6	9.0
25	L	6.3	4.9	6.0	4.1	4.6	5.6	3.8	4.8	7.2
26	M	3.9	5.3	6.1	5.8	6.6	6.5	2.6	4.8	8.4
27	L	41.1	52.6	46.1	11.9	11.6	12.4	5.4	7.2	8.6

		Spring 2003 0 to 2.5 cm	Spring 2003 2.5 to 5 cm	Spring 2003 5 to 15 cm	Spring 2004 0 to 2.5 cm	Spring 2004 2.5 to 5 cm	Spring 2004 5 to 15 cm	Spring 2005 0 to 2.5 cm	Spring 2005 2.5 to 5 cm	Spring 2005 5 to 15 cm
		--------- mg kg^{-1} ---------			--------- mg kg^{-1} ---------			--------- mg kg^{-1} ---------		
1	L	30.0	30.0	25.0	16.6	23.8	20.2	35.0	26.0	31.0
2	D	63.0	49.0	86.0	79.6	62.2	63.2	85.0	59.0	98.0
3	L	30.0	29.0	71.0	46.8	54.6	55.4	40.0	35.0	81.0
4	L	44.0	41.0	29.0	72.4	35.0	38.6	14.0	20.0	64.0
5	L	22.0	32.0	24.0	15.0	23.4	30.6	10.0	14.0	27.0
6	M	41.0	29.0	18.0	20.4	22.0	33.2	20.0	21.0	48.0

[z] D = depression; L = lower slope; M = mid slope; U = upper slope.

Appendix 5. Runoff N concentrations from the microwatershed sites.

Table A5.1. Runoff N concentrations from the Stavely (STV) site.

Site	Sample d/mo/yr h:m	NH_3-N (mg L^{-1})	NO_3-N (mg L^{-1})	NO_2-N (mg L^{-1})	Total N (mg L^{-1})
STV	13/03/03		0.255	0.004	1.279
STV	15/03/03	0.558	0.103	0.009	2.292
STV	16/03/03	0.673	0.068	0.011	2.399
STV	16/03/03	0.324	0.013	0.089	3.132
STV	18/03/04 14:32	0.025	0.0	0.025	0.425
STV	18/03/04 14:42	0.025	0.0	0.025	0.425
STV	08/06/05 11:30	0.030	0.0	0.030	0.625
STV	28/06/05 15:16	0.030	0.0	0.030	0.925

Table A5.2. Runoff N concentrations from the Crowfoot Creek (CFT) site.

Site	Sample d/mo/yr h:m	NH_3-N (mg L^{-1})	NO_3-N (mg L^{-1})	NO_2-N (mg L^{-1})	Total N (mg L^{-1})
CFT	14/03/03 13:17	1.470	3.282	0.148	8.54
CFT	14/03/03 22:18	1.170	1.233	0.047	4.32
CFT	15/03/03 04:18	1.200	1.350	0.050	4.25
CFT	15/03/03 09:18	1.230	1.288	0.052	4.22
CFT	15/03/03 18:19	0.433	0.695	0.025	2.21
CFT	16/03/03 03:20	0.537	0.737	0.023	3.00
CFT	16/03/03 15:35	0.424	1.072	0.028	3.82
CFT	16/03/03 23:06	0.406	1.042	0.028	2.89
CFT	17/03/03 02:06	0.371	1.121	0.029	2.56
CFT	17/03/03 11:52	0.284	1.141	0.029	2.68
CFT	17/03/03 19:22	0.181	0.991	0.029	2.74
CFT	18/03/03 02:53	0.222	1.342	0.038	4.70
CFT	18/03/03 13:38	0.268	1.871	0.069	4.87
CFT	18/03/03 18:09	0.184	1.287	0.053	3.89
CFT	19/03/03 01:39	0.003	1.947	0.053	4.61
CFT	19/03/03 09:40	0.003	1.913	0.057	6.64
CFT	19/03/03 18:40	0.003	1.846	0.064	5.49
CFT	20/03/03 03:41	0.165	1.935	0.065	5.79
CFT	20/03/03 10:11	0.126	1.794	0.056	4.70
CFT	20/03/03 13:27	0.195	2.260	0.060	5.61
CFT	20/03/03 20:57	0.524	2.492	0.108	5.47
CFT	21/03/03 04:28	0.467	2.129	0.081	5.16
CFT	21/03/03 07:28	0.138	1.890	0.060	5.08
CFT	21/03/03 10:28	0.154	2.243	0.047	5.84
CFT	21/03/03 12:58	0.175	2.003	0.097	5.13
CFT	21/03/03 21:59	0.058	2.751	0.149	6.17
CFT	22/03/03 05:30	0.069	2.524	0.156	5.79
CFT	22/03/03 07:30	0.060	2.801	0.089	5.99
CFT	22/03/03 10:30	0.107	2.474	0.066	5.20
CFT	22/03/03 13:01	0.168	1.916	0.124	4.75
CFT	22/03/03 22:01	0.097	1.994	0.096	4.90
CFT	23/03/03 05:31	0.064	2.129	0.051	5.15
CFT	23/03/03 07:17	0.062	2.139	0.051	3.76
CFT	23/03/03 10:17	0.062	1.954	0.046	5.24
CFT	23/03/03 12:32	0.085	2.110	0.050	4.49
CFT	23/03/03 20:02	0.088	1.352	0.048	3.44
CFT	24/03/03 02:03	0.105	1.536	0.064	3.89
CFT	24/03/03 11:34	0.079	0.629	0.034	2.25
CFT	24/03/03 17:34	0.065	0.872	0.038	2.89
CFT	24/03/03 23:34	0.078	1.120	0.050	3.36
CFT	25/03/03 12:20	0.098	0.150	0.031	1.59
CFT	09/03/04 15:15	1.010	1.800	0.050	4.85
CFT	09/03/04 19:45	1.200	1.690	0.060	4.55
CFT	10/03/04 01:46	1.270	1.760	0.060	4.72
CFT	10/03/04 13:03	1.300	1.640	0.100	4.74
CFT	10/03/04 19:03	1.230	1.540	0.080	4.52
CFT	11/03/04 01:04	1.200	1.580	0.090	4.67
CFT	11/03/04 12:05	1.160	1.500	0.070	4.47
CFT	11/03/04 19:06	0.750	1.400	0.140	5.14
CFT	12/03/04 02:37	0.650	1.380	0.140	4.62

Table A5.2. Runoff N concentrations from the Crowfoot Creek (CFT) site.

Site	Sample d/mo/yr h:m	NH_3-N (mg L^{-1})	NO_3-N (mg L^{-1})	NO_2-N (mg L^{-1})	Total N (mg L^{-1})
CFT	12/03/04 11:38	0.470	1.290	0.140	3.930
CFT	12/03/04 19:09	0.450	1.370	0.140	4.010
CFT	13/03/04 02:55	0.450	1.360	0.140	4.200
CFT	13/03/04 13:26	0.140	1.100	0.250	3.850
CFT	13/03/04 16:26	0.140	1.130	0.230	3.860
CFT	13/03/04 20:57	0.110	1.080	0.140	3.820
CFT	14/03/04 11:14	0.025	0.940	0.130	3.570
CFT	14/03/04 18:29	0.025	1.090	0.080	3.070
CFT	15/03/04 00:30	0.025	0.920	0.090	2.810
CFT	15/03/04 12:02	0.025	0.820	0.070	2.690
CFT	15/03/04 17:47	0.025	0.520	0.070	2.690
CFT	15/03/04 23:46	0.025	0.440	0.060	2.400
CFT	16/03/04 12:20	0.025	0.220	0.080	2.300
CFT	16/03/04 21:21	0.025	0.125	0.025	1.850
CFT	17/03/04 04:39	0.025	0.055	0.025	1.780
CFT	17/03/04 06:22	0.025	0.140	0.060	1.600
CFT	17/03/04 09:07	0.025	0.145	0.025	1.770
CFT	17/03/04 19:38	0.025	0.095	0.025	1.720
CFT	18/03/04 12:10	0.025	0.000	0.025	1.725
CFT	18/03/04 21:12	0.025	0.205	0.025	1.530
CFT	19/03/04 06:13	0.025	0.425	0.025	1.850
CFT	19/03/04 08:28		0.445	0.025	0.470
CFT	19/03/04 17:14		0.795	0.025	0.820
CFT	20/03/04 00:45		0.705	0.025	0.730
CFT	20/03/04 11:46	0.025	1.150	0.090	3.740
CFT	20/03/04 19:17	0.025	0.775	0.025	3.500
CFT	21/03/04 01:18	0.025	0.725	0.025	3.250
CFT	21/03/04 11:45	0.025	0.345	0.025	2.170
CFT	21/03/04 15:05	0.050	0.205	0.025	1.730
CFT	02/02/05 01:46	0.100	0.735	0.025	4.960
CFT	02/02/05 12:17	0.090	0.415	0.025	3.640
CFT	03/02/05 00:18	0.025	0.205	0.025	2.930
CFT	03/02/05 12:04	0.025	0.465	0.025	3.090
CFT	03/02/05 21:05	0.025	0.765	0.025	3.690
CFT	04/02/05 04:35	0.025	0.635	0.025	3.960
CFT	26/02/05 13:03	0.120	0.260	0.080	3.940
CFT	26/02/05 16:03	0.080	0.230	0.090	3.820
CFT	26/02/05 20:03	0.060	0.200	0.100	3.800
CFT	27/02/04 12:04	0.240	0.280	0.100	5.780
CFT	27/02/04 18:05	0.160	0.160	0.070	4.530
CFT	28/02/05 00:05	0.140	0.140	0.070	4.510
CFT	28/02/05 10:21	0.025	0.170	0.080	4.050
CFT	28/02/05 16:21	0.070	0.100	0.060	4.060
CFT	28/02/05 20:52	0.060	0.090	0.050	3.740
CFT	01/03/05 11:36	0.025	0.060	0.050	3.310
CFT	01/03/05 17:38	0.050	0.035	0.025	3.060
CFT	01/03/05 23:39	0.025	0.090	0.050	3.240
CFT	02/03/05 10:54	0.025	0.035	0.025	3.060
CFT	02/03/05 19:40	0.025	0.045	0.025	2.670
CFT	03/03/05 03:11	0.025	0.080	0.070	3.250

Table A5.2. Runoff N concentrations from the Crowfoot Creek (CFT) site.

Site	Sample d/mo/yr h:m	NH_3-N (mg L^{-1})	NO_3-N (mg L^{-1})	NO_2-N (mg L^{-1})	Total N (mg L^{-1})
CFT	03/03/05 11:11	0.025	0.000	0.025	3.125
CFT	03/03/05 17:12	0.025	0.000	0.025	2.625
CFT	04/03/05 00:42	0.050	0.035	0.025	2.260
CFT	04/03/05 11:28	0.025	0.000	0.025	2.925
CFT	04/03/05 18:58	0.025	0.000	0.025	2.225
CFT	05/03/05 02:29	0.025	0.000	0.025	2.525
CFT	05/03/05 10:00	0.025	0.000	0.025	2.525
CFT	05/03/05 21:30	0.025	0.035	0.025	2.160
CFT	06/03/05 06:31	0.025	0.000	0.025	2.425
CFT	06/03/05 08:16	0.070	0.000	0.025	2.325
CFT	06/03/05 15:47	0.025	0.110	0.050	2.160
CFT	06/03/05 23:17	0.025	0.055	0.025	1.780
CFT	07/03/05 13:33	0.025	0.140	0.050	2.090
CFT	07/03/05 19:34	0.025	0.120	0.080	1.900
CFT	08/03/05 01:34	0.025	0.120	0.050	1.970
CFT	08/03/05 10:05	0.025	0.050	0.060	2.010
CFT	08/03/05 19:05	0.025	0.000	0.025	1.725
CFT	09/03/05 05:36	0.025	0.000	0.025	1.525
CFT	09/03/05 08:21	0.080	0.000	0.025	1.825
CFT	09/03/05 17:22	0.090	0.000	0.025	1.925
CFT	10/03/05 11:23	0.025	0.000	0.025	1.725
CFT	10/03/05 12:23	0.120	0.000	0.025	1.625
CFT	10/03/05 22:54	0.025	0.000	0.025	1.625
CFT	11/03/05 09:25	0.025	0.000	0.025	1.425
CFT	11/03/05 11:25	0.110	0.070	0.050	1.820
CFT	11/03/05 20:32	0.060	0.000	0.025	2.025
CFT	12/03/05 07:03	0.025	0.000	0.025	1.425
CFT	27/03/05 12:43	0.080	0.000	0.025	0.525
CFT	27/03/05 21:46	0.090	0.000	0.025	0.525
CFT	28/03/05 06:46	0.080	0.000	0.025	0.525
CFT	28/03/05 17:55	0.070	0.000	0.025	2.825
CFT	28/03/05 23:56	0.025	0.000	0.025	2.125
CFT	29/03/05 05:56	0.025	0.000	0.025	2.625

Table A5.3. Runoff N concentrations from the Grande Prairie Creek (GPC) site.

Site	Sample d/mo/yr h:m	NH_3-N (mg L^{-1})	NO_3-N (mg L^{-1})	NO_2-N (mg L^{-1})	Total N (mg L^{-1})
GPC	14/04/03	0.179	2.344	0.006	4.500
GPC	14/04/03	0.144	2.105	0.005	4.340
GPC	14/04/03	0.141	3.133	0.007	5.570
GPC	14/04/03	0.136	2.716	0.024	4.840
GPC	15/04/03	0.112	2.557	0.023	4.690
GPC	15/04/03	0.107	2.577	0.023	5.310
GPC	15/04/03	0.086	2.342	0.028	4.630
GPC	15/04/03	0.057	1.412	0.018	2.790
GPC	16/04/03	0.003	1.451	0.019	2.730
GPC	16/04/03	0.014	1.434	0.016	2.880
GPC	16/04/03	0.065	0.948	0.021	3.469
GPC	17/04/03	0.021	0.961	0.017	2.508
GPC	17/04/03	0.007	0.658	0.010	2.438
GPC	17/04/03	0.068	0.589	0.003	2.412
GPC	18/04/03	0.039	0.472	0.005	1.937
GPC	18/04/03	0.076	0.726	0.006	2.332
GPC	19/04/03	0.101	0.713	0.007	1.920
GPC	19/04/03	0.054	0.701	0.006	1.947
GPC	19/04/03	0.092	0.587	0.013	2.230
GPC	20/04/03	0.082	0.730	0.003	1.923
GPC	20/04/03	0.115	0.827	0.016	2.233
GPC	20/04/03	0.105	0.471	0.008	2.089
GPC	21/04/03	0.124	0.786	0.004	2.430
GPC	21/04/03	0.103	0.899	0.012	2.561
GPC	21/04/03	0.131	0.811	0.006	2.687
GPC	22/04/03	0.142	1.552	0.008	3.650
GPC	22/04/03	0.175	1.714	0.016	3.560
GPC	22/04/03	0.164	2.317	0.053	5.400
GPC	23/04/03	0.200	1.982	0.028	5.100
GPC	23/04/03	0.162	1.984	0.036	4.610
GPC	23/04/03	0.179	0.926	0.144	4.280
GPC	24/04/03	0.132	0.204	0.015	2.799
GPC	24/04/03	0.279	0.249	0.038	2.577
GPC	24/04/03	0.272	0.186	0.041	2.957
GPC	25/04/03	0.284	0.163	0.029	2.962
GPC	28/04/03	0.029	0.085	0.009	2.194
GPC	28/04/03	0.003	0	0.018	1.549
GPC	29/04/03	0.056	0	0.003	1.583
GPC	29/04/03	0.003	0.062	0.018	1.790
GPC	29/04/03	0.009	0	0.007	1.793
GPC	30/04/03	0.003		0.004	
GPC	30/04/03	0.036	0.025	0.014	1.849
GPC	30/04/03	0.012	0	0.005	2.093
GPC	30/04/03	0.010	0	0.006	2.103
GPC	4/5/04 0:08	0.110	7.880	0.040	10.720
GPC	4/5/04 8:02	0.120	7.470	0.040	10.810
GPC	4/5/04 12:08	0.120	1.950	0.040	3.890
GPC	4/5/04 18:08	0.120	6.580	0.040	9.320
GPC	4/5/04 19:16	0.110	2.480	0.040	4.020
GPC	4/6/04 6:40	0.300	12.260	0.040	17.000

Table A5.3. Runoff N concentrations from the Grande Prairie Creek (GPC) site.

Site	Sample d/mo/yr h:m	NH_3-N (mg L^{-1})	NO_3-N (mg L^{-1})	NO_2-N (mg L^{-1})	Total N (mg L^{-1})
GPC	4/6/04 9:27	0.120	6.380	0.040	9.220
GPC	4/6/04 10:00	0.025	0.010	0.040	0.150
GPC	4/6/04 16:49	0.210	8.610	0.040	12.650
GPC	4/7/04 6:29	0.160	1.990	0.040	3.930
GPC	4/7/04 8:56	0.990	6.670	0.040	11.210
GPC	4/7/04 17:57	0.260	8.350	0.110	10.760
GPC	4/8/04 7:29	0.140	2.070	0.040	3.910
GPC	4/8/04 13:06	0.180	3.880	0.110	6.990
GPC	4/8/04 15:00	0.170	2.790	0.040	5.630
GPC	4/8/04 15:45	0.180	2.880	0.040	6.420
GPC	4/8/04 22:42	0.200	2.840	0.040	5.980
GPC	7/3/04 15:15	0.025	14.460	0.040	17.600
GPC	7/3/04 19:46	0.025	16.260	0.040	19.900
GPC	7/4/04 0:16	0.025	15.960	0.040	19.600
GPC	7/8/04 5:11	0.025	4.640	0.040	9.280
GPC	7/8/04 20:54	0.025	5.290	0.040	9.330
GPC	7/9/04 5:55	0.025	5.480	0.040	9.820
GPC	7/9/04 7:10	0.025	5.310	0.040	9.550
GPC	7/9/04 18:56	0.025	1.150	0.040	5.390
GPC	7/10/04 5:27	0.025	0.550	0.040	3.990
GPC	7/10/04 7:27	0.025	0.280	0.040	3.620
GPC	7/10/04 14:58	0.025	0.010	0.040	3.850
GPC	7/10/04 20:59	0.025	0.080	0.040	4.320
GPC	9/1/04 15:55	0.025	0.010	0.040	0.650
GPC	9/2/04 6:27	0.025	0.100	0.040	0.940
GPC	9/2/04 8:12	0.025	0.390	0.040	2.730
GPC	9/2/04 9:42	0.070	0.680	0.040	3.420
GPC	9/2/04 18:42	0.025	1.440	0.040	4.580
GPC	9/3/04 3:44	0.025	1.020	0.040	3.960
GPC	9/4/04 14:09	0.690	0.360	0.040	6.600
GPC	9/5/04 2:00	0.025	0.100	0.040	3.540
GPC	9/5/04 12:31	0.025	0.110	0.040	3.950
GPC	9/6/04 0:33	0.025	0.630	0.040	4.570
GPC	9/8/04 1:49	0.025	0.380	0.040	3.220
GPC	9/8/04 16:57	0.025	0.190	0.040	4.230
GPC	9/9/04 6:22	0.090	0.130	0.040	3.270
GPC	9/9/04 7:52	0.025	0.070	0.040	3.510
GPC	9/9/04 18:23	0.025	0.010	0.040	3.050
GPC	9/10/04 9:24	0.050	0.010	0.040	3.050
GPC	9/10/04 21:25	0.050	0.010	0.040	3.150
GPC	9/11/04 7:56	0.025	0.110	0.040	3.150
GPC	9/11/04 9:26	0.025	0.280	0.040	3.720
GPC	9/11/04 18:27	0.050	0.570	0.040	4.610
GPC	9/12/04 4:58	0.070	0.600	0.040	4.840
GPC	9/12/04 7:28	0.025	0.490	0.040	3.430
GPC	9/12/04 11:58	0.025	0.410	0.040	4.150
GPC	9/12/04 16:33	0.025	0.740	0.040	3.780
GPC	9/17/04 10:21	0.060	0.180	0.040	3.220
GPC	9/17/04 21:14	0.025	0.320	0.040	3.960
GPC	9/18/04 6:14	0.060	0.600	0.040	6.740

Table A5.3. Runoff N concentrations from the Grande Prairie Creek (GPC) site.

Site	Sample d/mo/yr h:m	NH_3-N (mg L^{-1})	NO_3-N (mg L^{-1})	NO_2-N (mg L^{-1})	Total N (mg L^{-1})
GPC	9/18/04 8:15	0.025	0.350	0.040	4.990
GPC	9/18/04 18:45	0.025	0.010	0.040	3.850
GPC	9/19/04 5:16	0.050	0.010	0.040	3.650
GPC	9/19/04 7:31	0.025	0.010	0.040	3.050
GPC	9/19/04 19:32	0.025	0.010	0.040	2.550
GPC	9/20/04 7:33	0.025	0.010	0.040	2.750
GPC	10/20/04 8:48	0.025	0.010	0.040	2.650
GPC	10/20/04 19:19	0.025	0.110	0.040	3.150
GPC	10/21/04 5:50	0.025	0.060	0.040	3.100
GPC	11/5/04 14:54	0.060	0.500	0.040	4.140
GPC	11/5/04 17:54	0.025	0.500	0.040	4.240
GPC	11/5/04 22:24	0.025	0.860	0.040	4.600
GPC	3/5/05 12:37	0.360	1.430	0.070	5.100
GPC	3/6/05 2:09	0.220	2.050	0.050	5.500
GPC	3/6/05 10:13	0.200	2.075	0.025	5.500
GPC	3/6/05 13:13	0.240	1.640	0.060	4.900
GPC	3/6/05 22:28	0.250	3.040	0.060	6.500
GPC	3/7/05 8:46	0.240	3.330	0.070	6.800
GPC	3/7/05 14:16	0.160	2.900	0.100	6.500
GPC	3/7/05 23:02	0.150	2.570	0.130	6.200
GPC	3/8/05 9:32	0.120	2.680	0.120	6.100
GPC	3/8/05 11:48	0.210	5.080	0.120	8.600
GPC	3/8/05 22:18	0.110	4.475	0.025	8.200
GPC	3/9/05 8:19	0.140	4.575	0.025	8.900
GPC	3/9/05 10:49	0.150	2.675	0.025	6.100
GPC	3/9/05 21:20	0.220	3.750	0.050	6.900
GPC	3/10/05 9:21	0.200	4.340	0.060	8.000
GPC	3/10/05 10:52	0.220	3.730	0.070	6.600
GPC	3/10/05 21:23	0.230	4.030	0.070	7.000
GPC	3/11/05 9:24	0.210	4.475	0.025	7.400
GPC	3/11/05 11:24	0.280	5.140	0.060	8.500
GPC	3/11/05 18:55	0.230	4.850	0.050	8.000
GPC	3/12/05 9:56	0.280	6.350	0.050	9.600
GPC	3/12/05 11:42	0.300	6.640	0.060	10.100
GPC	3/12/05 17:43	0.380	6.630	0.070	9.800
GPC	3/13/05 9:48	0.720	7.200	0.100	11.000
GPC	3/13/05 12:24	0.510	10.800	0.100	14.900
GPC	3/13/05 23:02	0.740	6.330	0.070	10.400
GPC	3/29/05 14:09	0.410	0.775	0.025	3.000
GPC	3/29/05 23:18	0.300	1.120	0.080	3.600
GPC	3/30/05 9:50	0.220	0.675	0.025	3.200
GPC	3/30/05 11:05	0.210	0.640	0.060	3.200
GPC	3/30/05 21:37	0.290	0.675	0.025	3.200
GPC	3/31/05 6:43	0.280	0.775	0.025	3.700
GPC	3/31/05 13:15	0.100	0.275	0.025	2.500
GPC	3/31/05 20:47	0.090	0.275	0.025	2.600
GPC	4/1/05 10:20	0.080	0.175	0.025	2.800
GPC	4/1/05 11:50	0.070	0.175	0.025	2.800
GPC	4/1/05 23:52	0.100	0.275	0.025	3.100
GPC	4/2/05 11:53	0.090	0.175	0.025	3.100

Table A5.4. Runoff N concentrations from the Lower Little Bow (LLB) site.

Site	Sample d/mo/yr h:m	NH_3-N (mg L^{-1})	NO_3-N (mg L^{-1})	NO_2-N (mg L^{-1})	Total N (mg L^{-1})
LLB	1/7/2003	1.280	6.143	0.367	10.180
LLB	2/10/2003	1.630	1.576	0.464	6.000
LLB	3/15/2003	1.090	21.501	0.699	31.750
LLB	3/15/2003	1.190	18.823	0.777	27.620
LLB	3/16/2003	0.917	32.230	1.170	41.890
LLB	3/16/2003	1.020	31.040	1.360	40.630
LLB	3/16/2003	1.060	24.700	1.300	33.320
LLB	3/16/2003	1.210	31.980	1.320	41.530
LLB	3/17/2003	0.742	34.680	1.320	43.920
LLB	3/17/2003	1.070	27.240	1.260	36.700
LLB	3/17/2003	1.040	22.900	1.100	31.320
LLB	3/17/2003	0.971	25.460	1.140	34.440
LLB	3/18/2003	0.804	30.656	0.844	37.040
LLB	3/18/2003	0.003	24.277	0.723	29.220
LLB	3/18/2003	0.003	21.240	0.760	27.820
LLB	3/19/2003	0.003	25.869	0.531	30.570
LLB	3/19/2003	0.836	19.384	0.716	27.820
LLB	3/19/2003	0.993	11.506	0.794	17.340
LLB	3/20/2003	1.190	13.585	0.715	23.110
LLB	3/20/2003	0.881	11.317	0.483	19.090
LLB	3/20/2003	1.130	7.205	0.685	16.500
LLB	3/21/2003	1.370	6.867	0.523	17.890
LLB	3/21/2003	1.060	5.736	0.754	14.470
LLB	3/21/2003	0.694	0.086	0.481	6.397
LLB	3/22/2003	0.629	3.091	0.429	9.290
LLB	4/26/2003	7.770	12.800	2.600	25.600
LLB	4/26/2003	10.800	22.100	4.900	39.000
LLB	4/26/2003	11.100	25.300	6.100	46.500
LLB	5/5/2003	0.204	9.379	0.121	15.110
LLB	5/5/2003	0.191	10.581	0.219	16.370
LLB	5/5/2003	0.195	15.869	0.431	22.840
LLB	5/6/2003	0.265	22.844	0.356	29.440
LLB	5/6/2003	0.471	16.790	1.410	24.590
LLB	5/6/2003	0.077	22.810	1.790	29.920
LLB	5/8/2003	0.194	16.490	0.210	22.560
LLB	5/8/2003	0.185	13.448	0.152	19.340
LLB	5/9/2003	0.174	10.918	0.082	16.540
LLB	5/9/2003	0.204	9.442	0.058	14.040
LLB	5/9/2003	0.259	18.332	0.268	25.040
LLB	5/10/2003	0.178	14.116	0.184	18.480
LLB	5/10/2003	0.171	15.439	0.161	21.430
LLB	5/10/2003	0.195	11.618	0.182	20.460
LLB	6/10/2003	0.297	11.000	0.100	14.430
LLB	6/10/2003	0.386	15.392	0.208	19.140
LLB	7/9/2003	0.667	6.095	0.705	17.600
LLB	7/10/2003	0.608	8.633	0.467	19.100
LLB	7/10/2003	0.437	6.721	0.279	13.600
LLB	7/12/2003	0.020	1.666	0.094	6.670
LLB	7/12/2003	0.070	4.886	0.114	9.320
LLB	7/12/2003	0.225	2.172	0.158	9.080

Table A5.4. Runoff N concentrations from the Lower Little Bow (LLB) site.

Site	Sample d/mo/yr h:m	NH_3-N (mg L^{-1})	NO_3-N (mg L^{-1})	NO_2-N (mg L^{-1})	Total N (mg L^{-1})
LLB	7/17/2003	0.256	3.038	3.140	12.020
LLB	7/18/2003	0.125	0.108	0.129	5.329
LLB	7/18/2003	0.242	0.075	0.080	5.220
LLB	7/19/2003	0.049	0.436	0.457	5.557
LLB	7/19/2003	0.059	1.333	1.390	5.930
LLB	7/20/2003	0.098	3.836	3.940	10.480
LLB	7/21/2003	0.077	0.056	0.078	5.878
LLB	7/21/2003	0.067	0.102	0.119	5.919
LLB	7/22/2003	0.082	3.217	3.340	9.230
LLB	7/22/2003	0.115	0.078	0.092	6.932
LLB	7/24/2003	0.024	0.227	0.259	5.229
LLB	7/24/2003	0.024	1.183	1.270	6.270
LLB	7/25/2003	0.027	1.704	1.830	7.530
LLB	7/25/2003	0.033	0.022	0.036	6.066
LLB	7/26/2003	0.029	0.117	0.130	5.710
LLB	7/27/2003	0.019	0.982	1.020	5.080
LLB	7/27/2003	0.020	1.926	1.960	5.280
LLB	8/9/2003	0.413	0.619	0.699	12.899
LLB	8/9/2003	0.336	0.794	0.823	5.213
LLB	8/10/2003	0.043	1.376	1.420	6.560
LLB	8/13/2003	0.055	0.099	0.112	3.162
LLB	8/13/2003	0.050	0.870	0.893	3.743
LLB	8/15/2003	0.084	0.025	0.050	4.250
LLB	8/15/2003	0.063	0.475	0.500	4.790
LLB	8/16/2003	0.060	0.675	0.700	3.800
LLB	8/16/2003	0.077	0.575	0.600	4.000
LLB	10/6/2003	0.054	6.275	6.300	11.510
LLB	10/6/2003	0.022	4.320	4.400	8.020
LLB	10/7/2003	0.034	1.175	1.200	4.120
LLB	10/7/2003	0.018	0.575	0.600	4.050
LLB	2/22/04 16:15	0.610	1.110	0.110	3.920
LLB	2/22/04 23:44	0.570	1.490	0.170	4.060
LLB	2/23/04 11:46	0.830	1.280	0.220	4.500
LLB	2/23/04 20:11	0.610	0.950	0.100	3.350
LLB	2/24/04 5:12	0.560	1.320	0.150	3.770
LLB	2/24/04 14:00	0.510	0.950	0.130	3.280
LLB	2/24/04 21:31	0.520	0.920	0.110	3.030
LLB	2/25/04 8:02	0.530	1.160	0.180	3.240
LLB	2/25/04 12:03	0.450	1.210	0.190	3.600
LLB	2/25/04 18:03	0.450	0.590	0.110	2.400
LLB	2/26/04 1:34	0.410	0.790	0.120	2.710
LLB	2/26/04 17:01	0.360	0.540	0.090	2.430
LLB	2/26/04 23:01	0.330	0.710	0.220	2.730
LLB	2/27/04 3:32	0.360	0.730	0.230	2.760
LLB	3/1/04 15:36	0.580	0.620	0.200	3.320
LLB	3/1/04 19:06	0.690	0.390	0.090	3.080
LLB	3/1/04 23:37	0.980	0.450	0.120	3.770
LLB	3/6/04 13:42	1.340	0.920	0.240	4.960
LLB	3/6/04 22:37	1.150	0.520	0.150	4.270
LLB	3/7/04 7:58	1.670	10.750	0.150	17.200

Table A5.4. Runoff N concentrations from the Lower Little Bow (LLB) site.

Site	Sample d/mo/yr h:m	NH_3-N (mg L^{-1})	NO_3-N (mg L^{-1})	NO_2-N (mg L^{-1})	Total N (mg L^{-1})
LLB	3/7/04 9:28	4.160	6.700	6.850	18.050
LLB	3/7/04 21:29	0.880	0.240	0.300	2.900
LLB	3/8/04 8:00	0.820	0.185	0.210	2.810
LLB	3/8/04 10:46	0.790	0.340	0.470	2.870
LLB	3/8/04 21:47	1.120	1.000	1.140	4.640
LLB	3/9/04 9:18	1.050	1.290	1.430	5.230
LLB	3/9/04 10:19	0.800	0.920	1.060	4.560
LLB	3/9/04 14:49	1.040	1.550	1.740	5.440
LLB	3/9/04 22:20	1.410	2.420	2.720	8.720
LLB	3/10/04 11:11	1.600	1.870	2.180	9.880
LLB	3/10/04 14:12	1.340	1.620	1.900	8.000
LLB	3/10/04 15:42	1.400	1.340	1.630	7.730
LLB	5/23/04 11:14	0.580	114.4	115.0	124.2
LLB	5/23/04 15:45	0.260	128.6	129.0	138.3
LLB	5/23/04 20:00	0.090	129.8	130.0	140.2
LLB	7/11/04 0:55	0.160	19.350	19.600	21.300
LLB	7/11/04 3:55	0.060	7.020	7.130	8.130
LLB	7/11/04 5:25	0.130	6.100	6.270	7.370
LLB	8/1/04 19:29	0.100	0.335	0.360	0.460
LLB	8/1/04 22:29	0.060	0.155	0.180	2.880
LLB	8/8/04 18:04	0.025	0.705	0.730	3.830
LLB	8/8/04 19:20	0.025	0.425	0.450	3.350
LLB	8/9/04 10:49	0.025	0.615	0.640	4.940
LLB	8/9/04 18:20	0.060	0.345	0.370	3.970
LLB	8/10/04 1:53	0.120	0.715	0.740	6.840
LLB	8/12/04 5:43	0.025	0.295	0.320	3.020
LLB	8/12/04 11:43	0.025	0.265	0.290	2.790
LLB	8/12/04 19:14	0.025	0.385	0.410	7.210
LLB	8/12/04 20:44	0.025	0.725	0.750	5.750
LLB	8/20/04 3:23	0.060	0.485	0.510	3.410
LLB	8/20/04 5:23	0.025	0.245	0.270	2.670
LLB	8/20/04 8:23	0.025	0.175	0.200	2.500
LLB	8/20/04 10:22	0.025	0.055	0.080	2.480
LLB	8/20/04 15:33	0.025	0.195	0.220	5.020
LLB	8/20/04 18:33	0.025	0.205	0.230	2.430
LLB	8/23/04 9:19	0.060	0.000	0.025	4.025
LLB	8/23/04 13:50	0.050	0.055	0.080	4.380
LLB	8/23/04 15:20	0.025	0.105	0.130	4.230
LLB	8/23/04 18:21	0.090	0.065	0.090	4.390
LLB	8/26/04 3:53	0.110	0.045	0.070	5.170
LLB	8/26/04 6:53	0.140	0.125	0.150	4.850
LLB	8/26/04 8:24	0.140	0.045	0.070	4.870
LLB	8/28/04 18:16	0.025	0.325	0.350	2.250
LLB	8/28/04 21:16	0.025	0.505	0.530	2.730
LLB	8/29/04 0:16	0.025	0.375	0.400	3.200
LLB	6/5/05 3:12	0.310	16.275	0.025	25.000
LLB	6/5/05 12:13	0.270	17.580	0.320	26.600
LLB	6/6/05 10:53	0.380	18.310	0.190	26.500
LLB	6/6/05 11:53	0.320	19.610	0.190	26.600
LLB	6/6/05 22:07	0.160	29.610	0.190	36.400

Table A5.4. Runoff N concentrations from the Lower Little Bow (LLB) site.

Site	Sample d/mo/yr h:m	NH_3-N (mg L^{-1})	NO_3-N (mg L^{-1})	NO_2-N (mg L^{-1})	Total N (mg L^{-1})
LLB	6/7/05 8:37	0.130	36.300	0.100	41.800
LLB	6/7/05 10:07	0.150	36.270	0.130	43.100
LLB	6/7/05 21:34	0.230	41.270	0.230	49.100
LLB	6/8/05 8:05	0.220	37.820	0.180	46.500
LLB	6/8/05 9:50	0.240	38.110	0.190	44.600
LLB	6/8/05 21:21	0.270	34.880	0.220	41.900
LLB	6/9/05 8:22	0.280	20.910	0.190	26.900
LLB	6/17/05 15:37	0.070	4.290	0.080	6.770
LLB	6/17/05 23:07	0.120	11.930	0.270	18.700
LLB	6/18/05 6:38	0.110	10.875	0.025	17.800
LLB	6/28/05 8:58	0.150	5.130	0.840	12.470
LLB	6/28/05 13:28	0.460	5.230	0.690	20.620
LLB	6/28/05 17:59	0.160	6.025	0.025	15.150
LLB	7/19/05 21:55	0.150	0.455	0.025	2.180
LLB	7/20/05 2:25	0.170	0.775	0.025	7.200
LLB	7/20/05 6:57	0.170	0.405	0.025	6.730
LLB	8/8/05 14:51	0.025	0.000	0.025	3.025
LLB	8/8/05 20:25	0.060	0.085	0.025	5.010
LLB	8/9/05 6:01	0.070	0.155	0.025	5.580
LLB	8/9/05 7:31	0.080	0.265	0.025	5.690
LLB	8/10/05 5:29	0.025	0.325	0.025	4.250
LLB	8/10/05 8:29	0.025	0.025	0.025	4.750
LLB	8/10/05 11:23	0.025	0.145	0.025	4.170
LLB	8/10/05 18:12	0.025	0.305	0.025	3.830
LLB	8/11/05 0:13	0.025	0.245	0.025	5.070
LLB	8/11/05 1:43	0.025	0.195	0.025	5.320
LLB	8/11/05 4:23	0.025	0.385	0.025	6.010
LLB	8/11/05 7:43	0.025	0.365	0.025	3.790
LLB	8/11/05 10:44	0.050	0.375	0.025	5.700
LLB	8/11/05 12:14	0.025	0.245	0.025	5.370
LLB	8/24/05 10:18	0.025	0.585	0.025	3.910

Table A5.5. Runoff N concentrations from the Ponoka (PON) site.

Site	Sample d/mo/yr h:m	NH_3-N (mg L^{-1})	NO_3-N (mg L^{-1})	NO_2-N (mg L^{-1})	Total N (mg L^{-1})
PON	4/1/2003	109.0	36.120	5.080	198.200
PON	4/1/2003	106.0	41.920	6.580	206.500
PON	4/7/2003	97.6	0.040	0.005	150.045
PON	4/8/2003	85.4	-0.002	0.005	113.003
PON	4/8/2003	48.5	0.011	0.039	65.150
PON	4/8/2003	45.8	0.052	0.005	4.797
PON	4/9/2003	40.7	0.802	0.072	69.874
PON	4/9/2003	54.1	0.320	0.077	88.797
PON	4/9/2003	57.8	0.058	0.005	145.063
PON	4/9/2003	47.3	0.048	0.005	178.053
PON	4/9/2003	47.7	-0.002	0.005	84.703
PON	4/10/2003	48.9	0.042	0.005	112.047
PON	4/10/2003	49.7	-0.002	0.005	106.003
PON	4/10/2003	52.5	-0.002	0.005	98.703
PON	4/11/2003	52.0	-0.002	0.005	93.203
PON	4/11/2003	50.4	-0.002	0.005	104.003
PON	4/11/2003	64.3	-0.002	0.005	105.003
PON	4/12/2003	52.8	-0.002	0.005	111.003
PON	4/12/2003	51.5	0.024	0.005	88.329
PON	4/12/2003	61.2	0.023	0.005	96.928
PON	4/13/2003	59.3	0.122	0.270	99.992
PON	4/13/2003	58.5	0.037	0.005	91.942
PON	4/13/2003	58.8	0.022	0.005	90.327
PON	4/13/2003	57.5	0.046	0.005	98.751
PON	4/14/2003	42.4	0.815	0.061	91.876
PON	4/14/2003	49.2	2.164	0.226	80.990
PON	4/14/2003	52.1	0.802	0.120	100.922
PON	4/15/2003	47.0	0.023	0.005	79.728
PON	4/15/2003	52.9	8.386	0.824	83.410
PON	4/15/2003	61.0	2.434	0.646	97.780
PON	4/15/2003	64.9	0.403	0.154	100.557
PON	7/8/04 17:09	0.350	19.575	0.025	27.200
PON	7/8/04 20:10	0.190	32.890	0.110	42.300
PON	7/11/04 14:54	0.290	18.080	0.120	24.700
PON	7/11/04 17:54	0.050	14.330	0.070	21.600
PON	7/11/04 22:24	0.025	14.075	0.025	20.300
PON	3/7/05 18:11	5.380	16.300	0.300	34.100
PON	3/8/05 0:11	3.090	18.080	0.320	29.700
PON	3/8/05 6:12	3.250	16.150	0.350	28.600
PON	3/8/05 13:27	2.480	11.720	0.280	20.300
PON	3/8/05 22:42	2.430	11.840	0.360	20.100
PON	3/9/05 10:43	2.710	8.980	0.420	16.900
PON	3/9/05 13:14	2.420	6.420	0.480	14.900
PON	3/9/05 20:44	1.900	3.230	0.270	8.700
PON	3/10/05 4:15	2.040	2.770	0.230	7.900
PON	3/10/05 14:00	2.650	3.170	0.230	9.700
PON	3/10/05 23:01	2.860	3.430	0.270	10.700
PON	3/11/05 9:32	3.700	3.140	0.260	10.100
PON	3/11/05 11:17	3.290	3.140	0.260	10.600
PON	3/11/05 21:48	3.140	3.080	0.220	10.300
PON	3/12/05 9:49	3.190	2.970	0.230	11.200
PON	3/12/05 11:34	3.270	3.360	0.240	11.800
PON	3/12/05 19:04	3.550	3.630	0.270	13.200
PON	3/13/05 4:05	3.330	3.470	0.330	12.500
PON	3/13/05 14:05	4.270	3.120	0.280	12.600
PON	3/13/05 23:06	2.920	1.980	0.220	8.900
PON	3/14/05 9:36	4.250	2.850	0.250	13.800
PON	3/14/05 14:07	3.690	2.560	0.240	12.400
PON	3/14/05 20:07	2.870	1.860	0.240	7.800
PON	3/29/05 18:38	9.600	1.700	0.200	15.400
PON	3/30/05 0:39	6.550	3.500	0.200	14.900
PON	3/30/05 12:59	4.470	1.730	0.170	12.000
PON	3/30/05 14:53	4.640	1.640	0.160	12.800
PON	3/30/05 19:23	2.410	1.150	0.250	6.800
PON	3/31/05 8:54	3.380	1.730	0.270	10.700
PON	3/31/05 11:10	3.340	1.760	0.240	9.900
PON	3/31/05 21:40	4.070	1.040	0.160	9.400
PON	4/1/05 9:41	2.980	0.950	0.150	8.000
PON	4/1/05 12:27	3.060	0.680	0.120	8.700
PON	4/1/05 22:57	3.610	0.480	0.120	9.000
PON	4/2/05 10:58	3.370	1.020	0.180	9.800
PON	4/2/05 14:14	2.410	0.500	0.100	6.700
PON	4/2/05 18:44	3.730	1.470	0.130	11.100
PON	4/2/05 23:14	4.760	1.470	0.130	12.200
PON	4/3/05 10:28	5.870	1.100	0.200	16.400
PON	4/3/05 16:28	3.380	1.660	0.140	14.800
PON	4/4/05 5:34	2.130	3.975	0.025	13.800
PON	4/4/05 10:40	4.660	1.150	0.150	15.100
PON	4/4/05 16:21	4.520	1.770	0.230	13.400
PON	4/4/05 20:52	5.560	4.470	0.130	17.600
PON	4/5/05 11:02	5.330	1.390	0.110	14.300
PON	4/5/05 17:03	5.150	0.960	0.140	14.400
PON	6/18/05 21:43	0.340	43.400	0.400	50.700

Table A5.6. Runoff N concentrations from the Renwick Creek (REN) site.

Site	Sample d/mo/yr h:m	NH_3-N (mg L^{-1})	NO_3-N (mg L^{-1})	NO_2-N (mg L^{-1})	Total N (mg L^{-1})
REN	3/22/2003	2.900	1.283	0.197	12.080
REN	3/22/2003	2.290	1.026	0.114	8.130
REN	3/23/2003	1.360	0.886	0.144	6.390
REN	3/23/2003	1.290	1.343	0.067	7.450
REN	3/23/2003	1.930	0.973	0.067	6.630
REN	3/24/2003	1.500	1.037	0.073	6.360
REN	3/24/2003	1.170	0.841	0.068	6.109
REN	3/24/2003	1.260	0.800	0.077	5.697
REN	3/24/2003	1.480	0.885	0.079	6.564
REN	3/25/2003	0.948	0.887	0.079	6.056
REN	3/25/2003	1.250	0.631	0.069	5.540
REN	3/26/2003	1.040	0.872	0.094	5.516
REN	3/26/2003	0.947	0.937	0.073	5.540
REN	3/26/2003	1.140	0.399	0.045	4.564
REN	3/27/2003	0.600	0.543	0.051	4.654
REN	3/27/2003	0.780	0.712	0.078	4.930
REN	3/27/2003	1.130	0.429	0.059	5.128
REN	3/27/2003	0.555	0.533	0.057	4.020
REN	3/28/2003	0.734	0.440	0.095	4.245
REN	3/28/2003	0.473	0.435	0.038	3.353
REN	3/29/2003	0.392	0.367	0.062	3.489
REN	3/29/2003	0.548	0.316	0.051	3.407
REN	3/29/2003	0.389	0.189	0.024	2.293
REN	3/30/2003	0.305	0.154	0.029	2.493
REN	3/30/2003	0.376	0.315	0.033	3.078
REN	3/30/2003	0.325	0.142	0.019	2.091
REN	3/31/2003	0.384	0.225	0.029	1.954
REN	3/31/2003	0.425	0.380	0.080	2.880
REN	3/31/2003	0.446	0.104	0.025	2.199
REN	3/31/2003	0.657	0.430	0.038	3.178
REN	4/7/2003	0.506	0.162	0.062	3.764
REN	4/7/2003	0.558	0.245	0.043	3.558
REN	4/7/2003	0.652	0.587	0.047	4.264
REN	4/8/2003	0.916	0.328	0.047	2.835
REN	4/8/2003	0.718	0.398	0.065	3.763
REN	6/10/2003	0.297	11.000	0.100	14.430
REN	6/10/2003	0.386	15.392	0.208	19.140
REN	2/25/04 15:31	1.830	1.510	0.510	13.720
REN	2/25/04 17:46	1.430	1.380	0.370	7.650
REN	3/8/04 12:38	2.760	2.040	0.450	13.890
REN	3/8/04 22:42	1.080	1.820	0.090	6.110
REN	3/9/04 0:00	1.040	1.970	0.170	5.540
REN	3/9/04 9:03	1.100	1.960	0.230	7.090
REN	3/9/04 15:04	0.650	1.730	0.050	5.480
REN	3/9/04 22:35	0.390	1.325	0.025	3.650
REN	3/10/04 10:02	0.320	1.570	0.070	4.640
REN	3/10/04 10:34	0.230	0.910	0.090	3.900
REN	3/10/04 14:33	0.710	1.340	0.140	5.780
REN	3/11/04 9:03	0.750	1.370	0.090	8.560
REN	3/11/04 19:36	0.160	0.830	0.070	3.100

Table A5.6. Runoff N concentrations from the Renwick Creek (REN) site.

Site	Sample d/mo/yr h:m	NH_3-N (mg L^{-1})	NO_3-N (mg L^{-1})	NO_2-N (mg L^{-1})	Total N (mg L^{-1})
REN	3/12/04 7:39	0.150	1.010	0.080	3.890
REN	3/12/04 9:22	0.300	1.130	0.090	4.620
REN	3/12/04 19:10	0.170	0.520	0.070	2.790
REN	3/13/04 4:11	0.230	1.170	0.090	4.260
REN	3/13/04 11:42	0.370	1.100	0.110	5.310
REN	3/13/04 17:43	0.180	0.365	0.025	7.290
REN	3/13/04 22:13	0.780	0.530	0.060	9.290
REN	3/14/04 11:38	0.270	0.510	0.080	3.390
REN	3/14/04 19:41	0.160	0.400	0.060	2.360
REN	3/15/04 3:12	0.150	0.670	0.090	2.860
REN	3/15/04 13:23	0.360	0.650	0.070	16.120
REN	3/15/04 20:54	0.110	0.430	0.070	2.800
REN	3/16/04 4:25	0.160	0.620	0.080	3.300
REN	3/16/04 13:43	0.360	0.710	0.100	25.310
REN	3/16/04 18:15	0.090	0.360	0.080	6.840
REN	3/16/04 22:46	0.690	1.140	0.210	7.050
REN	3/17/04 14:25	0.120	0.530	0.080	7.110
REN	3/17/04 20:02	0.025	0.280	0.100	3.280
REN	3/18/04 10:57	0.150	0.295	0.025	4.420
REN	3/18/04 21:40	0.220	0.275	0.025	2.300
REN	3/19/04 8:11	0.170	0.295	0.025	3.020
REN	3/19/04 11:12	0.170	0.255	0.025	5.880
REN	3/19/04 15:48	0.770	0.355	0.025	57.480
REN	3/19/04 20:34	0.150	0.565	0.025	3.790
REN	3/21/04 15:40	0.200	0.355	0.025	3.280
REN	3/22/04 11:17	0.220	0.575	0.025	5.200
REN	3/23/04 15:32	0.180	0.275	0.025	4.900
REN	7/7/04 19:31	0.150	6.710	0.170	17.280
REN	7/8/04 8:56	0.590	7.780	0.270	15.250
REN	8/3/04 10:32	0.025	1.920	0.180	2.900
REN	8/4/04 19:00	0.025	2.020	0.120	11.440
REN	8/22/04 8:55	0.060	4.140	0.210	5.750
REN	8/22/04 10:56	0.025	2.000	0.190	4.790
REN	2/2/05 13:05	0.110	0.605	0.025	4.830
REN	2/3/05 10:20	0.100	0.245	0.025	5.870
REN	3/1/05 13:42	0.550	0.690	0.150	3.940
REN	3/1/05 20:04	0.500	0.500	0.080	2.080
REN	3/2/05 2:05	0.370	0.430	0.080	2.310
REN	3/3/05 9:16	0.490	0.370	0.080	5.850
REN	3/3/05 18:14	0.670	0.270	0.060	5.930
REN	3/4/05 6:15	0.580	0.320	0.070	6.090
REN	3/4/05 10:16	0.490	0.300	0.150	5.750
REN	3/4/05 17:46	0.670	0.180	0.050	5.030
REN	3/5/05 4:17	0.610	0.240	0.080	5.620
REN	3/5/05 10:18	0.570	0.210	0.100	5.310
REN	3/5/05 17:49	0.530	0.160	0.060	5.320
REN	3/6/05 2:50	0.480	0.180	0.050	5.430
REN	3/6/05 10:20	0.570	0.220	0.080	5.000
REN	3/6/05 11:05	0.650	0.240	0.070	6.310
REN	3/6/05 17:06	0.700	0.390	0.070	4.060

Table A5.6. Runoff N concentrations from the Renwick Creek (REN) site.

Site	Sample d/mo/yr h:m	NH_3-N (mg L^{-1})	NO_3-N (mg L^{-1})	NO_2-N (mg L^{-1})	Total N (mg L^{-1})
REN	3/6/05 23:07	0.850	0.510	0.070	5.480
REN	3/7/05 10:31	0.810	0.570	0.100	6.470
REN	3/7/05 19:49	0.610	0.460	0.110	5.970
REN	3/8/05 10:53	0.650	0.830	0.170	6.700
REN	3/8/05 14:16	1.010	0.270	0.070	4.940
REN	3/9/05 7:00	0.800	0.980	0.160	5.340
REN	3/9/05 13:38	1.050	0.400	0.060	4.660
REN	3/25/05 18:31	1.910	1.050	0.090	6.940
REN	3/27/05 1:29	0.880	0.610	0.100	6.110
REN	3/28/05 0:11	0.230	1.180	0.080	5.960
REN	3/28/05 13:55	0.550	0.880	0.070	5.250
REN	3/28/05 15:10	0.580	1.350	0.080	5.830
REN	3/28/05 16:47	0.770	1.690	0.090	6.880
REN	6/8/05 8:23	0.130	2.160	0.130	10.790
REN	6/13/05 19:02	0.380	3.850	0.070	12.920
REN	6/17/05 14:02	0.250	4.380	0.190	27.970
REN	6/17/05 22:25	0.110	1.500	0.190	6.390
REN	6/18/05 7:33	0.230	0.940	0.160	3.300
REN	8/17/05 7:02	0.140	1.985	0.025	5.310
REN	8/17/05 8:41	0.070	1.345	0.025	3.770
REN	8/23/05 9:17	0.120	3.085	0.025	8.710
REN	8/24/05 5:59	0.025	0.405	0.025	1.930
REN	8/24/05 10:34	0.025	0.425	0.025	2.350
REN	8/24/05 12:05	0.060	0.285	0.025	3.110
REN	8/24/05 16:35	0.025	0.095	0.025	1.820
REN	8/24/05 21:05	0.025	0.025	0.025	1.050

Table A5.7. Runoff N concentrations from the Threehills Creek (THC) site.

Site	Sample d/mo/yr h:m	NH_3-N (mg L^{-1})	NO_3-N (mg L^{-1})	NO_2-N (mg L^{-1})	Total N (mg L^{-1})
THC	3/23/03 22:01	2.470	4.747	0.213	11.740
THC	3/25/03 14:23	1.790	0.858	0.142	6.380
THC	3/25/03 20:20	2.000	1.043	0.197	7.300
THC	3/25/03 21:50	2.070	1.192	0.248	7.490
THC	3/27/03 19:15	2.810	1.284	0.176	8.990
THC	3/28/03 14:33	3.040	0.903	0.157	8.590
THC	3/28/03 20:33	2.180	0.889	0.131	7.550
THC	3/29/03 2:34	2.060	0.748	0.146	7.484
THC	3/29/03 13:50	1.930	0.903	0.117	7.590
THC	3/30/03 0:21	1.180	0.754	0.070	5.544
THC	3/30/03 10:52	1.050	0.670	0.038	5.118
THC	3/30/03 12:53	1.260	0.769	0.078	5.897
THC	3/30/03 23:24	0.701	0.658	0.047	4.495
THC	3/31/03 9:55	0.720	0.648	0.050	4.548
THC	3/31/03 11:40	0.900	0.684	0.067	4.111
THC	3/31/03 19:11	0.631	0.683	0.065	2.888
THC	4/1/03 4:12	0.596	0.905	0.077	4.242
THC	4/1/03 11:13	0.678	0.944	0.066	4.780
THC	4/1/03 16:45	0.698	0.861	0.075	4.396
THC	4/1/03 23:12	0.735	0.895	0.102	5.287
THC	4/7/03 12:01	1.790	1.421	0.069	6.430
THC	4/7/03 21:02	0.568	0.538	0.031	3.529
THC	4/8/03 9:02	0.489	0.606	0.039	3.535
THC	4/8/03 12:03	0.561	0.314	0.020	2.664
THC	4/8/03 19:33	0.652	0.347	0.029	2.706
THC	4/9/03 8:15	0.822	0.393	0.042	3.115
THC	4/9/03 11:16	1.400	0.630	0.068	4.218
THC	4/9/03 12:47	1.240	0.870	0.083	4.613
THC	4/9/03 14:19	1.200	1.069	0.091	4.730
THC	3/12/04 12:13	0.920	5.160	0.060	10.520
THC	3/12/04 22:21	0.850	4.430	0.070	10.200
THC	3/12/04 23:51	0.820	3.860	0.070	9.130
THC	3/13/04 8:27	0.240	2.890	0.070	6.860
THC	3/13/04 14:01	0.180	3.420	0.090	7.410
THC	3/13/04 18:32	0.190	3.350	0.090	7.240
THC	3/14/04 9:03	0.130	3.060	0.070	7.030
THC	3/14/04 18:04	0.140	2.180	0.070	6.050
THC	3/15/04 4:35	0.170	1.940	0.090	5.530
THC	3/15/04 8:48	0.100	2.480	0.080	6.460
THC	3/15/04 19:19	0.090	1.920	0.070	4.990
THC	3/16/04 7:20	0.050	2.510	0.070	6.180
THC	3/16/04 11:36	0.090	2.660	0.100	6.660
THC	3/16/04 19:06	0.050	1.770	0.080	5.150
THC	3/17/04 1:07	0.050	1.500	0.070	4.270
THC	3/17/04 9:17	0.025	1.980	0.080	5.460
THC	3/17/04 16:47	0.025	1.880	0.130	5.210
THC	3/18/04 3:19	0.025	1.550	0.120	4.770
THC	3/18/04 8:49	0.025	1.515	0.025	4.540
THC	3/18/04 19:20	0.130	1.305	0.025	3.430
THC	3/19/04 7:22	4.140	2.400	0.250	15.750

Table A5.7. Runoff N concentrations from the Threehills Creek (THC) site.

Site	Sample d/mo/yr h:m	NH_3-N (mg L^{-1})	NO_3-N (mg L^{-1})	NO_2-N (mg L^{-1})	Total N (mg L^{-1})
THC	3/19/04 8:37	0.070	1.945	0.025	4.470
THC	3/19/04 14:37	0.070	1.395	0.025	3.420
THC	3/19/04 22:08	0.050	1.815	0.025	4.140
THC	3/20/04 8:36	0.025	1.445	0.025	3.570
THC	3/20/04 14:36	0.025	1.545	0.025	3.970
THC	3/20/04 22:07	0.850	1.840	0.080	7.620
THC	3/21/04 8:38	0.025	1.225	0.025	3.850
THC	3/21/04 14:39	0.050	0.985	0.025	3.210
THC	3/21/04 23:40	0.070	0.895	0.025	3.520
THC	3/22/04 8:46	0.025	0.890	0.060	3.850
THC	3/22/04 16:16	0.060	0.675	0.025	2.900
THC	3/22/04 22:47	0.080	0.725	0.025	3.350
THC	3/23/04 10:02	0.110	0.555	0.025	3.280
THC	3/23/04 17:32	0.025	0.655	0.025	2.380
THC	3/24/04 1:33	0.070	0.775	0.025	2.800
THC	3/24/04 9:21	0.025	0.855	0.025	3.180
THC	3/24/04 19:52	0.025	0.775	0.025	2.600
THC	3/25/04 6:23	0.025	1.025	0.025	2.750
THC	3/25/04 8:14	0.025	1.055	0.025	2.580
THC	3/25/04 15:30	0.025	1.135	0.025	2.860
THC	3/25/04 23:01	0.025	1.425	0.025	3.350
THC	3/26/04 9:01	0.025	1.495	0.025	3.520
THC	3/26/04 16:32	0.025	1.275	0.025	3.100
THC	3/27/04 0:02	0.025	1.355	0.025	2.880
THC	3/27/04 10:23	0.025	1.385	0.025	2.710
THC	3/27/04 20:54	0.060	1.255	0.025	2.480
THC	3/28/04 7:25	0.025	2.105	0.025	3.630
THC	3/28/04 10:15	0.060	1.645	0.025	2.970
THC	3/28/04 14:45	0.100	1.375	0.025	2.400
THC	3/28/04 23:23	0.050	6.415	0.025	8.140
THC	3/29/04 12:46	0.130	0.975	0.025	2.900
THC	3/29/04 15:26	0.120	1.775	0.025	3.400
THC	3/29/04 18:26	0.060	2.585	0.025	4.410
THC	2/2/05 13:05	0.110	0.605	0.025	4.830
THC	2/3/05 10:20	0.100	0.245	0.025	5.870
THC	3/1/05 13:42	0.550	0.690	0.150	3.940
THC	3/1/05 20:04	0.500	0.500	0.080	2.080
THC	3/2/05 2:05	0.370	0.430	0.080	2.310
THC	3/3/05 9:16	0.490	0.370	0.080	5.850
THC	3/3/05 18:14	0.670	0.270	0.060	5.930
THC	3/4/05 6:15	0.580	0.320	0.070	6.090
THC	3/4/05 10:16	0.490	0.300	0.150	5.750
THC	3/4/05 17:46	0.670	0.180	0.050	5.030
THC	3/5/05 4:17	0.610	0.240	0.080	5.620
THC	3/5/05 10:18	0.570	0.210	0.100	5.310
THC	3/5/05 17:49	0.530	0.160	0.060	5.320
THC	3/6/05 2:50	0.480	0.180	0.050	5.430
THC	3/6/05 10:20	0.570	0.220	0.080	5.000
THC	3/6/05 11:05	0.650	0.240	0.070	6.310
THC	3/6/05 17:06	0.700	0.390	0.070	4.060

Table A5.7. Runoff N concentrations from the Threehills Creek (THC) site.

Site	Sample d/mo/yr h:m	NH_3-N (mg L^{-1})	NO_3-N (mg L^{-1})	NO_2-N (mg L^{-1})	Total N (mg L^{-1})
THC	3/6/05 23:07	0.850	0.510	0.070	5.480
THC	3/7/05 10:31	0.810	0.570	0.100	6.470
THC	3/7/05 19:49	0.610	0.460	0.110	5.970
THC	3/8/05 10:53	0.650	0.830	0.170	6.700
THC	3/8/05 14:16	1.010	0.270	0.070	4.940
THC	3/9/05 7:00	0.800	0.980	0.160	5.340
THC	3/9/05 13:38	1.050	0.400	0.060	4.660
THC	3/25/05 18:31	1.910	1.050	0.090	6.940
THC	3/27/05 1:29	0.880	0.610	0.100	6.110
THC	3/28/05 0:11	0.230	1.180	0.080	5.960
THC	3/28/05 13:55	0.550	0.880	0.070	5.250
THC	3/28/05 15:10	0.580	1.350	0.080	5.830
THC	3/28/05 16:47	0.770	1.690	0.090	6.880
THC	6/8/05 8:23	0.130	2.160	0.130	10.790
THC	6/13/05 19:02	0.380	3.850	0.070	12.920
THC	6/17/05 14:02	0.250	4.380	0.190	27.970
THC	6/17/05 22:25	0.110	1.500	0.190	6.390
THC	6/18/05 7:33	0.230	0.940	0.160	3.300
THC	8/17/05 7:02	0.140	1.985	0.025	5.310
THC	8/17/05 8:41	0.070	1.345	0.025	3.770
THC	8/23/05 9:17	0.120	3.085	0.025	8.710
THC	8/24/05 5:59	0.025	0.405	0.025	1.930
THC	8/24/05 10:34	0.025	0.425	0.025	2.350
THC	8/24/05 12:05	0.060	0.285	0.025	3.110
THC	8/24/05 16:35	0.025	0.095	0.025	1.820
THC	8/24/05 21:05	0.025	0.025	0.025	1.050

Table A5.8. Runoff N concentrations from the Wabash Creek (WAB) site.

Site	Sample d/mo/yr h:m	NH_3-N (mg L^{-1})	NO_3-N (mg L^{-1})	NO_2-N (mg L^{-1})	Total N (mg L^{-1})
WAB	4/11/2003	0.325	1.253	0.047	2.95
WAB	4/11/2003	0.451	1.220	0.04	3.510
WAB	4/12/2003	0.210	0.981	0.039	2.730
WAB	4/12/2003	0.183	1.071	0.039	3.450
WAB	4/12/2003	0.165	1.119	0.041	5.190
WAB	4/12/2003	0.149	1.128	0.022	3.610
WAB	4/13/2003	0.173	1.685	0.065	11.27
WAB	4/13/2003	0.200	1.716	0.044	4.290
WAB	4/13/2003	0.143	1.355	0.035	3.540
WAB	4/13/2003	0.156	1.451	0.039	3.780
WAB	4/14/2003	0.157	1.965	0.065	4.460
WAB	4/14/2003	0.149	1.865	0.055	3.870
WAB	4/15/2003	0.141	1.727	0.053	4.540
WAB	4/15/2003	0.172	1.942	0.018	3.890
WAB	4/15/2003	0.147	1.825	0.005	3.810
WAB	4/15/2003	0.164	1.895	0.005	3.830
WAB	4/16/2003	0.170	2.433	0.067	4.840
WAB	4/16/2003	0.160	2.092	0.068	4.230
WAB	4/17/2003	0.194	1.922	0.078	4.510
WAB	4/17/2003	0.141	1.971	0.089	4.700
WAB	4/17/2003	0.153	1.643	0.067	3.680
WAB	4/18/2003	0.112	2.065	0.055	3.940
WAB	2/25/04 15:31	1.830	1.510	0.510	13.720
WAB	2/25/04 17:46	1.430	1.380	0.370	7.650
WAB	3/8/04 12:38	2.760	2.040	0.450	13.890
WAB	3/8/04 22:42	1.080	1.820	0.090	6.110
WAB	3/9/04 0:00	1.040	1.970	0.170	5.540
WAB	3/9/04 9:03	1.100	1.960	0.230	7.090
WAB	3/9/04 15:04	0.650	1.730	0.050	5.480
WAB	3/9/04 22:35	0.390	1.325	0.025	3.650
WAB	3/10/04 10:02	0.320	1.570	0.070	4.640
WAB	3/10/04 10:34	0.230	0.910	0.090	3.900
WAB	3/10/04 14:33	0.710	1.340	0.140	5.780
WAB	3/11/04 9:03	0.750	1.370	0.090	8.560
WAB	3/11/04 19:36	0.160	0.830	0.070	3.100
WAB	3/12/04 7:39	0.150	1.010	0.080	3.890
WAB	3/12/04 9:22	0.300	1.130	0.090	4.620
WAB	3/12/04 19:10	0.170	0.520	0.070	2.790
WAB	3/13/04 4:11	0.230	1.170	0.090	4.260
WAB	3/13/04 11:42	0.370	1.100	0.110	5.310
WAB	3/13/04 17:43	0.180	0.365	0.025	7.290
WAB	3/13/04 22:13	0.780	0.530	0.060	9.290
WAB	3/14/04 11:38	0.270	0.510	0.080	3.390
WAB	3/14/04 19:41	0.160	0.400	0.060	2.360
WAB	3/15/04 3:12	0.150	0.670	0.090	2.860
WAB	3/15/04 13:23	0.360	0.650	0.070	16.120
WAB	3/15/04 20:54	0.110	0.430	0.070	2.800
WAB	3/16/04 4:25	0.160	0.620	0.080	3.300
WAB	3/16/04 13:43	0.360	0.710	0.100	25.310
WAB	3/16/04 18:15	0.090	0.360	0.080	6.840

Table A5.8. Runoff N concentrations from the Wabash Creek (WAB) site.

Site	Sample d/mo/yr h:m	NH_3-N (mg L^{-1})	NO_3-N (mg L^{-1})	NO_2-N (mg L^{-1})	Total N (mg L^{-1})
WAB	3/16/04 22:46	0.690	1.140	0.210	7.050
WAB	3/17/04 14:25	0.120	0.530	0.080	7.110
WAB	3/17/04 20:02	0.025	0.280	0.100	3.280
WAB	3/18/04 10:57	0.150	0.295	0.025	4.420
WAB	3/18/04 21:40	0.220	0.275	0.025	2.300
WAB	3/19/04 8:11	0.170	0.295	0.025	3.020
WAB	3/19/04 11:12	0.170	0.255	0.025	5.880
WAB	3/19/04 15:48	0.770	0.355	0.025	57.480
WAB	3/19/04 20:34	0.150	0.565	0.025	3.790
WAB	3/21/04 15:40	0.200	0.355	0.025	3.280
WAB	3/22/04 11:17	0.220	0.575	0.025	5.200
WAB	3/23/04 15:32	0.180	0.275	0.025	4.900
WAB	7/7/04 19:31	0.150	6.710	0.170	17.280
WAB	7/8/04 8:56	0.590	7.780	0.270	15.250
WAB	8/3/04 10:32	0.025	1.920	0.180	2.900
WAB	8/4/04 19:00	0.025	2.020	0.120	11.440
WAB	8/22/04 8:55	0.060	4.140	0.210	5.750
WAB	8/22/04 10:56	0.025	2.000	0.190	4.790
WAB	3/5/05 12:37	0.360	1.430	0.070	5.100
WAB	3/6/05 2:09	0.220	2.050	0.050	5.500
WAB	3/6/05 10:13	0.200	2.075	0.025	5.500
WAB	3/6/05 13:13	0.240	1.640	0.060	4.900
WAB	3/6/05 22:28	0.250	3.040	0.060	6.500
WAB	3/7/05 8:46	0.240	3.330	0.070	6.800
WAB	3/7/05 14:16	0.160	2.900	0.100	6.500
WAB	3/7/05 23:02	0.150	2.570	0.130	6.200
WAB	3/8/05 9:32	0.120	2.680	0.120	6.100
WAB	3/8/05 11:48	0.210	5.080	0.120	8.600
WAB	3/8/05 22:18	0.110	4.475	0.025	8.200
WAB	3/9/05 8:19	0.140	4.575	0.025	8.900
WAB	3/9/05 10:49	0.150	2.675	0.025	6.100
WAB	3/9/05 21:20	0.220	3.750	0.050	6.900
WAB	3/10/05 9:21	0.200	4.340	0.060	8.000
WAB	3/10/05 10:52	0.220	3.730	0.070	6.600
WAB	3/10/05 21:23	0.230	4.030	0.070	7.000
WAB	3/11/05 9:24	0.210	4.475	0.025	7.400
WAB	3/11/05 11:24	0.280	5.140	0.060	8.500
WAB	3/11/05 18:55	0.230	4.850	0.050	8.000
WAB	3/12/05 9:56	0.280	6.350	0.050	9.600
WAB	3/12/05 11:42	0.300	6.640	0.060	10.100
WAB	3/12/05 17:43	0.380	6.630	0.070	9.800
WAB	3/13/05 9:48	0.720	7.200	0.100	11.000
WAB	3/13/05 12:24	0.510	10.800	0.100	14.900
WAB	3/13/05 23:02	0.740	6.330	0.070	10.400
WAB	3/29/05 14:09	0.410	0.775	0.025	3.000
WAB	3/29/05 23:18	0.300	1.120	0.080	3.600
WAB	3/30/05 9:50	0.220	0.675	0.025	3.200
WAB	3/30/05 11:05	0.210	0.640	0.060	3.200
WAB	3/30/05 21:37	0.290	0.675	0.025	3.200
WAB	3/31/05 6:43	0.280	0.775	0.025	3.700

Table A5.8. Runoff N concentrations from the Wabash Creek (WAB) site.

Site	Sample d/mo/yr h:m	NH_3-N (mg L^{-1})	NO_3-N (mg L^{-1})	NO_2-N (mg L^{-1})	Total N (mg L^{-1})
WAB	3/31/05 13:15	0.100	0.275	0.025	2.500
WAB	3/31/05 20:47	0.090	0.275	0.025	2.600
WAB	4/1/05 10:20	0.080	0.175	0.025	2.800
WAB	4/1/05 11:50	0.070	0.175	0.025	2.800
WAB	4/1/05 23:52	0.100	0.275	0.025	3.100
WAB	4/2/05 11:53	0.090	0.175	0.025	3.100