Suspended Sediment and Nutrient loading for Tributaries in the Eau Galle River Basin, Wisconsin

Upper Eau Galle River Near U.S. 12, Woodville, Wisconsin

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PREFACE

This research was conducted in response to a request from the State of Wisconsin Department of Natural Resources (WI-DNR) to the U.S. Army Engineer District (USAED), St. Paul, for planning assistance under Section 22 of the Water Resources Development Act (Public Law 93-251). Funding was provided by the WI-DNR and USAED, St. Paul. The study coordinator for WI-DNR was Mr. Patrick W. Sorge and the Section 22 coordinators for the USAED, St. Paul, were Mr. Terry J. Engel and Mr. Roland O. Hamborg.

The report was written by Mr. William F. James of the Eau Galle Aquatic Ecology Laboratory (EGAEL) of the Environmental Processes and Effects Division (EPED) of the Engineer Research and Development Center (ERDC). Mr. Harry L. Eakin and Ms. Laura J. Pommier of EGAEL are gratefully acknowledged for conducting field sampling and flow gauging of the various tributaries, sample processing and analysis.

BACKGROUND

Runoff of soil and associated nutrients from the landscape is dictated by many complex factors including agricultural management practices, soil erosion and overland runoff potential, soil type, and soil nutrient concentration (Lemunyon and Gilbert 1993; Sharpley 1995). In particular, management of soils for crop production via fertilization and manure application can result in nutrient storage in the soil in excess of crop demand (particularly for P), leading to enhanced potential for soil nutrient loss during overland flow (Sims 1993; Sharpley et al. 1996) and accelerated eutrophication of receiving waters (Sharpley et al. 1994). Simulation of suspended solids and nutrient runoff via modeling is critical for the development of management scenarios to control excessive nutrient loading in agriculturally-managed watersheds. The objectives of this study were to examine loadings of suspended solids and various nitrogen and phosphorus species from selected tributaries of the Eau Galle River basin for use in watershed modeling verification and calibration and future development of BMP's to reduce runoff from the landscape.

METHODS

The Eau Galle River drains a predominantly agricultural watershed in west-central Wisconsin. The CE flood control impoundment, Eau Galle Reservoir (Lake George) is located approximately 28 km downstream of the river's headwaters (St. Croix County). Another impoundment (non Federal) is located upstream of the river's confluence with the Chippewa River in the County of Dunn. The CE Eau Galle Reservoir is currently eutrophic (trophic state index for chlorophyll of 66; Carlson 1977) with mean summer phosphorus and chlorophyll concentrations of ~ 0.092 mg/L and 37.2 mg/m^3 (Barko et al. 1990).

Water sampling and flow gauging stations were established on the Upper Eau Galle River at Boston Road (St. Croix County, Wisconsin) near its entrance to the CE Eau

Galle Reservoir., Cady Creek at County P near Elmwood, Wisconsin, and Knights Creek at County K near Weston, Wisconsin. Both Cady and Knights Creeks are major (3-4 order) tributaries flowing into the Eau Galle River. At each station, stage height was recorded at 15-min intervals (ISCO Model 750 bubbler or Model 4150 pressure transducer; ISCO Inc., Lincoln, Nebraska). A stage-discharge relationship was determined over a variety of flow regimes to convert stage height to volumetric flow. Flows were monitored between April and October of 2002 and 2003.

Grab samples from all flow monitoring stations were collected from mid-stream at biweekly intervals for analysis. Samples were analyzed for total suspended solids (TSS), particulate organic matter (as loss-on-ignition; LOI), total and total soluble nitrogen (N) and phosphorus (P), nitrate-nitrite N (NO_3NO_2-N), ammonium-N (NH_4-N), and soluble reactive P. For TSS, suspended material retained on a precombusted glass fiber filter (Gelman (A/E) was dried to a constant weight at 105 ^oC (APHA 1998). The filter was heated to 500 ^oC in a muffle furnace for 2 hours for determination of LOI (APHA 1998). Samples for total and total soluble N and P were predigested with potassium persulfate according to Ameel et al. (1993) before analysis. Water samples for analysis of soluble constituents were filtered through a 0.45 µm filter (Gelman Metricel) prior to analysis. N and P were measured colorimetrically on a Lachat QuikChem automated water chemistry system (Zellweger Analytics, Lachat Div., Milwaukee, WI). Particulate organic nitrogen and particulate phosphorus was calculated as total N or P minus total soluble N or P, respectively. Dissolved organic N was calculated as total soluble N minus the sum of NO_3NO_2-N and NH_4-N. Soluble unreactive P was calculated as the difference between total soluble P and soluble reactive P. Seasonal (i.e., May through September) TSS and nutrient loadings were estimated using the computer model *Flux* (Walker 1996).

SUMMARY OF RESULTS

Flows from the various tributaries varied as a function of storm runoff as peaks in flow were associated with precipitation events (Figure 1 and 2). Mean summer flow was greater in 2002 than in 2003 for all monitored tributaries (Table 1), coinciding with a period of extended drought in August through September, 2003.

Seasonal variations in mean daily loading of TSS for the various tributaries are shown in Figures 3 and 4. Mean summer TSS loading was greatest for the Eau Galle River, followed by Knights Creek and Cady Creek (Table 2). Flow-weighted TSS concentrations ranged between 17 and > 60 mg/L for the three tributaries. LOI accounted for > 20% of the TSS load from the Eau Galle River during both summers. This fraction represented > 16% of the TSS load for Knights and Cady Creek over the study period.

The Eau Galle River also exhibited the greatest total nitrogen load during both summer periods (Figures 5 and 6 and Table 2). Unlike TSS loading, however, total N loading from Knights Creek was lower compared to total N loading from Cady Creek (Table 2). The total N load of Knights and Cady Creeks were overwhelmingly dominated by the NO_3NO_2-N fraction (i.e., > 80%; Figure 7). Particulate and dissolved organic N and NH_4-N combined represented < 15% of the total N composition from these tributaries. In contrast, NO_3NO_2-N represented only 54% of the total N composition of the Eau Galle River. Particulate and dissolved organic N comprised a larger percentage (i.e., > 18%) of the total N load of this river, compared to Knights and Cady Creek. For all tributaries, NH_4-N was a minor component of the total N load.

Total P loadings were also much greater for the Eau Galle River during both summers, versus Cady and Knights Creek (Figure 8 and 9 and Table 2). Flow-weighted concentrations of total P were greater than ~ 0.110 mg/L for the Eau Galle River and Cady Creek. In contrast, Knights Creek exhibited a much lower flow-weighted total P concentration (i.e., < 0.075 mg/L). For all tributaries, soluble reactive P accounted for 42% to 56% of the total P load composition (Figure 10), and flow-weighted concentrations were greatest for the Eau Galle River and Cady Creek (Table 2). Particulate P comprised 45%, 31%, and 21% of the total P load of the Eau Galle River and Knights and Cady Creek, respectively (Figure 10).

A significant finding of this study was the occurrence of high flow-weighted concentrations of NO_3NO_2-N and soluble reactive P in the runoff of all tributaries monitored in the Eau Galle River basin. High NO_3NO_2-N was most likely due to transformations of ammonia-based fertilizers and manure on the landscape to NO_3NO_2-N via nitrification. In addition, James et al. (2003a) found that soils in the Upper Eau Galle River watershed had very high mean crop-available P concentrations ranging between 120 and 180 ppm (as Mehlich-3 P; Mehlich 1984), well above crop needs of about 40-50 ppm (Fixen 1998; Sharpley et al. 1994). Solubilization and erosion of this material from agricultural settings, coupled with P kinetic and equilibrium processes in receiving streams, could increase the bioavailability of P (as soluble reactive P) as loads move through the basin, depending on equilibrium relationships between solid and aqueous phases (Sharpley et al. 1993).

The CE Eau Galle Reservoir, which receives runoff from the Upper Eau Galle River watershed, is highly eutrophic and exhibits algal blooms in the summer in excess of 100 mg m^{-3} as chlorophyll. High SRP loading (flow-weighted concentration ~ 0.060 to 0.10 mg L^{-1}) from the watershed during storms contributes directly to high productivity in the lake during the summer (James et al. 2003b). James and Barko (1991, 1993) demonstrated that particulate P loads retained in the lake also contribute substantially to the P budget of the lake via diffusive flux as a function of eH and pH and can sustain high algal growth in the summer when external P loading is nominal. Thus, it appears that TSS derived from agricultural soils is contributing to high concentrations of P and P loads entering the reservoir. Information from this study will be used to calibrate and verify a watershed model of the Eau Galle River basin for future use in the development of BMP's to reduce high runoff of TSS, N, and P from the landscape and further eutrophication of reservoirs in the basin.

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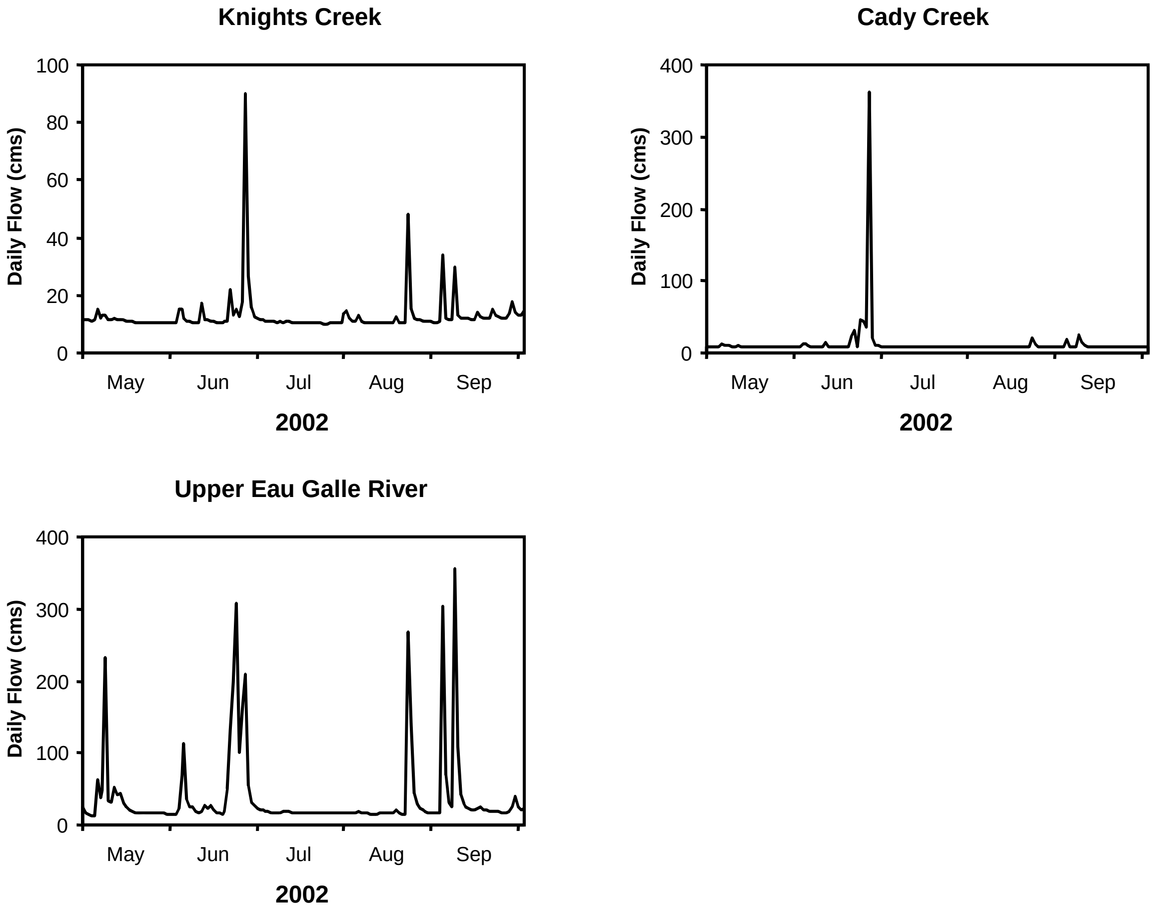
Table 1. Mean summer (May - September) flow for the Upper Eau Galle River and Cady and Knights Creek in 2002 and 2003

Tributary	Mean Summer Flow (cfs)	
	2002	2003
Upper Eau Galle River	37.4	22.8
Cady Creek	12.2	11.8
Knights Creek	12.8	11.4

Table 2. Summer (May - September) loading (kg/d) and flow-weighted concentrations (mg/L) for total suspended solids (TSS), loss-on-ignition (i.e., particulate organic matter), total and total soluble nitrogen (N) and phosphorus (P), nitrate-nitrite-N, ammonium-N, and soluble reactive P for various monitored tributaries of the Eau Galle River basin in 2002 and 2003.

MAY-SEP 2002	TSS		Loss-on-Ignition		Total N		Total Soluble N		Nitrate-Nitrite-N		Ammonium-N		Total P		Total Soluble P		Soluble Reactive P	
	(kg/d)	(mg/L)	(kg/d)	(mg/L)	(kg/d)	(mg/L)	(kg/d)	(mg/L)	(kg/d)	(mg/L)	(kg/d)	(mg/L)	(kg/d)	(mg/L)	(kg/d)	(mg/L)	(kg/d)	(mg/L)
Eau Galle River	2580.3	28.2	605.7	6.6	177.1	1.937	144.6	1.581	94.7	1.036	3.9	0.043	13.2	0.144	7.3	0.079	5.5	0.060
Cady Creek	612.1	20.5	99.9	3.3	75.5	2.528	70.0	2.344	62.4	2.091	2.3	0.077	3.9	0.132	3.1	0.103	2.3	0.075
Knights Creek	997.7	31.9	116.7	3.7	53.6	1.713	50.3	1.605	45.1	1.443	1.2	0.038	2.0	0.063	1.3	0.041	1.1	0.036

MAY-SEP 2003	TSS		Loss-on-Ignition		Total N		Total Soluble N		Nitrate-Nitrite-N		Ammonium-N		Total P		Total Soluble P		Soluble Reactive P	
	(kg/d)	(mg/L)	(kg/d)	(mg/L)	(kg/d)	(mg/L)	(kg/d)	(mg/L)	(kg/d)	(mg/L)	(kg/d)	(mg/L)	(kg/d)	(mg/L)	(kg/d)	(mg/L)	(kg/d)	(mg/L)
Eau Galle River	3405.6	61.1	722.3	13.0	111.0	1.994	87.3	1.567	54.8	0.984	2.9	0.052	14.7	0.264	7.3	0.131	6.8	0.122
Cady Creek	490.3	17.1	81.1	2.8	72.8	2.530	68.6	2.385	61.3	2.130	2.0	0.069	3.4	0.118	2.6	0.091	2.0	0.069
Knights Creek	709.4	25.4	86.1	3.1	47.1	1.689	45.1	1.617	42.0	1.507	1.0	0.035	1.4	0.049	0.8	0.030	0.8	0.030


Knights Creek

Cady Creek

Upper Eau Galle River

Figure 1. Seasonal variations in mean daily flows in 2002.

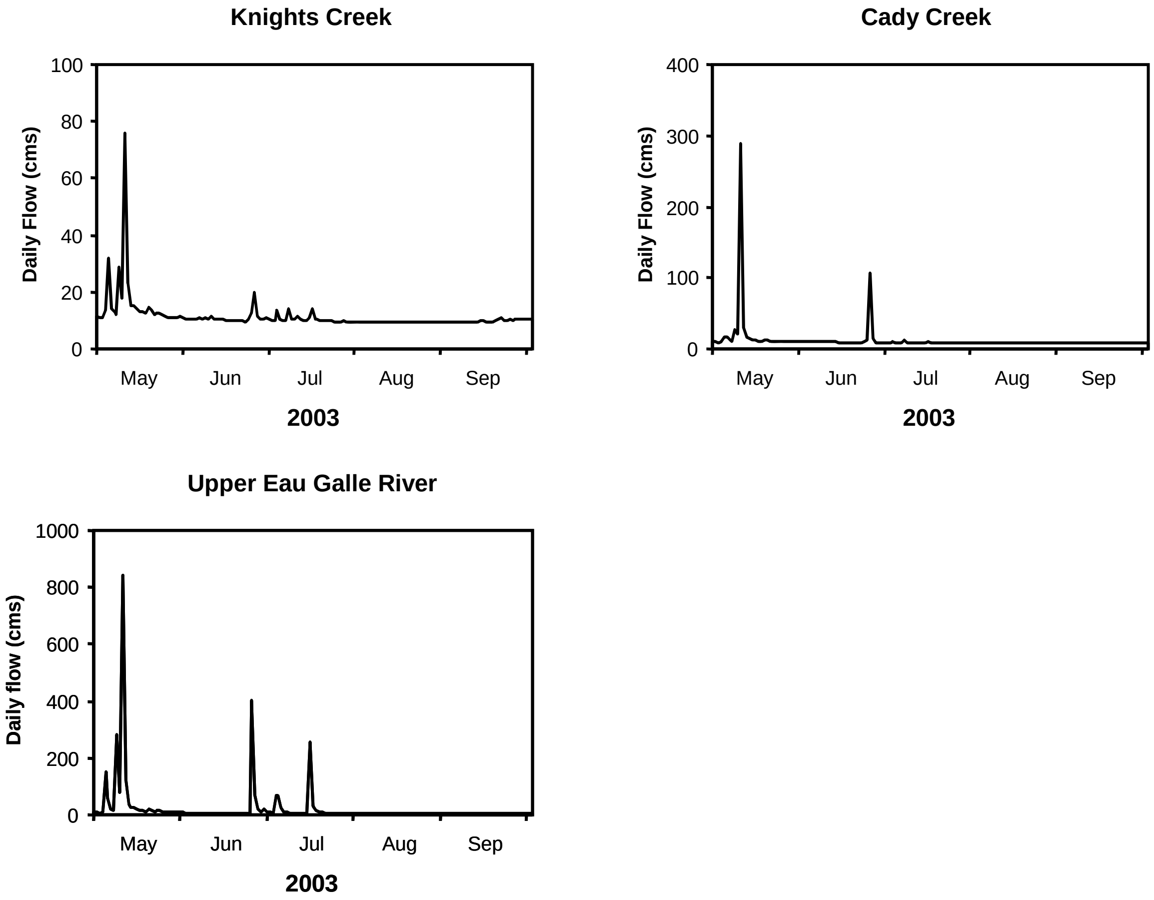


Figure 2. Seasonal variations in mean daily flows in 2003.

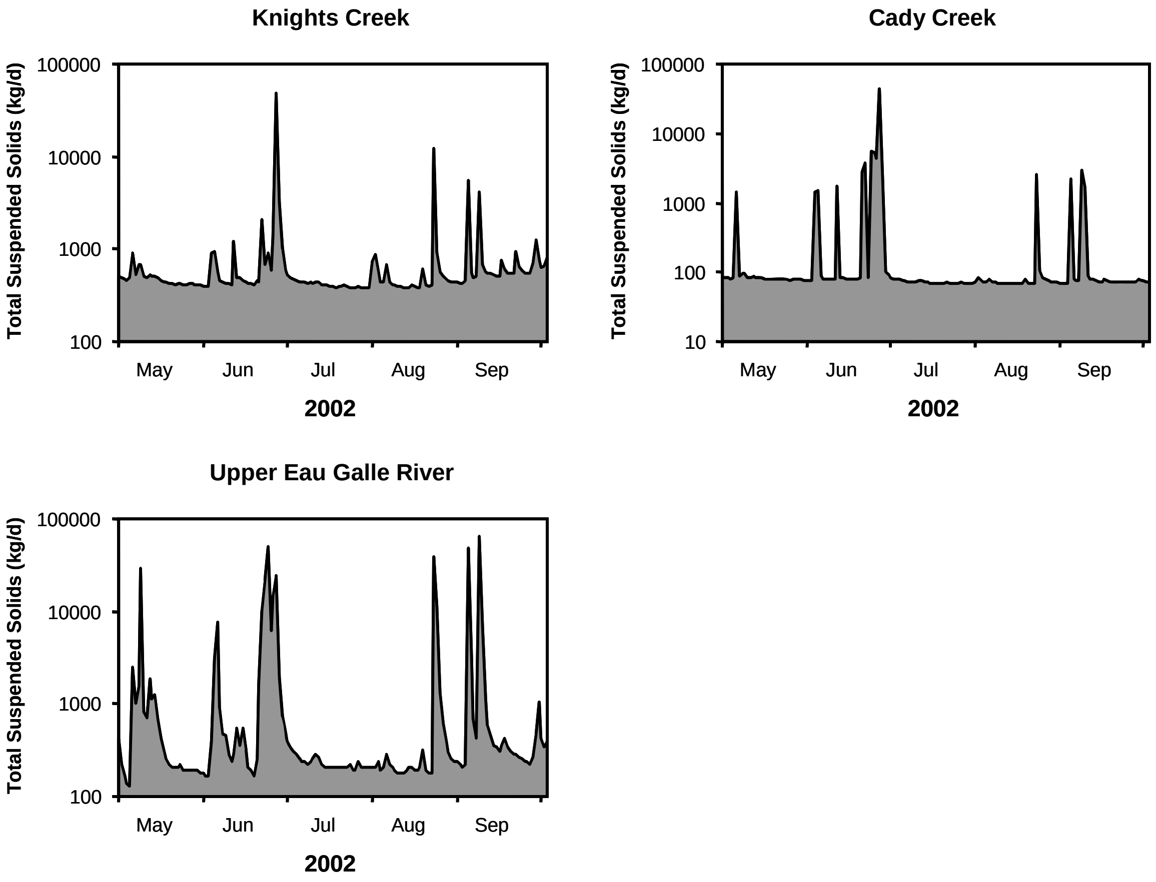


Figure 3. Seasonal variations in daily total suspended solids loading in 2002. Note logarithmic scale.

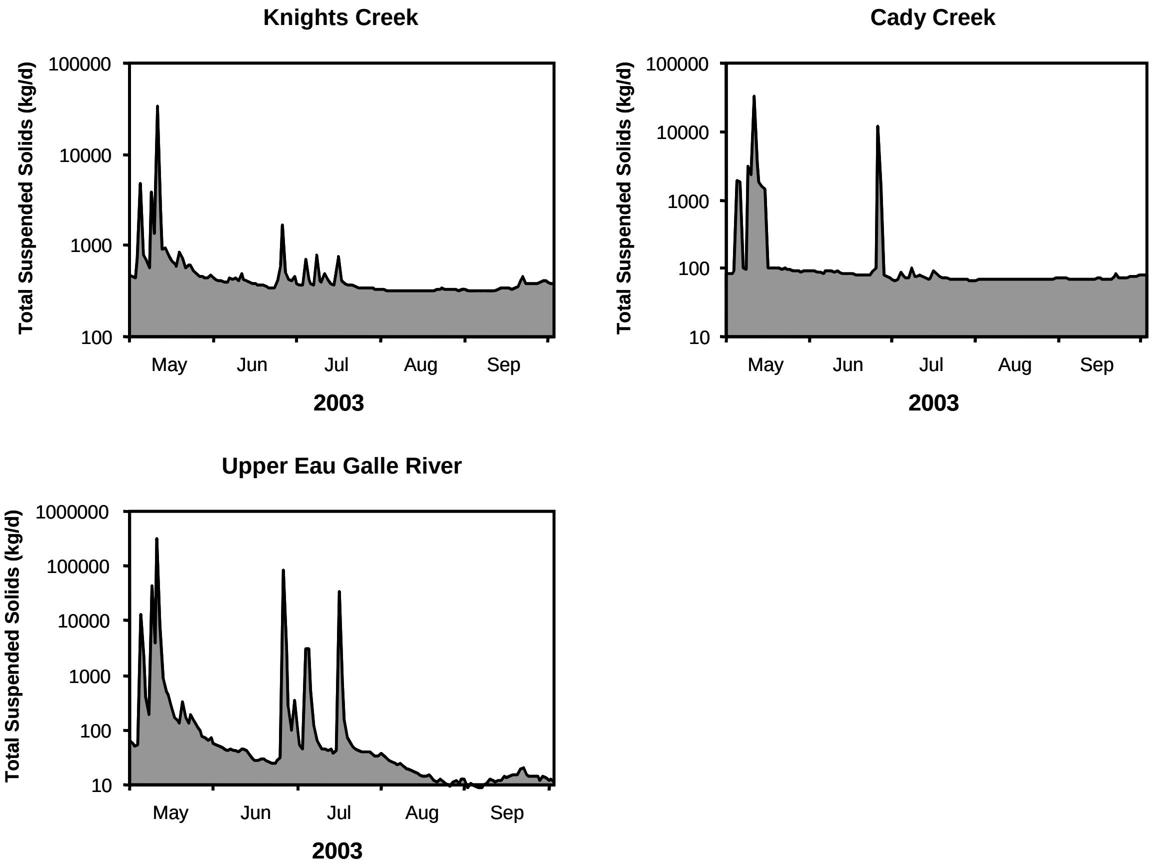


Figure 4. Seasonal variations in daily total suspended solids loading in 2003. Note logarithmic scale.

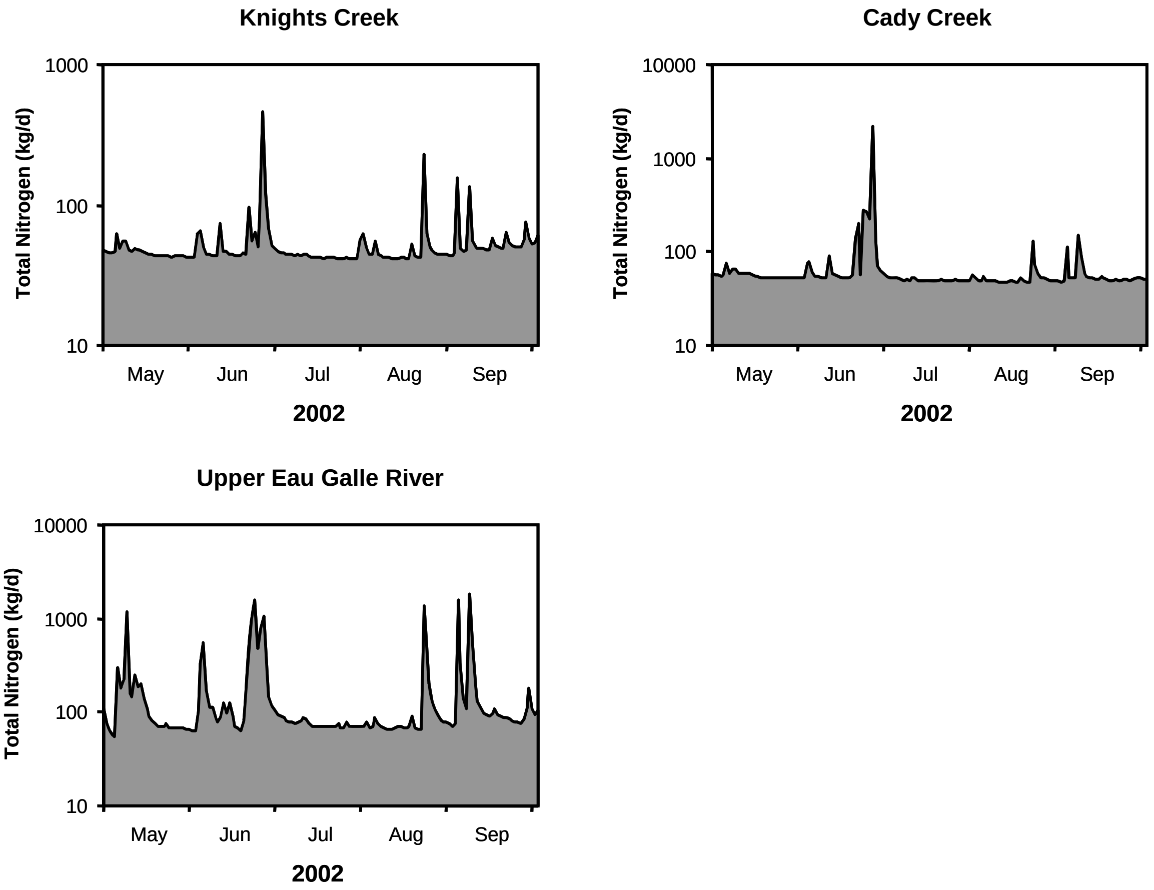


Figure 5. Seasonal variations in daily total nitrogen loading in 2002. Note logarithmic scale.

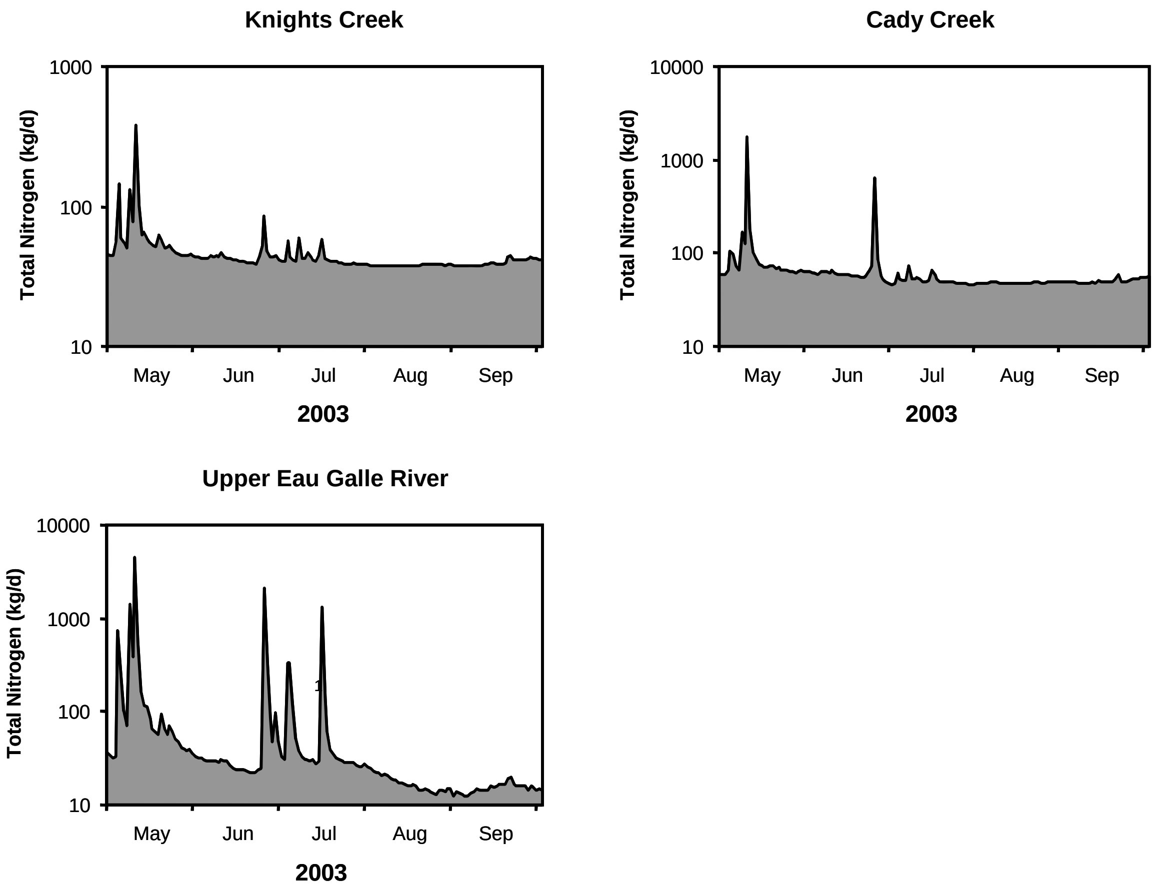
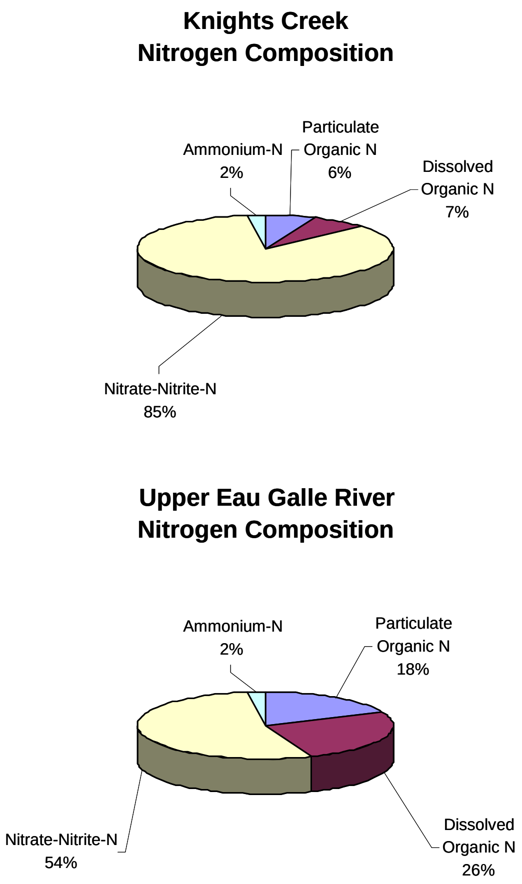


Figure 6. Seasonal variations in daily total nitrogen loading in 2003. Note logarithmic scale.


Knights Creek Nitrogen Composition

Cady Creek Nitrogen Composition

Upper Eau Galle River Nitrogen Composition

Figure 7. Compositional characteristics of nitrogen loads from the various tributaries.

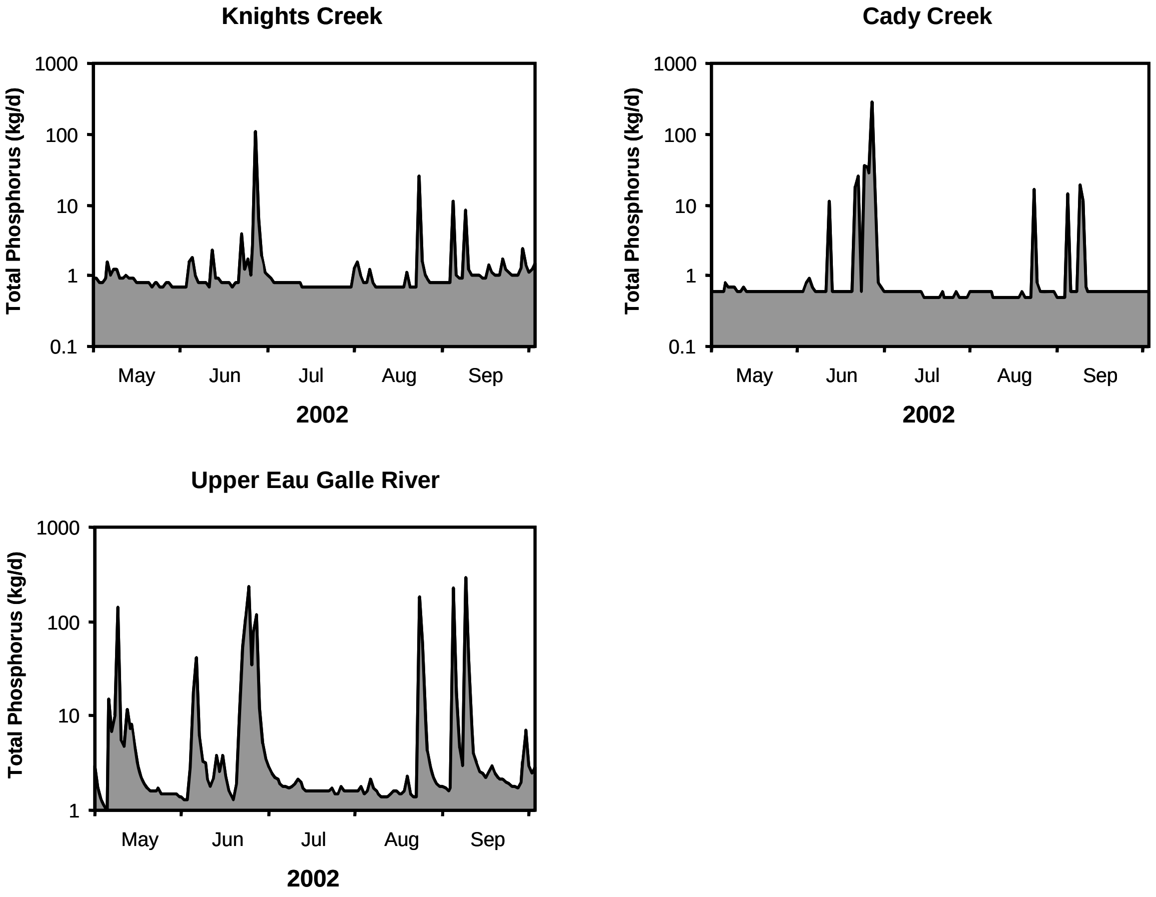


Figure 8. Seasonal variations in daily total phosphorus loading in 2002. Note logarithmic scale.

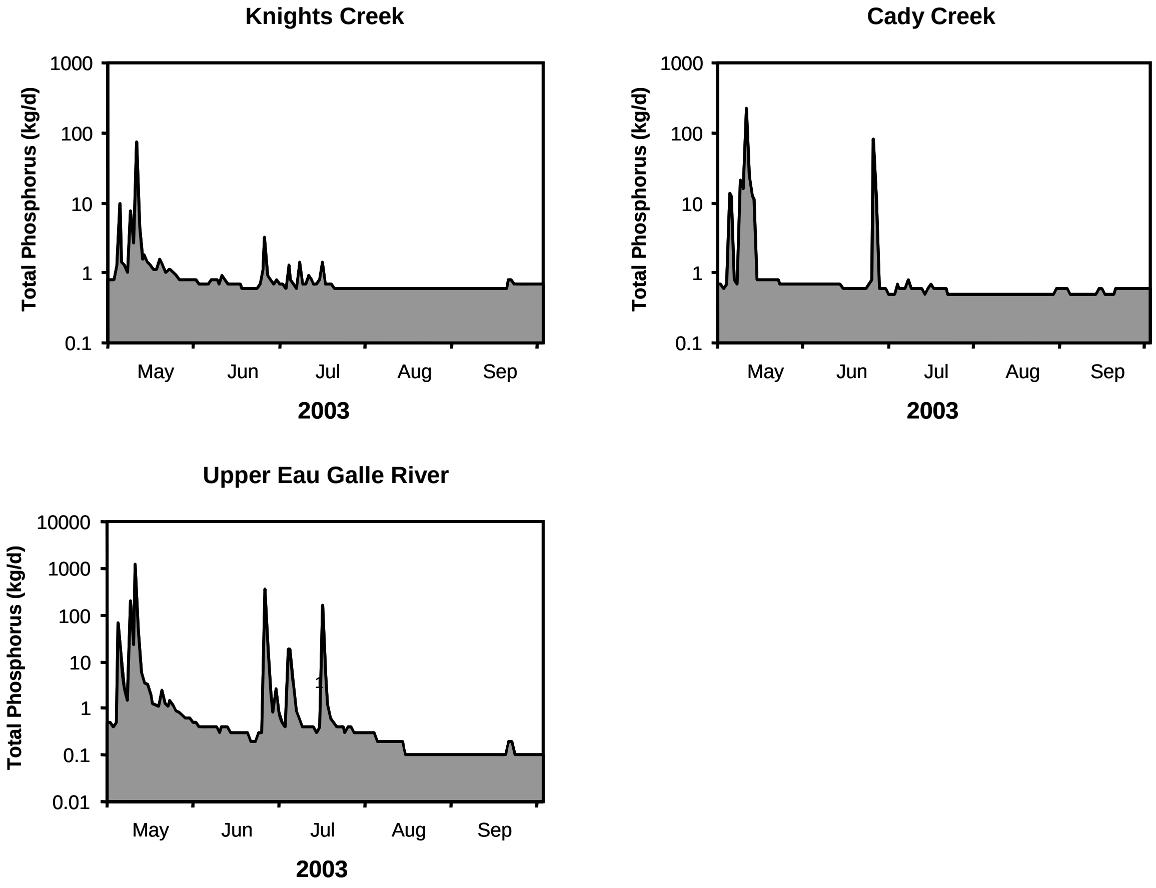


Figure 9. Seasonal variations in daily total phosphorus loading in 2009. Note logarithmic scale.

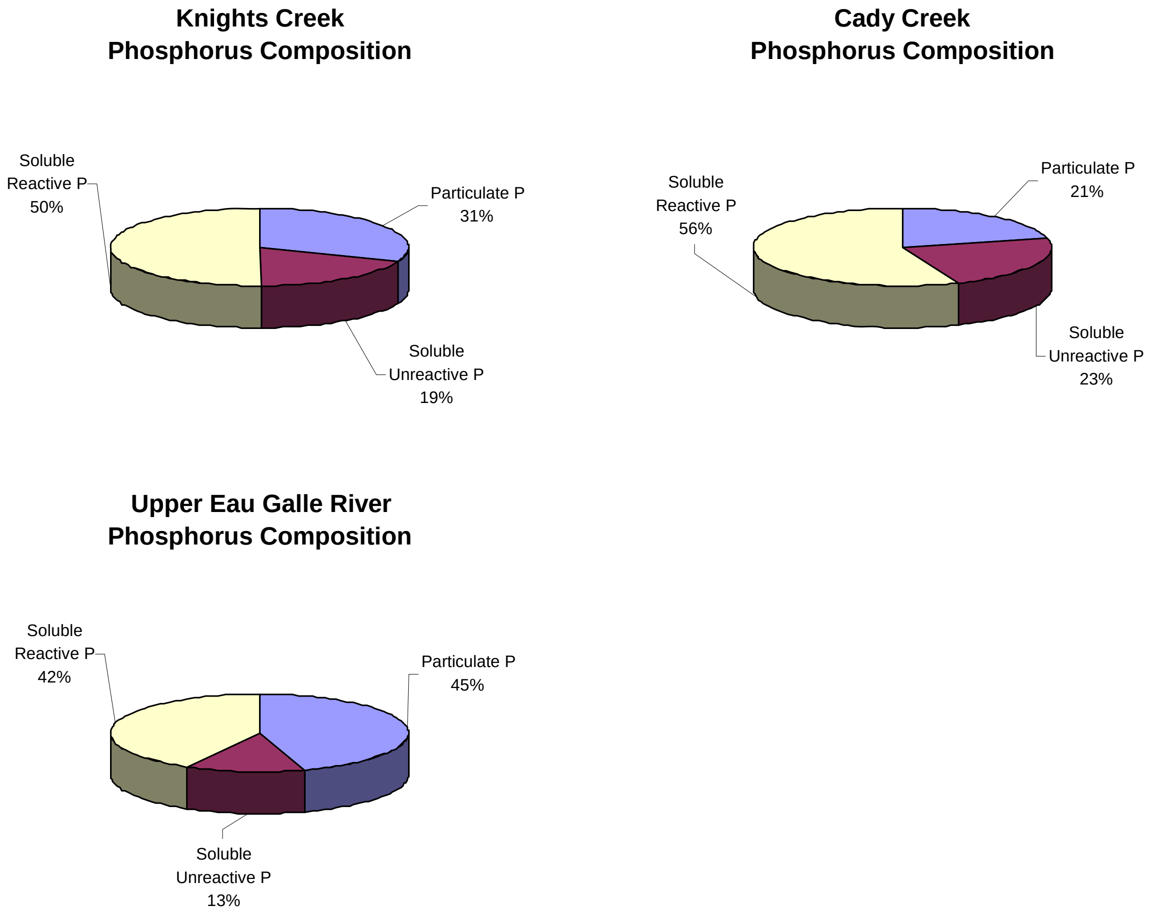


Figure 10. Compositional characteristics of phosphorus loads from the various tributaries.