Turfgrass and Environmental Research Online

...Using Science to Benefit Golf

Researchers at Kansas State University conducted research at Colbert Hills Golf Course near Manhattan, KS, to establish background surface water quality (total N, total P, and sediment concentrations) and evaluate changes of water quality during construction and operation of the golf course.

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PURPOSE

The purpose of *USGA Turfgrass and Environmental Research Online* is to effectively communicate the results of research projects funded under USGA's Turfgrass and Environmental Research Program to all who can benefit from such knowledge. Since 1983, the USGA has funded more than 290 projects at a cost of $25 million. The private, non-profit research program provides funding opportunities to university faculty interested in working on environmental and turf management problems affecting golf courses. The outstanding playing conditions of today's golf courses are a direct result of ***using science to benefit golf***.

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Nutrient Runoff from Three Phases of a Golf Course Project

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SUMMARY

Kansas State University, in cooperation with Jim Colbert, the PGA TOUR, the Golf Course Superintendents Association of America (GCSAA), and various alumni, built an 18-hole championship golf course near Manhattan, Kansas. The new golf course community occupies a land area of about 410 hectares (1,012 acres) with 60% of its area in the Little Kitten Creek watershed (430 hectares, 1,060 acres). The Little Kitten Creek watershed, previously native grassland, undertook a dramatic change in land-use and watershed management since golf course construction in July, 1998. A research project initiated in early 1998 enabled researchers to establish background surface water quality (total N, TN; total P, TP; and sediment concentrations, TSS) and evaluate changes in water quality during construction and operation of the golf course. Water quality data generated included the following:

- Water quality data were divided into three sets namely: pre-construction, during-construction, and early operation following construction.
- The mean concentrations of TN, TP, and sediment (TSS, total suspended solids) in pre-construction period were 1.18, 0.39, and 477 mg/L; during construction are 3.88, 0.93, and 2,754 mg/L; and during early operation 2.02, 0.49, and 550 mg/L; respectively.
- In general, construction activities had the greatest adverse impact on water quality. Nutrient concentrations in streams were greatly improved during early operation compared to the construction period, but still remain higher than the native prairie levels.

Human activities can have a profound impact on the environment. Alteration of the land surface for a variety of uses including light and heavy industry, urbanization, and suburban development has changed water pathways and induced changes to natural processes.

Kansas State University, in cooperation with Jim Colbert, the PGA TOUR, the Golf Course Superintendents Association of America (GCSAA), and various alumni, built an 18-hole championship golf course (Colbert Hills Golf Course) near Manhattan, Kansas. The new golf course community occupies a land area of about 410 hectares (1,012 acres) with 60% of its area in the Little Kitten Creek watershed (Figure 1).

The Little Kitten Creek watershed undertook a dramatic change in land use since golf course construction was initiated in July, 1998. In order to monitor the impacts of construction and operation of the golf course on surface water quality, the USGA granted an eight-year research project to the Civil Engineering Department of Kansas State University to compare nutrient losses via runoff from the new golf course and the golf course site's previous native condition.

To date, more than 1000 surface water samples have been collected during runoff events

Sampling equipment was obtained, and three monitoring stations were set up to monitor the impacts of construction and operation of the golf course on surface water quality.

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and evaluated. The time span of water sampling covered three periods: pre-construction (before July, 1998), during construction (August, 1998 to April, 2000), post-construction or early operation (May, 2000 to today). The purposes of this study are (1) to evaluate the impacts of construction and operation of Colbert Hills Golf Course on surface water quality of Little Kitten Creek, in terms of sediment content and nutrient concentrations (total N, total P); (2) to identify the source of nutrients during construction and operation of the golf course; (3) to determine the influences of fertilizer applications on nutrient concentrations in streams during golf course operation; and (4) to find out the relationship between stream discharge and pollutant concentrations.

Previous research projects have been initiated in an effort to establish baseline water quality of native grasslands (1, 2, 4, 5). Other researchers have also conducted studies on golf courses to evaluate the impacts of operation of golf courses on surface water quality (3). The research project started well before the commencement of golf course construction and has run five years into the golf course operation. We are thus able to determine the trend of surface water quality during the golf course construction and operation by comparing that with the baseline water quality under native prairie conditions, and to assess the impacts of golf course construction and operation on surface water quality.

Materials and Methods

Little Kitten Creek Watershed

Little Kitten Creek watershed is located in southwestern Riley County on the west side of Manhattan, Kansas (Figure 1). The watershed, covering 430 hectares (1,060 acres) has a typical Midwest topography with elevations ranging from 340 to 420 meters (1,115 to 1,380 ft), decreasing from north to south. Land surface slope ranges from 4 to 14% with an average channel gradient of 3.2%. Originating from the northwest of the watershed, Little Kitten Creek flows about 3.2 kilometers (2 miles) from north to south before it

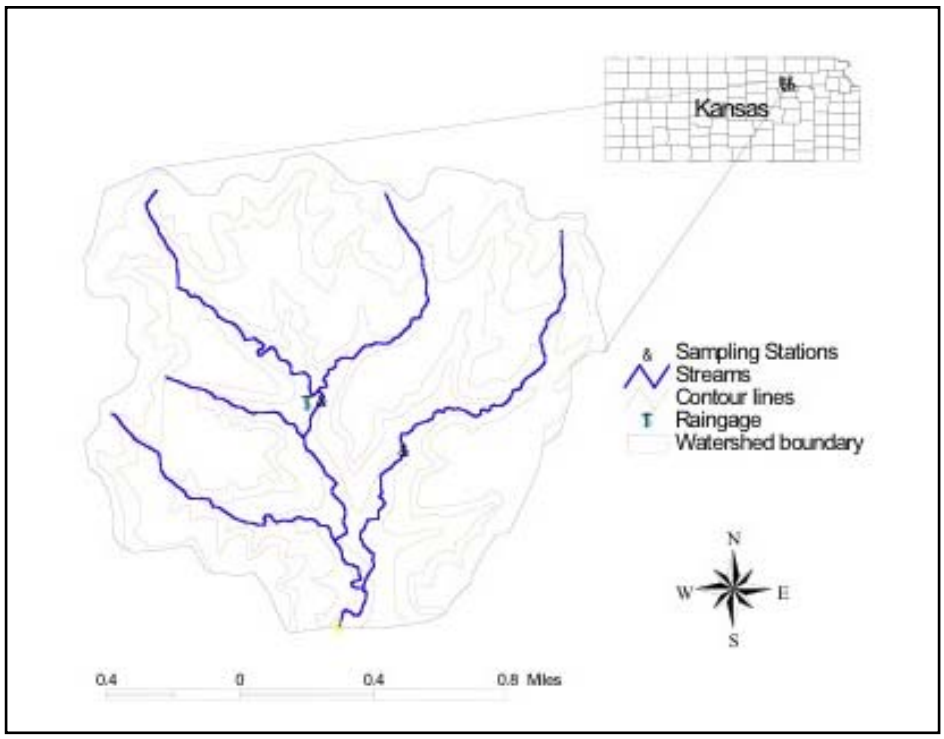

Figure 1. Layout of Little Kitten Creek watershed. About 10% of the 430-hectare (1,060-acre) watershed is golf course fairways, greens, tees, and irrigated rough. Three water-sampling stations were set up.

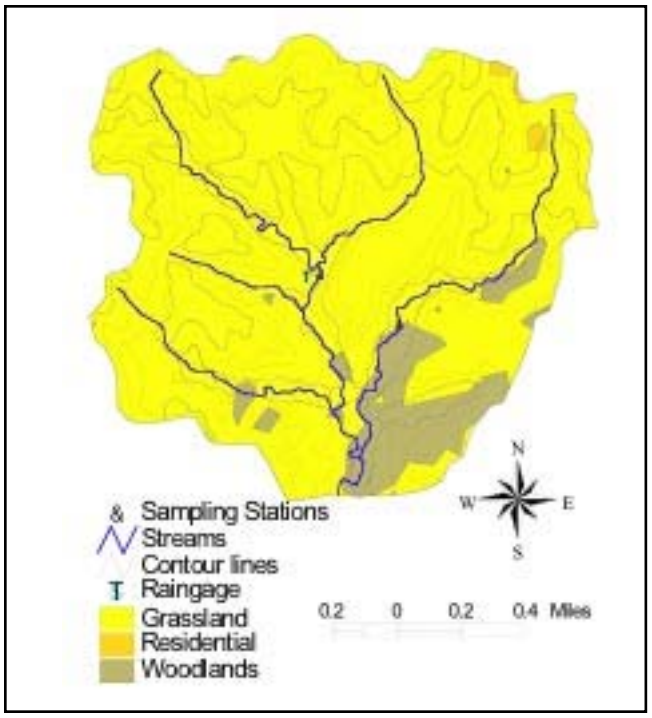

Figure 2. Landuses of Little Kitten Creek watershed before construction (89% native grassland, 11% woodland). Residential land use was negligible.

exits the studied watershed. It continues to run until it joins Wildcat Creek, a tributary of the Kansas River. Little Kitten Creek is an intermittent stream. During a typical year, approximately 5 to 10 runoff events occur resulting from intense, convective thunderstorms. The channels of the drainage network are dry for most of the remaining time.

As part of the Flint Hills rangeland in northeastern Kansas, the Little Kitten Creek watershed had a pre-construction land use of a typical mixture of tall grasses and woodlands with approximately 89% grasslands, 11% woodlands and negligible residential lands (Figure 2). Construction of the golf course started in July, 1998. By early 1999, alteration of land cover had attained its peak when about 88 hectares (217 acres, 20% of the total) of native cover was removed (Figure 3). By April, 2000, most of the construction work was completed, and disturbed lands were re-established with turfgrass. Application of fertilizers, pesticides, and routine irrigation of turfgrass was initiated.

Data Collection and Analysis

In order to monitor the environmental impacts of the construction and operation of the golf course, three stream-gauging stations were set up in the watershed. Two stations, N16 (north of hole 16) and N14 (north of hole 14), are located on the north boundary of course to monitor the quality of water entering the golf course. South Little Kitten Creek is located at the southern boundary of the golf course to monitor the quality of water leaving the golf course.

Portable water samplers were set up at each of the three stations to collect water samples during runoff events. Liquid detectors actuate the samplers at the beginning of a runoff event, and the samplers collect composite samples at a predetermined time interval (i.e. 1 or 2 hours). Raw samples were stored in a freezer for future laboratory analyses. Analyses were conducted at the Soil and Water Test Laboratory of the Department of Agronomy, Kansas State University. Water samples were analyzed for total nitrogen, NH_4-N, NO_3-N, total phosphorus, ortho-P, total suspended

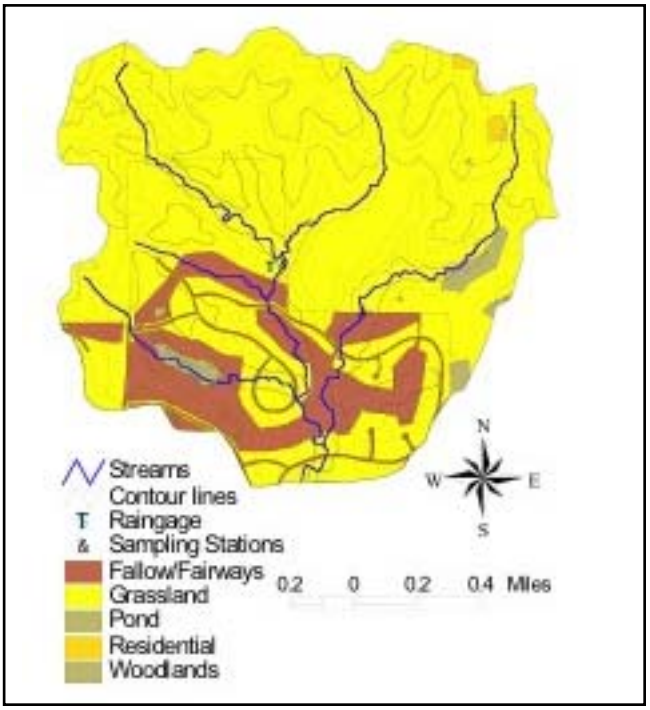

Figure 3. Land uses of Little Kitten Creek watershed during and post construction of Colbert Hills Golf Course. Golf course fairways, greens, tees, and irrigated rough account for about 10% of the watershed area.

Phase	Number of samples	Total N (mg/L)			Total P (mg/L)			TSS (mg/L)		
		Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum
Pre-	28	1.18	0.30	4.80	0.39	0.01	1.70	477	116	2,496
During	138	3.88	0.02	13.40	0.93	0.01	8.36	2,754	4,598	24,000
Post-	264	2.02	0.05	21.53	0.49	0.01	2.83	550	2	15,903

Table 1. Concentrations (mg/L) of total N, total P, and total suspended solids sampled from South Little Kitten Creek which received runoff water of the watershed including fairways of Colbert Hills Golf Course before (Pre-), during, and after (Post-) the golf course was constructed.

solids (TSS), and total dissolved solids (TDS). Field parameters measured at the time of sampling included specific conductivity, hydrogen-ion activity (pH), water temperature, and dissolved oxygen concentration (DO).

To determine runoff volume, natural channel cross sections at the three stations were surveyed. Water level loggers were installed at the stations to record water levels at 5-minute intervals. A Model 201 portable water-flow meter (Marsh-McBirney, Inc.) was used to measure flow velocities during runoff events. Rating curves (flow depth versus discharge) for the three stations were developed. A CSI model CS700-L tipping bucket rain gauge was installed at the center of the watershed. The rain gauge has a resolution of 0.254 mm (0.01 inch). Rainfall data were recorded at 10-minute intervals.

Impact of Three Distinct Phases on Water Quality

Pre-construction

The water quality of unpolluted water bodies is dependent on local geological, biological, and climatological conditions. These conditions control the mineral quality, ion balances, and biological cycles of the water body. To preserve the quality of the aquatic environment, the natural balances should be maintained. Knowledge of the background quality is necessary to assess the suitability of water for use and to detect future human impacts. Background water quality monitoring was conducted prior to the start of golf course construction in July, 1998. Water quality during this period serves as a baseline for evaluating the impacts of construction and operation of Colbert Hills Golf Course.

During construction

The water quality monitoring program covered the whole construction period from August, 1998 when construction work started, to April, 2000 when the golf course officially opened for play. Preliminary studies have indicated a substantial increase in sediment content (TSS) from 100 to 2,000 mg/L at pre-construction to 100 to 24,000 mg/L during construction. Concentrations of total nitrogen and total phosphorus are also found significantly greater than those in the pre-construction period. Since there are no human inputs of these compounds, the increases of nitrogen and phosphorus in this period are believed to be due to the increase of eroded soils that carry particle-bound nitrogen and phosphorus.

Early Operation

In this period, turfgrass is being fertilized and irrigated. This poses a potential danger of polluting the surface water systems through irrigation return water and rainfall runoff. Information regarding fertilizer application (names of applied chemicals, date and amount applied, etc.) was obtained from the Colbert Hills Golf Course management office. The relationship between nutrient concentration in streams and fertilizer applications was examined.

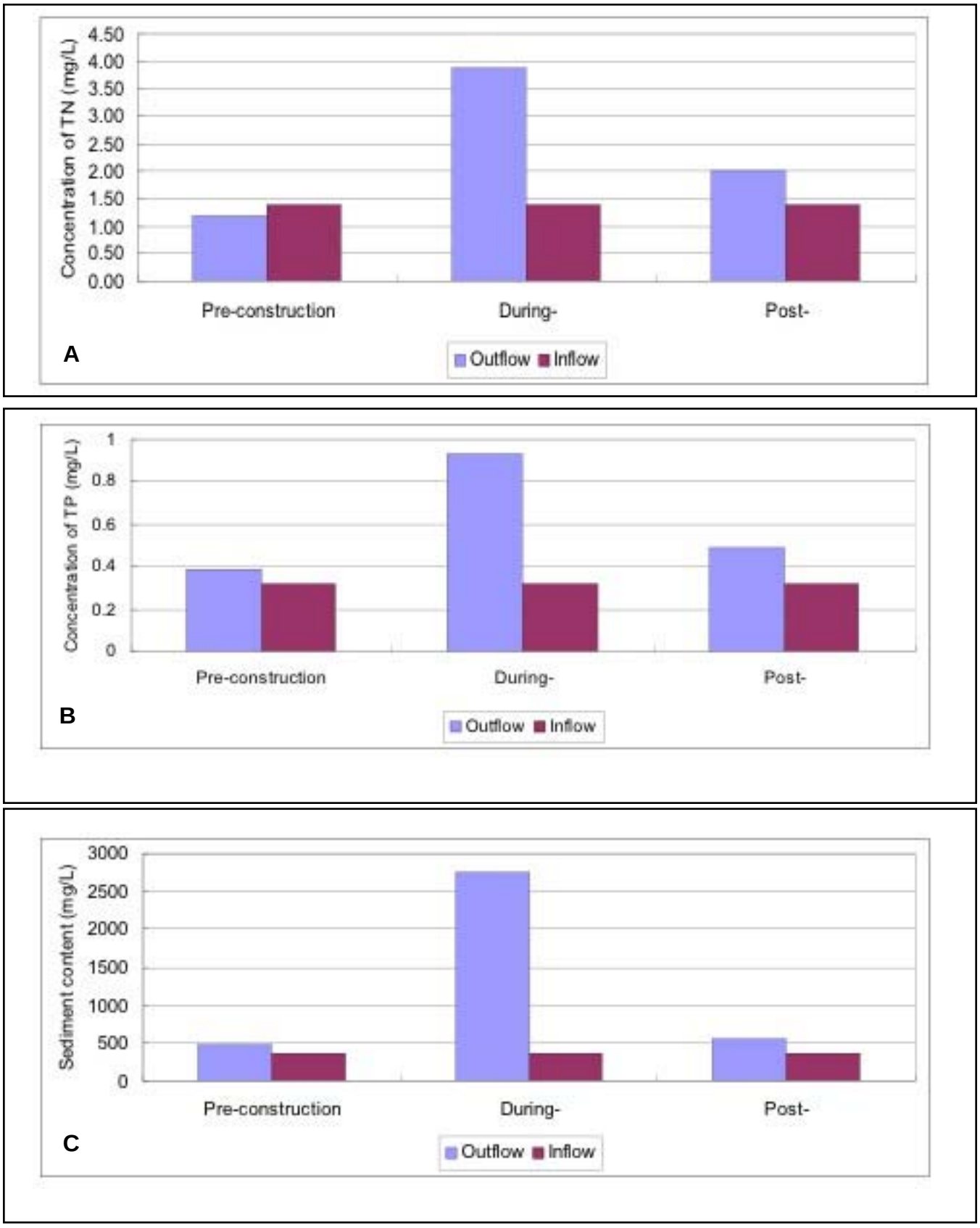

Figure 4. Inflow and outflow average concentrations of TN (A, total nitrogen, mg/L), TP (B, total phosphorus, mg/L) and TSS (C, total suspended solids, or sediment, concentration, mg/L) of water sampled from Little Kitten Creek before construction (pre-), during construction, and after (post-) construction of Colbert Hills Golf Course.

Results

Concentration Variation

Water quality data are divided into three sets: pre-construction, during construction, and early operation. At N16, one of the major inflows into the golf course, 25, 141, and 151 water samples were taken during runoff events at the three stages, respectively. Statistic analyses show that the development of the golf course has little impact on stream water quality at this point, in terms of concentrations of TN, TP, and TSS. Indeed, this observation station was designed right upstream of the development area. At N14, another control point of inflow into the golf course, data show a similar trend.

However at South Litten Kitten Creek, the major outflow, the results are quite different. Twenty-eight, 138, and 264 samples were taken during runoff events during the three development stages at this location. Statistical analyses indicate that the average concentrations of TN and TP during construction were two to three times of those under native land cover conditions. The sediment content was even higher. During early operation, sediment content was brought down significantly to an average of 550 mg/L, similar to that at the native prairie condition. The average concentrations of TN and TP were 2.02 mg/L and 0.49 mg/L, respectively, much lower than those in construction period, but still about twice as much as those in the native prairie condition (Table 1). Spatial (inflow and outflow) and temporal (pre-, during-, and post-construction) variations of average concentrations of TN, TP, and TSS are shown in Figure 4.

Sources of Nutrients in Streams

Atmospheric deposition is a constant input of nutrients throughout the three periods in this study. In the pre-construction period and during golf course construction, there were no human inputs of nutrients (fertilizer). It is therefore assumed that soil erosion is the major source of nutrients in streams during these periods. In fact, land covers of about 20% of the watershed area were altered during construction. The original land covers were primarily undisturbed thick and dense grasses and forestry. The rootzone was composed of a large percentage of organic matter that contains nutrients. The loose topsoils were vulnerable to rainfall runoffs, and the hilly topography of the watershed accelerated the process of soil erosion. During early golf course operation, intensive care is required to maintain turfgrass at acceptable levels.

Concentrations of TN, TP, and TSS over time are plotted in Figure 5. From these three figures, differences in TN, TP, and TSS are obvious. The linkage of TSS concentration and both TN and TP is also evident. When TSS spikes, so does TN and TP. It is also obvious that the construction phase is most vulnerable to nutrient loss. Take TN as an example. During the pre-construction phase, maximum values for TN are about 5 mg/L with most of the values around 1 mg/L. During construction, TN is commonly found in runoff water at 4-5 mg/L with the maximum value at about 13 mg/L. During operation, the majority of values are around the 1-2 mg/L range with a few samples exhibiting higher amounts.

Conclusions

We have seen a significant change in land uses in Little Kitten Creek watershed in the process of turning a native prairie into a championship golf course. The period having the worst water quality was during golf course construction from August, 1998 to April, 2000. During golf course operation, TSS concentration was back near the native prairie level. Nutrient concentrations in stream were greatly improved during operation from the construction period, but still higher than the native prairie levels (i.e. about twice the native condition for total nitrogen, and 30% greater for total phosphorus). Sources of nutrient in stream are identified. In addition to atmospheric deposition, soil erosion is the major source of stream nutrients at native prairie conditions and during construction. Since the TSS level

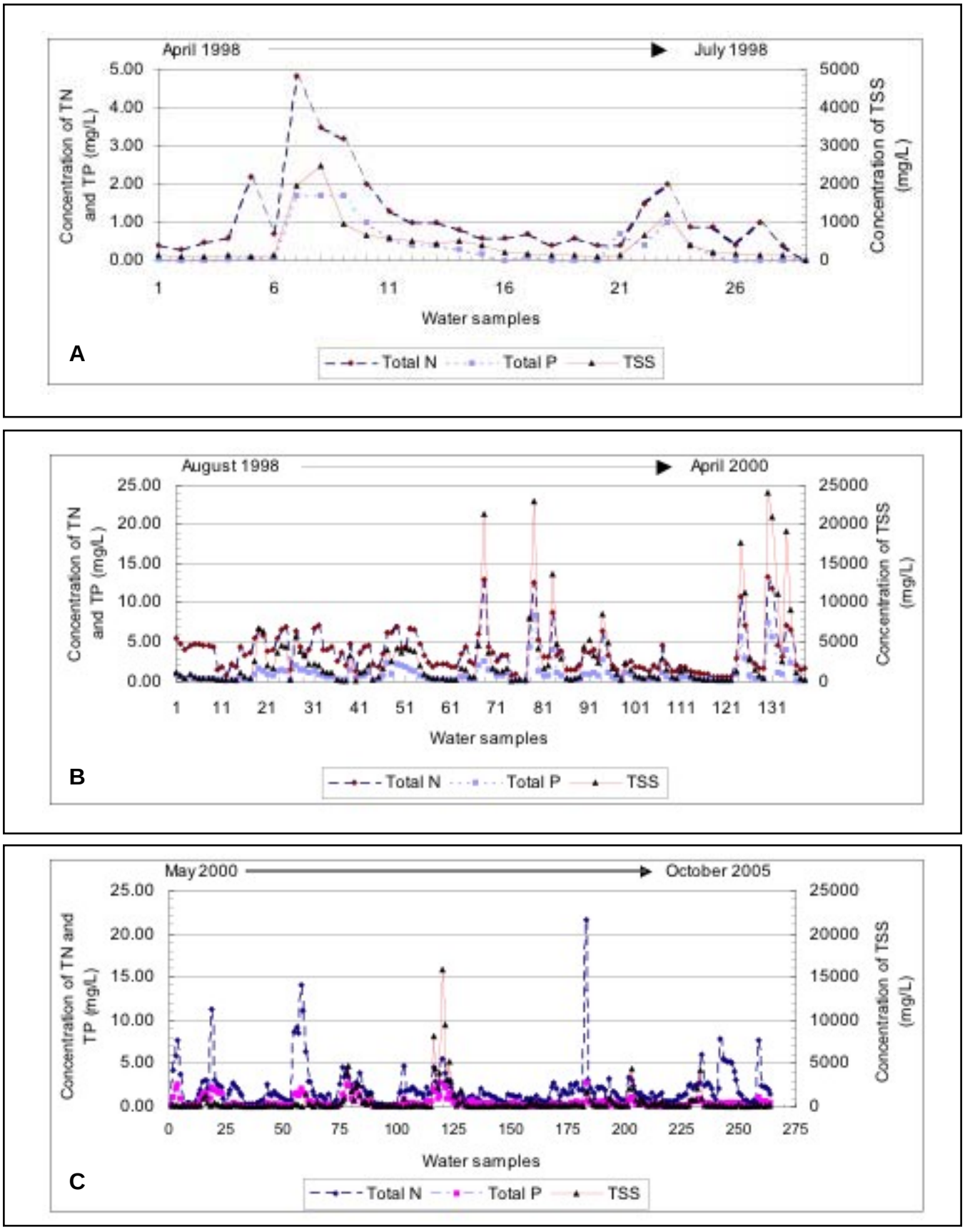

Figure 5. Concentrations of TN (total nitrogen), TP (total phosphorus), and TSS (total suspended solids, sediment) during pre-construction (A), during construction (B), and during early operation after contruction (C).

was brought down to normal during early operation, human inputs (i.e. golf course fertlization) accounted for the majority of nutrients in water samples.

Construction of Colbert Hills Golf Course greatly deteriorated the surface water quality by tripling the mass transport rates of nitrogen and phosphorus, and increasing the mass transport of TSS by a factor of 10. Once estabalished, there was little, if any, impact of the golf course operation on surface water quality from a mass transport point of view, even though nutrient concentrations in streams was elevated compared to preconstruction values. This was the result of reduction of runoff volume by turfgrass. During this early operation period, the overall losses of fertilizer through surface runoff were less than 5% of that applied. However, losses from individual runoff events could be very high if fertilizer was applied shortly before a significant rainfall. With judicious fertilizer application timing, however, losses of fertilizer through surface runoff are managebly low.

The watershed is now starting to develop as a residential community. It will be very interesting to learn how the watershed runoff characteristics become affected by the development of homes surrounding the golf course, particularly how this residential development affects the surface water quality as more and more land in the watershed is developed into housing.

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Literature Cited

1. Dodds, W.K., J. M. Blair, G.M. Henebry, J.K. Koelliker, R. Ramundo, and C.M. Tate. 1996. Nitrogen transport from tall grass prairie watersheds. *J. Environ. Qual.* 25:973-981. (TGIF Record 110497)

2. Olness, A., E.D. Rhoades, S.J. Smith, and R.G. Menzel. 1980. Fertilizer nutrient losses from rangeland in central Oklahoma. *J. Environ. Qual.* 9:81-86. (TGIF Record 110494)

3. Ryals, S.C., M.B. Genter, and R.B. Leidy. 1998. Assessment of surface water quality on three eastern north Carolina golf courses. *Environmental Toxicology and Chemistry* 17:1934-1942. (TGIF Record 66409)

4. Smith, S.J., A.N. Sharpley, W.A. Berg, J.W. Naney, and G.A. Coleman. 1992. Water quality characteristics associated with Southern Plains grasslands. *J. Environ. Qual.* 12:595-601. (TGIF Record 24949)

5. Webb, B.W., and D.E. Walling. 1985. Nitrate behavior in stream-flow from a grassland catchment in Devon, U.K. *Water Res.* 19:1005-1016. (TGIF Record 110493)