Nutrient and Sediment Runoff from a Prairie Golf Course

Tracking runoff offers important insights for management.

BY STEVE STARRETT and YUNSHENG SU

The Colbert Hills Golf Course community in Manhattan, Kansas, occupies a land area of more than 1,000 acres, with 60% of its area in the Little Kitten Creek watershed. As the golf course was constructed, the Little Kitten Creek watershed undertook a dramatic change in land use, from native prairie to a golf course. In an effort to understand the impact of golf course construction on water quality, the USGA's Turfgrass and Environmental Research Program granted a five-year research project to Kansas State University to compare nutrient runoff losses from the new golf course with nutrient losses when the site was in its previous native prairie condition.

More than 900 surface water samples were collected and tested from three time periods. These periods included: (1) pre-construction (before July 1998), (2) during construction (August 1998 to April 2000), and (3) early stage of golf course operation (May 2000 to July 2001). The project was designed to determine nutrient and sediment losses as a result of golf course construction. Specifically, these determinations included efforts to: (1) 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) identify the source of nutrients lost during construction and operation of the golf course, (3) determine the influence of fertilizer applications on nutrient concentrations in streams during golf course operation, (4) find out the relationship between stream discharge and pollutant concentrations.

SITE DESCRIPTION

The Little Kitten Creek watershed has a typical Midwest topography, with elevations ranging from approximately 1,100 to 1,400 feet, decreasing from north to south. Alluvial lands are located near channels and are frequently flooded. The soil series most common in the watershed are well drained, with medium-to-rapid surface runoff and low permeability.

As part of the Flint Hills rangeland in northeastern Kansas, the Little Kitten Creek watershed had a pre-construction land use of the typical mixture of tall grasses (89%), forests (11%), and negligible residential lands. Construction of the golf course began in July 1998. By early 1999, alteration of land cover had attained its peak when about 220 acres (20% of the total) of native cover was removed. By April 2000, most of the construction work was completed, and disturbed lands were reestablished with turfgrass. Application of fertilizers, pesticides, and irrigation was initiated during turf establishment.

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 were positioned on the north side of the area to monitor the quality of water entering the golf course, and one station was located at the south boundary of the golf course to monitor the quality of water leaving the course. Water samples were taken during runoff events; therefore, resulting concentration values were much higher than a quarterly or monthly sampling regime would have produced because our samples are only from high-flow conditions. Commonly, water samples collected quarterly or monthly would be from low-flow conditions.

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

DURING AND POST CONSTRUCTION

Water quality monitoring spanned the entire construction period from August 1998, when construction work officially started, to April 2000, when the golf course officially opened for play. Preliminary studies indicated a substantial increase in sediment content (TSS) from 100-2,000 mg L^{-1} at pre-construction to

100-24,000 mg L^{-1} during construction. Concentrations of total nitrogen and total phosphorus were significantly greater during the construction period compared to pre-construction. Since there were no human inputs of these compounds, the nitrogen and phosphorus increases in this period were believed to be due to the increase of eroded soils that carry particle-bound nitrogen and phosphorus.

During turf establishment, turfgrass care intensified with fertilizer applications and irrigation. This posed a potential danger of polluting the surface water systems through irrigation return water and rainfall runoff. Information regarding fertilizer applications (names of applied chemicals, date and amount applied, etc.) was obtained from Colbert Hills Golf Course management. Relationships between fertilizer applications and nutrient concentration in streams were analyzed. It must be noted, however, that since this is an ongoing project, more data will be added and continued to be analyzed.

RESULTS REFLECT CONSTRUCTION IMPACT

Water quality data were divided into three sets: pre-construction, during construction, and post-construction. At one of the major inflows into the golf course, 25, 141, and 43 water samples were taken at the three development stages. As expected, statistical analyses show that the development of the golf course has little impact on stream water quality at this location in terms of concentrations of total nitrogen, total phosphorus, and total sediment load.

However, at the major outflow the results are quite different. Twenty-eight, 138, and 87 samples were taken at the three development stages at this location. Statistical analyses indicate that the average concentrations of total nitrogen and total phosphorus during construction were two to three times those under native land cover conditions. The sediment content was even higher.

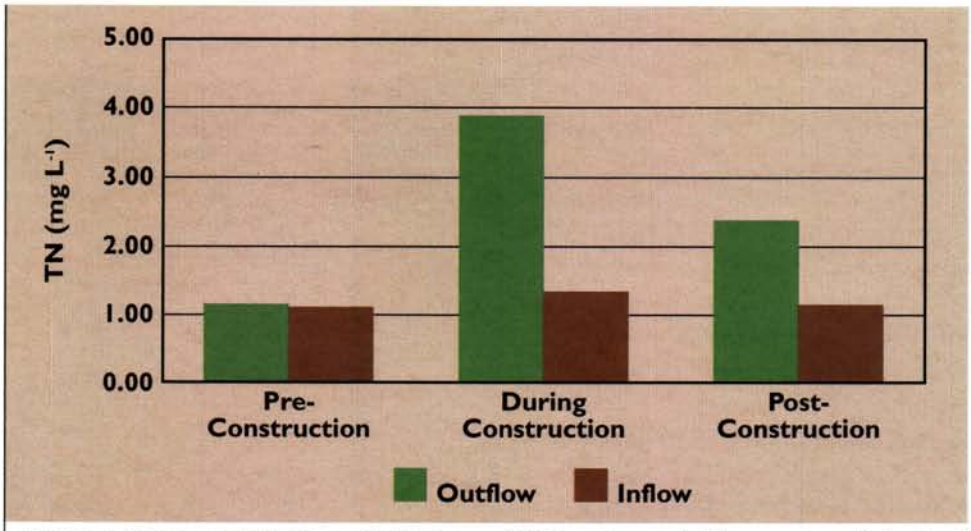


Figure 1. Average concentrations of total nitrogen (TN) in water sampled from upstream (inflow) and downstream (outflow) of Colbert Hills Golf Course before course construction, during construction, and post-construction after turf was established.

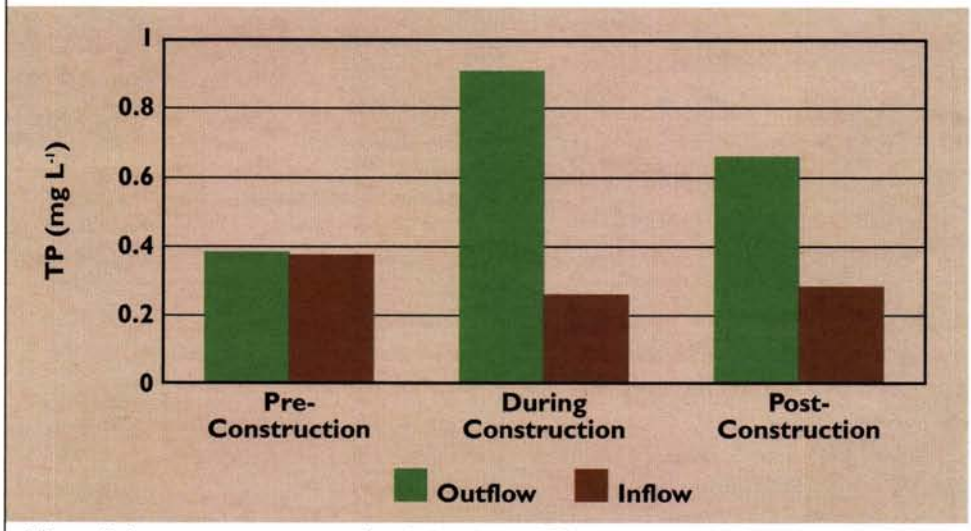


Figure 2. Average concentrations of total phosphorus (TP) in water sampled from upstream (inflow) and downstream (outflow) of Colbert Hills Golf Course before course construction, during construction, and post-construction after turf was established.

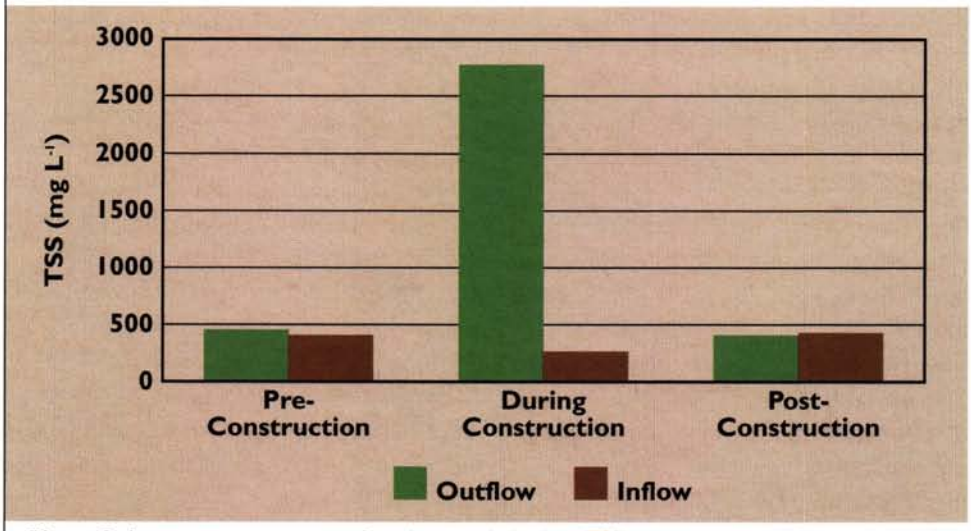


Figure 3. Average concentrations of total suspended solids (TSS) in water sampled from upstream (inflow) and downstream (outflow) of Colbert Hills Golf Course before course construction, during construction, and post-construction after turf was established.

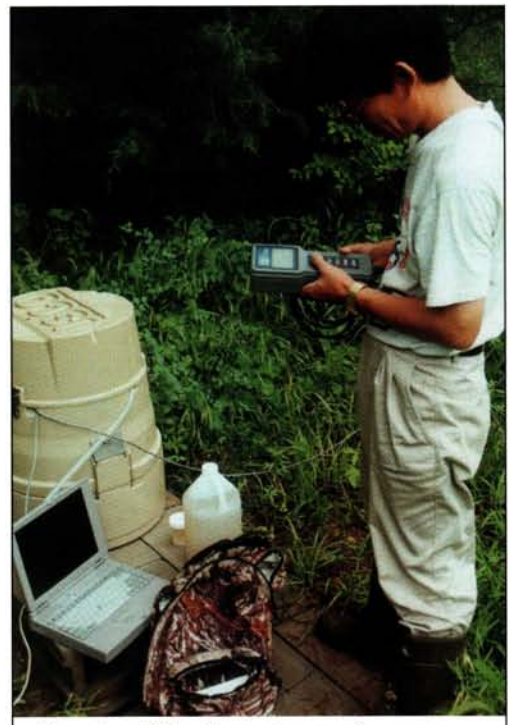
During operation, however, sediment content was brought down significantly, to an average of 397 mg L^{-1} — lower than that at the native prairie condition. This reduction is no doubt due to the turfgrass establishment. The average concentrations of total nitrogen and total phosphorus were 2.38 mg L^{-1} and 0.67 mg L^{-1}, respectively, much lower than those in the construction period, but still about twice as much as those in the native prairie condition. Spatial (inflow and outflow) and temporal (pre-, during, and post-construction) variations of average concentrations of total nitrogen, total phosphorus, and total sediment load are shown in Figures 1-3.

SOURCES OF NUTRIENTS IN STREAMS

Various researchers (1) studied a forested and rangeland watershed and found that streams in forested and rangeland areas have significantly smaller nutrient concentrations than streams in urban and agricultural land-use areas. This may indicate that large nutrient concentrations in streams in urban and agricultural areas are a result of human activity, especially soil tillage, as well as fertilizer and manure applications in watershed areas.

During the pre-construction and construction periods, there were no human inputs of nutrients (fertilizer). It can be reasoned that soil erosion is the major source of nutrients in streams during these periods. In fact, vegetation of about 20% of the watershed area was removed during golf course construction. The original land covers were primarily undisturbed thick and dense grasses and forests. The rootzone of those undisturbed areas contained a large percentage of organic matter that contained nutrients. During construction, topsoil was vulnerable to runoff, and the hilly topography of the watershed accelerated the soil erosion process.

During golf course operation, both fertilizer and pesticide applications



More than 900 surface water samples were collected in an effort to understand the impact of golf course construction on water quality at the Colbert Hills Golf Course (Kansas).

are necessary to maintain turfgrass at acceptable levels (2). In addition to plant uptake and adsorption, and absorption by soil and thatch, applied fertilizers and pesticides are capable of being washed into streams by significant rainfall or irrigation, especially when soils are already saturated.

Fertilizer application records registered information about the date of application, name of fertilizer, fertilizer analysis, type of fertilizer (soluble or granular), rate of application, total area treated, and so on. As expected, impacts of fertilizer applications on nutrient concentrations in streams depended largely on the amount (rate) of fertilizer applied and timing of application. To minimize the potential for nutrient runoff into surrounding surface waters, fertilizer applications should be avoided immediately preceding significant rainfall. In reviewing the fertilization records of Colbert Hills Golf Course, however, the impacts of fertilizer applications on nutrient concentrations in streams were minimal during the 1.5-year monitoring period. Few incidents were observed when fertilizer applications coincided with spikes of high nutrient concentrations in streams of Little Kitten Creek watershed.

THE POWER OF MATURE TURF TO INHIBIT EROSION

A significant land-use change was observed in the 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. Once the turfgrass was established, however, total sediment load was reduced to levels even lower than that of the native prairie.

Nutrient concentrations in streams were greatly improved during operation from the construction period, but still higher than the native prairie levels. Soil erosion is the major source of stream nutrients in native prairie conditions and during construction. Since total sediment load was significantly reduced after turf establishment, fertilization practices were contributing to nutrients detected in the watershed streams during operation. However, if care is taken to avoid fertilizer applications just prior to significant rainfall events, the potential for nutrient runoff is greatly reduced.

LITERATURE CITED

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