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Figure 1. Project location.

IN THIS ISSUE

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PROJECT SPOTLIGHT

Nutrient Load Reductions and Streambank Stabilization in Oklahoma's Peacheater Creek Watershed: Successful Implementation of Agricultural BMPs

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Background and Introduction

Peacheater Creek is located in eastern Oklahoma and is part of the larger Illinois River watershed (see Figure 1). The Illinois River and its two major tributaries, Flint Creek and the Baron Fork, are designated Scenic Rivers and considered by Oklahomans to be among the finest rivers in the state. They provide major recreational resources for many state residents and significant benefits for the local economy, as well as serving as drinking water supplies. Lake Tenkiller, the result of impoundment of the Illinois River, is also recognized as one of the outstanding recreational and water supply reservoirs in the state.

However, since the early 1980s, the Illinois River and Lake Tenkiller have experienced water quality degradation, notably decreased water clarity resulting from frequent algae blooms. Initial research concluded that the cause of impairment was excess nutrients, particularly phosphorus. Potential sources identified included wastewater effluent (from both Arkansas and Oklahoma) and nonpoint sources associated with the poultry industry, plant nurseries, and various agricultural operations. Streambank erosion due to loss of riparian zones and direct cattle access to streams, as well as conversion of forested land to pastures, was also affecting the water resources (see Figures 2 and 3). Research and assessment concluded that watersheds with the greatest concentration of poultry

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and cattle were the greatest contributors to the water quality problems.

EDITOR'S NOTE

In this issue of *NWQEP NOTES*, we continue our series on National Nonpoint Source Monitoring Program (NMP) projects that have been completed and have documented improvements in water quality due to best management practice (BMP) implementation.

The Illinois River watershed, in eastern Oklahoma, was the subject of a 10-year study to address nonpoint source pollution from poultry and cattle operations, primarily nutrients, bacteria and sediment. The study employed a paired-watershed monitoring design to assess potential pollutant load reductions and streambank improvements due to installation of BMPs focusing on riparian, land and waste management. Practices included establishment of riparian buffers, alternative water supplies for cattle, construction of heavy use areas for feeding and storing wastes, poultry litter transport, pasture management, and septic tank installation and repair. Project results documented significant reductions in stream phosphorus loading (71%), stream total nitrogen loading (58%), and erosion and nutrient loading from streambanks following BMP implementation.

This project illustrates the power of the paired-watershed design to isolate changes caused by BMPs from changes caused by hydrological or other climatic variations. It also serves as a good example of how such designs can be used to detect true changes in a shorter time period and more reliably than other watershed monitoring designs. The authors note that the success of this project has lead to increased funding and monitoring support for other nonpoint source control projects in the Illinois River watershed and in other watersheds throughout Oklahoma.

As always, please feel free to contact me regarding your ideas, suggestions, and possible contributions to this newsletter.

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Lake Tenkiller, Flint Creek, the Baron Fork, and segments of the Illinois River are currently impaired by bacteria, excess phosphorus, low dissolved oxygen and other causes related to eutrophication. Arkansas, in a show of good faith to help meet the recently promulgated Oklahoma phosphorus standard of 0.037 mg/L for Scenic Rivers, agreed to upgrade sewage treatment for the cities of Siloam Springs, Springdale, Fayetteville, Bentonville, and Rogers to meet 1.0 mg/L phosphorus effluent limits. With this attention to point source pollution in the watershed, remaining efforts must focus on reduction of nonpoint source (NPS) pollution.

To accurately quantify the potential for best management practices (BMPs) to improve water quality impaired by NPS pollution in the Illinois River watershed, a paired watershed project was designed using two similar sub-watersheds, Peacheater Creek and Tyner Creek. The project design was developed in accordance with requirements for analysis of paired watershed data as outlined in Clausen and Spooner (1993). The relatively small size of the Peacheater Creek watershed, its land use characteristics, and its location entirely within Oklahoma made it a good candidate for assessing the potential pollutant load reductions and streambank improvements associated with various types of BMPs in the Illinois River Watershed as a whole. Tyner Creek, the control watershed, is located adjacent to Peacheater and is similar in many ways. Land use and potential sources of NPS pollution in both watersheds are typical of the Illinois River Watershed, although there are no point sources in either watershed. Both Peacheater and Tyner Creeks currently violate Oklahoma Water Quality Standards for *Enterococcus* bacteria, resulting in nonattainment of the Primary Body Contact Recreation designated use.

This project was funded through an Environmental Protection Agency (EPA) 319 program grant as part of the National Nonpoint Source Monitoring Program. Initiated in 1991, this project was established to evaluate the effectiveness of nonpoint source pollution controls in selected study watersheds. All projects under this program were designed to effectively integrate water quality monitoring with BMP implementation to evaluate the effectiveness of pollution control practices. On a local level, the Oklahoma Conservation Commission (OCC) collaborated with the Cherokee County Conservation District to implement the cost share program in the watershed.

Pre-implementation (calibration period) monitoring was initiated in the Peacheater and Tyner Creek watersheds in 1995 and continued until 1998, when BMP implementation began in Peacheater. BMPs installed through 2002 included establishment of riparian buffers, alternative water supplies for cattle, construction of heavy use areas for feeding and storing wastes, poultry litter transport, pasture management, and septic tank installation or repair. Post-implementation (treatment period) monitoring began in 2003 and was concluded in 2005.

Figure 2. Streams in the watershed have become shallower and wider due to bank erosion.

Figure 3. Areas that were once heavily forested have been cleared for pastures.

Study Objectives and Design

There were two primary objectives in this project: 1) to demonstrate successful implementation of BMPs to reduce NPS pollution, and 2) to demonstrate a method of water quality monitoring that would allow quantification of the effectiveness of BMPs in reducing NPS pollution. Restoration of the recreational beneficial use in Peacheater Creek as a result of BMP implementation was also an objective, as was reducing eutrophication impacts on the Illinois River and Lake Tenkiller. BMPs implemented through the project focused on riparian management and improvement in addition to proper animal waste management and education.

This project followed a paired-watershed design (Clausen and Spooner 1993). This approach uses two different time periods consisting of calibration and treatment phases. During calibration, at least two watersheds similar in size and location are monitored over time, with one acting as the control and the other as the treatment. During this period no land use changes occur and regressions are developed between paired observations of runoff and water quality variables. Once a satisfactory relationship with respect to hydrology and water quality variables has been determined, treatment of one of the watersheds can begin whereupon changes over time can be monitored and new regressions can be developed. Differences due to treatment are evaluated by statistical comparisons of calibration and treatment regressions. Changes between the periods are determined based on a comparison of predicted values calculated from the calibration regression equations and observed values during the treatment period.

In the Peacheater Creek Project, the pre-BMP calibration phase began in December 1995 and ended in August 1998. Implementation of BMPs was initiated in March 1999 and was completed in December 2001; no monitoring was conducted during the implementation period. Treatment period monitoring began in early 2003 and continued through 2005 to document the effects of BMPs.

Study Sites

The objective of this project was to assess the effect of BMPs on reduction of pollutant loads and streambank erosion through monitoring at the watershed level, following a paired-watershed design. The Peacheater Creek watershed (treatment watershed) was selected based upon its size, land use, number of landowners and their willingness to participate in cost-share programs, and its position in the prioritization ranking within the Illinois River watershed. Upper Tyner Creek, the control watershed, was chosen for its similarity to the treatment watershed based on size, geologic structure, soils, slope, population, and land use. The sites were also chosen for geographic proximity to each other to insure that both received similar weather inputs. This paired design allows documentation of water quality changes due to treatment, while controlling for the effects of hydrologic variation. (Clausen and Spooner 1993). Figure 4 shows the location of the Peacheater Creek and Tyner Creek watersheds.

Both Peacheater and Tyner Creeks are typical of others in the Illinois River basin, which are characterized by very low turbidity and a substrate composed of flint gravel. Average base flow for Upper Tyner and Peacheater Creeks is 2-13 ft^3/s (0.06-0.37 m^3/s) (dry years-wet years). Both watersheds are located in the Ozark Highlands ecoregion, characterized by a dissected limestone plateau contributing to karstic geology and forested predominantly with oak-hickory forests (Woods et al. 2005). Project area soils are generally gravelly silt loams with high infiltration rates. Typical slopes in the floodplains range from 2 to 5%, although a large portion of the watershed is steeply sloping (15-40%). In most cases, in-stream habitat is rated poor, and the quality of the riparian corridor varies from good to absent in these streams. Significant areas exist on each stream where riparian vegetation, other than streamside grasses, sedges, and rushes, is absent. Additional areas exist where even streamside sedges and rushes are absent and replaced by Bermuda or fescue grass or bare soil.

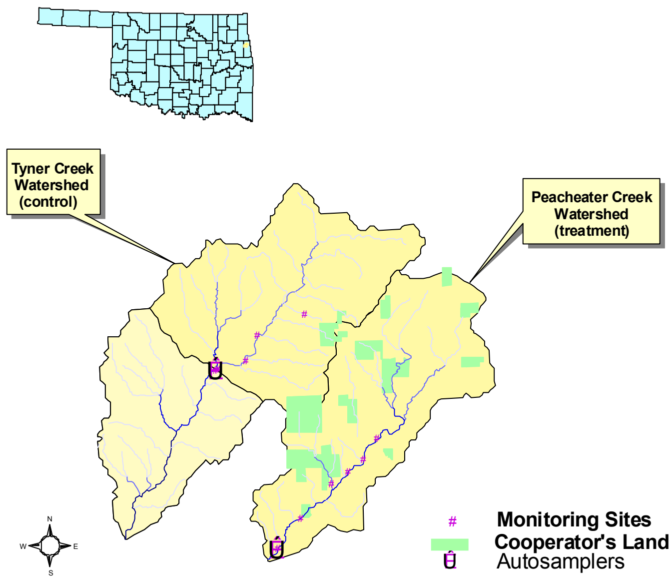


Figure 4. Peacheater and Tyner Creek (upper portion) watersheds. Monitoring sites and land where BMPs were implemented are depicted here.

Land use in the 16,209 ac (6,560 ha) Peacheater Creek watershed is primarily pastureland (54%) and forestland (36%), with small amounts of cropland (3%) and rangeland (7%). There are approximately 65 poultry houses and four dairies in the watershed, as well as about 1200 beef cattle and 176 private residences. Cattle traffic and poorly managed riparian land clearing activities are known to be major contributors to streambank erosion. Base flow monitoring shows intermittently high nutrient levels that contribute to creek eutrophication. Impacts downstream of Peacheater Creek include streambank erosion, habitat degradation, and nuisance periphyton growth in the Baron Fork and the Illinois River, as well as phytoplankton blooms and summer hypolimnetic anoxia in Lake Tenkiller.

The 16,000 ac (6,475 ha) Upper Tyner Creek watershed includes approximately 150 private residences, 61 poultry houses, and three dairies, and landuse is very similar to the Peacheater watershed. Broilers are the primary poultry type grown in both watersheds. Each broiler house usually produces 5 broods (each with approximately 20,000 birds) a year. The total number of dairies in both watersheds declined during the project period.

The primary nonpoint sources of nutrients, bacteria, and sediments in the Peacheater watershed include improper management of cattle and poultry waste, poor pasture maintenance, and possible onsite wastewater system failure. Excessive gravel deposition from streambank erosion, evidenced by channel aggradation and widening, is also a major concern. Riparian activities such as grazing and clearing, poorly managed/implemented silvicultural activities, and various clearing activities on steep slopes without proper erosion controls are important sources of the gravel. Streams have become wider, shallower, and loaded with nutrients and soil, which has resulted in loss of fish habitat and increased primary productivity.

BMP Implementation

Eleven landowners participated in the program: two were dairy producers, three were combined dairy and poultry producers, two had poultry houses and beef cattle, and four had only beef cattle. Acreage included in the program totaled 3,643 ac (1,474 ha), representing 22% of the watershed (Figure 4). Best management practice implementation in the Peacheater Creek watershed consisted of installation of practices addressing riparian management, land management, and waste management (Table 1).

Table 1. BMPs implemented in the Peacheater Creek watershed.

Practice	Total # Cooperators	Amount Implemented	Units
Riparian management			
Riparian buffer	4	49	acres
Riparian buffer with haying and limited grazing	1	58	acres
Offsite watering--pond	2	2	ponds
Offsite watering--tank	4	14	tanks
Fencing	2	5,800	linear feet
Land management			
Pasture management	4	375	acres
Cross fencing / travel lane fencing	4	15,970	linear feet
Heavy use area protection (concrete pad)	3	175	cubic yards
PVC pipe, trenching, and cover (associated with ponds and/or freeze-proof tanks)	5	7,200	linear feet
Filter / buffer strip	1	9	acres
Waste management			
Septic system installation	2	2	systems
Poultry litter storage / cakeout house	2	2	houses
Poultry composter	5	5	composters
Transport litter out of watershed	2	22,921	pounds
Dairy lagoon cleanout, repair, or construction	3	4	lagoons
Cattle feeding facility / waste storage	2	2	structures

Riparian Management

Many landowners consider riparian areas to be critically needed, highly productive pasture. However, heavily grazed riparian areas function poorly as nutrient traps, and cattle trails become channels for direct transport of nutrients and bacteria to the stream. Fencing to exclude cattle from a certain area along a stream was recommended to control these problems. Incentives were used to establish a buffer of 100 feet on each side of the stream. A riparian buffer of this size would be the equivalent of 25 ac/mi (6 ha/km) of stream. In order to take advantage of existing fences, buffer widths varied slightly on occasion. Fences were located above the flood prone area elevation to lower maintenance costs.

Landowners were given the option of creating riparian buffer zones (total livestock exclusion), field buffers (limited hay production allowed only in vegetative zone of the buffer and only during a time of the year to allow sufficient regrowth prior to the end of the growing season), or riparian protection with limited grazing. Limited grazing or flash grazing would allow landowners to grant livestock access to the riparian zone for a brief period in summer when streambanks were most stable (due to lack of rain) and with sufficient time for regrowth before the end of the growing season. In addition, during limited grazing, landowners agreed to pull livestock out of the area prior to the point where it became overgrazed. One participant in the project established field buffers and four landowners created riparian buffer zones.

Pastures where the stream was the primary or sole source of water for livestock were provided with an alternate water source to facilitate riparian protection. Studies have shown that off-stream water sources can substantially reduce the impact of cattle even without fencing off the stream. Off-stream watering was budgeted only for the perennial sections of the stream because the landowners already had provided water supplies for livestock where the stream did not supply permanent water. Watering options included pond excavation and two types of freeze-proof water tanks. Two ponds were constructed and 11 freeze-proof tanks were installed in the Peacheater watershed. Three ponds were also fenced to prevent cattle from loafing there (see Figure 5).

Land Management

In order to keep pastures in optimal condition, overgrazing must be avoided. Landowners may use cross-fencing to rotate cattle to various pastures and, thus, prevent overgrazing. In this project, eight planned grazing systems were implemented. Nearly 16,000 linear feet (4,876 m) of fence were erected to exclude livestock from pastures at certain times (20 cross-fences), and travel and/or feeding lanes were installed at two dairies.

As large animals, cattle can severely impact areas around feeding or watering facilities where heavy traffic compacts soil and destroys stabilizing vegetative cover, increasing soil erosion from the area. In addition, heavy traffic is usually accompanied by increased waste deposition, which can lead to increased nutrients and bacteria in runoff from these areas. Installation of concrete feeding pads for round hay bale feeding or gravel and grading in loafing areas are modifications that can reduce runoff of soil, nutrients, and bacteria from these heavy use areas. Three of these pads were installed in the Peacheater watershed (see Figure 6).

Figure 5. Before BMP implementation, cattle often had access to streams (top photo). After implementation, cattle were fenced out of streams (middle photo) and provided alternative water sources such as freeze-proof tanks or ponds (bottom photo).

Figure 6. Before BMP implementation, cattle trails from feeding and milking areas to the stream, as well as areas around the barn, were composed of bare soil (left photo); after implementation, paved or geotextile travel lanes and feeding pads reduced the amount of bare soil and erosion around the areas (right photo).

Waste Management

Winter feeding facilities are more elaborate structures than the heavy use pads but are similarly designed to reduce runoff of nutrients, bacteria, and sediment from cattle supplemental feeding areas. Landowners typically overwinter and often feed cattle in the same areas of a pasture, areas that are chosen because they are easy to get to and provide a reliable source of shelter and water for overwintering stock. This often means they are close to the creek or a ravine or dry channel where shelter from the wind is available and the running water in the creek does not usually freeze. Unfortunately, these areas become trampled, overgrazed, and laden with waste, and hence, are susceptible to runoff. Winter feeding facilities provide a sheltered feeding area away from the stream to reduce this problem. The structure has a concrete floor with a lip all around to contain waste. In addition, the back portion of the structure is devoted to dry manure storage, sized sufficiently to store up to 3 months worth of manure until a time that it can be properly land applied. Two cooperators built winter feeding facilities for livestock in the Peacheater watershed (see Figure 7).

The large number of poultry houses in the Peacheater watershed meant that a large amount of poultry waste was being produced. In this area of the state, many landowners spread poultry litter on their pastures for fertilizer. Sustained over recent decades, litter application has resulted in high soil phosphorus levels as indicated by soil tests. Litter application at rates much higher than necessary and at incorrect times is one of the major sources of phosphorus in the greater Illinois River watershed (Storm et al. 2006). To rectify this, a cost-share program was initiated to haul litter out of the watershed for use in areas of the state that need and can assimilate the phosphorus and nitrogen in the litter. Additionally, two poultry litter "cakeout" houses were installed. This type of structure provides covered storage for poultry litter so that runoff is prevented until it can either be applied properly (if soil tests confirm the need for it) or hauled to another location for application (see Figure 8).

Due to the especially mobile soil types and karstic geology in the area, failing septic systems were also a concern. Although the exact percentage of watershed residents with inadequate onsite wastewater systems was unknown, previous projects in similar watersheds suggested that as many as 70% of watershed residents have inadequate or nonexistent onsite wastewater systems. Two septic tanks were installed to reduce NPS pollution from onsite wastewater.

Figure 7. Winter feeding facilities with waste storage capabilities were effective at reducing the amount of soil erosion and nutrient runoff.

Figure 8. Before education and BMP implementation, poultry and cattle waste was often spread on adjacent fields at incorrect times or at improper rates (left photo); after implementation, wastes were placed in covered storage areas until proper application or transport out of the watershed was possible (right photo).

Methods

Monitoring

Monitoring was conducted in an identical fashion in both the treated (Peacheater) and the control (Tyner) watersheds, and through the calibration and treatment periods, as required in the paired watershed design. Water quality monitoring occurred at each watershed outlet (upper half of Tyner) as well as at several points along the streams (Figure 4). Calibration monitoring began in December 1995 and continued until August 1998, when BMP implementation began in Peacheater. Post-implementation monitoring began in January 2003 and concluded in September 2005.

Automated samplers were installed at two locations. For Peacheater Creek, the sampler location was just upstream of its confluence with the Baron Fork of the Illinois River. The Tyner Creek automated sampler was installed at a point on the stream where the watershed size upstream was comparable to the size of the entire Peacheater watershed (Figure 4). The goal was to capture a minimum of four runoff events per year utilizing these samplers. Storm event monitoring was stage-activated, and samples were taken continuously over the hydrograph. Concentration analyses were conducted on flow-weighted composites. Grab samples were collected monthly from July through January and weekly during February through June at four sites in the Upper Tyner Creek watershed and six sites in the Peacheater Creek watershed (Figure 4). Samples were analyzed for total phosphorus, total Kjeldahl nitrogen (TKN), nitrate-nitrogen, nitrite-nitrogen, total suspended solids, hardness, chloride, and sulfate. Dissolved oxygen, pH, conductivity, alkalinity, and temperature were measured in the field for each sample.

To document streambank erosion and any potential improvements made following implementation of BMPs, banks were measured at seven sites on Tyner Creek (4 in the upper watershed and 3 in the watershed below the autosampler) and at four sites on Peacheater Creek. Figure 9 illustrates the procedure. Erosion measurements were taken at permanent

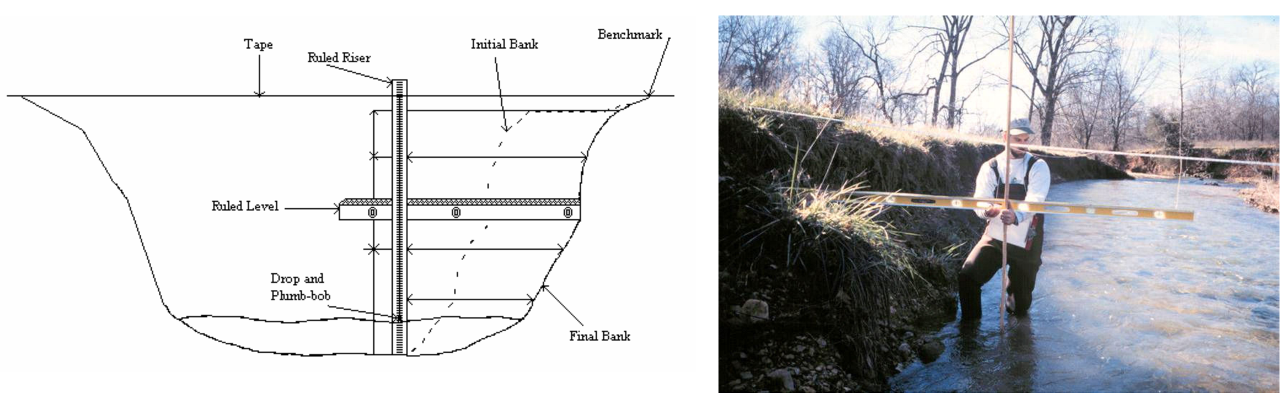


Figure 9. Bank erosion measurement method and demonstration.

benchmarks set on each bank of the stream cross section. A tape was connected to each benchmark and a drop (cord and plumb bob) was placed at a known interval from the reference benchmark. A ruled riser was held plumb along the drop from the stream bottom to above the top edge of the bank. Vertical and horizontal measurements taken with a ruled level were recorded wherever the soil type or bank slopes changed. The measurements were completed quarterly at each benchmark using consistent procedures. Erosion rates/volumes were calculated using the average soil layer thickness and the horizontal erosion distance over the one-year period, multiplied by the eroded bank length. In addition, streambank sediment samples were collected at three sites (one in Peacheater and two in Tyner) before and after implementation and analyzed for nutrient concentrations.

Fish and macroinvertebrates were sampled during both pre- and post-implementation periods by methods discussed in detail elsewhere (OCC 2007).

Data Analysis

Data analysis was conducted according to procedures outlined in Clausen and Spooner (1993). The relationship between water quality variables from the two watersheds during the calibration phase was described by simple linear regression. For purposes of calibration, the relationship between Peacheater and Tyner Creeks was evaluated using autosampler data collected between December 1995 and April 1997 under three different flow regimes: all flows, high flow only (>2 * average flow), and base flow only (<0.5 * average flow). All analyses were conducted on log-transformed data to satisfy assumptions of parametric statistical analysis. The significance of the regression between paired observations was tested using analysis of variance (ANOVA). The probability (P) value associated with the resulting F statistic indicated whether the regression explained a significant amount of the variation in the paired data ($P \leq 0.05$). The coefficient of determination (r^2) indicated the quality of the regression (i.e., its utility in predicting y from x). Significant ($P \leq 0.05$) relationships between Peacheater and Tyner Creek watersheds were obtained for all nutrient parameters under all three flow regimes.

At the end of the treatment period, the significance of the effect of the BMPs was determined using analysis of covariance (ANCOVA). Specifically, the analysis determined:

- the significance of the treatment regression equation,
- the significance of the overall regression which combines the calibration and treatment period data,
- the difference between the slopes of the calibration and treatment regressions, and
- the difference between the intercepts of the calibration and treatment regressions.

Item 1 was determined through an ANCOVA for the treatment period regression. Items 2 – 4 were determined through an ANCOVA comparing the treatment and calibration period regressions.

A detailed description of analytical methods, including all parameters and models used may be accessed in the "*Illinois River Watershed Monitoring Program Post-Implementation Monitoring Summary Report-Year 2*" (OCC 2007).

Results

Pre-implementation Water Quality

Although all collected parameters were analyzed, only nutrient data are discussed in this article (Table 2). Average total phosphorus concentrations of 0.02 mg/L and 0.04 mg/L and average total nitrogen concentrations of 2.86 mg/L and 3.53 mg/L in Tyner and Peacheater Creeks, respectively, were high enough to indicate a high probability of nuisance algae growth during the growing season. Although concentrations were higher in Peacheater Creek than in Tyner Creek for all nutrient constituents measured, the differences were not statistically significant.

Regressions performed on the pre-implementation data verified that Peacheater and Tyner Creeks have similar water quality. A statistically significant relationship, based on USEPA requirements for paired watershed studies (Clausen and Spooner 1993), was established during the calibration phase between the water quality of Tyner and Peacheater Creeks. The creeks were found to respond similarly to disturbances such as high flow events, and both creeks had elevated nutrient concentrations, with phosphorus the primary nutrient of concern. Both creeks also had problems with riparian destruction resulting in bank erosion and increased bedload. This bedload was highly mobile during storm events, which further exacerbated the bank erosion problem and made it difficult for stabilizing vegetation to develop. Although anthropogenic influences were more intensive in the Peacheater Creek watershed, overall landuse was still very similar between watersheds.

Comparison of Water Quality Data

Table 3 documents the results of the ANCOVAs for the various parameters analyzed as well as the average values for the nutrient parameters (combined base and high flows). ANCOVAs were used to test for differences between the calibration and treatment periods. The relationships between treatment and calibration periods were significantly different for all parameters with significant treatment period regressions. Some relationships differed either positively or negatively both in slope and intercept (e.g., total phosphorus loading and nitrite; yellow rows). Some relationships differed in intercept, but not slope, meaning that there was an overall parallel shift in the relationship over the range of environmental conditions

Table 2. Nutrient concentrations and loadings for Peacheater and Tyner Creeks, pre-implementation, 1995-1998.

Parameter	Value type	Tyner Creek	Peacheater Creek
Ortho-Phosphorus Concentration (mg/L)	*Average*	0.01	0.03
	Median	0.01	0.02
Ortho-Phosphorus Daily Load (kg/day)	*Average*	1.2	3.0
	Median	0.4	0.7
Ortho-Phosphorus Yearly Load (kg/yr)	*Average*	446	1,088
	Median	148	253
Total Phosphorus Concentration (mg/L)	*Average*	0.02	0.04
	Median	0.02	0.03
Total Phosphorus Daily Load (kg/day)	*Average*	2.0	6.3
	Median	0.9	1.2
Total Phosphorus Yearly Load (kg/yr)	*Average*	710	2,312
	Median	313	427
NO_3 Concentration (mg/L)	*Average*	2.67	3.27
	Median	2.77	3.17
NO_3 Daily Load (kg/day)	*Average*	199	295
	Median	103	88
NO_3 Yearly Load (kg/yr)	*Average*	72,646	107,606
	Median	37,485	31,941
NO_2 Concentration (mg/L)	*Average*	0.00	0.01
	Median	0.00	0.00
NO_2 Daily Load (kg/day)	*Average*	0.1	1.0
	Median	0.1	0.1
NO_2 Yearly Load (kg/yr)	*Average*	50	365
	Median	23	27
TKN Concentration (mg/L)	*Average*	0.17	0.22
	Median	0.17	0.18
TKN Daily Load (kg/day)	*Average*	14	39
	Median	4.8	6.1
TKN Yearly Load (kg/yr)	*Average*	4,974	14,307
	Median	1,740	2,239
Total Nitrogen* Concentration (mg/L)	Average	2.87	3.53
	Median	2.98	3.45
Total Nitrogen* Daily Load (kg/day)	*Average*	217	348
	Median	112	121
Total Nitrogen* Yearly Load (kg/yr)	*Average*	79,322	127,076
	Median	40,733	44,158
Total Nitrogen : Total Phosphorus Ratio	*Average*	135	105
	Median	128	88

*Total Nitrogen = TKN + NO_3 + NO_2

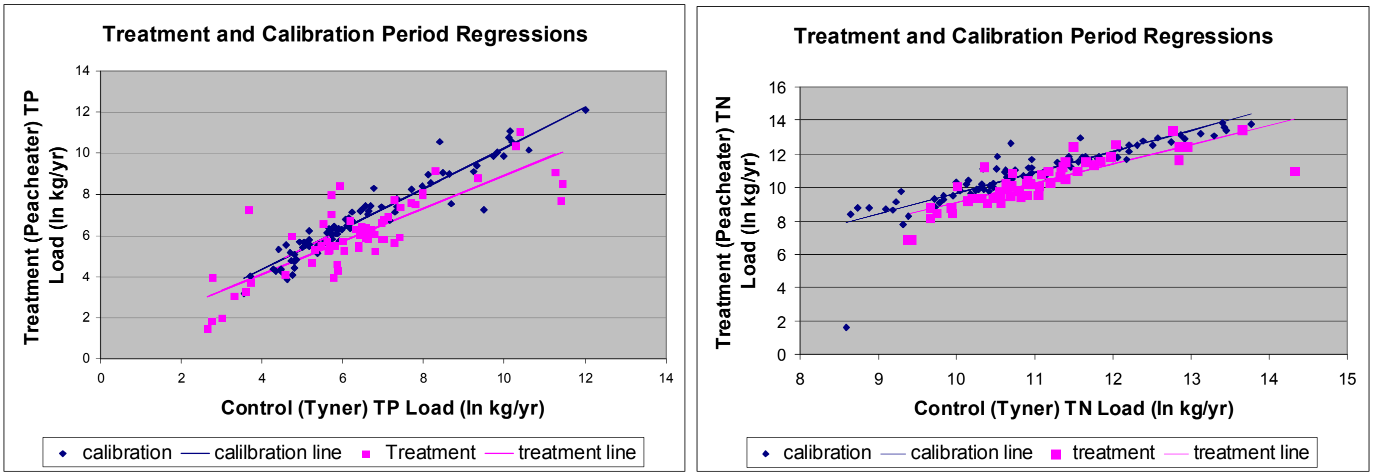
(e.g., total phosphorus concentrations, nitrate, and total nitrogen loading; blue rows). And finally, some relationships differed significantly in slope, but not in intercept, suggesting that the relationship between the two streams did not change significantly over all environmental conditions measured (e.g., TKN; green row).

Comparisons between observed and predicted values are useful for documenting a change due to implementation activities in the watershed. The last column in Table 3 depicts differences between observed and predicted values at the Peacheater site divided by the predicted value. Total phosphorus concentration and loading were 9% and 71% lower than predicted values, respectively. Nitrate and TKN concentrations were 23% and 21% less than expected, respectively and total nitrogen loading was 58% lower than expected. Although comparison of pre-implementation and post-implementation nitrite values suggests a potential 53% reduction, detection limits differed by an order of magnitude between pre- and post-implementation periods such that the detected difference might be due to detection limit differences rather than actual chemical changes. The detection limit was lower during post-implementation monitoring. However, both pre- and post-implementation monitoring nitrite values are below environmentally significant levels and do not significantly affect total nitrogen loading, so a change or lack of

Table 3. ANCOVA results for calibration and treatment period regressions (all flow regimes combined). "S" indicates a significant result ($p<0.05$), "NS" indicates a non-significant result, "PE Obs." is the average of the observed values at the Peacheater site, and "PE Pred." is the predicted value at the Peacheater site based on the calibrated model.

Parameter	n		ANCOVA Results			Calibration Average		Treatment Average			% Difference
	Calib	Trmt	Model	Slope	Intercept	Tyner	Peacheater	Tyner	PE Obs.	PE Pred.	
Total Phosphorus (mg/L)	**94**	**61**	**S**	**NS**	**S**	**0.045**	**0.061**	**0.092**	**0.081**	**0.089**	-9%
Total Phosphorus Loading (kg/yr)	**92**	**55**	**S**	**S**	**S**	**4721**	**6245**	**6784**	**2989**	**10,207**	-71%
Nitrate (mg/L)	**90**	**62**	**S**	**NS**	**S**	**2.75**	**3.06**	**3.33**	**2.66**	**3.45**	-23%
Nitrite (mg/L)	**95**	**64**	**S**	**S**	**S**	**0.002**	**0.005**	**0.015**	**0.009**	**0.019**	-53%
TKN (mg/L)	**95**	**62**	**S**	**S**	**NS**	**0.212**	**0.258**	**0.138**	**0.120**	**0.151**	-21%
Total Nitrogen Loading (kg/yr)	**82**	**53**	**S**	**NS**	**S**	**125,729**	**145,860**	**127,681**	**78,337**	**184,395**	-58%

Figure 10. Treatment vs. calibration regressions for total phosphorus (TP) and total nitrogen (TN) loads.



change in pre- vs. post-implementation nitrite concentrations is not environmentally significant. Figure 10 shows the regressions for total phosphorus (TP) loading and total nitrogen (TN) loading during the treatment period relative to the calibration period.

The relationship between pre- and post-implementation monitoring was also evaluated under the different flow regimes separately (elevated vs. baseflow) to determine whether practices implemented were having a different effect on runoff versus groundwater loading. Elevated flow was considered to be 20 ft^3/s (0.6 m^3/s) or greater in Peacheater Creek. Water quality changes tended to be greater during baseflow conditions than highflow conditions, although highflow averages were also significantly reduced. The primary water quality variable of concern, average total phosphorus, decreased significantly in baseflow concentration (16%), baseflow loading (77%), and high flow loading (25%). The calibration and post-implementation period regressions were not significantly different for high flow total phosphorus concentration. Baseflow average nitrate, nitrite, and total nitrogen loading were significantly lower (20%, 43%, and 47%, respectively) during the post-implementation period. High flow nitrate, nitrite, TKN, and total nitrogen loading were also significantly lower (20%, 29%, 19%, and 29%, respectively) during the post-implementation period. Baseflow regression equations were not significant for TKN. In some cases, lack of significance may have been related to small sample size for high flow events (ranged from 14 to 19).

Comparison of Bank Erosion Data

Average horizontal erosion areas for each site compared between pre- and post-implementation are seen in Figure 11. Differences in average horizontal erosion area between pre- and post-implementation periods were greater at some sites than at others. When the erosional areas from the major eroding banks in Peacheater were compared between the pre- and post-implementation period, analysis suggested that pre-implementation median erosion of 4.1 ft^2 (0.4 m^2) was significantly greater at the 90% confidence level than the post-implementation erosion of 1.7 ft^2 (0.2 m^2) based on a Mann-Whitney test (Table 4). Comparison of erosional areas from Tyner Creek between pre- and post-implementation periods did not indicate a significant difference between median values (pre-implementation=5.6 ft^2 (0.5 m^2) and post-implementation=3.6 ft^2 (0.3 m^2) (Table 4). These comparisons suggest that the implementation in Peacheater played a role in reducing streambank erosion. Comparison of pre- and post-implementation aerial photography suggests that a similar amount of pasture clearing

Figure 11. Comparison of pre-implementation and post-implementation streambank erosion in the Peacheater and Tyner Creek watersheds. The top and bottom box edges mark the first and third quartiles of the data. Median values are indicated by the horizontal line within each box. Whiskers extend ± 1.5 times the inter-quartile range beyond the box edges. Outliers are represented by asterisks.

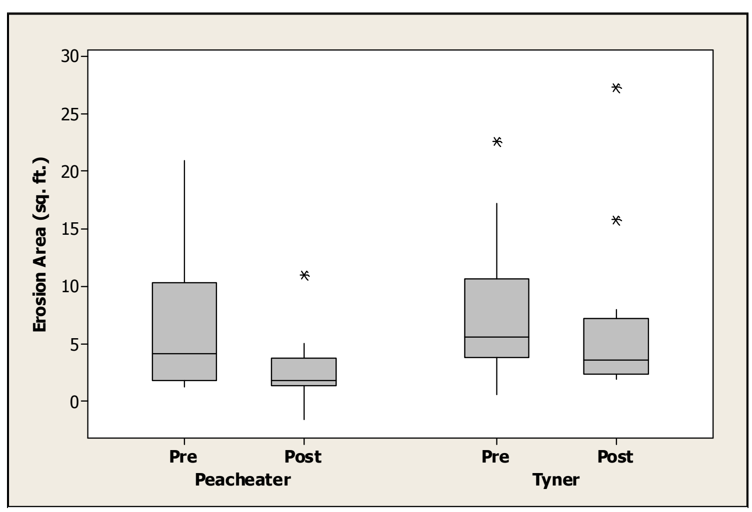


Table 4. Median streambank erosional areas, measured in square feet. There was a significant reduction in streambank erosion in the Peacheater watershed after BMP implementation.

Watershed	Pre-Implementation		Post-Implementation		Significance
	n	Median Erosional Area (ft^2)	n	Median Erosional Area (ft^2)	
Peacheater	10	4.100	11	1.747	p = 0.0980*
Tyner	19	5.600	15	3.559	NS

occurred in both watersheds during the project period. Therefore, it is unlikely that more significant development in Tyner Creek than Peacheater Creek led to the greater decreases observed in Peacheater Creek streambank erosion.

Comparison between measured pre- and post-implementation nutrient concentrations in streambank sediments at the three sites suggests that concentrations of nitrogen and phosphorus in streambanks were higher during the post-implementation period than during pre-implementation. However, comparison of pre- and post-implementation loadings, calculated based on particle size analyses from the pre-implementation period, suggests reductions in loadings in the Peacheater watershed, while Tyner Creek results suggest increases in nutrient loadings from streambank erosion (Table 5). This difference indicates that implementation in the Peacheater watershed reduced nutrient loading from streambank erosion.

Additional Findings

The results of fish and macroinvertebrate monitoring are discussed in detail in the final report (OCC 2007). In general, the biological communities of both watersheds were very good. Post-implementation fish collections enumerated greater numbers of fish than did pre-implementation collections for both watersheds (Table 6). Although not significant (P>0.05), probably due to small sample size, Peacheater showed a greater increase in this parameter than did Tyner, which could indicate some improvement in habitat that is promoting more successful reproduction and recruitment of fish. Also, there was a significant (P=0.0001) improvement in the IBI score for the summer index samples of macroinvertebrates for Peacheater, while Tyner showed no significant difference (Table 7). These results suggest improved habitat and water quality and concur with the findings of reduced nutrient loading and decreased streambank erosion observed in the Peacheater watershed as a result of BMP implementation.

Discussion

The use of the paired watershed method allowed assessment of the differences in water quality and streambank erosion between the pre- and post-implementation periods due to differences in management practices implemented in the Peacheater Creek watershed. The project demonstrated that, in small agricultural watersheds, water quality improvement is

Table 5. Estimated average nutrient loading rates from streambank erosion. PE5 is the Peacheater site, and TB indicates Tyner sites. Increases between pre- and post-implementation are shown in green; decreases between pre- and post-implementation are shown in blue.

Site	Period	Ammonia ($kg/ft^2/yr * 10^{-4}$)	TKN ($kg/ft^2/yr * 10^{-2}$)	Nitrate ($kg/ft^2/yr * 10^{-4}$)	Nitrite ($kg/ft^2/yr * 10^{-6}$)	Tot. Nitrogen ($kg/ft^2/yr * 10^{-2}$)	OrthoPhos. ($kg/ft^2/yr * 10^{-5}$)	Total Phos. ($kg/ft^2/yr * 10^{-3}$)
PE5	Pre	2.64	1.48	1.14	0.61	1.49	4.04	2.21
	Post	0.31	0.81	0.37	7.62	0.82	0.22	1.25
TB2	Pre	2.65	2.14	1.18	1.02	2.15	2.55	1.95
	Post	8.54	10.10	6.91	101.00	10.20	6.36	20.90
TB4	Pre	1.96	2.50	2.42	0.14	2.47	0.06	2.0
	Post	0.63	2.19	2.75	2.52	2.22	0.48	4.23

Table 6. Median numbers of individuals collected in fish surveys. There was not a significant difference (p>0.05) between pre- and post-implementation periods for either watershed.

Watershed	Pre-Implementation		Post-Implementation		Significance
	# Surveys	Median Number of Individuals	# Surveys	Median Number of Individuals	
Peacheater	3	89	10	275	NS
Tyner	3	293	9	349	NS

Table 7. IBI scores for summer benthic macroinvertebrate collections. There was a significant improvement in the Peacheater watershed after implementation of BMPs, but a nonsignificant difference in the Tyner watershed.

Watershed	Pre-Implementation		Post-Implementation		Significance
	n	Median IBI Score	n	Median IBI Score	
Peacheater	19	29	10	34	p = 0.0001*
Tyner	21	32	10	30	NS

possible with a relatively low investment in implementation of BMPs; the total cost of this project was approximately $800,000, an average of only about $220 per acre treated by the BMPs. Funding for the project was a combination of federal monies from the EPA 319 program and state monies. Additional practices are planned for the watershed to further reduce loading, but even without 100% participation in the program, management at many of the problem areas was sufficient to significantly improve water quality in the treated watershed.

The demonstrated value of the paired watershed monitoring methodology has encouraged the Oklahoma Nonpoint Source Program to conduct this type of monitoring whenever possible as an evaluation tool for implementation efforts in other watersheds. In addition, the success demonstrated through this program has encouraged significant additional funding from the State legislature and local governments for similar and follow-up projects. The observed nutrient reductions that resulted from implementation of BMPs in the Peacheater Creek watershed indicate that practices implemented at a similar intensity throughout the larger Illinois River watershed might provide significant reductions in loading to downstream Lake Tenkiller. However, additional types of practices and/or more intensive implementation of practices will likely be necessary to meet the 0.037 mg/L phosphorus standard in the watershed.

Nonpoint source implementation projects will continue in the Illinois River Watershed to reduce the impacts on the Illinois River and Lake Tenkiller. Both Oklahoma and Arkansas are in the process of developing Watershed Based Plans for the watershed to address pollution problems originating in their portions of the watershed. Both states are beginning Conservation Reserve Enhancement Programs (CREP) to encourage long-term protection of riparian areas to serve as a buffer between upland development and land management and the waterbodies. Each state will continue to support and work cooperatively, when possible, on programs to improve water quality in the watersheds.

Although monitoring in Peacheater and Tyner was discontinued following completion of the project, it may be resumed in the near future to gauge long-term impacts of ongoing programs in the watershed. Peacheater and Tyner represent a portion of the Illinois River where development will likely be limited compared to other parts of the watershed. Should Peacheater/Tyner residents choose to participate in the CREP program, it would be an excellent benchmark of the long-term potential impacts of this program.

Conclusions

In conclusion, comparison between pre-implementation and post-implementation monitoring periods revealed the following beneficial changes due to implementation of BMPs in the Peacheater Creek watershed:

- Decreased phosphorus concentrations and loading in Peacheater Creek over what was expected based on pre-implementation conditions:
  - phosphorus concentrations decreased approximately 9% overall; baseflow condition reductions (16% decrease) were greater than highflow condition reductions (not significant).
  - phosphorus loading decreased approximately 71% overall; baseflow loading (decreased by 77%) was affected more than highflow loading (decreased by 25%).
- Decreased nitrogen concentrations and loading in Peacheater Creek over what was expected based on pre-implementation conditions:
  - nitrate concentrations decreased approximately 23% overall; baseflow reductions and highflow concentrations were both reduced by approximately 20%.
  - total Kjeldahl nitrogen concentrations decreased by approximately 21% overall; TKN concentration reductions were greater in highflow conditions (19% decrease) than baseflow conditions (no significant reduction).
  - total nitrogen loading decreased by approximately 58% overall; average baseflow loading (47% reduction) decreased more than highflow loading (29% reduction).

- Significantly decreased streambank erosion and nutrient loading from streambanks in Peacheater Creek after BMP implementation.

For full detail on project activities and results, the reader is encouraged to refer to the final report, "*Illinois River Watershed Monitoring Program Post-Implementation Monitoring Summary Report-Year 2,*" posted online at:

http://www.ok.gov/okcc/Agency_Divisions/Water_Quality_Division/WQ_Reports/WQ_Project_Reports/WQ_Reports:_Watershed_Specific.html

For additional information or any questions about the project, please contact:

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INFORMATION

New Tool for Stream Channel Assessment

A method to calculate hydrologic "flashiness" — the R-B Index — was developed by Pete Richards and David Baker of Heidelberg College in 2004. Using that methodology, the Michigan Department of Environmental Quality's NPS program staff calculated flashiness values and assessed trends for 279 USGS gages in Michigan that had at least five years of data. Some of the data sets extended back prior to 1910. An increase in flashiness, often due to changing land use, is a common cause of stream channel instability and excessive erosion, and is the focus of numerous NPS grant proposals. The flashiness report is one tool for diagnosing the scale of a particular stream channel problem. If the R-B Index values are steady over time, channel erosion problems in the vicinity of the USGS gage may have local causes that can be addressed with local BMPs. Conversely, if the R-B Index trend indicates that flashiness is increasing over time, channel erosion problems in the vicinity of the gage station may have large-scale causes and will require a large-scale solution. The report titled *Application of the Richards-Baker Flashiness Index to Gaged Michigan Rivers and Streams* is available at http://www.michigan.gov/documents/deq/lwm-hsu-rb-flashiness_204776_7.pdf

For more information, contact Dave Fongers or Joe Rathbun with Michigan Department of Environmental Quality at 517-373-8868.

New Fundamentals of Urban Runoff Management Document Now Available

A second edition of the publication titled *Fundamentals of Urban Runoff Management: Technical and Institutional Issues* was recently published by the North American Lake Management Society (NALMS). This document is available at no cost on NALMS' Web site. This document revises an earlier 1994 edition and was prepared with support from EPA's Office of Wastewater Management and the Nonpoint Source Control Branch in EPA's Office of Wetlands, Oceans and Watersheds. The authors sought to update the original document because of the tremendous amount of new information available as well as the significant shift in stormwater program direction from the historic mitigation-based approach to a more source-based approach. Copies of the document are posted in pdf format at: http://www.nalms.org/

EPA Issues National Management Measures to Control Nonpoint Source Pollution from Hydromodification

EPA has issued a guidance document called National Management Measures to Control Nonpoint Source Pollution from Hydromodification. This guidance document provides background information about nonpoint (NPS) source pollution and offers a variety of solutions for reducing NPS pollution resulting from hydromodification activities including dams, channelization and channel modification, and streambank and shoreline erosion. The background information includes a discussion of sources of NPS pollution associated with hydromodification and how the generated pollutants enter the Nation's waters. The document presents practices that can be used to implement the management measures discussed in this guidance and provides a discussion of assessing and addressing water quality problems on a watershed level. Available models and assessment approaches that could be used to determine the effects of hydromodification activities are also discussed and dam removal information, including permitting requirements, process, and techniques for dam removal are provided.

This guidance document is posted at: http://www.epa.gov/nps/hydromod

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MEETINGS

Call for Abstracts

16th National Nonpoint Source Monitoring Workshop – Getting the Point About Nonpoint: September 14-18, 2008, Columbus, OH. Abstracts are due April 4, 2008. Website: http://streams.osu.edu/conf.php. See Workshop Highlight on Page 15 for more information.

Meeting Announcements — 2008

February

2008 USDA-CSREES National Water Conference: February 3-7, 2008, Sparks, NV. Website: http://www.soil.ncsu.edu/swetc/waterconf/2008/home08.htm

May

11th National Mitigation & Ecosystem Banking Conference: Banking on the Environment (*formerly* National Mitigation & Conservation Banking Conference): May 6-9, 2008, Jacksonville, FL. Telephone: 703-548-5473. Website: http://www.mitigationbankingconference.com

Sixth National Water Quality Monitoring Council Conference: Monitoring – Key to Understanding Our Waters: May 18-22, 2008, Atlantic City, NJ. Website: http://www.wef.org/monitoring

9th Annual Nonpoint Source Pollution Conference: Progress Through Partnerships: Collaborating to Protect Our Watersheds: May 19-21, 2008, Groton, CT. Website: http://www.neiwpcc.org/npsconference

July

2008 UCOWR/NIWR Annual Conference – International Water Resources: Challenges for the 21st Century and Water Resources Education: July 22-24, 2008, Durham, NC. Website: http://www.ucowr.siu.edu

August

7th annual StormCon – the North American Surface Water Quality Conference & Exposition: August 3-7, 2008, Orlando, FL. Website: http://www.StormCon.com

September

16th National Nonpoint Source Monitoring Workshop – Getting the Point About Nonpoint: September 14-18, 2008, Columbus, OH. See full announcement and call for abstracts on page 15.

November

2008 Southeast Regional Stream Restoration Conference, November 3-6, 2008, Asheville, NC. Website: http://www.ncsu.edu/sri

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Production of NWQEP NOTES is funded through U.S. Environmental Protection Agency (EPA). Project Officer: Tom Davenport, Office of Wetlands, Oceans, and Watersheds, EPA. 77 W. Jackson St., Chicago, IL 60604. Website: http://www.epa.gov/OWOW/NPS

16th National Nonpoint Source Monitoring Workshop

Getting the Point about Nonpoint

September 14-18, 2008
Marriott Renaissance Hotel
Columbus, Ohio
http://streams.osu.edu/conf.php

Call for Papers: Abstracts (500 words max) are due by **April 4, 2008**. Requirements for submission are available on the website. Please make your submissions online or by email to dambrosio.9@osu.edu.

About the Conference: The National Nonpoint Source (NPS) Monitoring Workshop is an important forum for sharing successes and improving communication regarding management and monitoring of NPS pollution control projects.

By bringing together NPS personnel from state, federal, Tribal and municipal governments, private sector, academia, environmental groups and local watershed organizations, the workshop will focus on innovative solutions to NPS issues, effective monitoring techniques, demonstrations of new technologies, application of Best Management Practices (BMPs), and lessons learned from Section 319 National Monitoring Program projects and other watershed projects from throughout the United States.

The workshop also will provide a number of technical workshops and tours. Technical workshops will include topics such as monitoring Low Impact Development (LID) projects, stream morphology analysis tools, and bio-assessment tools. Tours will include Conservation Effects Assessment Project (CEAP) monitoring sites, stream restoration sites, alternative urban and agricultural BMPs, and much more.

Specific topics of interest to be highlighted at the 16th annual workshop will include:

- ⇨ Stream Restoration & Renaturalization Project Monitoring
- ⇨ Alternative Agricultural Best Management Practices
- ⇨ Urban NPS & Stormwater Management Practices
- ⇨ TMDL & Watershed Action Plan Implementation
- ⇨ Bio-Assessment & Water Quality Monitoring Tools & Methodology
- ⇨ Lake and Coastal NPS Issues
- ⇨ Linking Water Quality Changes to Best Management Practices
- ⇨ Social Indicators Associating with Monitoring Behavioral Changes

Applicants will be notified of the selection committee's decisions by May 16, 2008. Successful applicants are required to provide completed presentations by August 15, 2008. Oral presentations are limited to 20 minutes.

All speakers must register in advance for the conference (discounted registration fees will apply).

Contact:

Jessica D'Ambrosio
Conference Coordinator
Phone (614) 688-4438
E-mail: dambrosio.9@osu.edu

The NCSU Water Quality Group publications list and order form can be downloaded by clicking on the link below:

http://www.ncsu.edu/waterquality/issues/pub_order.html

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