NWQEP NOTES

The NCSU Water Quality Group Newsletter

Number 120 February 2006 ISSN 1062-9149

NC STATE UNIVERSITY

NC STATE UNIVERSITY A&T STATE UNIVERSITY COOPERATIVE EXTENSION
Helping People Put Knowledge to Work

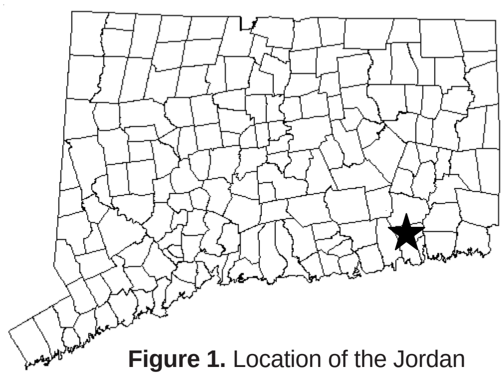


Figure 1. Location of the Jordan Cove Urban Watershed NMP Study.

IN THIS ISSUE

NWQEP NOTES is issued quarterly. Subscriptions are free. *NWQEP NOTES* is also available on the World Wide Web at http://www5.bae.ncsu.edu/programs/extension/wqg/issues/Default.htm. To request that your name be added to the mailing list, use the enclosed publication order form or send an email message to wq_puborder@ncsu.edu.

PROJECT SPOTLIGHT

Jordan Cove Urban Watershed Section 319 National Monitoring Program Project

John C. Clausen[1], Mel Cote[2], Bruce Morton[3], Eric Thomas[4], Stan Zaremba[4], Tom Wagner[5], Chet Arnold[1], Don Gerwick[6], John Alexopoulos[1], Karl Guillard[1], Mary Hull[1], John Engdahl[1], Robert Phillips[1], Michael Dietz[1], Jennifer Gilbert[1], Mark Hood[1], Erik Bedan[1].

Introduction

Nonpoint sources are responsible for a large portion of the remaining water quality impairments in our Nation's waters (USEPA 2000b). Urban stormwater runoff is one source of nonpoint pollution, and is responsible for contributing excess nutrients, bacteria, and toxic metals to receiving waters (USEPA 1994b). Additionally, runoff from urban construction and development is reported as a source of pollution for 14 of the 18 National Estuaries (USEPA 1994a). Urban development has been shown to increase runoff volume and peak discharge (Leopold 1968) and cause water quality degradation (Brabec et al. 2002, Klein 1979). Traditional stormwater controls used in urban areas were designed to collect, convey, and discharge water quickly and efficiently away from a site, causing on-site and downstream hydrologic impacts (USEPA 2000a). Recently, the concept of low impact development (LID) has been introduced to mitigate the problems associated with urban stormwater runoff (Prince George's County 1999). LID is a design strategy to retain the hydrologic functions of storage, infiltration, runoff, evapotranspiration, and groundwater recharge that existed before development of urban areas (USEPA 2000a). The

[1]University of Connecticut
[2]Environmental Protection Agency
[3]Aquasolutions
[4]Connecticut Department of Environmental Protection
[5]Town of Waterford
[6]Gerwick Engineering

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 Jordan Cove Urban Watershed NMP project in Connecticut is unique among NMP projects, focusing on stormwater runoff control from residential development. The 10-year monitoring study evaluated and compared low impact development (LID) principles and practices with conventional development. LID has been promoted as an environmentally-sensitive form of development, with goals of maintaining the pre-development stormwater runoff quantity and quality. LID practices employed in the Jordan Cove project included impervious surface reduction (narrow road, permeable pavement roadway and driveways, shared driveways), cluster housing with open space, grassed swales in place of curb and gutter, bioretention units in the cul-de-sac and on individual lots, low- and no-mow areas, deed restrictions, homeowner education, as well as construction BMPs for erosion and sediment control.

The study results for runoff quantity and quality were an interesting mix. During construction, the LID subdivision outperformed the traditional subdivision in terms of maintaining pre-development runoff volume, peak flow and export of most nutrients and metals, with the exception of phosphorus. Low export values in the LID subdivision were attributed to reduced stormwater runoff. In contrast, concentrations of sediment and nutrients where higher. The authors' speculate that temporary soil disturbance in the LID subdivision during construction of the swales and bioretention areas, and fertilization of the swales may have contributed to concentration spikes. Post-construction, the LID subdivision was effective at reducing runoff volume and export of most nutrients and metals. Overall, it appeared that LID offered stormwater benefits over traditional development.

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

Laura Lombardo Szpir
Editor, *NWQEP NOTES*
Water Quality Extension Associate
NCSU Water Quality Group
Campus Box 7637, NCSU
Raleigh, NC 27695-7637
Tel: 919-515-3723, Fax: 919-515-7448
Email: notes_editor@ncsu.edu

LID concepts utilize innovative site planning together with various best management practices (BMPs) such as bioretention, cluster housing, grassed swales, permeable pavements, and public education (Prince George's County 1999) to reduce stormwater impacts.

Most studies of stormwater BMPs have focused on individual practices and few have incorporated more than one BMP into an investigation. There are even fewer studies on comprehensive LID designs, and these have relied mostly on assumptions about their effectiveness for stormwater management. However, no studies have monitored the effects of a LID design on stormwater runoff.

The Jordan Cove Urban Watershed Section 319 National Monitoring Program (NMP) Project, located in southeastern Connecticut (Figure 1), was a ten-year study designed to determine the water quantity and quality benefits of an urban subdivision developed using LID principles and pollution prevention best management practices (BMPs). This project was conducted because the effects of watershed-wide implementation of residential BMPs on water quality and quantity were largely unknown.

Jordan Cove is a small (200 ha, 500 ac) estuary connected to Long Island Sound. The Cove is impaired for shellfish due to excess fecal coliform bacteria (CT DEP 2004). Long Island Sound is impaired due to excess nitrogen-caused hypoxia, and in some locations, indicator bacteria. A TMDL for total nitrogen was developed in 2001 for the Sound that calls for a 58% reduction in nitrogen loading by 2014 (NY DEC & CT DEP 2000).

The overall objective of the project was to demonstrate the water quantity and water quality benefits of developing urban residential subdivisions with LID principles and BMP nonpoint source controls. There were a number of specific objectives related to the project: 1) to reduce the amount of runoff and sediment, bacteria, nitrogen (N), and phosphorus (P) from residential developments *during construction*; 2) to reduce the amount of runoff and sediment, bacteria, N, and P exported from completed residential developments *following construction*; 3) to demonstrate the use of residential nonpoint source controls for educational purposes; and 4) to investigate the effectiveness of individual BMPs including alternative driveway pavement treatments.

Monitoring of stormwater runoff was conducted in three separate stages of this project to isolate impacts from different phases of development. The first stage was the calibration period to evaluate background conditions prior to any construction on the site. The second stage was the construction period to evaluate impacts due to the building process. The third stage was the post-construction period to evaluate impacts of residential build-out.

The following quantitative treatment goals were developed for the project:

1. To implement BMPs on 100% of the lots in the BMP watershed.
2. To maintain post-development peak runoff rate and volume at levels equal to pre-development rates.
3. To maintain post-development loading of TSS at levels equal to pre-development rates.
4. To retain sediment onsite during construction.
5. To reduce nitrogen export by 65%.
6. To reduce bacterial export by 85%.
7. To reduce phosphorus export by 40%.

METHODS

Study Design

The overall study design was the paired watershed approach (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 Jordan Cove project, the study design consisted of one control watershed and two treatment watersheds. The treatment watersheds consisted of a traditional watershed and a BMP watershed, as further described below. The paired watershed approach was applied between the control and traditional watersheds, and between the control and BMP watersheds, separately. Also, the study employed two treatment periods: construction and post-construction, that were analyzed separately. The general schedule for the project is summarized in Figure 2, although the calibration and treatment periods started at different dates depending on the site.

Study Area

The project was located in the town of Waterford, CT (Figure 1). The climate of the area is influenced by both continental polar and maritime tropical air masses (Brumbach 1965). Average annual precipitation is approximately 1,265 mm (50 in) and is distributed uniformly throughout the year. Hurricanes enter the state periodically. Soils on the sites are mapped as Canton and Charlton with an increasingly disturbed urban land classification associated with construction.

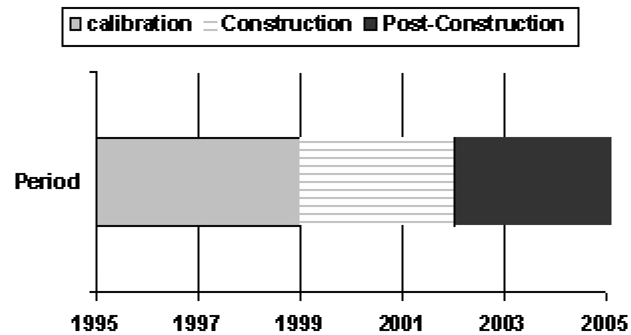


Figure 2. Schedule of the Jordan Cove Urban Watershed NMP Project.

Three watersheds located in the drainage basin contributing to Jordan Cove were included in the study design. The control watershed was a 5.5 ha (13.6 ac) residential development containing 43 lots, ranging in size from 0.14 to 0.19 ha (0.3-0.5 ac), that was built in 1988 (Figure 3A). The first treatment watershed, to be developed using current standard regulations and construction practices (the "traditional watershed") contained 18 lots on 2.0 ha (4.9 ac) (Figure 3B). The past use of the property was a poultry farm. The traditional practices to be employed in development of the residential subdivision included traditional lot zoning, a curb and gutter stormwater collection system, a typical 8.5 m- (28 ft-) wide asphalt road, and standard landscaping and turf. Roof runoff was directed to lawn areas or onto driveways. Erosion and sediment controls used during construction were typical of other construction sites statewide. Impervious surface coverage was 32% (Table 1).

Table 1. Characteristics of study watersheds in Waterford, CT.

	Control	Traditional	BMP
Watershed area (ha)	5.5	2.0	1.7
Number of lots	43	17	12
Average lot size (ha)	0.16	0.15	0.10
% Total Impervious	29	32	22
% Buildings	9.6	10.1	8.3
% Driveways	6.7	8.9	6.1*
% Road	12.6	11.8	5.5*
% Sidewalks	unknown	0.8	1.1

*Ecostone pavers assumed to be 88% impervious and included in calculations.

The second treatment watershed, to be developed using BMPs (the "BMP watershed"), incorporated several pollution prevention measures as part of its design (Figure 3C). This subdivision had 12 units on 1.7 ha (4.2 ac) (Table 1). Its watershed included a closed-out gravel pit. About 26% of the entire subdivision was maintained in open space, mostly along the periphery. Land treatment included the replacement of a traditional 8.5 m- (28 ft-) wide asphalt road and curbs-and gutters with a 6.1 m- (20 ft-) wide concrete paver road and grassed bioretention swales (Figure 4). A bioretention cul-de-sac that allows for detention and infiltration of runoff was constructed in lieu of a conventional paved area (Figure 5). Individual bioretention areas ("rain gardens") were incorporated into each lot to detain roof and lot runoff (Figure 6). Adjacent lots used shared driveway entrances to reduce impervious surface area. Several alternative driveway surfaces were installed including concrete pavers and gravel. Infiltration and runoff from alternative driveway surfaces were compared against traditional asphalt in a study not reported here. Houses were constructed in a cluster layout with zero side lot setbacks, reduced lawn areas, and establishment of low-mow and no-mow areas. Low-mow areas were mowed once or twice each year. No-mow areas were not mowed and maintenance was restricted to invasive plant removal. Deed

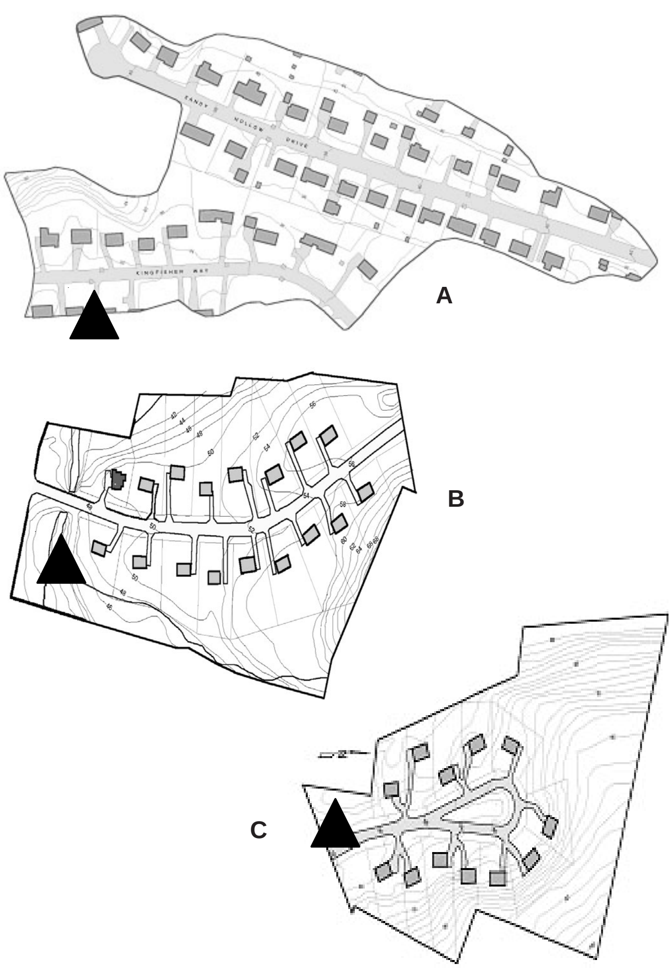


Figure 3. Jordan Cove study watersheds, showing the control subdivision (A), traditional subdivision (B) and best management practices subdivision (C). Monitoring locations are shown with dark triangles.

Figure 4. Photograph of BMP portion of the Jordan Cove Urban Watershed NMP Project showing a grassed swale, concrete paver road, and the bioretention cul-de-sac.

Figure 5. Photograph of the bioretention cul-de-sac at the Jordan Cove NMP project.

Figure 6. Photograph of a bioretention area installed on each lot at the Jordan Cove NMP project.

restrictions were developed to prevent certain activities during the study and education programs were conducted to instruct owners on good housekeeping practices. Several waivers of the subdivision regulations for the Town of Waterford were obtained as part of this study. These waivers included the reduction of road width from 8.5 to 6 m (28 to 20 ft) in the BMP watershed, eliminating curbs, and allowing paver blocks instead of asphalt. Also, the cul-de-sac was modified to allow an oblique form vs. a standard 15 m (50 ft) radius, with one-way traffic flow and a center depressed island serving as a bioretention area. Additional BMPs were used during construction, including locating and seeding stockpiles to prevent sediment loss, hay bales, silt fence, and post-storm maintenance. The developer also utilized earthen berms and basement excavations to retain stormwater onsite, although these practices were not originally planned.

A comparison of imperviousness among the watersheds indicates that the BMP watershed had less impervious area than the traditional watershed (Table 1). The percentage in road and driveways was also lower for the BMP watershed than the traditional watershed.

Monitoring Methods

Monitoring was conducted at the outlet of each of the three study watersheds – control, traditional and BMP. Precipitation was recorded at the BMP site using a heated tipping bucket rain gauge. Air temperature was continuously monitored to allow separation of snowmelt periods from precipitation events. Stormwater flow was monitored continuously during storm events from the three watersheds using ISCO 4230 bubbler flowmeters. Devices to measure flow varied by the site depending on whether discharge occurred overland or in a stormwater pipe. The monitoring site at the control watershed had a combination rectangular/V-notch weir, installed in a 76 cm (30 in) stormwater pipe. Both the traditional and BMP monitoring sites used a 45.72 cm (1.5 ft) H-flume to measure overland flow during the calibration period. During the treatment period, the traditional monitoring site used a 38.1 cm (15 in) Palmer-Bowlus flume inserted in a stormwater pipe located in a monitoring manhole, while the BMP monitoring site used a 45.72 cm (1.5 ft) H-flume at the end of the grassed swale.

Samples were collected automatically by an ISCO 2900 or 3710 sampler that had been programmed to collect a sample every 15 m^3 (530 ft^3) of discharge. Collected samples were refrigerated in-situ. At each flow interval, the sample was split into three containers; one pre-acidified with sulfuric acid for nutrient preservation, the second pre-acidified with nitric acid for metals analysis, and the third not acidified. The third container was used for suspended sediment analysis. If flow was occurring during the field visit, a grab sample was taken for biochemical oxygen demand (BOD) and fecal coliform analysis.

Acidified composite stormwater samples were analyzed for nitrate+nitrite nitrogen (NO_3+NO_2-N), ammonia-nitrogen (NH_3-N), total Kjeldahl nitrogen (TKN), and total phosphorus (TP) using a Lachat colorimetric flow injection system (US EPA 1983a). Non-acidified samples were analyzed for total suspended solids (TSS) using an approved EPA gravimetric method (APHA 1989, US EPA 1983a). Acidified unfiltered samples were composited on a monthly basis and analyzed for copper (Cu), lead (Pb), and zinc (Zn) (US EPA 1991). Grab samples were performed on site visits when stormflow was present and analyzed for fecal coliform bacteria and 5-day BOD (US EPA 1983a).

The project sent a 10-question survey to all residents of the three watersheds each spring beginning in 1999 to track information that might affect the study results. Questions focused on pets, lawn care, fertilizers, watering, leaf disposal, rain gutters, and car washing. This survey was also an opportunity to communicate study results.

All data were statistically analyzed using SAS version 8.0 software (SAS Institute, Inc. 2001). Analysis of variance (ANOVA) was used to test the significane of the regressions in each period. Analysis of covariance (ANCOVA) was used to test the differences between the two regression slopes and intercepts. Most water quality data were log-normally distributed; therefore, means presented are anti-logs of log-transformed data (geometric means). Percent changes in flow, concentration, and export were calculated by comparing mean predicted values from the calibration regression equations to observed values using the equation:

$$\%change = \frac{(O-P)}{P} \times 100$$

where O = observed value and P = predicted value.

Results and Discussion

BMP Watershed

Runoff

During construction, mean weekly flow volume decreased 97% compared to what was expected through calibration (Figure 7). The decrease in runoff can be attributed to landform changes that retained water onsite and promoted infiltration after storm events. Specifically, an earthen berm of topsoil was constructed upstream of the BMP monitoring station. The berm was not originally planned but was added by the developer to prevent runoff from reaching an adjacent property. The berm pooled water and obstructed flow to the station for several months during the construction period. Additionally, excavations for basements on all lots occurred within a short period because rock blasting was required. These cellar holes became mini ‘detention basins’ that held stormwater onsite.

Lastly, the fill needed to raise the elevation of the area likely allowed for higher infiltration than the remaining mined gravel pit soil present before the construction phase. After construction, observed flow decreased 78% compared to the flow predicted by the pre-construction (calibration period) regression (Figure 8). The LID goal of preventing post-development runoff volume from exceeding pre-development levels was achieved in this study.

Peak discharge also did not increase during either the construction or post-construction periods (Figures 7 and 8). The maintenance of pre-development peak discharge is another goal of low impact development that was achieved.

Sediment

Concentration. TSS concentrations significantly increased ($P < 0.001$) during construction compared to those predicted by the calibration regression (Figure 7). TSS concentrations in stormwater varied through the construction period. On a temporal basis, highest TSS concentrations were observed during the installation of the permanent monitoring station and when the swales were constructed. The swales were reconstructed a second time because they did not meet town requirements. Higher TSS concentrations in runoff were also observed during this second construction of the swales. Erosion control recommendations, including the use of erosion control fabric and silt fence check dams, were not followed during either swale construction effort. During the post-construction period, TSS concentrations have remained significantly higher than predevelopment concentrations (Figure 8). However, mean concentrations are not very high (Table 2). The paired watershed approach has the ability to detect small changes, especially when there are a large number of samples, even though the change might not have a large ecological impact.

Nitrogen

Export. During construction, sediment export increased significantly compared to export predicted by the calibration regression due to land disturbance (Figure 7). Because decreased flows were documented, this increase in TSS export was due to increased sediment concentrations during construction. Following construction, TSS export was not significantly different from pre-development (Figure 8) levels.

Concentration**.** During the construction period, the concentrations of NO_3+NO_2-N, NH_3-N, and TKN all increased significantly in runoff from the BMP watershed (Figure 7) compared to concentrations predicted from the pre-construction (calibration) regression. The increase in NO_3+NO_2-N concentrations was detected following starter fertilizer applications. During the post-construction period, only the TKN concentrations remained higher than expected due to higher organic N in the water (Figure 8). These greater organic N and NO_3+NO_2-N concentrations were likely associated with fertilizer use and grass clippings within the swales. NH_3-N concentrations declined following construction although values were already near detection limits. Total nitrogen in runoff was similar to NURP observations (Table 2).

Export. During construction, the export of NO_3+NO_2-N, NH_3-N and TKN did not change significantly even though concentrations had increased (Figure 7). Following construction, the export of NH_3-N, and TKN decreased while the export of NO_3+NO_2-N did not change (Figure 8). The flow decrease is responsible for these export decreases observed since concentrations had increased.

Total Phosphorus

Concentration. The concentration of TP in stormwater runoff increased significantly during both the construction and post-construction periods (Figures 7 and 8), compared to predictions based on the pre-construction regression. The increases during construction were noticeable following the application of starter fertilizers in swale establishment. TP concentrations observed are similar to NURP values.

Export. TP export increased during the construction period even though flow decreased (Figure 7). During the post-construction period, TP export remained higher than expected but export rates were 25% of construction period rates (Figure 8).

Bacteria

There were no significant differences in either the concentration or export of fecal coliform bacteria in runoff during construction and post-construction periods, compared to predictions from the pre-construction calibration regression. The low number of samples collected may explain the lack of de-

Table 2. Geometric mean concentrations during the post-construction period for the study watersheds, and median event mean concentrations (EMC) for residential areas from the Nation-wide Urban Runoff Project (NURP) (US EPA 1983b).

	Control	Traditional	BMP	NURP
Total suspended solids (mg/L)	21	17	11	101
Total Phosphorus (mg/L)	0.176	0.175	0.324	0.383
Total Nitrogen (mg/L)	2.7	1.3	2.1	2.6
Zn (mg/L)	53	44	27	135

Continued on p. 9

NCSU Water Quality Group Publications List and Order Form (February 2006)

Publication Number	Reports & Journal Articles	Price($)	Quantity	Total($)
WQ-131	Stream Restoration: A Natural Channel Design Handbook (2003) (129p) http://www.ncsu.edu/sri/stream_rest_guidebook/guidebook.html	35.00		
WQ-130	Changes in a Stream's Physical and Biological Conditions Following Livestock Exclusion (2003) (7p)	Free		
WQ-129	Changes in Land Use/Management and Water Quality in the Long Creek Watershed (2002) (11p)	Free		
WQ-128	2002 NC Stream Restoration Conference (Conference Agenda and Proceedings) (2002) (73p)	10.00		
WQ-127	Hydraulic Geometry Relationships for Urban Streams Throughout the Piedmont of North Carolina (2002) (11p)...	Free		
WQ-126	Pollutant Export from Various Land Uses in the Upper Neuse River Basin (2002) (9p)...	Free		
WQ-125	Efficiencies of Temporary Sediment Traps on Two North Carolina Construction Sites (2001) (9p)...	Free		
WQ-124	Section 319 Nonpoint Source National Monitoring Program: Successes and Recommendations (2000) (32p)... (http://www.ncsu.edu/waterquality/section319/index.html)	Free		
WQ-123	Nonpoint-Source Pollutant Load Reductions Associated with Livestock Exclusion (2000) (9p)...	Free		
WQ-120	Comparing Sampling Schemes for Monitoring Pollutant Export From a Dairy Pasture (1998)	Free		
WQ-119	Performance Evaluation of Innovative and Alternative On-Site Wastewater Treatment Systems in Craven County, NC (1998) (12 p)	Free		
WQ-109	Techniques for Tracking, Evaluating, and Reporting the Implementation of Nonpoint Source Control Measures: Forestry (EPA/841-B-97-009) (1997)	Free		
WQ-103	WATERSHEDSS: A Decision Support System for Watershed-Scale Nonpoint Source Water Quality Problems (Journal of the American Water Resources Association) (1997) (14p)	Free		
WQ-105	Linear Regression for Nonpoint Source Pollution Analyses (EPA-841-B-97-007) (1997) (8p)	Free		
WQ-104	Water Quality of First Flush Runoff from 20 Industrial Sites (Water Environment Research) (1997) (6p)	Free		
WQ-100	Water Quality of Stormwater Runoff from Ten Industrial Sites (Water Resources Bulletin) (1996) (10p)	Free		
WQ-96	Goal-Oriented Agricultural Water Quality Legislation (Water Resources Bulletin) (1996) (14p)	Free		
WQ-92	The Rural Clean Water Program: A Voluntary, Experimental Nonpoint Source Pollution Control Program and its Relevance to Developing Countries (1995) (18p)	Free		
WQ-83	Effective Monitoring Strategies for Demonstrating Water Quality Changes from Nonpoint Source Controls on a Watershed Scale (Wat. Sci. Tech.) (1993) (6p)	Free		
WQ-21	Setting Priorities: The Key to Nonpoint Source Control (EPA 841-B-87-110) (1987) (50p)	Free		
WQ-60	Selecting Priority Nonpoint Source Projects: You Better Shop Around (EPA/506/2-89/003) (1989) (39p)	5.00		
WQ-24	Selecting Critical Areas for NPS Pollution Control (J. Soil & Water Conservation) (1985) (4p)	Free		
WQ-26	Appropriate Designs for Documenting Water Quality Improvements from Agricultural NPS Control Programs (USEPA) (1985) (5p)	Free		
WQ-27	Increasing Sensitivity of NPS Control Monitoring Programs (Water Res. Assoc. Proc.) (1987) (15p)	Free		
WQ-30	Pollution From Nonpoint Sources: Where We Are and Where We Should Go (J. Env. Science & Technology) (1987) (6p)	Free		
WQ-32	Determining Statistically Significant Changes in Water Pollutant Concentrations (J. Lake & Reservoir Mgmt.) (1987) (7p)	Free		

* new addition to publication list

Publication Number	Reports & Journal Articles (continued)	Price($)	Quantity	Total($)
WQ-33	Water and Sediment Sampler for Plot and Field Studies (J. Environmental Quality) (1987) (6p)	Free	_______	
WQ-35	Agricultural Nonpoint Source Control: Experiences from the Rural Clean Water Program (J. Lake & Reservoir Management) (1988) (6p)	Free	_______	
WQ-36	Determining the Statistical Sensitivity of the Water Quality Monitoring Program in the Taylor Creek Nubbin Slough, Florida, Project (J. Lake & Reservoir Management) (1988) (12p)	Free	_______	
WQ-65	Determining and Increasing the Statistical Sensitivity of Nonpoint Source Control Grab Sample Monitoring Programs (Colorado Water Resources Research Institute) (1990) (17p)	Free	_______	
WQ-70	North Carolina's Sediment Control Program (Public Works) (1991) (3p)	Free	_______	
WQ-98	Farm*A*Syst Fact Sheets (7 fact sheets) (1997) (http://h2osparc.wq.ncsu.edu/info/farmassit/index.html)	Free	_______	
WQ-99	Home*A*Syst Fact Sheets (5 fact sheets) (1997) (http://h2osparc.wq.ncsu.edu/info/farmassit/homeindx.html)			
WQ-89	Rural Clean Water Program Technology Transfer Fact Sheets (10 fact sheets) (1995) (http://h2osparc.wq.ncsu.edu/info/concepts.html)	Free	_______	
WQ-91	Watershed Management: Planning and Managing a Successful Project to Control Nonpoint Source Pollution (contains a list of resources specific to North Carolina) (1995) (8p) (http://www.bae.ncsu.edu/bae/programs/extension/publicat/wqwm/ag522.html)	Free	_______	
WQ-86	Paired Watershed Study Design (EPA 841-F-93-009) (1993)	Free	_______	
WQ-48	Pesticide Fact Sheets (10 fact sheets) (1988)	4.00	_______	_______
	Literature Reviews and Bibliographies			
WQ-121	Nonpoint Sources (Review of 1998 Literature) (Water Environment Research) (1999) (16p)	Free		
WQ-118	Nonpoint Sources (Review of 1997 Literature) (Water Environment Research) (1998) (17p)	Free	_______	
WQ-106	Nonpoint Sources (Review of 1996 Literature) (Water Environment Research) (1997) (17p)	Free	_______	
TOTAL =	Total Amount of Purchase		$__________	

IMPORTANT NOTES ABOUT ORDERING PUBLICATIONS:

Prices include postage within the U.S. Prices for publications to be sent outside the U.S. may be higher. Please call or write for this information. All prices are subject to change without notice. The price list is updated with each issue of NWQEP NOTES. Requests are filled while supplies last. Only one copy of each free publication is available. FEIN #56-6000-756

To order: Fill out order form and enclose with payment. Please make checks payable to NCSU Water Quality Group

___ Check here if requesting we bill your institution
___ Check here if enclosing payment

Please note: Only institutions can be billed. Individuals must enclose payment with order form.

Send order to: Publications Coordinator, NCSU Water Quality Group, Campus Box 7637, Raleigh, NC 27695-7637 Fax: 919-515-7448, email: wq_puborder@ncsu.edu. An electronic order form is also available at: http://www.ncsu.edu/waterquality/issues/pub_order.html.

Ordered by:
Name:____
Institution:______________________________________
Street Address:___________________________________
City,State, Zipcode: ______________________________
Telephone:____

_______ Please place my name on the mailing list for NWQEP NOTES, the quarterly newsletter on nonpoint source pollution published by the NCSU Water Quality Group (with support from the U.S. Environmental Protection Agency) (subscriptions are free).

- NCSU Water Quality Group home page: http://www.ncsu.edu/waterquality/
- U.S. Environmental Protection Agency's Office of Water publications list: http://www.epa.gov/OW/info
- WATERSHEDSS — Water, Soil, Hydro-Environmental Decision Support System, Internet-based management tool: http://www.water.ncsu.edu/watershedss/
- Understanding the Role of Agricultural Landscape Feature Function and Position in Achieving Environmental Endpoints: Final Project Report (to the U.S. Environmental Protection Agency) (1996) (118p) (abstract and instructions for downloading the report available at: ftp://ftp.epa.gov/epa_ceam/wwwhtml/software.htm

Production of NWQEP NOTES is funded through U.S. Environmental Protection Agency (EPA) Grant No. X825012. 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

tectable differences. Regression relationships between the control and treatment watersheds were not significant during either calibration or treatment periods.

Metals

Concentration. The concentrations of both Cu and Pb in stormwater runoff significantly increased during construction but Zn concentrations did not increase (Figure 7). During the post-construction period, the concentrations of Pb and Zn decreased from predevelopment levels, while Cu concentrations did not change (Figure 8). Zinc concentrations in runoff from the BMP watershed during post-construction were lower than observed in the NURP study (Table 2).

Export. There was no change in the export of Cu and Pb during construction at the BMP site, but Zn concentrations declined compared to predictions from the calibration regression (Figure 7). The export of Pb and Zn decreased following construction, due to the decrease in both flow and concentration (Figure 8). Cu export did not change.

Traditional Watershed

Runoff

Flow volume increased significantly from that predicted by the pre-development regression during construction in the traditional watershed (Figure 7). The major cause of the increase in flow volume was the creation of the asphalt roadway that was directly connected to a curb and gutter stormwater collection system. Peak flow rate similarly increased during construction. Higher peak flow rates are expected in traditional residential construction because the impervious asphalt road reduces the lag time of flow as well as increases the flow volume. Post-construction flow data are still being examined.

Sediment

Concentration. There was no change in the observed concentration of TSS in runoff during construction in the traditional watershed compared to concentrations predicted from the pre-construction regression (Figure 7). This finding indicates that the erosion and sediment controls typically used in Connecticut were adequate during construction. These controls include the use of silt fence, hay bales and fabric over catch basin inlets, location of soil stockpiles to prevent sediment loss, and seeding of exposed soil. Also, the developer used post-storm maintenance, including sweeping of eroded soil found on the asphalt road. Following construction, sediment concentrations have declined as compared to the calibration period (Figure 8). Post-construction sediment concentrations were lower than observed in the NURP study (Table 2).

Export. The export of TSS increased over 99% during the construction period, due to the increase in runoff.

Nitrogen

Concentration**.** During construction, the concentration of NO_3+NO_2-N and NH_3-N in runoff did not change, while the concentration of TKN decreased significantly compared to levels predicted from the pre-construction regression (Figure 7). There is no apparent explanation for this decrease but it would represent a decrease in organic-N concentrations. Perhaps there was a reduction in lawn litter in runoff. Following construction, the concentrations of NO_3+NO_2-N and NH_3-N did not change while the concentration of TKN decreased significantly (Figure 8).

Export. The export of TKN, NH_3-N, and NO_3+NO_2-N all increased significantly during construction, due to the increase in runoff.

Phosphorus

Concentration. The concentration of TP in runoff decreased during both construction and post-construction periods (Figures 7 and 8) compared to concentration predicted by the pre-construction regression. This decrease may represent phosphorus contamination on-site during the calibration period due to historical poultry use.

Export. TP export increased significantly during construction, due to the increase in runoff.

Metals

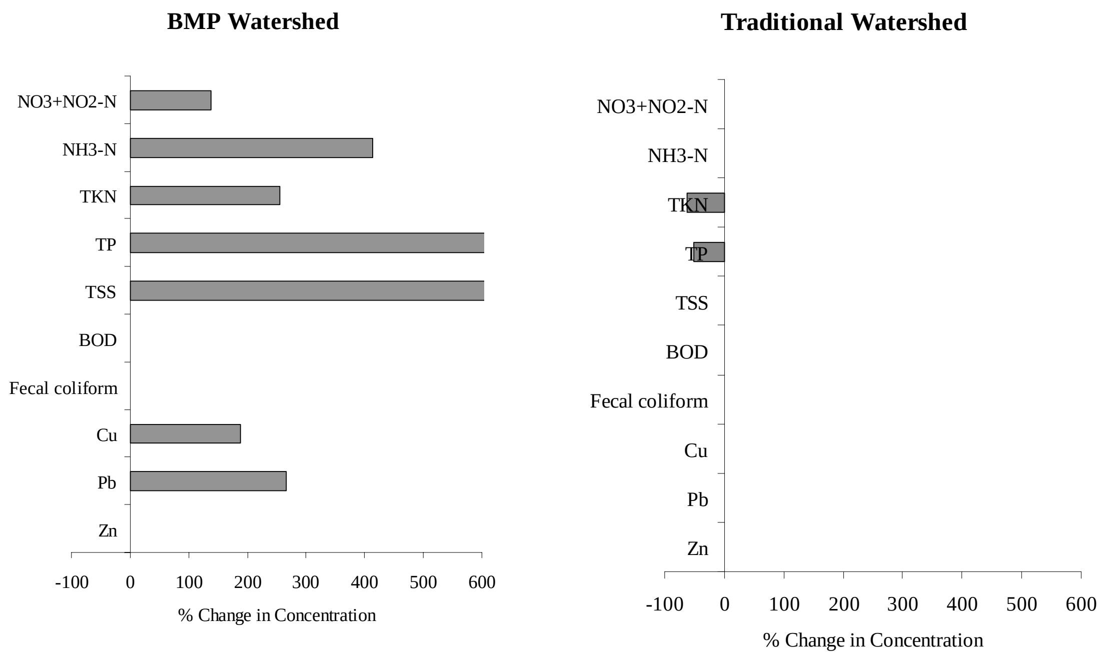
Concentration. The concentration of Cu, Pb, and Zn did not change during or following construction in the traditional watershed (Figures 7 and 8). Zn concentrations were lower than NURP EMCs (Table 2).

Export. The export of metals increased significantly during construction in the traditional watershed; these increases were associated with increases in flow.

Household Survey

Despite the implementation of BMPs and the educational outreach efforts conducted in the BMP watershed, the household surveys did not document great differences in behavior of residents among the three watersheds. Behaviors also did not change across years in all three watersheds; an important consideration in the control watershed. Maintaining consistent conditions in the control watershed through the study period is a key requirement of the paired watershed design. There were, for example, no differences among watershed residents in terms of pet waste handling, lawn clipping management, lawn fertilization frequency, decisions on how much to fertilize, and where the car was washed. More homeowners composted leaves and mowed their own lawns in the BMP watershed. More homeowners in the traditional watershed used automatic sprinklers.

CONCENTRATION



EXPORT

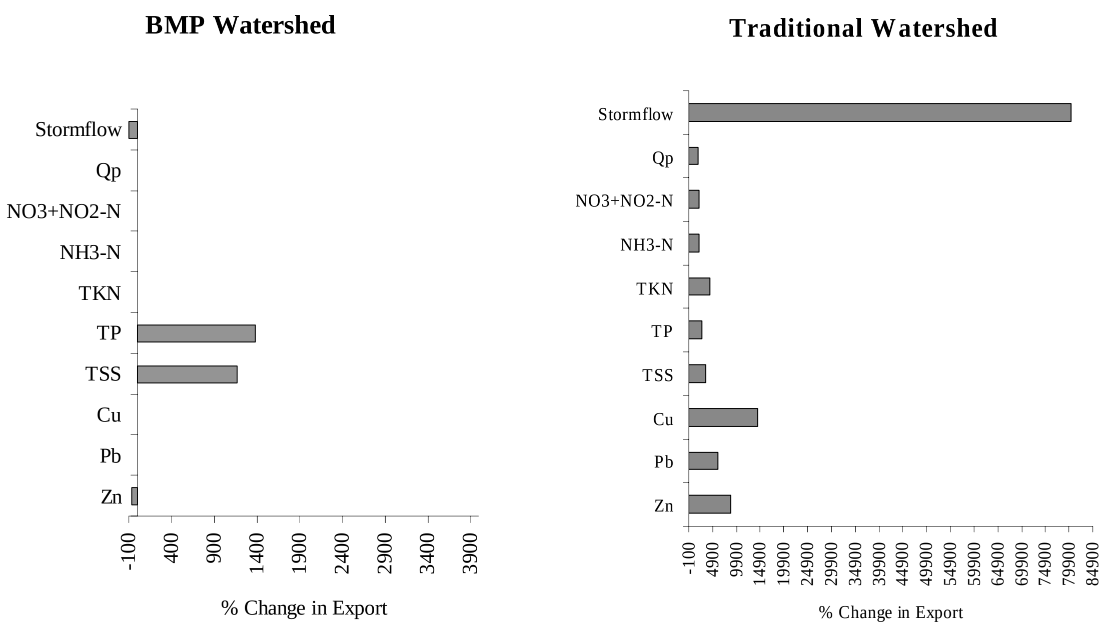
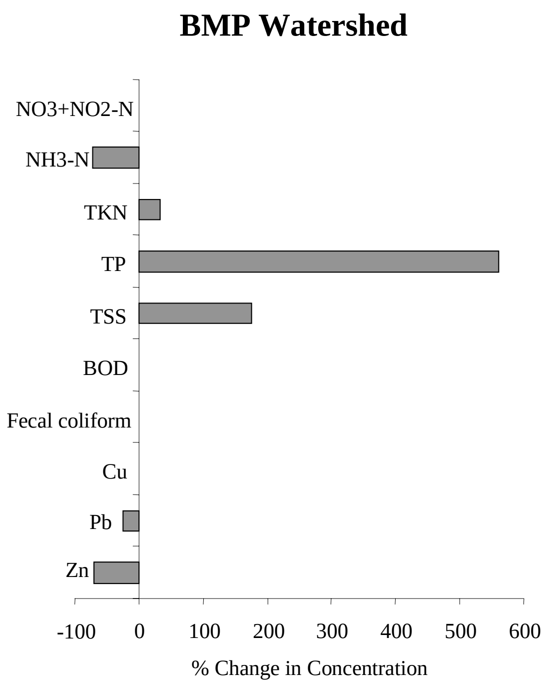
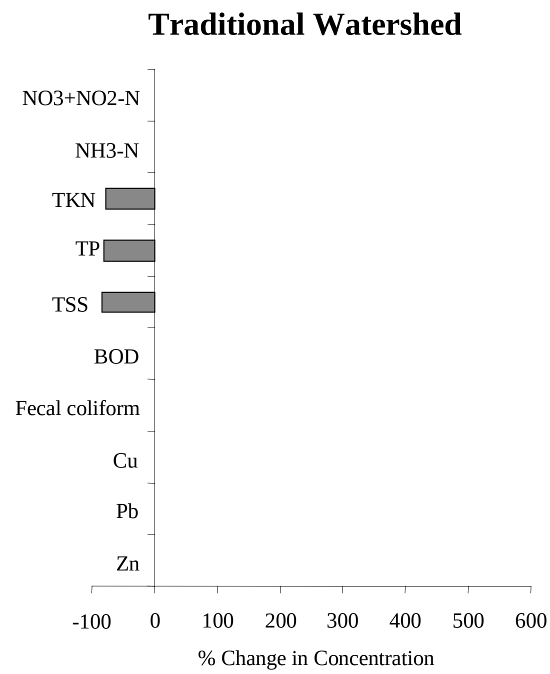


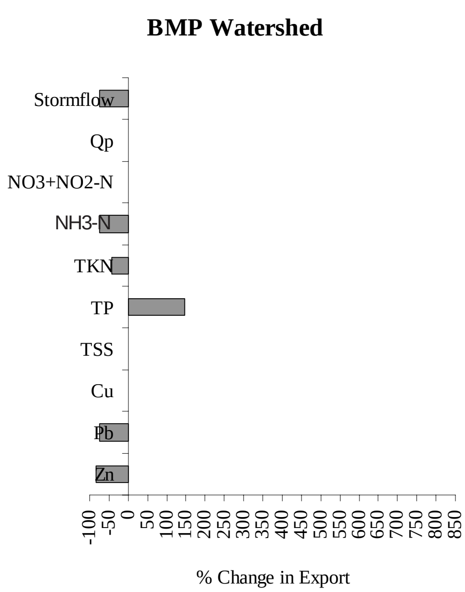
Figure 7. CONSTRUCTION PERIOD RESULTS for the BMP and traditional watersheds. Bars represent the percent change observed due to construction that is calculated from the difference between the observed value and the value predicted by the calibration regression equation. Bars are not shown for non-significant differences.

CONCENTRATION





EXPORT



Post-construction export analysis pending.

Figure 8. POST-CONSTRUCTION PERIOD RESULTS for the BMP and traditional watershed. Bars represent the percent change observed post-construction that is calculated from the difference between the observed value and the value predicted by the calibration regression equation. Bars are not shown for non-significant differences.

Conclusions

Traditional residential construction significantly increased stormwater runoff as expected. However, in the BMP subdivision, during and following construction, runoff peaks and volume decreased. During the construction period, runoff per unit area was 50 times greater from the traditional watershed than from the BMP watershed. The control of runoff is a major goal of LID and it was achieved in this project.

Surprisingly, concentrations of sediment, N, and P significantly increased in stormwater runoff from the BMP watershed during and after construction compared to concentrations that would have been expected under pre-development conditions. However, the concentrations observed were not high when compared to NURP data. The higher values may have been due to runoff leaving the BMP watershed via the swales, as swales can contribute more sediment, N and P than an asphalt road during unstabilized soil conditions and following fertilization. Secondly, installation of BMPs is not common knowledge to construction personnel. In this study, some BMPs, such as rain gardens, required removal and reinstallation, leading to temporary soil disturbance. It was difficult to supervise BMP use and installation without being on the site at all times during construction.

In contrast, TSS, NO_3+NO_2-N, and NH_3-N concentrations in traditional watershed runoff did not increase during construction, and TKN and TP concentrations experienced a significant reduction. These concentration results for the traditional watershed indicate that erosion and sediment controls utilized on the site were effective. Following the construction period at the traditional watershed, concentrations of TSS, TP, and TKN remained significantly lower than expected under pre-development conditions. These findings suggest that runoff predominantly from an asphalt road had less pollutants than lawn runoff at this site. This result, although perhaps unexpected, is consistent with Bannerman et al. (1993) who found higher TP and suspended solids in lawn runoff in Wisconsin than in street runoff. Rushton (2001) reported higher TP and TN concentrations in runoff from asphalt parking lots with grassed swales compared to just asphalt parking lot runoff. However, because the runoff volume from pavement would be much higher than from grassed areas, loads from pavement would tend to be higher than from grassed areas.

Single transient activities in the BMP watershed contributed to concentration spikes and are important to overall watershed water quality. These events included TSS increases during unstabilized soil conditions in the swales and N and P increases following fertilization.

Mass exports were driven primarily by flow responses in each treatment watershed. Export in runoff from the BMP watershed generally did not increase during construction, except for TSS and TP. Zn export declined in both construction and post-construction periods. In contrast, traditional watershed export increased in sediment, N, P, and metals during construction. The export of sediment during construction from the traditional watershed was four times that from the BMP watershed on a per unit area basis.

In terms of the treatment goals established for the BMP watershed, BMPs were implemented on 100% of the lots in the BMP subdivision. Post-development peak runoff rate and volumes were maintained at levels equal to pre-development rates. Post-development loading of TSS was maintained at levels equal to pre-development rates. Sediment was not maintained onsite during construction. Nitrogen export was not reduced by 65% compared to traditional development. Bacterial export was not reduced by 85%. Phosphorus export was reduced by 40% compared to traditional development.

Overall, this study has shown that BMPs can maintain runoff and TSS export at pre-development conditions but that controlling some pollutant concentrations may be more difficult. Traditional watershed development increased flow dramatically but typical erosion and sediment control appeared to work in maintaining pre-development sediment concentrations. Significant runoff and export savings can be achieved using LID as compared to traditional residential development.

Acknowledgements

This study was funded in part by the CT DEP through a US EPA nonpoint source grant under Sect. 319 Clean Water Act. We thank Mr. Donald W. Meals, Ice-Nine LLC, for editorial assistance.

For More Information

John C. Clausen
University of Connecticut
Department of Natural Resources
Management & Engineering
1376 Storrs Rd.
Storrs, CT 06269-4087
(860) 486-0139
John.clausen@uconn.edu

References

American Public Health Association. 1989. Standard methods for the examination of water and wastewater. 17th Edition. American Public Health Association, Washington, D.C.

Bannerman, R.T., Owens, D.W., Dodds, R.B., and Hornewer, N.J. 1993. Sources of pollutants in Wisconsin stormwater. *Water Sci. Technol*. 28 (3-5): 241-259.

Brabec E, Schulte S, Richards PL. 2002. Impervious surfaces and water quality: A review of current literature and its implications for watershed planning. *J. Plann. Lit*.;16 (4): 499–514.

Brumbach, J.J. 1965. The climate of Connecticut. State Geological and Natural History Survey of Connecticut. Department of Agriculture and Natural Resources, Bulletin No. 99.

Clausen J.C. and J. Spooner. 1993. Paired Watershed Study Design. United States Environmental Protection Agency. USEPA 841-F-93-009. Washington, D.C. 20460.

Connecticut Department of Environmental Protection. 2004. 2004 list of Connecticut waterbodies not meeting water quality standards. Department of Environmental Protection. Hartford, CT.

Klein RD. 1979. Urbanization and stream quality impairment. *Water Resour. Bull*.15(4):948-63.

Leopold, L., 1968. Hydrology for Urban Land Planning- A guidebook of Urban Land Use. U. S. Geological Survey Circular 554, Washington, D.C. 10 pp.

New York Department of Environmental Conservation and Connecticut Department of Environmental Protection. 2000. A total maximum daily load analysis to achieve water quality standards for dissolved oxygen in Long Island Sound. New York Department of Environmental Conservation, Albany, NY. Connecticut Department of Environmental Protection. Hartford, CT.

Prince George's County. 1999. Low-impact development design strategies. An integrated design approach. Prince George's County and Maryland Department of Environmental Resources, Largo, MD.

Rushton, B.T. 2001. Low-impact parking lot design reduces runoff and pollutant loads. *J. Water Resour. Planning and Manage.* 127 (3): 172-179.

SAS Institute Inc. 2001. The SAS System for Windows (Release 8.02). Cary, NC

United States Environmental Protection Agency. 1983a. Methods for chemical analysis of water and wastes. EPA-600/4-79-020. Office of Research and Development. Cincinnati, Ohio. 45268.

United States Environmental Protection Agency. 1983b. Results of the Nationwide Urban Runoff Program. December 1983. Volume I – Final Report. Water Planning Division. NTIS Accession Number PB84-185552.

United States Environmental Protection Agency. 1991. Method 200.8, determination of trace elements in waters and wastes by inductively coupled plasma-mass spectrometer. Revision 4.4. Office of Research and Development, Cincinnati, Ohio, 45268.

United States Environmental Protection Agency. 1994a . The Long Island Sound Study: The Comprehensive Conservation and Management Plan Office of Water, Washington, D.C.

United States Environmental Protection Agency. 1994b. Status and trends in the health of Long Island Sound. Long Island Sound Study. Stamford, CT and Stony Brook, NY.

United States Environmental Protection Agency. (2000a) Low impact development (LID): A literature review. EPA-841-B-00-005. Office of Water, W., D.C.

United States Environmental Protection Agency. (2000b) National Water Quality Inventory. EPA-841-R-02-001. Office of Water. Washington, D.C.

■

INFORMATION

NC Stormwater Survey Results Available

The N.C. Department of Environment and Natural Resources has released findings from its first statewide, stormwater phone survey. Designed to assist outreach and education efforts, the survey measures North Carolina residents' knowledge, attitudes and behaviors with regard to stormwater. East Carolina University's Center for Survey Research administered the survey in August and September 2005. Two subsequent surveys will be administered in 2006 and 2007.

Findings show that most residents are unaware stormwater receives no treatment before-flowing to local waters. Other items of interest include:

- soil testing is not widely used before lawn fertilization,
- homes earning $100,000 or more are most likely to fertilize their lawns monthly,
- only one-fifth of N.C. residents change their own oil,
- more women than men dispose of pet waste properly, and
- one-third of home car washers use their driveways.

Survey data are helpful when targeting outreach and education efforts. Demographic data allow messages to be tailored to a given audience and distributed using that target's preferred media choices.

The full analysis is now available at **http://www.ncstormwater.org/pdfs/stormwater_survey_12506.pdf**

2005 Summary Report of Section 319 National Monitoring Program Projects

The annual report of the Section 319 National Nonpoint Source Monitoring Program (NMP) Projects is available online at **http://www.ncsu.edu/waterquality/319index.htm**. This report provides profiles for 25 watershed projects in the NMP that are being monitored over a 6-10 year period to evaluate effectiveness of best management practices in reducing nonpoint source water pollution. For more information contact Cathy Smith, NCSU Water Quality Group, at 919-515-3723 or cathy_smith@ncsu.edu.

EPA Issues Guidance to Control Urban Runoff Pollution

In December 2005, EPA released *National Management Measures to Control Nonpoint Source Pollution from Urban Areas.* The comprehensive 512-page guidance will help local governments and others protect water resources from polluted runoff that can result from everyday activities and urban development. The guidance will also help municipalities and other regulated entities implement Phase I and Phase II Stormwater Permit Programs. This publication includes voluntary guidance on 12 management measures designed to prevent and control runoff pollutants from urban and suburban lands. The management measures cover topics such as watershed assessment and protection; runoff from new and existing development, road networks, and construction sites; septic system impacts; pollution prevention; and inspection and maintenance of urban runoff management practices.

The guidance is free and available online at **http://www.epa.gov/owow/nps/urbanmm/**. Hard copies are available at the National Service Center for Environmental Publications via phone at 1-800-490-9198 or via the Web site (**http://www.epa.gov/ncepihom/**). Request Publication # EPA 841-B-05-004.

New EPA Watershed Planning Handbook Available

EPA's Office of Water has published a guide to watershed management to help various organizations develop and implement watershed plans. *The Handbook for Developing Watershed Plans to Restore and Protect Our Waters* is aimed toward communities, watershed groups, and local, state, tribal, and federal environmental agencies.

The 414 page handbook is designed to take the user through each step of the watershed planning process: watershed monitoring and assessment, community outreach, selection and application of available models, best management practices, effectiveness data bases, implementation, feedback and plan adjustment.

The handbook is intended to supplement existing watershed planning guides that have been developed by agencies, universities, and other nonprofit organizations. This handbook is more specific than other guides about quantifying existing pollutant loads, developing estimates of the load reductions required to meet water-quality standards, developing effective management measures, and tracking progress once the plan is implemented.

The handbook is available online at **http://www.epa.gov/owow/nps/watershed_handbook**. Free hard copies are available from the National Service Center for Environmental Publications by calling 800-490-9198 or e-mail **ncepimal@one.net**. Request Publication # EPA 841-B-05-005.

EPA NPS Outreach Toolbox (beta) Now Online

The Nonpoint Source (NPS) Outreach Digital Toolbox is intended for use by state and local agencies and other organizations interested in educating the public on nonpoint source pollution or stormwater runoff. The Toolbox contains a set of tools to help you develop an effective outreach campaign tailored to your community.

NPS Outreach Digital Toolbox: **http://www.epa.gov/nps/toolbox/beta/index.html** Search information at: **http://www.epa.gov/nps/toolbox/beta/search.html**

EPA Releases New Report on Density and Water Resources

EPA has released a new report, *Protecting Water Resources with Higher-Density Development*, for water quality professionals, communities, local governments, and state and regional planners who are grappling with protecting or enhancing their water resources while accommodating growing populations.

The U.S. Census Bureau projects that the U.S. population will grow by 50 million people, or approximately 18 percent, between 2000 and 2020. Many communities are asking where and how they can accommodate this growth while maintaining and improving their water resources. Some communities have interpreted water-quality research to mean that low-density development will best protect water resources. However, some water-quality experts argue that this strategy can backfire and actually harm water resources. Higher-density development, they believe, may be a better way to protect water resources. This report helps guide communities through this debate to better understand the impacts of high- and low-density development on water resources.

The report is available for downloading at **www.epa.gov/smartgrowth/water_density.htm**

For hard copies, send an e-mail to **ncepimal@one.net** or call (800) 490-9198 and request EPA publication 231-R-06-001.

■

WWW RESOURCES

New EPA Watershed Funding Web Site

EPA's Office of Wetlands, Oceans & Watersheds has launched a new *Watershed Funding* section of EPA's Web site. The new pages contain links to tools, databases, and resources about grants, funding and fundraising. The Web site is designed to help nonprofit watershed organizations, state and local governments, and funders (such as foundations) more easily find information on how to effectively obtain and invest resources to improve watershed health.

Visit the Watershed Funding homepage at **http://www.epa.gov/owow/funding.html**.

■

MEETINGS

Meeting Announcements — 2006

May

5th Natl Monitoring Conf Monitoring Networks: Connecting for Clean Water: May 7–11, San José, CA. For more information, contact the Conference Coordinator at NWQMC2006@tetratech-ffx.com; Tel: 410-356-8993; Website: http://www.nwqmc.org (click on "2006 National Monitoring Conference").

AWRA 2006 Spring Specialty Conf: GIS & Water Resources IV: May 8-10, Houston, TX. Conference Website: http://www.awra.org/meetings/Houston2006/index.html.

4th Annual Intl Greening Rooftops for Sustainable Communities Conf, Awards & Trade Show: May 11-12, Boston, MA. See website: http://greenroofs.org/boston/

Challenges in Coastal Hydrology & Water Quality: May 21-24, Baton Rouge, LA. See website: http://www.aihydro.org/.

June

Greater Everglades Ecosystem Restoration Conf: Planning, Policy & Science: June 5-9, Lake Buena Vista, FL. See website: http://conference.ifas.ufl.edu/GEER2006

AWRA Stream Restoration & Protection in the Mid-Atlantic Region: June 14-16, New Jersey School of Conservation, Branchville, NJ. See website: http://www.njawra.org/

July

StormCon '06: 5th Annual North American Surface Water Quality Conf & Expo: July 24 to 27, Denver, CO. See website: http://www.stormcon.com/sc.html.

■

14th National Nonpoint Source Monitoring Workshop

Measuring Project and Program Effectiveness
September 24-28, 2006
Minneapolis, Minnesota
Courtyard Marriott at the Depot

About the Conference: The 14th year of this workshop will once again bring together land managers and water quality specialists to share information on the effectiveness of BMPs in improving water quality, effective monitoring techniques, anad statistical analysis of watershed data. The workshop will focus on the successes of Section 319 National Monitoring Program projects and other innovative projects from throughout the U.S. Topics include: detecting change in water quality from agricultural or urban BMP implementation; modeling applications for NPS pollution control; integrating social indicators and environmental monitoring; innovative management and monitoring in agricultural and urban landscapes; nonpoint source TMDLs; monitoring impacts from agricultural drainage management; riparian area and stream protection/restoration; and programs for animal operations and nutrient management.

Conference website: **http://www.ctic.purdue.edu/NPSWorkshop/NPSWorkshop.html**

Contact:
Greg Johnson
Minnesota Pollution Control Agency
651-296-6938
gregory.johnson@pca.state.mn.us

Tammy Taylor
CTIC
765-494-1814
taylor@ctic.purdue.edu

Production of NWQEP NOTES is funded through U.S. Environmental Protection Agency (EPA) Grant No. X825012. 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

NCSU Water Quality Group
Department of Biological and Agricultural Engineering
North Carolina Cooperative Extension Service
Campus Box 7637
North Carolina State University
Raleigh, NC 27695-7637

NC STATE UNIVERSITY

NCSU Water Quality Group
Campus Box 7637
North Carolina State University
Raleigh, NC 27695-7637
Telephone: (919) 515-3723
Fax: (919) 515-7448
Website: http://www.ncsu.edu/waterquality/

Personnel