DRAFT

NMP Lessons Learned

Animal Waste Management/Nutrient Management

The U.S. Environmental Protection Agency (USEPA) established the National Monitoring Program (NMP) in 1991 under Section 319 of the Clean Water Act to achieve the following two objectives:

1. To scientifically evaluate the effectiveness of watershed technologies designed to control nonpoint source pollution, and
2. To improve our understanding of nonpoint source pollution.

State and local watershed projects included in the NMP conduct six to ten years of intensive water quality and land treatment monitoring in accordance with a nationally consistent set of guidelines to accomplish these objectives. Implementation of pollution control technologies is expected to occur in a controlled manner supportive of the experimental designs (e.g., paired watersheds, upstream-downstream) used by the projects. USEPA funding is directed primarily to monitoring and evaluation, while other sources are typically tapped to fund the implementation of pollution control measures.

As of September 2005, USEPA had approved 25 projects in the lower 48 States. These projects addressed a range of water quality problems caused by such sources as cropland, livestock operations, grazing land, stream modification, urban runoff, septic systems, recreation, and coal mining. Pollution control measures implemented include stream restoration, erosion and sediment control, urban runoff control, nutrient management, riparian protection, acid neutralization, septic system repairs, and a host of others.

While the NMP is ongoing, many of the NMP projects have reported final results, and several others have reported early findings. It is against this backdrop that lessons learned by NMP projects have been gathered and summarized in a series of evaluations including this one focused on animal waste management and nutrient management. The findings in this document are based on analysis and reporting by Don Meals and Steve Dressing (Tetra Tech, Inc.) of project reports, annual project summaries (Szpir et al. 2005), and direct communication with project personnel.

The primary emphasis of this evaluation relates to the two NMP objectives, but the success of watershed projects is dependent upon a foundation of design, process, cooperation, and resources. For this reason, lessons learned address a range of factors known to play significant roles in determining the outcome of watershed projects.

The Projects
Several of the NMP projects evaluated some combination of animal waste management, livestock exclusion, and nutrient management; these treatments were a principal focus of six projects:

- Warner Creek, Maryland
- New York City Watershed, New York
- Long Creek, North Carolina
- Peacheater Creek, Oklahoma
- Totten and Eld Inlets, Washington
- Otter Creek, Wisconsin.

Nutrient runoff from dairy agriculture was the major nonpoint source of pollutants to Warner Creek, MD, which drains into the Monocacy River in the nutrient-plagued Chesapeake Bay watershed. The project used the above/below-watershed design to measure the effectiveness of waste storage, nutrient management, loafing area runoff management, conservation cropping, residue management, and cover crop management at dairies and associated cropland. Monitoring data were used to evaluate the suitability of the CREAMS and SWAT models for use in the larger Monocacy River Basin. The project was completed in 2003.

The New York City Watershed project is comprehensively addressing nonpoint sources of sediment and nutrients on a single dairy farm within the NYC Watershed Agricultural Program, a voluntary incentive-based program to implement agricultural nonpoint source management as the primary means of protecting New York City water supplies from agricultural nonpoint source pollutants. Major pollutants of concern on the study farm are phosphorus (P), nitrogen (N), pathogens, and suspended sediment. Best management practices (BMPs) implemented through the Whole Farm Planning process include manure storage and management, barnyard runoff management, milkhouse waste diversion, rotational grazing, livestock exclusion, and crop rotation. Monitoring will continue through 2006.

Agricultural activities related to crop and dairy production were the major nonpoint sources of pollutants to Long Creek, NC. Sediment from eroding cropland was the major problem in the upper third of the watershed, upstream of a municipal water supply intake. Below the intake, Long Creek is impaired primarily by nutrients and bacteria from animal holding facilities and urban areas. BMPs implemented in the project area included erosion control, comprehensive nutrient management, waste holding structures, and grazing management. The project completed monitoring in 2001.

Peacheater Creek drains a pasture and forested watershed in eastern Oklahoma where cattle traffic and forestry activities are major contributors to streambank erosion. Nutrients are the primary problem downstream in the Illinois River and Lake Tenkiller, while sedimentation and gravel deposits from streambank erosion and other upstream sources are the primary water quality problems in Peacheater and Tyner Creeks. A paired-watershed design including chemical, biological, and habitat monitoring was conducted to measure the effectiveness of animal waste management practices, planned grazing systems, mortality composting, riparian buffer zones, and nutrient management at poultry, dairy, and beef operations.

The Totten and Eld Inlets, WA project was designed to address shellfish production problems caused by fecal coliform bacteria from on-site wastewater treatment systems and livestock production practices along the streams and marine shorelines. The project evaluated the effectiveness of pasture and grazing management, stream fencing, stream buffer zones, rainwater and runoff management, livestock density reduction, and animal waste management BMPs in reducing fecal coliform contamination of shellfish production areas.

Streambed sediments originating from cropland erosion, eroding streambanks, and overgrazed dairy pastures are impairing a high-quality fishery in Otter Creek, WI. Otter Creek is additionally degraded by organic matter, phosphorus and bacteria from dairy barnyards, pastures, and cropland. Upland fields were treated with cropland erosion control practices, streambanks have been fenced to limit cattle access, and nutrient and pesticide management was implemented. Structural practices to control barnyard runoff were evaluated using an above/below monitoring design. Post-BMP monitoring was completed in 2002.

The Bottom Line: Water Quality Results

Three of the projects that focused mainly on animal waste and nutrient management clearly documented significant positive water quality effects, while a fourth project demonstrated likely improvements (Table 1). Principal effects related to animal waste and nutrient management included decreased counts of indicator bacteria (fecal coliform, *E. coli*), as well as decreased levels of P, TSS (total suspended solids), BOD (biochemical oxygen demand), and some forms of N.

The Maryland project was discontinued in 2003 before monitoring could measure the combined effects of BMPs installed in 1996 (manure storage system), 2000 (waste retention pit and subsurface interceptor tiles for trench silo), and 2001 (riparian zone) (Shirmohammadi and Montas, 2004). Hurricane Elizabeth drenched the watershed in 2003, further complicating data analysis. Despite these problems, data did show that subsurface flow was the major source of nitrate, indicating a need for improved nutrient management across the watershed.

Macroinvertebrate sampling in the first few years of the New York project showed significant improvement of the farm site in terms of species diversity and numbers of pollution-intolerant EPT species. A comprehensive suite of BMPs implemented on a dairy farm in the NY resulted in a particulate P load reduction of 29% and a total dissolved P reduction of 43% during storm events (Bishop, et al., 2005).

Median fecal coliform and streptococci bacteria levels declined 48% and 54%, respectively, on Long Creek below three dairy farms where dairy waste holding ponds and waste irrigation systems were installed. The extent to which improved storage and handling of domestic animal wastes was responsible for the improvements is unknown because elimination of a large source of wildlife waste (mine tailings ponds used by waterfowl) occurred just before the greatest reductions in bacteria levels were measured. Livestock exclusion fencing was also installed on several farms. Measured reductions in P and suspended sediment concentrations were not attributed to improved animal waste or nutrient management. Nitrate-nitrite levels increased slightly at both the above and below sites at one dairy farm, indicating that improved management of animal waste was not the cause of decreased nitrate-nitrite levels in Long Creek. In addition to the results related to animal waste management, installation of livestock exclusion and establishment of riparian buffers on the pasture of a large dairy operation resulted in a 75% reduction in TKN (total Kjeldahl nitrogen) loads, a 74% reduction in total P loads, and an 85% reduction in TSS loads (Line and Jennings, 2002).

Calibration of the paired watersheds has been achieved in Oklahoma, but analysis of post-implementation data has not been completed.

Fecal coliform counts were reduced by 35-71% in the Perry (single-watershed) and Schneider (treatment site in paired-watershed design) sub-basins but not in the other three treated sub-basins of the Washington project (Batts and Seiders, 2003). The BMPs applied in the Perry and Schneider watersheds included waste storage, fencing, use exclusion, improved grazing, nutrient management, waste utilization, and roof runoff management, but fecal coliform reductions could not be attributed to BMPs because there was no control for Perry Creek and a change in the number of horses in Schneider Creek watershed was a significant factor affecting fecal coliform levels. Still, it would appear that it is fair to claim that animal waste management BMPs including reduced herd size did contribute substantially to reduced fecal coliform levels in Schneider Creek.

In Wisconsin, management practices installed at a 0.7-acre barnyard area with about 50 cows (diversion of clean water from livestock areas; conveyance of precipitation for collection and settling of solids, with effluent spread evenly over a grass filter strip bordering the stream; livestock exclusion from stream; gravel-lined stream crossing for cows; and a grassed swale downgradient from a field near the barnyard) reduced runoff TSS loads by 85%, P_T loads by 85%, NH_3 loads by 94%, BOD_5 (5-day BOD) by 83%, and FC loads (total colony-forming units) by 81% (Stuntebeck, 1995). Because sampling did not include all runoff events occurring with frozen ground, a period when filter strips are not expected to work efficiently, overall load reductions may be lower.

Conclusions:

- Animal waste and nutrient management can yield significant water quality improvements in several different ecoregions of the U.S.
- Improvements in water quality following treatment were most consistently demonstrated by measurements of indicator bacteria counts, BOD, and P and TSS concentration and load; benthic macroinvertebrates were used with some success and N forms gave mixed results.
- Animal waste management without nutrient management, riparian buffers, and management of both surface and subsurface flows (e.g., drain tiles) will not solve nutrient problems.
- Projects focused tightly on installing and evaluating animal waste and nutrient management practices at the farm or small watershed level were more successful at documenting response to treatment than were projects that included such treatment as part of a broader package of practices across a larger area.

Table 1. Animal Waste and Nutrient Management

State	Treatment	Physical/Chemical				Biological				Temperature	Other	Notes
		Turbidity/TSS	P	N	Other	Bacteria	Invertebrates	Fish	Habitat			
MD	Animal waste mgt., grazing mgt, numerous other BMPs											1
NY	Animal waste mgt., barnyard and milkhouse waste trt., crop rotation, grazing mgt.		↓				↑					2
NC	Animal waste mgt., nutrient mgt.	↓[7]	↓[7]	↑ NO_3-NO_2		↓	↑[7]					
OK	Animal waste mgt., grazing mgt, nutrient mgt., other BMPs											3
WA	Animal waste mgt., nutrient mgt., livestock exclusion, other BMPs					↓						4
WI	Livestock exclusion/other barnyard mgt BMPs	↓	↓	↓NH_3	↓BOD_5	↓		↓[7]	↑[7]			5
Range of % change		85%	29 – 85%	Up to 94%	83%	35 – 81%						6

Notes:

1 Monitoring was discontinued before full suite of BMPs was implemented at treatment site of paired-watershed design.
2 Macroinvertebrate species diversity and numbers of EPT species improved in first few years of project.
3 No post-treatment water quality data or results have been reported
4 Fecal coliform reductions in two subbasins but not in other three treated subbasins. No control in one subbasin and animal reductions in other subbasin prohibit linkage to BMPs.
5 Results pertain to above/below-watershed design at single dairy.
6 Percent change values are for very general examples only; percent reductions are only valid in the proper context.
7 Other measured water quality changes not specifically linked to animal waste and nutrient management.

Table explanation and caveats:

- Shaded rows represent projects providing most definitive evaluation of livestock exclusion/riparian practices; other projects included some livestock and/or riparian practices, but were less tightly focused.
- Downward arrows (↓) represent significant decrease in concentration or load. Upward arrows (↑) represent significant increase in concentration or load or significant improvement (e.g., in invertebrates). Sideways arrows (⇔) indicate no significant change. Empty cells indicate that project did not measure that variable or has not reported results.
- Percent reductions should be interpreted only as very general examples. Their utility is limited by the facts that:
  a) Some important variables like habitat cannot be expressed as a percent;
  b) For simplicity, the matrix does not distinguish between concentration and load; concentration and load may change in opposite directions if, for example, a BMP greatly reduces flow while slightly increasing concentration;
  c) Percent reduction depends largely on the starting point – the same BMP may give a much larger percent reduction in a situation of extreme impairment compared to a lesser initial problem; and
  d) In most cases, the range of percent reductions is so wide that choosing a specific value becomes an arbitrary exercise.

Impacts on State Nonpoint Source programs: Applicability of results to state policies and programs

Experiences and results of NMP projects in this group have direct applicability to state nonpoint source policies and programs. These applications occurred in several categories:

- **Understanding of nonpoint source pollution**: Evaluation and refinement of the SWAT model in the Warner Creek watershed project supported the use of SWAT in the TMDL process in Maryland. In addition, subsurface contributions of nitrate from outside of the surface watershed were found to be important in Warner Creek.
- **Design of treatments for nonpoint sources**: The New York City Watershed NMP project demonstrated that pollutant mass balance analysis is an essential part of designing land treatment programs and that in the case of P it is important to reduce P inputs as well as reducing P export to water bodies.
- **Nonpoint source monitoring design:** The New York City Watershed NMP project developed numerous refinements in the application, management, and analysis of the paired-watershed approach for nonpoint source monitoring and has demonstrated that paired-watershed studies are better than single-station studies for documenting the effectiveness of BMPs. The Oklahoma project demonstrated flow-proportional automatic sampling, intensive habitat surveys, streambank stabilization monitoring, and improved use of satellite information that is applicable to other monitoring projects. Both the New York and Wisconsin projects demonstrated the benefits of precipitation-triggered monitoring in above/below-watershed monitoring designs.
- **Significant water quality response to land treatment**: New York City Watershed, Long Creek, Totten and Eld Inlets, and Otter Creek projects all demonstrated positive water quality response to a program of land treatment addressing animal waste and nutrient management issues.

Impacts on State Nonpoint Source programs: Communications by projects to disseminate results

Few projects reported making a special effort to communicate their results to state or regional agencies beyond routine reports, posting information on web sites, and other project information and education efforts. The Peacheater Creek and Otter Creek projects reported making particular efforts to communicate project results to regional, state, and county agencies, but in Wisconsin there has been little interest in the results of the project beyond the Wisconsin Department of Natural Resources. The Long Creek project conducted workshops and tours for state agency and USDA (U.S. Department of Agriculture) employees.

In general, projects like New York and Washington that were run out of or in close cooperation with state agencies had better opportunities to communicate their results and lessons learned than did projects operated mainly outside of state government.

Impacts on State Nonpoint Source programs: Documented impacts on state programs

Results from NMP projects have had significant impacts on state nonpoint source programs in a number of areas:

- **Approach to NPS monitoring**
  - The Otter Creek Watershed project enhanced the credibility of the state nonpoint source program and promoted the concept of evaluating the effects of nonpoint source treatment in Wisconsin.
  - NMP projects have raised the standards of nonpoint source monitoring design. In New York, NMP monitoring has brought paired-watershed monitoring to the forefront. In Oklahoma, application of the paired watershed design in the Peacheater Creek watershed has been successful enough that it is being applied successfully elsewhere in the state.
  - Specific nonpoint source monitoring techniques such as sampling techniques and schedules have benefited from NMP projects (OK).

- **NPS watershed projects**
  - NMP experience has improved the criteria for selection of future nonpoint source watershed studies in Oklahoma.
  - Cost-share rates and structure for BMPs has been adjusted based on NMP experience in Oklahoma.
  - Oklahoma has improved targeting of BMPs to areas contributing greatest share of pollutant loads.
  - Numerous lessons for operation and coordination of nonpoint source projects have been presented in Washington.
  - Oklahoma now uses watershed advisory groups consisting of stakeholders, influential landowners, and community leaders to increase likelihood of project success.

- **NMP BMPs**
  - BMPs monitored by NMP projects have been adopted into nonpoint source programs in several states.
  - Based on data from the New York NMP project, a precision feeding/forage system BMP is being promoted as a better long-term solution to P problems in the New York City Watersheds program.
  - The Oklahoma NMP project was one of the first watersheds in the state to offer a winter feeding facility as a BMP, a practice that has become enormously popular with landowners.

Project Design and Execution: Observations and Lessons

Measured water quality improvements are the end product of a series of choices and actions that begin with project selection. USEPA selected NMP projects using criteria that addressed problem identification, nonpoint source control objectives, size of the project area, institutional roles and responsibilities, critical areas, the watershed treatment plan, monitoring, and evaluation (USEPA, 1991). Observations and lessons learned by the six animal waste and nutrient management NMP projects in these and related areas are discussed below to aid future projects.

Project Design: Water quality problem characterization

Some projects had specific, on-site data to document water quality impairments, including identification of the pollutants causing the impairments and the sources of those pollutants.

ALL pollutant sources need to be characterized to develop an effective watershed plan.

Other projects demonstrated that general or regional information can be used successfully to establish water quality impairments, pollutants, and sources. Both the Maryland and North Carolina projects, however, highlighted the importance of carefully searching for *all* sources of pollutants during pre-project characterization to avoid surprises and confounding influences. Further, the six projects collectively demonstrated that in order to treat the right problem with the right solution, there must be an accurate identification of the pollutants and sources in the project area. Although not recommended as a substitute for rigorous pre-project characterization, it was found that projects employing the paired-watershed design can use calibration period data to document impairments, pollutants, and sources. Analysis of data from the calibration period may also yield surprises, so projects must be flexible enough to adjust land treatment and post-treatment monitoring as needed.

Project Design: Nonpoint source control objectives

Objectives varied among the six projects, ranging from the general objectives (i.e., "demonstrate or quantify effectiveness") stated by the Maryland, North Carolina, and New York projects, to the quantitative goals (i.e., % reductions in fecal coliform levels) of the Washington project, the restoration of beneficial uses in Oklahoma, and the modeling objectives of the Maryland project. In fact, Maryland and North Carolina had both general and quantitative goals covering different components of the project. While projects should set objectives for all aspects of their efforts, it is important to recognize that objectives for treatment design, installation, or extent are not water quality objectives. Based on the experiences of these and other projects, the following should be considered when setting project objectives:

- If stated, quantitative goals should be tied to success in restoring beneficial uses. For example, if a 50% reduction in bacteria levels is stated as a goal, that goal should be related to a water quality standard or other indicator that shows whether achieving that goal will solve the impairment.
- If only qualitative goals are stated (e.g., document effectiveness), the variables by which effectiveness is to be documented should be stated, e.g., document effectiveness on sediment load or P concentration.

The Long Creek, Peacheater Creek, and Warner Creek projects all demonstrated the need to be flexible in setting objectives. It is often the case that projects will need to redirect their efforts to new objective(s) because of what is learned from early analysis of monitoring data.

Project Design: Identification of critical areas

The NMP included both projects designed to solve watershed-scale problems and projects designed to assess the effectiveness of practices at the subwatershed, field, or practice scale. Some projects encompassed all three scales. The importance of traditional critical area delineation varies with project objectives, ranging from crucial for the cost-effective solution of watershed-scale problems to unimportant for some demonstrations of specific practices at individual sites.

Critical area delineation at the watershed scale was performed using a range of approaches including a whole-farm planning process (NY), watershed models (NC, OK, WI), streamwalks and habitat assessments (OK), and field surveys (MD, WA). For example, eight of nine dairy operations and cropland on two of the eight dairies were designated as critical areas in the Otter Creek watershed; the USDA-Natural Resources Conservation Service (NRCS) model BARNY was used to determine which barnyards were critical. One of the eight critical dairies was monitored with an above/below-watershed design. Although the Oklahoma project was initially focused on downstream nutrient problems, data collected by the project showed that streambank erosion and bedload sediment were more critical problems in the monitored watersheds.

Project Design: Land treatment plan

For the most part, NMP projects ultimately relied on voluntary implementation of control measures by landowners. However, achievement of NMP objectives was more likely when the NMP project had full control over the targeting and scheduling of practice implementation, rather than relying on another agency or program to implement land treatments. Control of implementation is key to the success of evaluation monitoring efforts at any scale, and projects such as the New York City Watershed were most successful because project directors responsible for water quality monitoring had direct or indirect control over land treatment design and implementation. Control was more easily obtained in smaller scale studies (NY, WI) and studies within areas owned or controlled by those groups or agencies conducting the studies. The control in New York was achieved with contract terms that included scheduling of implementation to fit the monitoring design.

Control of practice selection and implementation scheduling is key to the success of all projects.

In a watershed project that relies on voluntary participation, the final land treatment plan is usually a compromise between "ideal" technical design and landowner choice. Practice selection is governed by landowners/managers, available financing options, and the programs administering or requiring the practices. Projects must identify and work within these constraints to achieve implementation of the best practices for solving the identified water quality problems. For example, the Oklahoma project showed that it is important to factor landowner preferences and cost tolerances into practice selection. The New York project considered the landowner's ability to maintain and operate the practices and the Oklahoma project provided annual incentive payments for maintenance of certain practices such as riparian area management, proper animal waste management or nutrient management. Long Creek found that increased cost-sharing rates or the provision of supplemental BMPs not offered through existing programs can help achieve desired implementation scheduling.

Project Design: Water quality monitoring

It is evident from the experiences of a few of the NMP projects that all key personnel should be trained before monitoring programs are designed. Those conducting monitoring must be knowledgeable of the water quality problems, the BMP implementation plan, and the monitoring design options prior to planning the monitoring program. It is also clear that adequate funding to achieve monitoring objectives must be secured before any monitoring occurs to ensure that suitable data are collected without interruption. In turn, those who conduct the monitoring should be held accountable for at least the following (WA):

- Detailed monitoring budgets with a justification for each monitoring site, parameter, and collection frequency, including funding for some degree of “over sampling,” particularly in the early years as those conducting the monitoring learn more about the system and problems through the collection and analysis of data. Additional monitoring stations, parameters, or samples may be needed to quantify unexpected inputs (MD).
- Clear statistical analysis plans before monitoring begins, with annual reassessments to ensure adequacy.
- Annual or more frequent analysis and reporting of monitoring data to ensure that the monitoring program is on track and capable of achieving its objectives.
- Annual reassessment of the monitoring program, with adjustments made as needed to ensure that monitoring objectives are achieved in the most cost efficient manner.

Project leaders must obtain support for the study approach, monitoring site locations, and access to monitoring sites prior to initiating the project (OK, WA). Monitoring should be focused on the variables most directly related to the water quality goals, the characteristics and constituents most likely to be affected by the implemented practices, and explanatory variables that can be used to improve the resolution of statistical analyses (NY, OK). In cold climates, the use of heated and unheated gauges provides a way to distinguish between snow and rain, allowing samplers to be triggered during rain events only (NY).

Projects should specify criteria for selecting monitoring sites based upon the project objectives and study design chosen (NY). It may take several months to find suitable sites, depending upon the selection criteria (e.g., ability to measure flow, accessibility, power supply), study scale, and study area characteristics (NY). It may be necessary to pay landowners to ensure site access for monitoring (NY).

The NMP projects used paired-watersheds, upstream-downstream designs, and single monitoring stations in their efforts to assess the water quality impacts of implemented pollution control measures. The following findings are based on project experiences:

Paired-watersheds are the best design for clear evaluation of land treatment effectiveness, but not possible in many situations.

- Paired-watershed designs are the best for assessing effectiveness.
    - Small watersheds are recommended (hundreds instead of thousands of acres) (e.g., NY).
    - The ability to direct land use and land management decisions in both treatment and control watersheds is necessary.
    - This design is most applicable for research projects.
    - Finding suitable pairs can be very difficult for a variety of reasons, including lack of a suitable match (NY, WI), distance between pairs, rapid urbanization, and lack of control over activities in the watersheds for the duration of the study (MD, OK, WA).
    - Paired sites can have different land uses. For example, a forested site was paired successfully with an agricultural site in one project (NY).

    - In cases where watersheds are larger or control is less than desired, fallback monitoring plans are needed in case calibration fails, implementation is not suitably controlled, or minimum detectable change is too great to achieve. Above/below pairs in the control and treatment watersheds provide a fallback in case the paired-watershed study is compromised (WA).
    - Land use and land management must be tracked in detail to provide opportunity for interpreting trends (e.g., WA).
    - Covariates such as discharge and precipitation that influence observed water quality patterns must be tracked.
    - Monitoring need not be conducted during the implementation phase unless it is important to document the transient effects of implementing structural practices (NY).
- Above/below-watershed designs are also generally satisfactory for assessing effectiveness.
    - Application of this design works best when the source isolated is a relatively large contributor of pollutants for which practices are expected to improve water quality dramatically; upstream contributions of pollutants need to be sufficiently small to not overwhelm the downstream station (WI). The triggering of time-integrated sample collection based on precipitation rather than stage level can be used to separate upstream impacts from source impacts in some cases (WI); precipitation-triggered sampling can also be used to give cleaner, baseline samples to aid in the estimation of loads in small watersheds (NY).
    - Distance between upstream and downstream paired stations needs to be considered with regard to potential contributions from untreated sources, significant changes in flow volume or patterns, and intervening habitat and geomorphology to ensure calibration is feasible (MD).
    - Pre- and post-implementation monitoring should be conducted, making this design essentially the same as a paired-watershed study with the exception of the concern regarding upstream contributions.
    - Land use and land management must be tracked in detail to provide opportunity for interpreting trends.
    - Covariates such as discharge and precipitation must be tracked.
- Single-station monitoring designs should be a last resort and part of a longer-term trend monitoring effort to maximize the potential for usefulness of the data collected. Big changes in water quality must be anticipated if this design is used (WA).
- Automated sample collection during high-flow conditions is necessary in most cases for assessing the effectiveness of implementation with chemical variables, and flow is often needed as a covariate for statistical analysis.
    - Grab sampling is insufficient for assessing effectiveness of practices when the pollutants of interest are transported via surface flow. Flow should be measured with each sample (WA).
    - Weekly composites of flow-proportional samples should be considered the minimum requirement for successful chemical monitoring when the pollutants of interest are transported via surface flow.

- The combination of biological, chemical, habitat, and physical parameters provides a more holistic picture of water resource conditions than can be obtained from chemical sampling alone (NY, OK).
- In watersheds with significant sedimentation problems the potential for huge gravel and sediment loads must be considered when designing stations and selecting sampling equipment; stable channels are needed for flow measurement (OK).

Project Design: Land treatment and land use monitoring

Geographic Information Systems (GIS) may be no better than spreadsheets at providing data needed to evaluate the effectiveness of implemented BMPs.

It is not clear from this group of projects that GIS-based tracking provides better analytic capabilities than less-expensive spreadsheet tracking of land-based data (OK, MD, NY, WA, WI). No clear advantages to GIS databases for evaluating the effectiveness of practice implementation were demonstrated by NMP projects. Land treatment and land use data can be obtained in a variety of ways including conservation plans (OK), satellite imagery/aerial photography (OK), and intensive field surveys (MD, NY, OK, WI). In Oklahoma, practice operation and maintenance was checked at least annually throughout the contract period

Other findings and recommendations include:

- Plans for meeting land use/land treatment data need to be optimized based on the equipment, technology, and resources available to the project (OK). It is more feasible to collect detailed land-based data in smaller study areas (NY).

- Land treatment and land use data are best obtained from landowners by a trusted and alert individual located within the study area (OK).

- In mixed land-use study areas, it will be necessary to work with a greater number of individuals and organizations to obtain the needed land-based information (WA).
    - Reporting cycles of data sources are likely to vary.
    - Level of detail and quality assurance provided by data sources are likely to vary.
    - Information management is likely to be more complicated because of different data management systems and data sharing protocols of the various data sources, as well as a greater likelihood of needing to address staff turnover problems.
    - All of the above creates challenges in relating practice implementation to water quality due to:
        - Variable ability to locate practices in space (spatial resolution)
        - Inability to tag practices with the year of implementation (temporal resolution)
        - Lack of information on the operation and maintenance of practices.

- Land use and land management information can be useful for estimating such parameters as nutrient and pesticide inputs (OK).

- Data regarding seasonal land management activities can be helpful in seasonal analyses of water quality data (NY).

Based on project reports it appears that the default frequency for reporting on agricultural lands is typically annual (WI).

Project Design: Evaluation and reporting plan

Most projects attempted to use USEPA's NPSMS software and/or STORET to report their monitoring, but there is no evidence that annual or final data summaries provided by the projects (either through NPSMS, STORET, or otherwise) have ever been evaluated or used. Centralized housing and management of data did not happen as envisioned by USEPA. Most NMP projects, however, followed USEPA's guidance for the paired-watershed design in developing their plans for evaluation of project monitoring data (e.g., NY, OK).

> *Projects tended to use their own database management systems in lieu of (or in addition to) those provided by USEPA.*

The Washington project developed a rigorous evaluation plan including statistically-determined estimates of minimum detectable change, pre-project monitoring to select monitoring sites, and clear plans for statistical analysis of data. Several projects found that regular reporting, including frequent (e.g., quarterly) progress reports kept participating agencies and stakeholders informed and facilitated early detection of trends, changes, and problems in the stream of monitoring data. The New York projects highlighted the benefits of keeping the farm community apprised of project results and providing feedback to the planners as to the success or failure of the practices.

Project annual and final (where available) reports are of widely varying depth, scope, and availability. Some, for example, focus exclusively on water quality monitoring data and lack any information on other aspects of the project. Some of this is due to limits on agency responsibility and available time or funding. In the future, required elements and organization of project final reports may need to be specified in advance and established as a requirement for participation in the NMP program.

Land treatment implementation: Treatment levels achieved

Most NMP projects were able to achieve planned levels of land treatment, but the Maryland, Oklahoma, and Washington projects were notable exceptions. The New York project benefited from an ability to make changes or adjustments to make practices perform better.

Implementation of treatment was easiest and most successful in projects designed as highly focused experiments looking at specific practices (e.g., NY); land treatment implementation was most challenging when applied to large watershed areas based on voluntary participation in a changing economic/social environment (e.g., MD, OK). The Washington project highlighted the effects external forces such as changes in agricultural management, land use, land ownership, cost-share structure, commodity programs, regulation, and legislation can have on practice adoption and implementation progress.

Land treatment implementation: Incentives and technical assistance
In most projects, technical assistance was provided by NRCS, often through the local conservation district. The Washington project learned that interruptions in cost-share can severely reduce practice adoption and disrupt project progress. The Oklahoma project found that raising cost-share rates to promote less popular practices, while lowering cost-share rates on more popular practices may be a cost-effective incentive strategy. Such adjustments were especially important in Oklahoma because drought dried up cash flow causing several landowners to not implement practices as planned. In addition to cost-sharing, the New York project found that a fear of future regulation can provide important psychological incentives for voluntary adoption of management practices.

Land treatment implementation: Scheduling of land treatment with water quality monitoring design
As discussed under Project Design, scheduling of land treatment to fit the monitoring design is absolutely essential to successful project evaluation. The New York project was able to schedule and direct land treatment for the paired-watershed design to ensure that no implementation occurred in the control watershed and that data were obtained from distinct pre- and post-treatment periods; the project is now evaluating the benefits of a second round of controlled BMP implementation. Delaying the implementation of BMPs was more difficult in Maryland where a waste storage structure was installed at one dairy site eight months before monitoring began, making it nearly impossible to assess the benefits of improved animal waste management with the above/below-watershed design. In addition, the project identified additional BMPs needed to solve the nutrient problems, but monitoring was discontinued before these practices could be evaluated. In North Carolina, control of funding for implementation was an important tool in dealing with the land treatment scheduling issue. The Washington project found that coordination is extremely difficult when implementation is done by a separate agency or organization.

Land treatment implementation: Tracking of installed land treatments
Coordination of land treatment and water quality monitoring is best accomplished when monitoring personnel have direct control over implementation, as in the New York project; otherwise, coordination is extremely difficult when implementation is done by a separate agency or organization (WA). For monitoring projects such as those in the NMP, more specific and intensive land treatment tracking is necessary than is generally done in large, broad-scale projects. In general, tracking of participation in land treatment implementation was fairly superficial in the cases of large watershed areas; the most common approach was through NRCS or Conservation District farm plan files or other records. Projects that occurred within larger watershed efforts like USDA's Demonstration projects, Hydrologic Unit Areas, and the like generally had poor success at effective tracking of land treatment. Projects that included intensive studies focused on subwatersheds or intensive treatment areas did a better job of tracking participation and implementation (MD, NY, NC, WI). With the exception of Oklahoma, tracking of the operation and maintenance of land treatments after implementation generally received inadequate attention from most watershed-scale projects. In Oklahoma, practice operation and maintenance was checked at least annually throughout the project/contract period. As would be expected, projects like New York and Wisconsin that intensively monitored single practices or limited areas did a better job of practice operation and maintenance.

Where watershed-level tracking was done effectively, it was generally accomplished by direct observation by monitoring personnel through frequent visits to the project area or through personal contact with landowners (NY). The Oklahoma project discovered that detailed land use monitoring, especially frequent visits to the watersheds, is extremely important in catching any unanticipated or unwanted "implementation" activities in the control watershed and any failures of installed practices. The Washington project found that poor institutional cooperation and a lack of accountability can seriously impair a project's ability to track land treatment implementation and operation in cases where monitoring and land treatment are very separate activities,

> *There is no substitute for ground-based tracking of practice implementation, operation, and maintenance.*

Project management: Agency participation, roles and responsibilities
NRCS was a frequent participant in projects, typically in the role of technical assistance for land treatment, and county and local conservation districts played a strong role in project interactions with landowners. State natural resource agencies and universities were commonly in charge of water quality monitoring and data analysis.

Project management: Coordination methods, success, and failure
Coordination among different agencies with different missions is essential to project success. Mechanisms to achieve coordination must be built into the project from the beginning. Effective coordination looks easy and seamless; failure of coordination can have disastrous results. Some findings from the NMP projects are:

- Regardless of the specific management structure in place, having a strong project manager who oversees both monitoring and implementation and who maintains a presence in the project area is a key to effective project coordination (OK).
- Local conservation districts are an effective means to link state and local activities and concerns.
- Coordination in long-term projects may be foreign territory to some state agencies; this needs to be considered in overall project management (WA). Many different participants and programs were involved in the Washington project, resulting in complex institutional relationships and a number of problems such as:
  - Poor coordination between monitoring and land treatment operations;
  - Differing program goals – i.e., protect shellfish vs. measure effectiveness of nonpoint source controls;
  - Lack of specific reporting requirements, especially lack of reporting requirements in BMP (best management practice) funding grants; and
  - Competing demands for staff time, including grants administration versus plan implementation.
- Annual funding is not a good way to run a 10-year project.

Project management: Stakeholder involvement
For most projects, stakeholders like state and federal agencies were highly involved in project design and operation. Stakeholder involvement is more than publicizing the project or

"educating" landowners; stakeholders should be aware of and contribute to the project from the beginning. For most projects, stakeholder involvement was limited to information and education efforts. The Oklahoma project found that significant participation in project management by local stakeholders would improve project success. When implementation of the project plan was in jeopardy because of landowner resistance, project leaders held a public meeting to discuss the project, receive feedback, and clear the air; while some hostility remained, the project was able to continue as planned after the meeting.

Project management: Information and education

Projects identified several typical I&E activities (e.g., newsletters, tours, field trials, meetings) but none related them specifically to either land treatment or water quality achievements. Information and education activities need to be evaluated in terms of their effectiveness and their contribution to project success.

Water quality response: Documented water quality improvements

Water quality response was measured at several scales using a range of variables and study designs (see Table 1). Water chemistry reductions presented in this report are the result of statistical analyses performed by project personnel and are typically but not always values that have been adjusted using data collected at control sites. Year to year variations in precipitation and runoff, for example, can have enormous influence on measured nonpoint source pollutant loads; these variations are accounted for in the paired-watershed design. For this reason, an 80% reduction in phosphorus load, for example, may not be an actual 80% reduction in the stream but rather an 80% reduction *compared* to the control site used in the analysis. These reductions, however, show the generally strong capability NMP projects had to measure changes that could then be related to the implementation of practices.

Water quality response: Relating water quality improvements to land treatment

Some projects found it difficult to relate changes in water quality to land treatment because of implementation of diverse practices, implementation of incorrect practices, lack of land use/land treatment monitoring, or an inadequate or corrupted control watershed (e.g., WA). In large watersheds where multiple BMPs are implemented at multiple sites, it is extremely difficult to relate changes in water quality to land treatment, especially without land use/land treatment monitoring and a solid experimental design. Projects taking place in small watersheds with clearly defined BMPs, appropriate monitoring designs, and effective land use/land treatment tracking (including operation and maintenance) stand the best chance of clearly relating water quality response to land treatment. Sub-studies of specific treatment-related phenomena within treated watersheds can help corroborate inferences with regard to cause and effect.

When projects were successful in relating water quality improvements to land treatment, it was because of the following:

- Documentation of the activity of treatment practice(s) through land treatment/land use monitoring (NY, WI).
- Intensive statistical analysis (NY).
- Tight experimental design, e.g., small-scale above/below (WI).

Water quality response: Interpretation and presentation of results

Many projects such as the New York, North Carolina, Washington, and Wisconsin projects did a reasonably good job interpreting and presenting their results in technical reports, but some of these projects either did not present results to other (non-technical) audiences or did not report such efforts. The Long Creek project presented their results to audiences in other ways in addition to technical reports. The Maryland project reported modeling reports in several technical documents and reports, but scientific evaluation of the implementation effort was lacking due to an apparent failure to perform statistical analysis of the paired-watershed data.

REFERENCES

Batts, D. and K. Seiders. 2003. *Totten and Eld Inlets clean water projects: Final report*. Publication No. 03-03-010. Washington State Dept. of Ecology, Environmental Assessment Program, Watershed Ecology Section, Olympia, WA. July 2003.

Bishop, P.L., W.D. Hively, J.R. Stedinger, M.R. Rafferty, J.L. Lojpersberger, and J.A. Bloomfield. 2005. *Multivariate analysis of paired watershed data to evaluate agricultural best management practice effects on stream water phosphorus*. J. Environ. Qual. 34:1087-1101.

Line, D.E. and G.D. Jennings. 2002. *Long Creek watershed nonpoint source water quality monitoring project-final report*. NC State University, Raleigh, NC.

Shirmohammadi, A. and H. Montas. 2004. FFY 03 Annual report: modeling and monitoring the hydrologic and water quality response of the mixed land use basin, Department of Biological Resources Engineering, University of Maryland, College Park, MD.

Stuntebeck, T.D. 1995. *Evaluating barnyard best management practices in Wisconsin using above/below watershed monitoring*. Fact Sheet FS-221-95, U.S. Department of the Interior, U.S. Geological Survey, Madison, WI.

USEPA. 1991. Watershed monitoring and reporting for Section 319 national monitoring program projects, Assessment and Watershed Protection Division; Office of Wetlands, Oceans, and Watersheds; Office of Water; Washington, DC.

USEPA. 2004. Section 319 national monitoring program projects 2004 summary report. Prepared by North Carolina State University Water Quality Group for Office of Water, Washington, DC.