DRAFT

NMP Lessons Learned

Grazing management/Riparian restoration

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 grazing management and riparian restoration. The findings in this document are based on project reports, annual project summaries (USEPA, 2004), and direct communication with project personnel.

The primary emphasis of this evaluation relates to the two NMP objectives, but just as a tree relies on its root structure for nutrition and support, 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
Twelve of the NMP projects evaluated some combination of livestock exclusion, grazing management, and riparian restoration; these treatments were the principal focus of five projects:

- Morro Bay Watershed, California
- Long Creek Watershed, North Carolina
- Pequea and Mill Creek Watershed, Pennsylvania
- Stroud Preserve Watershed, Pennsylvania
- Lake Champlain Basin Watersheds, Vermont.

The water quality problems addressed by the Morro Bay, CA project were impairment of the fishery by sedimentation in the bay and tributaries, loss of oyster beds from sedimentation, closures of shellfish beds due to bacteria, and the loss of 25% of bay volume due to sedimentation. Major pollutants were sediment, coliform bacteria, metals, and nutrients. Sheet and rill erosion from upland brushlands, rangelands, livestock grazing in riparian areas, and unvegetated streambanks were the major pollutant sources. The principal practices (BMPs) applied were livestock exclusion, fencing with gaps, watering devices, grazing management, and riparian improvement.

The Long Creek, NC project addressed a range of water quality problems, including sediment, nutrient, and bacteria loading from a large dairy. Monitoring was conducted to measure the effectiveness of improved animal waste and pasture management, livestock exclusion, and streambank stabilization at this site.

The Pequea and Mill Creek, PA project addressed water quality problems typical for the surrounding area - riparian area destruction and nutrient and sediment loads from livestock operations. The objective of the project was to evaluate the effectiveness of livestock exclusion fencing by monitoring sediment, nutrients, macroinvertebrates, and habitat parameters.

The Stroud Preserve Watershed, PA project is an experiment intended to evaluate the nonpoint source reductions of a riparian forest buffer system in the relatively high-relief terrain of the mid-Atlantic piedmont, assess the time required after reforestation to achieve significant mitigation, and establish specific guidelines for planting and managing forest buffer zones in the mid-Atlantic region. Monitoring is focused on total suspended solids (TSS), nitrogen (N), phosphorus (P), and vegetation parameters in the riparian zone because these are the parameters most likely to be affected by the forest buffer system.

The Lake Champlain Basin, VT project was selected to test the hypothesis that keeping dairy cows out of the stream and restoring the riparian zone will improve water quality. The Lake Champlain Basin has had frequent impairments due to phosphorus and bacteria; the project monitored phosphorus, nitrogen, total suspended solids, indicator bacteria, fish, macroinvertebrates, and habitat to assess the effectiveness of riparian fencing and streambank restoration.

The Bottom Line: Water Quality Results

All of the projects that focused mainly on livestock exclusion/riparian restoration clearly documented significant positive water quality effects (Table 1). Principal effects included decreases in concentration and load of TSS, P, and N (some forms), as well as decreased counts of indicator bacteria (fecal coliform, *E. coli*). In Long Creek, for example, the 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 TP (total P) loads, and an 85% reduction in TSS loads. In Vermont, livestock exclusion and riparian restoration yielded a 10 – 15% decrease in mean TP and TKN concentrations, a 34% decrease in mean TSS concentration, a 49% decrease in annual TP export, a 38% decrease in annual TKN export, a 28% decrease in annual TSS export, and a 30 – 40% decrease in mean indicator bacteria counts.

Two of three projects that evaluated benthic macroinvertebrates reported significant improvements in response to land treatment (Pequea/Mill Creek and Vermont). Neither of the two projects that evaluated fish reported significant improvements in the fish community, although two projects (Pequea/Mill Creek and Vermont) reported some improvements in stream habitat. Improvements in the fish community may take additional time.

Small but significant improvements in water temperature were reported in Morro Bay Watershed and Vermont. Dissolved oxygen levels also improved in Morro Bay Watershed. Four projects (Morro Bay, Pequea/Mill Creek, Stroud Preserve, and Vermont) presented qualitative or quantitative documentation of improvements in riparian vegetation in response to treatment; the Stroud Reserve project has provided detailed data on the reestablishment of trees in a riparian forest buffer. Finally, the Morro Bay and Long Creek projects demonstrated significant reductions in peak stream discharges (Q) in response to increased infiltration and evapotranspiration in revegetated riparian zones.

Conclusions:

- Livestock exclusion and riparian restoration 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 TSS, P, and N concentration and load and by indicator bacteria counts; biomonitoring results were more difficult to demonstrate.
- Improvements in water quality due to livestock exclusion/riparian restoration were mainly attributed to excluding animal waste from the stream and to the reduction of streambank erosion, rather than to action by a riparian buffer. The Stroud Reserve project was an exception, as it is evaluating the processing of sediment and nutrients in surface runoff and groundwater from cropland.
- Projects focused tightly on livestock exclusion/riparian restoration were more successful at documenting response to treatment than were projects that included such treatment as part of a broader package of practices.

Table 1. Grazing management/riparian restoration

State	Treatment	Chemistry				Biology				Temperature	Riparian vegetation	Other	Notes
		Turbidity/TSS	P	N	Other	Bacteria	Invertebrates	Fish	Habitat				
CA	livestock exclusion	↓		↑	↑D.O.	↓				↓	↑	↓Q	
MD	grazing mgt, numerous other BMPs												1
NE	grazing mgt and many other BMPs	⇔					⇔	⇔		⇔			2
NC	Livestock exclusion/riparian buffers	↓	↓	↓		↓						↓Q	
OK	grazing mgt, buffers, other BMPs												3
OR	livestock exclusion,								⇔				
PA1	livestock exclusion	↓	↓	↓			↑		↑		↑		
PA2	riparian forest buffer	↓		↓							↑		4
SD	fencing/grazing mgt												5
VT	Livestock exclusion/riparian restoration	↓	↓	↓	↓ Conductance	↓	↑	⇔	↑	↓	↑		
WA	Livestock exclusion/other BMPs					⇔							6
WI	Livestock exclusion/other barnyard mgt BMPs	↓	↓	↓		↓							7
Range of % change		21 – 85%	10 – 85%	10 – 75%		30 – 90%				6 – 8%			8

Notes:

1 Project failed to document the impacts of BMPs because it failed to perform the statistical analyses required
2 No documented changes in water quality
3 No post-treatment water quality data or results have been reported
4 RFB in early vegetative stage; some improvements due to changes in agriculture in watershed
5 No information available
6 Other practices implemented; poor participation
7 Too many other practices to attribute water quality improvements to riparian/grazing mgt alone
8 Percent change values are for very general examples only; percent reductions are only valid in the proper context

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

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

- **Understanding of nonpoint source pollution**: the Morro Bay Watershed project provided documentation to identify and prioritize nonpoint source water quality problems in large watersheds
- **Design of treatments for nonpoint sources**: the Stroud Preserve project is documenting the design and growth of a riparian forest buffer
- **Significant water quality response to land treatment**: The Morro Bay, Pequea/Mill Creek, Long Creek, and Vermont projects all documented a water quality response to livestock exclusion

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. A few projects such as the Pequea/Mill Creek, Stroud Preserve, and Vermont projects reported making efforts to communicate project results to regional, state, and county agencies. In general, projects like Vermont 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:

- **NMP Project data**
  - NMP project data have been used in TMDL projects, estuary management plans, and as a baseline for volunteer monitoring in California.
- **NMP BMPs**
  - BMPs monitored by NMP projects have been adopted into nonpoint source programs in several states.
  - Data from the livestock exclusion BMP in Pequea/Mill Creek are being incorporated into nutrient load reduction estimates in the Chesapeake Bay watershed.
  - Results from the Vermont NMP project have led to the active encouragement of livestock exclusion in the state Conservation Reserve Enhancement Program (CREP) effort, adoption of modified livestock exclusion in recent revisions to the state minimum standards required by all farms, and addition of livestock exclusion to the list of BMPs eligible for funding in the state BMP cost-share program.

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 five grazing management/riparian restoration NMP projects in these and related areas are discussed below to aid future projects.

Project Design: Water quality problem characterization

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

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. Other projects relied on general or regional information, and results indicate that projects such as those in the NMP can successfully use regional or generic information to establish water quality impairments, pollutants, and sources. Both the Long Creek and Vermont 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 five 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 five projects, ranging from the general objectives (i.e., "demonstrate effectiveness") stated by the Long Creek, Pequea/Mill Creek, and Vermont projects, to the research objectives of the Stroud Preserve project. In fact, Long Creek 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 or to hypothesized treatment effectiveness. 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, or to an hypothesis that treatments to be implemented can achieve that reduction.

- 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 mean P concentration.

As with problem definition, both the Long Creek and Vermont projects 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 the 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 or field scale. Some projects encompassed both 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.

Streamwalks may be more useful than modeling when identifying critical areas.

Critical area delineation at the watershed scale was performed using a range of approaches including conservative assumptions based on land-based or water quality information at hand (Pequea/Mill Creek), watershed models (Long Creek), streamwalks and habitat assessments (Vermont), and field surveys (Long Creek and Vermont). Streamwalks and habitat surveys were very useful and less expensive than modeling efforts in Vermont. The Pequea/Mill Creek project, however, showed that visual observation alone may not be adequate to identify critical areas when pollutants such as nutrients or other runoff constituents are part of the problem.

Projects, especially those using paired studies such as Morro Bay and Pequea/Mill Creek, often selected critical areas based both on the magnitude of the problem and the willingness of the landowner to cooperate. This approach may ultimately be more effective than selecting critical areas in which lack of control over practice implementation results in land treatment that is either insufficient or untimely with regard to the monitoring effort.

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 Morro Bay Watershed, Stroud Preserve, and Vermont 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 and studies within areas owned or controlled by those groups or agencies conducting the studies (e.g., Morro Bay and Stroud Preserve). The "control" in Vermont was largely based on the project director's constant communication with the landowners.

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 who controls the land, the financing options, and the programs administering or requiring the practices. Projects must identify and work within the constraints of these controlling factors to achieve implementation of the best practices for solving the identified water quality problems. For example, the Vermont project showed that it is important to factor landowner preferences and cost tolerances into practice selection, and the Pequea/Mill Creek project illustrated the need to consider the landowner's ability to maintain and operate the practices. 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.

Both the Stroud Preserve and Vermont projects showed that well-documented cost, applicability, and performance data are essential to the selection and site-specific implementation of appropriate practices, yet this information is often not available. Those involved in the Long Creek project recognized the need for better coordination between monitoring and land treatment agencies to guide implementation within the constraints of the chosen monitoring design. Pequea/Mill Creek project leaders discovered that clear communication with all stakeholders is important throughout the project to maximize potential cooperation and prevent false information from hindering implementation efforts.

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:

- 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.
- 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.

The Vermont project provided a useful model in which criteria were specified for selecting monitoring sites based upon the project objectives and study design chosen. Monitoring site selection is typically more difficult than predicted, perhaps taking several months to find suitable sites, depending upon the selection criteria (e.g., ability to measure flow, accessibility, power supply), available data, study scale, and study area characteristics. The monitoring timeline should include time to design the monitoring program, work with landowners and local experts to find and secure access to monitoring sites, construct the monitoring stations, and test the equipment before collection of real data. Local support was essential to monitoring site selection in both the Vermont and Pequea/Mill Creek projects.

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. According to the Vermont project, parameter selection, where options exist, should also be based on factors such as cost, logistics, and sample preservation needs.

Unscheduled breaks in the data record can severely compromise statistical analyses.

The Pequea/Mill Creek project highlighted the potential need for additional monitoring stations, parameters, or samples to characterize new sources, and the Vermont project discovered a need to fill in information gaps regarding water quality dynamics during storm events. This additional monitoring may be temporary or "permanent" depending upon project needs, and project planners should develop contingency plans for such flexibility. In addition, based on the Stroud Preserve experience it is recommended that projects be prepared to repair damaged or replace missing sampling equipment rapidly to avoid unscheduled breaks in the data record that can severely compromise statistical analyses.

Although we talk about pre-implementation and post-implementation monitoring, in some cases the "line" between pre-implementation and post-implementation can be blurred. For example, the forested buffers in the Stroud Preserve will take several years to reach performance expectations, resulting in limited water quality improvements until peak performance is reached. This may increase the time needed for the monitoring effort and complicate statistical analyses.

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, but not possible in many situations.

- Paired-watersheds are the best design for assessing effectiveness.
    - Small watersheds are recommended (hundreds instead of thousands of acres).
    - 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, distance between pairs, rapid urbanization (e.g., Pequea/Mill Creek), and lack of control over activities in the watersheds for the duration of the study.
    - 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.
    - Control of management changes and tracking land use in the control watershed is critical to successful application of the design.

- Upstream-downstream 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 (Long Creek).
  - Pre- and post-implementation monitoring should be conducted, making this design essentially the same as a paired-watershed study with the exception that upstream contributions can be a concern.
  - 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.
- Stage-discharge relationships and storm-event monitoring are necessary in most cases for assessing the effectiveness of implementation with chemical constituents in a nonpoint-source impacted watershed.
  - Grab sampling is insufficient for assessing effectiveness of practices when the pollutants of interest are transported via surface flow.
  - 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. Weekly composites reduce analytic costs compared to event-based sample collection, and weekly samples should be suitable for determining annual loads and the long-term effectiveness of practice implementation (Vermont). Flow should be measured continuously in perennial streams and over the entire course of the event for intermittent storm flows.
- Biological and habitat monitoring provide valuable information regarding in-stream impacts and in-stream benefits of practice implementation.
  - Habitat parameters tend to respond more quickly when in-stream practices are installed, followed by macroinvertebrates, with fish generally the least responsive (Vermont). Emphasis should be placed on those habitat/physical parameters that change with treatment and influence biological response.
  - Fish sampling can be time consuming and macroinvertebrate sample analysis can be slow relative to chemical sample collection and analysis (Vermont).
  - Macroinvertebrates can be responsive to practice implementation, but they may also be overly sensitive to short-term events, compromising their use in longer-term analyses (Vermont).

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 the Pequea/Mill Creek and Vermont projects that GIS-based tracking provides better analytic capabilities than less-expensive spreadsheet tracking of land-based data. 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, satellite imagery/aerial photography (Morro Bay and Vermont), and intensive field surveys (Morro Bay, Pequea/Mill Creek, Stroud Preserve, and Vermont).

It was found in both Pequea Mill/Creek and Vermont that land treatment and land use data are best obtained from landowners by a trusted and observant individual located within the study area. The Vermont project also learned that close observation and maintenance of dynamic practices like livestock and grazing management are necessary to understand what is going on in the field (e.g., cow pies) that could contribute to observed water quality.

Although only the Vermont project developed creative measures to track practice implementation, a number of useful measures were used by the grazing/riparian projects. As a general rule, the projects demonstrated that it is most important to track land use and land treatment variables that relate to the water quality problem and should be impacted by the implementation of practices. Other findings and recommendations include:

- Targeting detailed tracking to priority sources most related to the water quality problems is appropriate (Vermont).
- For streambank fencing, track the time over which animals are in the pasture in both the treated and control watersheds (Pequea/Mill Creek). Animal populations, grazing schedules, and waste applications are important variables to consider, as are livestock movements, use of pasture, and exclusions from streams in real time (Vermont).
- For nutrient problems, track nutrient application rates over time and space in the study area (Pequea/Mill Creek).
- For forest buffer growth, conduct annual inventory of diameter of each tree, annual estimate of canopy cover, and biweekly collections of litterfall between August and December (Stroud Preserve).

Based on project reports it appears that the default frequency for reporting on agricultural lands is typically annual. The Pequea/Mill Creek project found that maintaining daily records of nutrient applications and animal activity is typically too burdensome even for willing cooperators, and that weekly or monthly record keeping of agricultural activities may be the most one can expect of cooperators.

Project Design: Evaluation and reporting plan

Most projects attempted to use USEPA's NPSMS software and/or STORET to report their monitoring, but the Vermont project did not use NPSMS because the software could not be adapted to its multiple-watershed study design. More troubling perhaps is the finding of 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.

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

The Morro Bay project highlighted the need to determine the statistical approach to data evaluation before monitoring begins. The Vermont project 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. Projects agreed that it is important to keep the farm community apprised of project results and to provide 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. The Vermont project demonstrated the need for and benefits of a strong project presence in the watershed to ensure that implementation occurs as planned and to respond to difficulties and surprises. This is particularly important given that external forces such as changes in agricultural management, land use, land ownership, cost-share structure, commodity programs, regulation, and legislation may significantly affect practice adoption and implementation progress. The Morro Bay, Stroud Preserve, and Vermont projects all benefited from an ability to make changes or adjustments to make practices perform better.

Land treatment implementation: Incentives and technical assistance

In most projects, technical assistance was provided by the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS), often through the local conservation district. In addition to cost-sharing, the Vermont project found that a fear of future regulation, a desire to show that farmers can improve water quality, and the value of improved farm facilities 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. For example, the Morro Bay and Vermont projects found that scheduling and directing land treatment were needed 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. Delaying the implementation of BMPs to collect baseline water quality data was difficult but essential to evaluating practice effectiveness in both the Long Creek and Vermont projects. In Long Creek, control of funding for implementation was an important tool in dealing with the land treatment scheduling issue.

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 Stroud Preserve project; otherwise, coordination is extremely difficult when implementation is done by a separate agency or organization. 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 (Morro Bay, Long Creek, Pequea/Mill Creek, Stroud Preserve). With the exception of Morro Bay, Pequea/Mill Creek, and Vermont, tracking of the operation and maintenance of land treatments after implementation generally received inadequate attention from most watershed-scale projects. As would be expected, projects like Stroud Preserve 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. Both the Pequea/Mill Creek and Vermont projects 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.

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. The Vermont project found that an advisory committee that brings in a wide range of interests, including state agency personnel and local stakeholders, is a valuable asset to project management.

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:

- Advisory committees that bring in a wide range of interests, including local stakeholders, are an effective way to accomplish project coordination (Vermont).

- 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 (Vermont).

- Projects should hire a technical person to oversee a project for the entire duration, especially if students or volunteers are used in the laboratory and field (Morro Bay).

- 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 (Vermont).

- 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; in the Pequea/Mill Creek and Stroud Preserve projects, environmental and industry groups were also involved. 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.

Project management: Information and education
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 parameters and study designs. 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. 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 (Morro Bay, Long Creek, Pequea/Mill Creek, Stroud Preserve, Vermont).
- Direct observation of treatment effects (Vermont).
- Detailed corroborative experiments or studies within project (Long Creek).
- Tight experimental design, e.g., above/below, input/output (Stroud Preserve).

Water quality response: Interpretation and presentation of results
Many projects such as the Morro Bay and Pequea/Mill Creek 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, Stroud Preserve, and Vermont projects presented their results to audiences in other ways in addition to technical reports.

REFERENCES

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.

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