Using Management Measures to Prevent and Solve Nonpoint Source Problems in Watersheds

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Watershed Approach

Watersheds are areas of land that drain to a single stream or other water resource. Watersheds are defined solely by drainage areas and not by land ownership or political boundaries. The *watershed approach* is a coordinating framework for environmental management that focuses public and private sector efforts to address priority problems within hydrologically defined geographic areas (e.g., watersheds), taking into consideration both ground and surface water flow (EPA, 1995b).

EPA supports watershed approaches that aim to prevent pollution, achieve and sustain environmental improvements and meet other goals important to the community. Although watershed approaches may vary in terms of specific objectives, priorities, elements, timing, and resources, all should be based on the following guiding principles.

- *Partnerships*: Those people most affected by management decisions are involved throughout and shape key decisions.

  This ensures that environmental objectives are well integrated with those for economic stability and other social and cultural goals. It also provides that the people who depend upon the natural resources within the watersheds are well informed of and participate in planning and implementation activities.

- *Geographic Focus:* Activities are directed within specific geographic areas, typically the areas that drain to surface water bodies or that recharge or overlay ground waters or a combination of both.

- *Sound Management Techniques based on Strong Science and Data*: Collectively, watershed stakeholders employ sound scientific data, tools, and techniques in an iterative decision making process. This includes:

  i. assessment and characterization of natural resources and the communities that depend upon them;

  ii. goal setting and identification of environmental objectives based on the condition or vulnerability of resources and the needs of the aquatic ecosystem and the people within the community;

  iii. identification of priority problems;

  iv. development of specific management options and action plans;

  v. implementation; and

  vi. evaluation of effectiveness and revision of plans, as needed.

Because stakeholders work together, actions are based upon shared information and a common understanding of the roles, priorities, and responsibilities of all involved parties. Concerns about environmental justice are addressed and, when possible, pollution prevention techniques are adopted. The iterative nature of the watershed approach encourages partners to set goals and targets and to make maximum progress based on available information while continuing analysis and verification in areas where information is incomplete.

Watershed projects should have a strong monitoring and evaluation component. Using monitoring data, stakeholders identify and prioritize stressors that may pose health and ecological risk in the watershed and any related aquifers. Monitoring is also essential to determining the effectiveness of management options chosen by stakeholders to address high priority stressors. Because many watershed protection activities require longterm commitments from stakeholders, stakeholders need to know whether their efforts are achieving real improvements in water quality. Monitoring is described in greater detail in Chapter 6.

Watershed projects should also be consistent with state regulatory programs such as development and implementation of total maximum daily loads (TMDLs) and basinwide water quality assessments. In fact, a watershed may be selected for special attention because of the need for a complex TMDL involving point and nonpoint sources (see Chapter 7 for a discussion of TMDLs).

Operating and coordinating programs on a watershed basis makes good sense for environmental, financial, social, and administrative reasons. For example, by jointly reviewing the results of assessment efforts for drinking water protection, point and nonpoint source pollution control, fish and wildlife habitat protection and other resource protection programs, managers from all levels of government can better understand the cumulative impacts of various human activities and determine the most critical problems within each watershed. Using this information to set priorities for action allows public and private managers from all levels to allocate limited financial and human resources to address the most critical needs. Establishing environmental indicators helps guide activities toward solving those priority problems and measuring success.

The final result of the watershed planning process is a plan that is a clear description of resource problems, goals to be attained, and identification of sources for technical, educational, and funding assistance needed. A comprehensive plan will provide a basis for seeking support and for maximizing the benefits of that support.

Implementing Management Measures in Watersheds

Management measures can be implemented in either a preventive or restorative mode depending upon the State and local needs identified through the watershed planning process. Similarly, although management measures are generally considered to be technology-based, they can also be used as key elements of a water quality-based approach to solving identified water quality problems. Technology-based pollution control measures are identified based upon technical and economic achievability rather than on the cause-and-effect linkages between particular land use activities and particular water quality problems that drive water quality-based approaches.

Technology-based Implementation

As noted earlier, a clear assessment of the problem is essential to identifying appropriate solutions. For example, the Section 6217 management measures were specified to address water quality problems in the Nation's coastal areas. These management measures were developed as affordable technology-based controls that could be implemented broadly within coastal drainage areas to improve and protect the quality of coastal waters. The Section 6217 program also includes provisions for implementing additional control measures where water quality problems are not solved through implementation of the management measures alone (USDOC and EPA, 1993). This iterative approach to solving coastal problems is consistent with the guiding principles of the watershed approach.

Primary justification for applying management measures through a technology-based approach is that the measures are known to reduce pollution and are generally acceptable and affordable. Therefore, the measures should be applied to as much land as possible, regardless of location. This has been the approach of most USDA and state agencies for many years. For example, Vermont's *Accepted Agricultural Practices* are "basic practices that all farmers must follow as part of their normal operations" (Vermont Department of Agriculture, 1995). They "are intended to reduce, not eliminate, pollutants associated with nonpoint sources." By implementing management measures or practices in a technology-based approach, a level of water quality protection can be achieved which makes it easier to then focus on remaining sources that need additional control.

The means by which management measures are implemented in a technology-based approach can range from voluntary to regulatory. All States have some form of voluntary program for addressing agricultural nonpoint source pollution. These programs include USDA's Farm Bill programs (Chapter 1) and State and local cost-share and assistance programs. Cost-share programs are very often technology-based and can be directed to high-priority watersheds in much the same way that Section 6217 is focused within coastal drainage areas. Private sector efforts are also technology-based in many cases, including, for example, precision farming techniques.

Water Quality-based Implementation

In areas where specific water quality problems have been identified and characterized in detail, it is possible to tailor implementation to achieve well-defined goals. For example, TMDLs result in allocations of the quantity of pollution that can be discharged from point sources (wasteload allocation) and nonpoint sources (load allocation) to ensure that water quality standards are achieved within a specified margin of safety (see Chapter 7). Management measures can be applied to achieve all or part of the pollution control needed by agricultural sources to achieve the load allocation. Management measures can also be used in permits to address the portion of a wasteload allocation assigned to animal operations designated as point sources.

Understanding Hydrology

Understanding site and watershed hydrology is essential to understanding nonpoint source problems and the impacts that management measure implementation may have on water quality. Each action taken on a farm has the potential to impact hydrology (see Garen et al., 1999). For example, diversions and buffers clearly affect water movement, and even grazing management affects hydrology through its changes to grazing land quality and/or riparian condition. Nutrient management can also affect hydrology directly if the application of nutrients includes liquids, and indirectly through its effects on crop growth which control plant water and nutrient uptake. The extent to which management decisions affect hydrology needs to be understood and estimated since hydrology is so important to the detachment, transport, and delivery of pollutants.

In agricultural watersheds, hydrology can be affected by a number of factors including the use of tile drains and irrigation practices, installation of grassed waterways and diversions, field buffers and buffer strips, crop type, and tillage type. The combined effects on hydrology of all management measures and management practices implemented should be considered both at the farm level and at the watershed scale in order to estimate the impacts on receiving water quality. Field-scale and watershed-scale models can aid analysis of the impacts on hydrology, and thus decisions on appropriate selection and placement of measures and practices in the watershed. In some cases, a thoughtful discussion or simple analysis will provide the answers regarding impacts to hydrology, but some form of modeling will usually be needed to integrate the various small and large impacts that management measures and practices are likely to have on watershed hydrology. However, models often have many limitations. Therefore, a thorough understanding of the hydrology of the area gained through monitoring or experience is usually needed to properly interpret model results.

If the watershed within which agricultural management measures will be implemented includes land uses other than agriculture, then planners will need to consider agriculture's role within the watershed. In other words, the degree to which agricultural lands control watershed hydrology should be investigated and understood to enable analysis of the potential impacts that management measures and practices will have on watershed hydrology. Once again, some sort of watershed modeling capability will usually be needed to aid this analysis.

Assessing On-Site Treatment Needs

Once watershed hydrology is understood, analysis of on-site treatment needs and the impacts of management measures on pollutant sources and delivery patterns can be conducted. At a particular farm it may be simple to determine which management measures are needed. For example, if nutrients and pesticides are applied, then nutrient and pesticide management should be implemented. If runoff from a confined animal facility leaves the farm without any attenuation or treatment, then storage and treatment of runoff is probably needed. More difficult cases will be those in which some management is practiced, but not enough to fully achieve the management measures. Even more difficult may be the cases where management measures are fully achieved but water quality goals or standards are still not being met.

On-site assessments should be performed to determine the needs on any individual farm. USDA-NRCS, soil and water conservation districts, state cooperative extension, and other public and private organizations have expertise in performing on-site assessments. EPA has developed guidance for tracking and evaluating the implementation of nonpoint source control measures (EPA, 1997b). Tools such as Farm*A*Syst (Jackston et al., undated) can be helpful when performing self-assessments of on-farm conditions.

It is usually beneficial to examine the water resource (e.g., to perform a stream walk) to view the watershed from the perspective of the receiving water body. This may lead to discovery of sources that would not be found from a typical on-site assessment. USDA's *Stream Visual Assessment Protocol* (USDA-NRCS, 1998) is a potential tool for stream assessment. In some watershed projects upland erosion control and riparian protection have been implemented with the expectation that sedimentation problems would be solved. Results, however, indicated that sedimentation problems persisted. For example, in the Rock Creek, Idaho, Rural Clean Water Program project, improved irrigation, sediment retention structures, filter strips, and conservation tillage were implemented to address sediment problems impacting a cold-water fishery (EPA, 1990a). The project did achieve and measure reduced levels of suspended sediment, but it was concluded that the project should have included the contribution of sediment from streambanks and the effects of hydromodification to fully achieve water quality objectives. A thorough examination of the water resource could have helped in the initial planning stages for this project.

Targeting

Even properly designed management practice systems constitute only part of an effective land treatment strategy. In order for a land treatment strategy to be most effective, properly designed management practice systems must be placed in the correct locations in the watershed (i.e., "critical areas") and the extent of land treatment must be sufficient to achieve water quality improvements (Line and Spooner, 1995). RCWP results indicate that 75% of the critical areas (as designated in that program) need to be treated to achieve water quality goals. For livestock-related water quality problems, generally 100% of the critical area should be treated with BMP systems (Meals, 1993). "Critical areas" are generally considered to be sub-areas within a watershed or recharge area that encompass the major pollutant sources that have a direct impact on the impaired water resource (Gale et al., 1993). The discussion below and in Chapter 7 provides information related to the delineation of critical areas. Although the term "critical area" is not generally used in TMDLs, the allocation of loads to sources in the watershed is entirely consistent with the concept.

In cases where implementation of management measures is water-quality based or voluntary, the implementation should be prioritized based upon the water quality benefits to be derived. Phased implementation on a priority basis may be best if financial resources are limited.

Estimating On-Site and Off-Site Impacts

On-site benefits are highly desirable, yet unless the needed off-site benefits are derived from the collective implementation of management measures and practices across the watershed, then implementation has not been fully successful. It is important to estimate the collective impacts of all management activities in the watershed to gage whether water quality goals will be achieved. In watersheds with easily characterized problems (e.g., bacterial contamination is due to a few obviously polluting animal operations in a watershed that has no other identifiable sources of pathogens) it may be very easy to project that water quality benefits will be achieved through implementation of the management measures for nutrient management, erosion and sediment control, and facility wastewater and runoff, for example. However, in a watershed with multiple land uses where agriculture is considered to contribute about one-third or so of the pollutants, it is more complicated to estimate the combined impacts of a variety of management measures and practices on a fairly large number of diverse farming operations. Further complicating the assessment may be that historic loading of pollutants has caused the water quality impairment and several years are required for the water resource to recover or cleanse itself (i.e., current loading may be low). In this type of situation, computer modeling may be needed.

A variety of models exist to help assess the relative benefits of implementing practices at the field and watershed level. However, an understanding of the model’s limitations and assumptions is necessary for appropriate interpretation of modeling results. It is also important that models be adequately validated and calibrated for a range of circumstances. The following are some models that have been evaluated for a relatively wide range of conditions and have been shown to be appropriate for the farm or field:

- ❒ GLEAMS (Knisel et al., 1991) simulates the effects of management practices and irrigation options on edge of field surface runoff, sediment, and dissolved and sediment attached nitrogen, phosphorus, and pesticides. The model considers the effects of crop planting date, irrigation, drainage, crop rotation, tillage, residue, commercial nitrogen and phosphorus applications, animal waste applications, and pesticides on pollutant movement. The model has been used to predict the movement of pesticides (Zacharias et al., 1992) and nutrients and sediment from various combinations of land uses and management (Knisel and Leonard, 1989; Smith et al., 1991).
- ❒ EPIC (Sharpley and Williams, 1990) simulates the effect of management strategies on edge of field water quality and nitrate nitrogen and pesticide leaching to the bottom of the soil profile. The model considers the effect of crop type, planting date, irrigation, drainage, rotations, tillage, residue, commercial fertilizer, animal waste, and pesticides on surface and shallow ground water quality. The EPIC model has been used to evaluate various cropland management practices (Sugiharto et al., 1994; Edwards et al., 1994).
- ❒ NLEAP (Follet et al., 1991) evaluates the potential of nitrate nitrogen leaching due to land use and management practices. The NLEAP model has been used to predict the potential for nitrogen leaching under various management scenarios (Wylie et al., 1994; Wylie et al., 1995).

- ❒ PRZM (Mullens et al. 1993) simulates the movement of pesticides in unsaturated soils within and immediately below the root zone. Several different field crops can be simulated and up to three pesticides are modeled simultaneously as separate parent compounds or metabolites. The PRZM model has been used under various conditions to assess pesticide leaching under fields (Zacharias et al., 1992; Smith et al., 1991).
- ❒ DRAINMOD (Skaggs, 1980) simulates the hydrology of poorly drained, high water table soils. Breve et al. (1997) developed DRAINMOD-N, a nitrogen version of the model to evaluate nitrogen dynamics in artificially drained soils. The DRAINMOD model has been used to predict pollutant losses associated with various drainage management scenarios (Deal et al., 1986). Website is http://www.bae.ncsu.edu/bae/research/soil_water/www/watmngmnt/drainmod/index.htm.
- ❒ REMM (Riparian Ecosystem Management Model) is a computer simulation model used to simulate hydrology, nutrient dynamics and plant growth for land areas between the edge of fields and a water body. Output from REMM allows designers to develop buffer systems to help control non-point source pollution. REMM was developed by ARS at the Southeast Watershed Research Laboratory, Coastal Plain Experiment Station, Tifton, GA. Web site is http://www.cpes.peachnet.edu/remmwww/.
- ❒ NTRM (Shaffer and Larson, 1985) simulates the impact of soil erosion on the short and long-term productivity of soil, and is intended to assist with evaluation of existing and proposed soil management practices in the subject areas of erosion, soil fertility, tillage, crop residues, and irrigation. The NTRM model has been applied to evaluate effects of conservation tillage, supplemental nitrogen and irrigation practices (Shaffer, 1985) and moldboard plow and chisel plow tillage (Shaffer et al., 1986) on soil erosion and productivity. This model has had limited use.

The following models can be used for either farm field or small watershed scale analysis:

- ❒ WEPP (Flanagan and Nearing, 1995) simulates water runoff, erosion, and sediment delivery from fields or small watersheds. Management practices including crop rotation, planting and harvest date, tillage, compaction, stripcropping, row arrangement, terraces, field borders, and windbreaks can be simulated. The WEPP model has been applied to various land use and management conditions (Tiscareno-Lopez et al., 1993; Liu et al., 1997). Web site is http://topsoil.nserl.purdue.edu/nserlweb/weppmain/wepp.html.
- ❒ SWAT (which incorporates SWRRBWQ) (Arnold et al., 1990) simulates the effect of agricultural management practices such as crop rotation, conservation tillage, residue, nutrient, and pesticide management; and improved animal waste application methods on water quality. The SWRRB model has been used on several watersheds to assess management practices and to test its validity (Arnold and Williams, 1987; Bingner et al., 1987). Web site is http://www.brc.tamus.edu/swat.
- ❒ AnnAGNPS (Cronshey and Theurer, 1998) is a spatially-distributed model for estimating pollutant runoff from agricultural watersheds.

BASINS 3.0: A Powerful and Improved Tool for Managing Watersheds

BASINS (Better Assessment Science Integrating Point and Nonpoint Sources) is a multipurpose environmental analysis system for use by regional, state, and local agencies in performing watershed and water quality-based studies. This software makes it possible to quickly assess large amounts of point source and nonpoint source data in a format that is easy to use and easy to understand. Installed on a personal computer, BASINS allows the user to assess water quality at selected stream sites or throughout an entire watershed. It is an invaluable tool that integrates environmental data, analytical tools, and modeling programs to support development of cost-effective approaches to environmental protection.

BASINS addresses three objectives: (1) to facilitate examination of environmental information, (2) to provide an integrated watershed and modeling framework, and (3) to support analysis of point and nonpoint source management alternatives. It also supports the development of total maximum daily loads, which requires a watershed-based approach that integrates both point and nonpoint sources. Basins can support a number of pollutants at a variety of scales, using tools that range from simple to sophisticated.

Originally released in 1996, with a second release in 1998, BASINS comprises a suite of interrelated components. BASINS' databases and assessment tools are directly integrated within an ArcView environment. These components work together to support the user performing various aspects of environmental analysis. The components include (1) nationally derived databases with Data Extraction and Project Builder tools; (2) assessment tools (TARGET, ASSESS, and Data Mining) that address large- and small-scale characterization needs; (3) utilities to facilitate importing local data and for organizing and evaluating data; (4) Watershed Delineation tools; (5) utilities for classifying elevation (DEM), land use, soils, and water quality data; (6) Watershed Characterization Reports that facilitate compilation and output of information on selected watersheds; (7) an in-stream water quality model; (8) two watershed loading and transport models and (9) a simplified GIS based nonpoint annual loading model.

What's New in BASINS 3.0?

This major release includes an overhaul of the system architecture that packages system components as ArcView extensions and external programs. This architecture is open and flexible. It promotes the growth of BASINS by allowing users and developers to write their own extensions to the system. BASINS 3.0 also includes many new features and improvements.

- An automatic delineation tool that allows users to delineate watershed based on a Digital Elevation Model (DEM) grid formatted data.
- An enhanced manual delineation tool that allows users additional flexibility in editing shapes and attributes of manually delineated watersheds.
- A new Windows interface for the HSPF model that fully supports interaction with the entire HSPF input sequence.
- A watershed model called Soil Water Assessment Tool (SWAT), developed by the U.S. Department of Agriculture's ARS.
- A model called PLOAD, developed by CH2M-Hill, which uses export coefficients to estimate watershed loading.
- A model postprocessor and scenario generator called GenScn. Originally developed for the U.S. Geological Survey (USGS), GenScn allows users to manage, visualize, analyze, and compare the results of several HSPF and/or SWAT simulations.
- A time series data management utility called WDMUtil.
- A grid projector that allows the user to project grid data.
- An improved Permit Compliance System point source (PCS) database with annual loadings updated through 1999.
- DEM (grid format) data on the distribution CD buffered to 8 digit HUC boundaries.

For more information on content, availability, and training, please contact:

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Within cells, the model can evaluate practices such as feedlot management, terraces, vegetative buffers, grassed waterways, and farm ponds. Simulated nutrient, sediment, and pesticide concentrations and yields are available for any cell within the watershed. The AnnAGNPS model has been applied to many field and watershed size areas to estimate pollutant runoff from various land uses and management practices (Bosch et al., 1998; Line et al., 1997; Young et al., 1994; Sugiharto et al., 1994; Bingner et al., 1987). Web site is http://www.sedlab.olemiss.edu/AGNPS.html.

- ANSWERS (Beasley et al., 1980) is a spatially-distributed watershed model. The model is primarily a runoff and sediment model as soil nutrient processes are not simulated. The ANSWERS model has been applied to several small field-sized areas with various management practices (Griffin et al., 1988; Bingner et al., 1987).
- BASINS (EPA, 2001d) is a user-friendly GIS-based program containing several models capable of simulating watershed loadings and receiving water impacts at various levels of complexity. This new version allows you to subdivide large watersheds into very small watershed segments using either an automated delineation tool or a manual delineation tool. BASINS 3.0 includes three watershed models. The HSPF model, present in earlier versions, is supported by a new Windows interface that makes it easier to run the urban and rural watershed simulations. A rural watershed model called Soil Water Assessment Tool (SWAT), developed by the U.S. Department of Agriculture's Agricultural Research Service, has been added to BASINS. It is anticipated that this model will be widely used in agricultural watersheds. A third very simple model called PLOAD has also been added. PLOAD is most applicable for screening analyses. In addition, there is a new model postprocessor and scenario generator called GenScn that allows users to manage, visualize, analyze, and compare the results of several HSPF and/or SWAT simulations. Web site is www.epa.gov/ost/basins.

A series of pollutant specific protocols has been developed by EPA to assist in the development of TMDLs and implementation plans to achieve the TMDLs (EPA, 1997d; 1999b; 1999c; 2001c). These protocols focus primarily on the application of computer models that simulate watershed conditions and the changes that could result from implementation of various land management scenarios. Some models contain default values for the quantity of pollutants that are delivered in runoff from various sources (e.g., cropland deliver X pounds of nitrogen per acre per inch of runoff). These default values can generally be replaced with better information that is available for a particular watershed. Models should have functions that are intended to simulate the implementation of management practices, enabling modelers to estimate changes due to a range of land management options. Such models can be helpful tools for planning the implementation of management measures to achieve water quality goals, but the limitations of models and appropriate interpretation of modeling results should be fully understood before implementation decisions are made. The application of models to estimate pollutant loads is discussed further in Chapter 7.

Adaptive Management

Because many of the decisions made regarding the appropriate type, extent, and location of management measures and practices are based upon estimates and partial information, it is highly likely that changes will be needed. If progress is monitored (see Chapter 6) adequately, managers and landowners will be able to adjust implementation plans, schedules, and models as needed to ensure more cost-efficient achievement of water quality objectives. One of the major findings from the Rural Clean Water Program is that water quality monitoring can provide valuable feedback for defining areas needing priority treatment (Gale et al., 1993).

Preventing Unintended Adverse Environmental Effects

As noted in Chapter 2, this guidance does not address all environmental considerations at a particular site or within a watershed. Resource management systems (RMS) are more broad, yet planners and managers should even go beyond the scope of an RMS to consider whether management measure or practice implementation at the site or watershed scale will have any unintended environmental impacts. For example, methane generation from structures implemented to store runoff and facility wastewater from confined animal facilities may be problematic in certain areas. Alternatives to conventional storage structures might be needed.

Similarly, extensive changes to water management could impact baseflows in streams. Different configurations and design specifications for diversions and storage devices might be able to provide needed water quality improvement without causing negative impacts to baseflow patterns. Whole-farm planning approaches such as those specified in Chapter 2 (e.g., Idaho One Plan) can go a long way toward preventing these types of unintended environmental impacts at the farm level, but potential watershed-wide or landscape-scale impacts need to considered from a more global perspective.

Estimating the Effectiveness of Management Measures and Management Practice Systems

It is very difficult to estimate the effectiveness of management practice systems. Some researchers have proposed that the effectiveness of management practice systems should be calculated by adding the average relative effectiveness of individual practices. As an example of this approach, assume a system to control sediment is composed of surface drainage, terraces, and conservation tillage. Based upon data in the literature (Foster et al., 1996), the average sediment load reductions achieved by these practices are 36% for surface drainage, 91% for terraces, and 69% for conservation tillage. Under this approach, the average pollutant load reduction for surface drainage is subtracted from the total load of 100% (100% – 36% = 64%). Thus, 64% of the sediment remains after surface drainage is accounted for. If terraces reduce sediment loads by 91%, then the remaining pollutant load after surface drainage and terraces is about 6% (.64 x [1.00 – .91] = .058 = 5.8%). The remaining practice in the system, conservation tillage, reduces sediment loads by 69%, resulting in a final sediment delivery of approximately 2% (.058 x [1.00 – .69] = .018 = 1.8%).

The Idaho RCWP project, however, demonstrated that the effectiveness of individual practices in a system of practices ***are not additive***. The effectiveness of some of the BMPs used in the project was measured by the USDA–Agricultural Research Service, and the results are given in Table 5-1 (Maret et al., 1991).

Table 5-1. Sediment removal effectiveness of selected individual BMPs used in the Snake River RCWP Project (Idaho).

Individual BMP	Mean % Effectiveness	% Effectiveness Range
Sediment Basins	87	75-95
Mini-basin	86	0-95
Buried Pipe Systems	83	75-95
Vegetative Filters	50	35-70
Straw Mulch	50	40-80

Sediment loads in the Idaho RCWP project were reduced by 75%. Even though the effectiveness of only five of the nineteen BMPs used in the project was measured (Table 5-1), it can be seen that the overall reduction of 75% would not have been estimated accurately by using the above approach in which average effectiveness of practices was considered to be additive. Using the additive approach, the sediment delivery would have been reduced to essentially zero if the mean effectiveness values for the five practices in Table 5-1 were used in the analysis.

In summary, the aggregate effectiveness of any system of management practices is a function of not only the mean effectiveness of individual practices, but also the interactions between the individual practices within the range of site-specific conditions experienced.