

Technical Issues Related To Nonpoint Source Management

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Abstract.--Nonpoint source pollution is one of the Nation's remaining water quality problems. Because of inherent differences between point sources and nonpoint sources, different control strategies are required. Nonpoint source control strategies rely primarily on the application of Best Management Practices (BMPs) as the means to achieve protection of designated beneficial uses. Increasingly, environmental groups and regulatory agencies are looking toward instream numeric water quality criteria as a regulatory mechanism for controlling nonpoint sources. Numerous technical problems exist with this approach. The most significant being the highly variable and poorly understood relationships between land use and the beneficial uses that need to be protected. The continued use of BMPs appears to offer important advantages over instream water quality standards and their continued use is suggested. In the long-term, monitoring data accumulated to evaluate BMPs can be used to build a sound scientific basis for eventual evolution to water quality based approaches.

INTRODUCTION

Passage of the Clean Water Act (CWA) in 1972 is generally regarded as the beginning of water quality management in the United States. In the Act, Congress established a national goal "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters." The legislation is couched in laymen terminology such as "swimmable," "fishable," and "propagation of aquatic life." For regulators and technical experts, terminology such as "maintenance and enhancement of designated beneficial uses" are more commonly used although their precise meaning is often purposefully ambiguous.

Water pollution control is generally divided into two primary categories: Point sources and nonpoint sources. Point sources of pollution generally come

out of a pipe. They are the effluent of discrete processing or manufacturing activities and are subject to direct end-of-pipe control. The quality of the water leaving a facility can be easily measured, the source is readily identified, and the responsible party is known. Regulatory control is accomplished by setting discharge standards through National Pollutant Discharge Elimination Permits (NPDES).

Nonpoint sources of pollution (NPS) are diffuse and result from diverse land disturbing activities such as agriculture, forestry, construction, resource extraction, urban runoff, hydromodification, and others. Pollution problems are the result of past and present land uses and the responsible party may be difficult to identify. Pollutants often come from many sources, travel numerous pathways to the stream, and the initiation of a pollution event is subject to storm events which are as unpredictable as the weather. Partially due to confusing regulations, control of NPS has proven to be more difficult than originally envisioned.

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Fisheries and domestic water are the designated beneficial uses of greatest concern to the public. Coldwater fisheries are generally regarded to be the most sensitive to forest management activities and an area of interest to much of the public, especially in the western United States. The body of knowledge about the interactions between land management and aquatic ecosystems has been reviewed in several recent publications (Salo and Cundy 1987; Chapman and McLeod 1987; MacDonald et al. 1991; Meehan 1991).

In spite of all we know, many believe that we lack the precise scientific knowledge needed to link on-the-ground management activities to coldwater fisheries or the biological integrity of aquatic ecosystems in the context of a regulatory framework. Others, fully recognizing the deficiencies of the available information, point out the magnitude of nonpoint source problems and the limited progress demonstrated to date, argue that it is time to change strategies and apply strict instream water quality criteria to protect and maintain existing beneficial uses. In the absence of scientific certainty, they conclude that it is best to err on the side of aquatic ecosystem protection instead of commodity users. To date, science has not resolved the conflict which is likely to become more emotional over the next few years.

On a national scale, progress has been slow. In forestry, few States have initiated regulatory (e.g., Oregon, Washington, Idaho, California, Alaska) or quasi-regulatory (e.g., Maine, Massachusetts, Nevada) programs which mostly rely on Best Management Practices (BMPs). As a result, environmental groups, professional societies, and some States are showing an increased interest in the establishment of numeric water quality criteria as performance standards. EPA's Nonpoint Source Agenda for the Future (EPA 1989) lists a national goal of having appropriate water quality standards, including fine sediment criteria for selected waters, adopted in all States by 1993. Within the Forest Service, the Columbia River Anadromous Fish Policy Implementation Guide contains a process which will establish *de facto* instream criteria, including sediment, as one way to measure progress aimed at protecting anadromous fish habitats.

HISTORY OF NONPOINT SOURCE CONTROL

Following passage of the Clean Water Act, the General Accounting Office estimated in 1986 that the Federal Government had spent \$37 billion of CWA funds to assist municipalities in the construction and upgrading of wastewater treatment plants (GAO 1986). Surface water pollution from industrial and municipal point sources was thought to be largely under control. While the Nation's waters appeared to be getting cleaner as a result of CWA programs, it was difficult to precisely assess the benefits of point source controls due to natural background levels and NSP. The Environmental Protection Agency (EPA) concluded that NSP was among the leading causes of the Nation's remaining water quality problems (Thomas 1985). While sources varied for different parts of the country, agricultural operations were identified as the most pervasive nonpoint source. Silvicultural sources, contributions from urban areas, mining, and construction sites were identified as important sources that should be addressed by local areas.

The resulting passage of the 1987 Water Quality Act (WQA) by Congress, placed special emphasis on nonpoint sources by making it "the national policy that programs for the control of nonpoint sources of pollution be developed and implemented in an expeditious manner." Consistent with section 319 of the WQA, States were directed to identify those waters where water quality standards cannot be met without the control of NSP and to develop nonpoint source assessment and management programs which will serve as the cornerstone of the National nonpoint source program for the future. In addition, Federal consistency provisions of the WQA encourages States to establish processes to assure that Federal projects and activities do not conflict with the State's nonpoint source management program. Should a State determine that a proposed Federal action is not "consistent" with its NPS Management Program, the Federal agency must accommodate the States's concerns or explain in a timely manner why it cannot do so.

While the Water Quality Act of 1987 reaffirmed national interest in nonpoint sources, NPS problems even though given little attention in the original Clean Water Act legislation, were the focus of na-

tional interest by the mid 1970's. Strategies successfully used in the point source program, were applied to NPS problems. This was an unfortunate choice and was soon discovered to be an inappropriate strategy for a variety of technical reasons to be discussed in this paper.

NONPOINT SOURCE CONTROL STRATEGY

While the effects of pollution on beneficial uses are identical regardless of the source, programs designed for their control must be distinctly different. Point sources are effectively controlled by end-of-pipe treatments which regulate the release of discharges. Nonpoint sources can only be effectively controlled by prevention. In recognition of this and in the absence of specific Congressional direction or regulatory requirements, EPA initiated a NPS control strategy that relied on voluntary, nonregulatory approaches utilizing preventive practices, or Best Management Practices (BMPs), as the primary control mechanism to assure State water quality standards are achieved.

The Forest Service and other interests worked several years with EPA to develop a mutually acceptable and technically appropriate strategy for controlling nonpoint source controls and meeting water quality standards (Harper 1987; Solomon 1988). Guidance to implement the strategy is contained in Chapter 2 of the EPA Water Quality Standards Handbook. The strategy attempts to explain the complex relationship between land management activities, water quality standards, and Best Management Practices as they pertain to nonpoint source control programs.

The EPA nonpoint control strategy recognizes Best Management Practices (BMPs) as a prime means to achieve protection of designated beneficial uses. BMPs are not the only component of the strategy, however, and attainment of State water quality standards is the ultimate objective. Water quality standards are identified by each State and consist of two components and an additional policy: (1) the beneficial uses of the water, (2) numeric and narrative criteria, and (3) an antidegradation policy (EPA 1988).

Under this strategy, both BMPs and water quality criteria are the standard for evaluating the attainment of CWA goals. Cost effective and reasonable BMPs are

applied in a manner designed to achieve water quality standards. After BMPs are applied, the States have primary responsibility to evaluate their effectiveness in protecting water quality through monitoring. If standards have been violated, the States and the responsible party take action to: (1) revise BMPs, (2) revise water quality standards, or (3) cease the activity. In implementing this strategy, many States have formalized BMPs in State regulations, such as forest practices acts, requiring use of specific BMPs for silvicultural activities. At the same time, States require adherence to water quality criteria as part of State water quality regulations.

At first it may appear that land owners (and land management agencies) are placed in double jeopardy under this arrangement. Once with respect to application of BMPs, and again with respect to attainment of water quality standards. In all fairness, the landowner should only be subject to one set of regulatory performance standards; either BMPs or instream water quality standards. For a number of technical and pragmatic reasons to be discussed later, the only appropriate performance standard is BMPs.

This does not mean that water quality standards are replaced by BMPs. Instead, water quality standards become the attainment measure by which BMPs are evaluated. They define the desired instream objective, or benchmark, specifying the amount of protection needed to fully protect specific beneficial uses.

For example, if State approved BMPs are properly applied and water quality standards are still violated, regulatory action would not be brought against the landowner. Rather, responsibility for not meeting the water quality standard is shared by the landowner and the State. Both parties would work together to identify the reason for the violation and devise additional practices which might be required to achieve the desired level of protection. Under this scenario, water quality standards are the benchmark for evaluating performance as part of the feedback loop concept (Figure 1).

In summary, BMPs are the performance standards used in regulatory programs and water quality standards are the attainment standards used to evaluate needed changes. A continual iterative process is used

BMP FEEDBACK LOOP

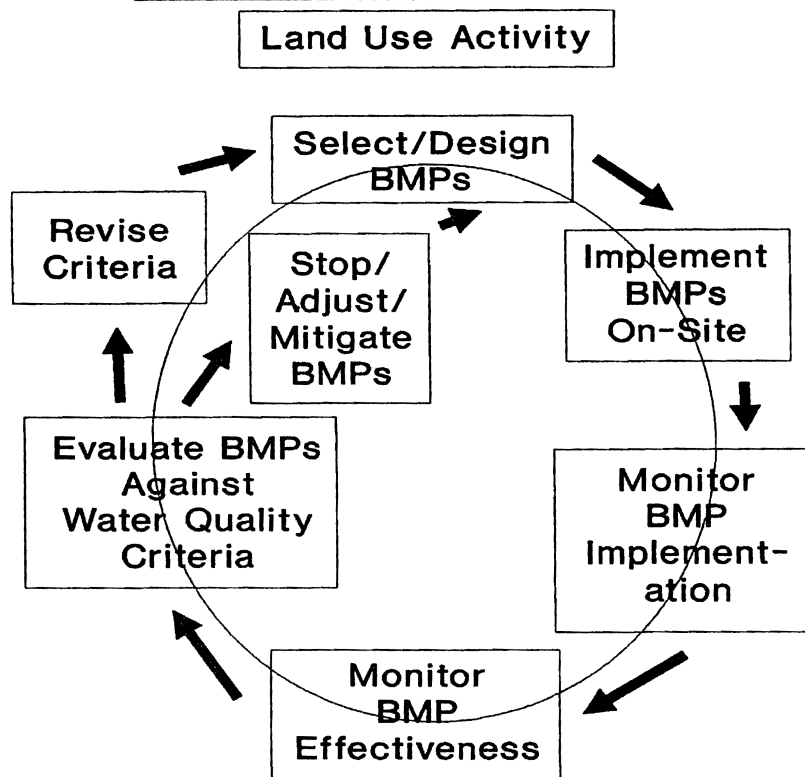


Figure 1. Best Management Practices feedback loop.

which progressively adjusts standards and practices until water quality is protected to the maximum extent feasible discussed in the original CWA legislation.

IMPORTANCE OF MONITORING

To a large extent the success or failure of the NPS strategy depends on monitoring (MacDonald et al. 1991). Monitoring has a direct bearing on such basis issues as whether or not water quality is limiting designated uses for a water body (water quality impaired) or if water quality standards are being met. Monitoring is also critical to evaluate first the implementation of BMPs and then their effectiveness. A critical part of the implementation feedback loop is the assurance that BMPs are properly integrated into on-the-ground land management. Finally, monitoring is needed to determine if water quality criteria are sufficiently and properly defined to protect beneficial uses.

Implementation monitoring is the most common and least technical form of monitoring. Its primary aim is to see if BMPs and forest practices rules were properly applied. Generally no measurements of water quality are made, although review teams may qualitatively evaluate management impacts on streams. Based largely on qualitative observations, review teams normally make recommendations regarding specific management practices and their improvement (Bauer 1985; Giles 1991).

Effectiveness monitoring is done to determine if practices were effective in controlling pollutants to planned levels. This is done on a sample basis selecting representative projects and usually involves detailed field measurements. For many BMPs, on-site monitoring outside of stream channels is adequate to properly evaluate impacts without the confounding influence inherent with instream measurements. The work of Swift (1986) where he evaluated filter strip designs and characteristics is an example of onsite effectiveness monitoring. Effectiveness monitoring

can also include biological indicators and physical surrogates for beneficial uses, such as cobble embeddedness or substrate composition. This approach generally evaluates combinations of practices applied at the watershed level. The work of Potyondy (1989) where he evaluated cobble embeddedness with respect to management activities within watersheds on Boise National Forest streams is an example of instream effectiveness monitoring. Regardless of the design, several iterative cycles are normally needed to establish and refine BMPs to acceptable levels of performance using the feedback loop concept.

Validation monitoring is the most intensive form of monitoring and is directly applicable to the establishment of water quality criteria. In most cases, validation monitoring is conducted by researchers utilizing permanent plots and long-term studies. The objective is to test: (1) whether water quality criteria limits are sufficient to protect beneficial uses, or (2) whether a selected criterion is an appropriate surrogate to protect beneficial uses. By documenting the changes in physical habitat (e.g., bed material particle size, turbidity, temperature) and the effect this has on designated uses (e.g., coldwater fish populations) the basis for the establishment of water quality criteria can be set based on firm scientific data.

TECHNICAL PROBLEMS WITH INSTREAM CRITERIA

Many technical issues need to be overcome before instream criteria can be established with respect to forestry and beneficial use protection and used for regulatory purposes.

Lack of Criteria Appropriate to Forest Management

Water quality standards were initially developed for control of point sources of pollution. Consequently, most criteria are either insensitive or irrelevant to forest management activities. Only five or six criteria (dissolved oxygen, turbidity, suspended solids, color, temperature, and perhaps nitrate-nitrogen) of more than 100 listed in EPA's "Gold Book" (EPA 1986) are affected by forest management (MacDonald

et al. 1991). Other parameters of significance to aquatic ecosystems and fisheries (e.g., intergravel dissolved oxygen, cobble embeddedness) have been identified and are being considered as water quality standards by some States (Harvey 1989). The technical basis and widespread testing of their geographic applicability has yet to be confirmed. A recent review of salmonid-habitat relationships in the western United States (Marcus et al. 1990) examined many of the existing water quality criteria and concluded that they did not apply well to these streams.

Criteria Based on "Best Guess"/Point Source Philosophy

Current water quality standards were largely developed for static point source situations. The CWA required that States develop standards within a specified time frame. Not much thought was given to nonpoint sources. The prevailing thought and direction was to make "best guess" estimates and worry about changes during subsequent reviews required by the CWA (Harper 1987). This approach ignored the realities of dealing with sensitive environmental issues since it is extremely difficult to change existing standards found to be inappropriate, particularly if the result is a lowering, or apparent weakening, of the standard.

Criteria Developed from Laboratory Studies

The laboratory conditions used to establish many water quality standards are not representative of the diversity and complexity found in natural stream systems. Field response of fish for example, is not always the same as that predicted by laboratory experiments. For example, fish may avoid adverse temperature fluctuations by seeking out groundwater seeps or cool tributary inlets and thereby survive temperatures thought to be lethal (Ice 1989). With respect to sediment, laboratory studies have demonstrated consistent negative effects of sediment on growth, emergence and survival of fish. Field studies, however, have not produced similarly consistent results primarily due to the introduction of confounding environmental effects in natural setting and our inability to isolate them (Everest et al. 1987, Chapman and McLeod 1987).

Problems with Background Variability

NPS pollutants are distinctly different from point source pollutants in that NPS pollutants occur in the natural environment. For a typical NPS pollutant, such as sediment, there is a base level of natural sediment plus some accelerated amount resulting from human activities. By contrast, the base level of a human-made toxic pollutant found in natural waters is zero. Separating the anthropogenic from the natural can be difficult especially since precise measurement of sediment, regardless of its source, is a technically difficult task. In addition, the availability of undisturbed watersheds of approximately comparable size and within similar geologic settings to serve as controls is severely limited to nonexistent.

High Complexity of Natural Systems

Three elements of natural variability need to be addressed: hydrology, site, and vegetation (Ice 1989). Hydrologic variability encompasses water quality conditions resulting from hydrologic events including peak flows, time since last storm event, discharge rates, and position on the hydrograph rising or falling limb as well as effects from episodic and seasonal conditions (wildfire, leaf fall). Site variability includes geology, soils, and geomorphology as they effect water quality response. Vegetation variability considered the type and age distribution of vegetation within the watershed. Because of the diversity of natural landscapes and the different processes operating in each, an unlimited number of combinations is possible.

Problems Dealing with High Natural Variability

Most of the criteria affected by forest management activities are sediment-related. The current state of knowledge about sediment production from forested watersheds in managed and unmanaged conditions and the movement of sediment through stream systems exhibits large temporal and spatial variation and is poorly understood (King 1992). Existing criteria have not adequately recognized the limited precision possible in the science of monitoring NPS water quality and have not allowed for the full range of natural variance found in streams. The variability of turbidity, suspended solids, and bedload measure-

ments and measurement difficulties are well documented in the literature (MacDonald et al. 1991). Many of the existing water quality standards related to temperature, dissolved oxygen, turbidity, and other variables are often exceeded even in undisturbed streams (Beschta and Ice 1990). Additional factors involving scale and uncertainty of sediment monitoring have only recently been recognized (MacDonald 1992). The problem of detecting change through monitoring is intensified given the variability introduced by dilution effects, storage effects, and measurement error.

High Cost of Monitoring

Because human-caused water quality conditions in forested watersheds are so masked by extremely variable natural and background conditions, monitoring that accurately detects the true water quality condition requires intense, long-term studies. The Bull Run Watershed near Portland, Oregon serves as an example of a forested watershed where water quality standards are being used to directly assess forest management effects. The current water quality of this municipal supply watershed is so high that sediment filtration is not needed. Annual monitoring costs for this one watershed are estimated to be about \$500,000 (Ice 1989). Routine application of this level of monitoring to a wide number of watersheds would obviously be prohibitively expensive.

Link Between Land Use and Beneficial Use is Poorly Understood

As has been pointed out previously, water quality criteria relevant to forest management are sediment-related and coldwater fisheries is the beneficial use of greatest concern. Consequently, sediment and its relation to fisheries is of great interest. It is generally agreed that our knowledge about sediment-fish interactions is incomplete. The published record shows that researchers have not successfully developed useful predictive relationships between fish populations and alterations of their environment by sediment (McIntyre 1992). In a 1987 review of sediment criteria funded by EPA, Chapman and McLeod (1987) examined the relationship between sediment and the effect it has on the biology of the fish. They concluded:

"We found no functional predictors that would serve environmental regulators in evaluating quantitative effects of sediment on the natural incubation, rearing, or wintering phases of salmonid life history in the northern Rockies."

The authors suggest that every system should be analyzed as a discrete unit and managed based on the best available scientific judgement with managers favoring conservation of the fisheries resource in light of existing uncertainty.

The more holistic analysis of the current situation is summarized by Everest et al. (1987):

"The capability of a stream to mobilize and transport fine sediment is highly variable and dependent on numerous physical factors, which can vary from reach to reach within the same basin. This level of variability makes it practically impossible to develop useful universal guidelines or criteria for protecting stream biota from turbidity and fine sediment. Past establishment of such guidelines stemmed from the assumption that any sediment entering streams as a result of land management had negative effects on aquatic biota. In any situation, this assumption might or might not be true."

The evident conclusion is that based on our present understanding and information, environmental regulators are currently without reliable methods to assess the quantitative effects of sediment on stream salmonids. It would appear obvious that the technology does not exist to establish instream sediment criteria at this time.

That unanimous opinion however, was not echoed by scientists invited to attend a joint EPA/Forest Service Technical Workshop on Sediments (Feb. 3-7, 1992, Corvallis, Oregon). Discussions among the participants indicated that, in general, physical scientists thought the current state of technology was such that we do not presently have technology with the precision and accuracy to establish criteria. In contrast, biological scientists generally felt variability was not much of a problem and that it could be dealt with satisfactorily in the establishment of criteria. These divergent viewpoints may be indicators of why progress in developing links between land management effects and the biological consequences has been so slow.

The development of instream criteria may in reality be more a political exercise than a technical one in that it involves value judgements. Involved are questions about who bears the cost if criteria are incorrectly specified; commodity users or the environment. Some would elect to err in favor of fish, others might choose economic interests over environmental protection, while purists might desire a higher degree of scientific certainty before making any judgements. Ultimately these are political questions which must be dealt with through existing institutions.

ADVANTAGES OF BMP APPROACH

The current NPS strategy of relying primarily on BMPs as the control mechanism for nonpoint source pollution evolved not so much as a result of the recognized deficiencies of using instream water quality standards, but rather because the BMP approach appears to work well. NPS assessments have been conducted by a number of states to determine the effectiveness of forest nonpoint source programs and State BMPs for forest management activities (Ice 1987). Assessments conducted in Oregon, Washington, California, Idaho, and Montana as well as other states all show that most water quality problems are avoided if BMPs are properly applied (Ice 1989).

BMPs have the following advantageous attributes:

1. A large body of knowledge is available that can be used to establish appropriate land management practices. Practices can be easily tailored to fit the diverse site specific conditions encountered in the field including soils, topography, geology, vegetation, and climate.
2. Practices can be designed to protect beneficial uses while incorporating concepts of risk and feasibility. Risk is important because it recognizes that some projects will fail to meet an absolute standard under extreme natural conditions. Feasibility is an important concept which recognizes that absolute control at all costs is not possible or desirable. The test of feasibility includes political, social, economic, and technical aspects. The number or the intensity of BMPs to be applied in particular

situations can be customized to fit the importance of the beneficial uses requiring protection.

3. Monitoring of BMP effectiveness is relative simple compared to monitoring of instream criteria. It is relatively easy to document misapplication or the absence of BMPs. Visual inspection is often adequate for many BMPs to see if they are working properly. Once problems are identified, it is easy to change management practices to correct the situation.
4. The benefits of BMP implementation or failure are readily understandable by field personnel. Because of this, it is easy to communicate necessary changes to the people doing the work in the field and gain understanding and support for needed improvement.
5. Most importantly, BMPs are preventive rather than curative measures. Beneficial uses are most practicably and efficiently protected by using a BMP process which prevents pollutants from leaving the source through careful site specific planning, design, and implementation of BMPs before activities take place. Compliance is based on surveillance and enforcement of how BMPs were applied. Compliance checks which depend on attainment of instream criteria are after the fact. Because of the nature of land disturbing activities, it may not be possible to correct an unacceptable situation or clearly identify the source of the problem. Little environmental protection is provided by citing an individual for violating water quality standards after the damage is done.

SUMMARY

The Clean Water Act established an objective of restoring and maintaining the Nation's waters. Point source problems have largely been solved and greater emphasis is now being given to the control of nonpoint source pollution. Technical considerations require development of management strategies for nonpoint sources which are distinctly different from point source controls. EPA has devised a strategy relying on preventive land management practices (BMPs) as the

primary mechanism to achieve protection of beneficial uses. Nevertheless, the agency continues to move toward water quality standard based approaches in attempting to address emerging nonpoint source issues such as Total Maximum Daily Loading or TMDL, and coastal zone management, ignoring or downplaying the technical difficulties associated with instream criteria.

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