Agricultural Issues: Eastern and Southern Experience

NONPOINT SOURCE POLLUTION: SCS PERSPECTIVE

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Nonpoint source pollution is the next major environmental issue facing this Nation. If we are ever to reach that cherished goal of swimmable, fishable waters throughout this land, then the problem of pollution from these diffuse sources must be seriously addressed. The American people want clean water, according to many public opinion polls, and they are willing to pay for it. (Counc. Environ. Qual. et al. 1980; Engineering News Record, 1982)

In an EPA report to Congress (U.S. Environ. Prot. Agency, 1984), there is a table listing the response of each State water pollution control agency to the question, "Do nonpoint sources cause a problem in your State?" Twenty States reported it to be a major problem, while the rest indicated that it was just a problem or potential problem. Alabama, at the time of the survey in 1982, reported NPS pollution to be just a problem. I am confident, however, that it would now be rated a major problem. The director of the Alabama Department of Environmental Management, the water quality regulatory agency in the State, recently stated that the industrial sector has done much to clean up its act, but industry and others are now pointing their collective finger at agriculture. Moreover, he has seen a rapid increase in complaints in the past 2 years regarding agricultural nonpoint source pollution.

A major difference between industry and agriculture is that industry can pass on the cost of pollution control to the consumer, whereas agriculture cannot. A recent study in Alabama suggests that small-scale hog operations would have a difficult time remaining in business if forced to install traditional, expensive waste management systems, especially if cost-sharing is not provided. Agriculture cannot be called upon to pay the total direct cost of pollution control because the mechanism is not and has never been in place to readily pass on the added cost to the consumer.

In those States that provide cost-sharing funds, State soil and water conservation boards or committees and districts are handling the administrative procedures. In many of these States, conservation districts have their own technical people. In others, the State relies upon the Soil Conservation Service for technical support. Where Federal funds are used, the institutions providing financial and technical assistance are also in place. This includes the Agricultural Stabilization and Conservation Service, which administers cost-share funds, and SCS and the Cooperative Extension Service, which provide technical assistance. In many States, these organizations are working in cooperation with 208 planning committees.

For its part, the SCS, with its conservationists and technicians located in nearly every county throughout the country, is uniquely situated to deal with nonpoint source pollution problems. In fact, we in SCS have been dealing with them directly and indirectly for a number of years. Each year our people are installing hundreds of miles of terraces, grassed waterways, and other engineering practices to reduce erosion. And our field people have been actively promoting conservation tillage throughout the Nation. Although conservation tillage greatly reduces soil loss and the loss of phosphorus in surface runoff, we are concerned that the increased use of "burn down" herbicides in conservation tillage could adversely affect water quality. We have been studying this issue but, unfortunately, all of the answers are not yet known.

SCS has been active in many areas in our efforts to reduce nonpoint source pollution. For instance, SCS is providing special training in water quality to our field personnel. By the end of this year, approximately 80 percent of our people nationwide will have had at least 15 hours of training on nonpoint source pollution.

SCS has also been involved in the development of the CREAMS computer model—CREAMS being an acronym for chemicals, runoff, and erosion from agricultural management systems. The model was developed by the Agricultural Research Service with input from SCS specialists.

We have conducted week-long training sessions for selected State office personnel on CREAMS, and the model is now being used extensively by SCS field staffs throughout the Country.

SCS, the States' soil and water conservation districts, and related agencies are working on water quality projects as never before. We are deeply involved in salinity control in the West and in the reduction of nutrients into the Great Lakes in the North. The 21 experimental Rural Clean Water Projects and the Model Implementation Program have required thousands of manhours of technical assistance from SCS and district personnel throughout the country. The thrust of these programs has been to reduce nonpoint source pollution in watersheds having especially critical problems.

SCS is involved in many other water quality programs, including our ongoing conservation programs that are daily reducing nonpoint source pollution: the Chesapeake Bay cleanup, the Cornell University/SCS workshops on water quality, and our contracted studies in the Northwest on bacterial pollution. And the list goes on. The question now is, where do we go from here?

We do not know yet how the budget cuts will affect SCS's overall program. If we are cut too severely, we may be forced to address only a narrow range of soil conservation programs. To be sure, these programs are important in reducing nonpoint source pollution, but they will not provide the level of water quality protection we would like to provide.

We have an organizational structure that lends itself to working with agricultural nonpoint source pollution. Our technical field personnel are working closely with farmers and ranchers on a daily basis and have established with them a rapport that is often needed to encourage them to install pollution control practices. We feel that friendly persuasion is a whole lot better than forced legislation wherever possible.

We need more research on best management practices, especially those for controlling pesticides. We know more than we used to about pesticide runoff but we still don't know enough.

Financial incentives for pollution control practices are essential if we are to see progress in reducing agricultural NPS pollution. If the practices we recommend do not increase crop yields or the margin of profit for livestock and poultry producers, we will be fighting a losing battle without financial incentives.

I am proud of what we have already accomplished in nonpoint source pollution control. And I am excited about what could lie ahead in this area for SCS and for those agencies with whom we are closely allied.

If, however, the public is not adequately concerned about our work, the effort to reduce nonpoint source pollution will be slow at best. Perhaps this conference will be the foundation on which a public awareness program is built. For the sake of our precious water resource, I certainly hope it will be.

NONPOINT SOURCE POLLUTION FROM PLANT NUTRIENTS

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Of the essential nutrients for plant growth, nitrogen and phosphorus are of greatest concern as pollutants. However, these two nutrients differ markedly in the way they act in the soil. Nitrogen is a mobile nutrient, while phosphorus is immobile. These nutrients are supplied in fertilizer to supplement soil supplies.

Soil nitrogen is released from organic forms. Decomposition of soil organic matter by microbial action at first produces ammonium. Ammonium ions are either adsorbed at the cation exchange sites of soil clay minerals or, with good aeration and temperatures conducive for nitrifying bacteria, are converted to nitrate. In the case of surface erosion, nitrogen is removed from cropland primarily as particulate organic matter or as ammonium attached to soil particles. Once nitrate is in the soil solution, however, it is subject to leaching and can ultimately enter the ground water. Fertilizer nitrogen is subject to these same processes.

Phosphorus is another case. Any phosphorus that appears in the soil solution, either from fertilizer or from the decomposition of organic matter, can become attached to soil clay minerals as a phosphate complex or be rapidly converted to an inorganic form of metal phosphate, the type depending on soil aeration and pH conditions. All of these inorganic forms of phosphates in the soil are relatively insoluble and result in low concentration in soil solution (generally < 0.2 mg/L). Hence, phosphorus losses to surface waters generally result through soil erosion.

Losses of phosphorus and inorganic nitrogen to surface waters can be reduced through soil management practices that slow surface runoff. The question remains as to the losses of nitrate to ground water because of its mobility.

Plant nutrients from either soil or fertilizer become potential pollutants when they are present in quantities that exceed either plant requirements or the capacity of the soil to act as a reservoir for future use in plant uptake. To a large degree, the soil type and climate, as well as agricultural practice, affect the movement of plant nutrients. For example, where irrigation is practiced, salts as well as nitrates can become a ground water problem. In the prairie regions, the residual fertility of these soils can add to a nitrate ground water problem even without the addition of fertilizer. The potential for nonpoint source pollution from plant nutrients is a natural one, and the degree to which the addition of fertilizer components exacerbates this problem may well be a question to be answered in the context of regional background levels based on soil type, climate, the quality of runoff, surface waters, and ground water of areas under natural cover. When the magnitude and variability of the water quality problem is illustrated by regional studies, a single comprehensive policy may not be practical.

MAGNITUDE OF POLLUTION FROM PLANT NUTRIENTS

Studies from such different regions as the Chesapeake Bay, the Great Lakes, the cropland areas of Kentucky, and other parts of the South including the Coastal Plains soils, underscore the potential seriousness of the problem created by plant nutrients when they are displaced and become pollutants. The Chesapeake Bay and Lake Erie studies reveal that excessive runoff causes pollution by plant nutrients. The Lake Erie Wastewater Management Study concentrated on phosphorus losses accompanying soil erosion from cropland. Phosphorus is considered to be the limiting factor in eutrophication of Lake Erie, and the Study's objective was to improve water quality by controlling phosphorus. In 1980, the Study revealed that 8,400 MT/yr or 51 percent of the total Lake Erie phosphorus loading came from runoff (nonpoint source) from rural land, principally cropland (U.S. Army Corps Eng., 1983).

The Chesapeake Bay study indicated that nonpoint source runoff from cropland is currently responsible for the greatest amount of nutrient load to the Bay. Nonpoint sources contribute approximately 67 percent of the nitrogen and 39 percent of the phosphorus load to the Bay (Macknis, 1984).

In the South, the source of nitrates in ground water has not been well identified nor have fluctuations in concentration been as sensational as in other parts of the country. A study of nitrogen contents in shallow ground water in the North Carolina Coastal Plain indicates that nitrate concentrations in the upper part of the ground water under fertilized cropland are greater than under adjacent wooded areas, and that nitrate levels are most likely to be higher under the better drained soils than under adjacent wet sites (Gilliam et al. 1974). A greater incidence of high water tables and tighter soils may contribute to a greater incidence of denitrification, especially with respect to Coastal Plain soils. However, separate studies in Georgia and North Carolina showed nitrate concentrations increased in surface waters after stream channelization (Bliven et al. 1980; Heath, 1975). The increases were attributed to the deeper channelization penetrating the shallow ground water table.

Many studies of nitrate concentrations in stream waters are concerned with subsurface flow. In Georgia and elsewhere most of the nitrate applied as nitrogen fertilizers is moved into the soil during the first few minutes of rainfall (White et al. 1967). Some of it then reappears in surface waters from tile drainage and subsurface flow. Subsurface flow of water in soils underlain by plinthite in the upland Georgia Coastal Plain is responsible for 99 percent of the total nitrate lost (Hubbard and Sheridan, 1983). Studies of North Carolina Coastal Plain soils show that nitrate enters surface streams via tile drainage flow (Gilliam et al. 1978). In the Lake Erie Basin, monitoring of storm events shows that most of the nitrate reaches surface water sampling stations during the falling portions of the hydrograph, in contrast to sediment and phosphorus.

The contribution of this nitrate to drinking water can be significant, and has reached major proportions in the Sandusky River in northwestern Ohio. Nitrate exceeds the standard limit for drinking water about 4 percent of the year, and about 16 percent of the time during May, June, and July (Baker, 1985). In addition to high mineralization and nitrification of organic N during those months, fertilizer use is most frequent then. Total N losses via stream flow are equivalent to about 43 percent of the fertilizer N applied (Baker, 1985). Some of this loss could, of course, have originated from organic sources; but in any event, serious implications for the fertilizer industry are evident.

Knowledge about the link between fertilizer nitrogen application and the nitrate concentration in drinking water also comes at a time when increased nitrogen application rates on agricultural lands are predicted. While a case can be made that fertilizer nitrate losses need to be weighed against potential improvements in nitrate utilization by the crop, the fact remains that nitrogen placed on croplands in a single application early in the season may be susceptible to loss to surface and ground waters.

CONTROL PRACTICES

Some steps have been taken toward abating pollution caused by plant nutrients. The first two steps in abatement usually involve identifying and inventorying the extent of the problem and projecting reasonably attainable goals (in terms of time, cost, and percent reduction).

The Lake Erie Wastewater Management Study can serve as an example. This investigation of nonpoint sources of phosphorus loading led to identifying soil erosion from cropland as a major source of the problem. The second step was to make projections on reducing soil erosion. This depended on the types of conservation practices instituted. A land resource information data base helped calculate potential soil erosion in the Lake Erie Basin. The conclusion: reduced tillage in suitable areas would achieve a 40-percent reduction of the erosion potential, and both no-till and reduced tillage could attain a reduction of 69 percent of the erosion potential in the Lake Erie Basin. The present goal is to reduce erosion by 48 percent, thereby reducing phosphorus loading of Lake Erie by 32 percent over a 20-year period, with 90 percent of the reduction occurring in the first 7 years (U.S. Army Corps Eng. 1983).

With goals identified, erosion control depends on a set of methods known as best management practices. BMP's tailor a management system for a specific site and can depend on a number of factors ranging from environmental, land, and economic considerations to effectiveness of a certain practice. For example, in certain parts of the Lake Erie Basin where plant-available phosphorus levels can be high, yearly soil tests are suggested to determine if phosphorus supplements are even needed during that growing season. In North Carolina and Virginia, buffer strips along waterways are employed to entrap phosphorus and associated sediment originating from field runoff, thus reducing nutrient loading and turbidity.

BMP's that control phosphorus are linked to controlling erosion. However, considerable question remains as to the control of nitrogen. Studies in North Carolina using buffer strips for sediment and phosphorus control have been expanded to consider nitrate control, especially from tile drainage and natural subsurface flow. Because the woody shrubs and trees in this riparian ecosystem–buffer zone can remove nutrients from subsurface flow, attempts have been made to study and manage this alluvial storage of nutrients for uptake by riparian vegetation. Careful management of these zones can prolong the usefulness of this riparian ecosystem as an energy source and as a nutrient filter (Lowrance et al. 1985).

The no-till system has received increased interest as both an energy-saving and erosion control measure in the South and East. A comparative study in Maryland of nutrient losses from two watersheds, one in conventional corn production and the other in no-till corn, reports a ninefold decrease in the amount of runoff with no-till corn; a twentyfold decrease in total P runoff with no-till corn; and a corresponding tenfold decrease in both NO_3–N and total nitrogen in runoff with no-till corn (Angle et al. 1984). A similar decrease in nitrate runoff was seen in no-till soybeans on soils formed in northern Mississippi loess (McDowell and McGregor, 1980). However, studies of ground water pollution from nitrate, particularly in the Midwest, cause concern about this nutrient moving into the ground water, especially when soils are of medium texture and well drained.

UNCERTAINTIES IN PLANT NUTRIENT CONTROL

As the preceding discussion intimates, the nutrient of major interest is nitrate. Largely because of its high mobility, nitrate may be extremely difficult to manage. Studies concerning the mobility of nitrogen in the plant/soil environment underscore growing concerns about nitrate's role as a source of pollution. Despite other researchers' concerns that the potential for leaching of nitrates to the ground water may be greater with no-till, a study in Kentucky seems to indicate that the potential for nitrate loss to ground water is related more to application rates than to tillage practices (Smith et al. 1984). Furthermore, questions remain as to the percent N tied up in crop residues and microbial populations, and the percent N that could be recovered in the grain a year after application.

Increased interest in residue management for no-till cultivation has also increased concerns about nitrogen leaching. Residue management in no-till requires the subsurface application of fertilizer and pesticides in the soil to reduce their loss from runoff without residue incorporation (Baker and Laflen, 1985).

Researchers have established the benefits of using and managing the riparian zone parallel to the Atlantic Coastal Plain rivers to control nitrate in subsurface flow and sediment and phosphorus in surface runoff. But this buffer zone is itself an ecosystem, and is of value only if it is used and monitored wisely. It cannot be regarded as a sink. The extent to which this nitrogen can be managed so that it remains in place until used by the riparian vegetation is a crucial question.

Also, predicted increases in ground water pollution based on projections of continued (and growing) high nitrogen rates, tillage practices, and other agricultural practices are questionable because of current efforts to inhibit N losses by controlling nitrification rates. If nitrification is controlled in such a way that nitrate is made available when needed by the plant, the nitrogen application rate may actually decrease in the future. The same concept holds for controlling losses of fertilizer nitrogen from volatilization. Reducing volatilization can decrease the rate of nitrogen application, and perhaps result in cutting projected losses to surface and ground waters.

NEEDS FOR FUTURE RESEARCH

A discussion of uncertainties necessitates deliberation of future research needs. The control of phosphorus losses through control of runoff and erosion is more certain than control of nitrogen losses. Future research must attempt to understand more completely the role of fertilizer nitrate as a nonpoint source pollutant.

Attempts to understand nitrate from a fertilizer point of view will involve studies in:

1. Use of various forms (ammonium, amide, nitrate) of N-fertilizers;
2. Use of urease and nitrification inhibitors;
3. Fertilizer application timing and placement system as it relates to crop requirement;

4. More thorough ^{15}N tracer accounting of nitrate pathways and losses;

5. Assessment of natural background levels of nitrate in ground water for different climatic and soil regions;

6. Assessment of BMP's for controlling nitrates given the crop under production; and

7. Careful monitoring and use of the riparian ecosystem for the eastern Coastal Plain.

Studies show that nitrate can be a problem in some areas. Is it confined to these identified pockets or is it a more general problem? We need to know how serious and pervasive nitrate is as a nonpoint source pollutant in ground water. Research should be expanded to provide this information.

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NONPOINT SOURCE POLLUTION: MANAGING NUTRIENTS A KEY TO CONTROL

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The problem of nonpoint source pollution came to light with the report from the Chesapeake Bay Study Committee and was confirmed by the Lake Erie Waste Water Management Study and reconfirmed by the Lake Wallenpaupack Study. While different agencies performed each study, the findings were almost an exact schematic. All of them found the major problem was excess nutrients: nitrogen and phosphorus. Nitrogen is very unstable, and can be leached from the soil. Phosphorus, on the other hand, very rapidly attaches itself to soil particles, and if it leaves the soil, it leaves through erosion.

We have discovered that we know quite a lot about controlling erosion, and by applying the best conservation practices we can, to a great degree, eliminate erosion, thereby reducing the phosphorus loss. But, while we're doing this we're slowing down the flow of water. More of it percolates into the ground carrying with it nitrogen, leaving us with a "Catch 22" situation.

A conservation program has to be matched with an equally efficient nutrient management program. However, we know very little about nutrient management. A reliable test for nitrogen in the soil does not exist. Also, the tests for manure nutrients are so slow in returning from the labs that they are virtually ineffective. By the time you have the tests back, you have already spread the manure.

We found almost no research on optimum levels of nutrients. Much research shows that you could increase poor soil yield by applying nutrients, but almost nothing demonstrates where you begin to have negative yield responses from too many nutrients. Yet, we are finding farmers who, from their own operating experience, indicate they have fields that will give them reduced yields when they apply more manure. All of this convinces our agricultural people looking into the nutrient situation that:

1. We must have fast, accurate soil tests for every field;
2. We must have fast, accurate tests for the manure stored in our waste management facilities;
3. We must develop ways to transport manure from those farms with a surplus to agricultural lands that need the excess nutrients; and
4. We must develop new uses for excess nutrients, including application to forest land, incorporation and resource recovery operations, and methane digestion.

Farmers can see substantial dollar losses (as high as \$90/acre on a wet year) if they don't begin to practice effective nutrient management.

Private industry has responded to the needs of the farmer facing net dollar losses. Fertilizer dealers are no longer just trying to move products; they are requesting that farmers have soil tests for each field. The soil test analysis correlates the amount of nutrient currently in the soil with the nutrient demand of the next crop, thereby determining the amount of nutrient that should be applied. The fertilizer dealers have also begun purchasing equipment so that they can split applications of nitrogen on corn. Farmers responded so positively that the dealers are now telling them, "We can't service you this year because our equipment is totally booked up."

Farmers are forming local crop improvement associations. These associations hire a professional to help analyze the soil tests, make nutrient application recommendations, and oversee their herbicide/pesticide programs. These farmers are paying \$4 and \$5/acre for this service; but they are finding that their net savings on nutrients can total as much as \$40/acre and as much as \$20/acre in pesticide applications. These professionals are actually making moth counts, computing degree days and rainfall, and helping to space applications so they are done at the most advantageous time. Many times they are finding that one or, at times, two whole sprays can be eliminated just by good management. These are some very positive steps that agriculture itself has been taking with the government helping only by providing facts on losses incurred by not adhering to best management practices.

Some areas will be more complicated and will require governmental assistance. The installation of waste management facilities is expensive, and responsible cost-sharing between government and agriculture is going to have to be addressed. Methane digestion is a very effective way of handling hog and dairy manure; but then you still wind up with nutrient-rich water, and I think government can help determine the best ways of handling that resource.

Growing fish and algae and then selling the fish and recycling the algae through the digester may give almost a perpetual motion machine—clean water and some profit in between. Where nitrogen is the problem and phosphorus is not, we can spray the effluent on the land, not work it in, and let the nitrogen aerate off. While this method is wasteful, it may be the most practical way of handling the problem. Chicken manure presents an entirely different set of problems. Because of the excess feathers, this resource may not work in a methane digester.

Therefore, we either have to find extra land for land application or incinerate and recapture the heat for steam, using it to make electricity. This could very well be a productive adjunct to municipal resource recovery plants since it would allow the plants a more uniform daily BTU loading. In Pennsylvania we have between 200,000 and 300,000 wood lot owners. The land would make an ideal area for land application since we would be able to generate much more wood biomass if we practiced good nutrient management in silviculture.

Obviously, one of the reasons for not applying manure to woodland is because there has been no practical way to do it; but today, with the big gun spray irrigation systems and slurry pumps, this type of application may be not only practical, but advantageous. Not only do we need a lot more government help from the experiment and research side, but we also need people to physically carry the message one on one and help in a hands-on way to develop these many opportunities.

Not long ago, I saw a church bulletin board that said, "We've all seen many great opportunities brilliantly disguised as impossible situations." I think with the help of all levels of government, and with the conscious desire of the farmer's family to save dollars, we will have a very productive working partnership. I'm equally convinced that if we educate the people, enough incentive exists—we will not need laws mandating these practices. Let's convert those impossible situations into great opportunities.

AGRICULTURAL LAND TREATMENT PROJECT PLANNING FOR OFF-SITE PHOSPHORUS REDUCTION

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Vermont's 1978 Water Quality Plan for Controlling Agricultural Pollution identified excessive phosphorus loading as the primary nonpoint source of water pollution in eight major drainages to Lakes Champlain and Memphremagog. The plan also recommends that 21 watersheds within these drainages be given priority for technical and financial assistance to treat agricultural nonpoint source pollution. The Lower Winooski River in northwestern Vermont is a priority watershed within the central Lake Champlain basin.

Water quality in central Lake Champlain is deteriorating under existing phosphorus loads. Algae and weed growth in the lake plague summer recreationists and lake-shore residents and cause public beaches to close intermittently. Water transparency, total phosphorus levels, and the abundance of diatoms and blue-green algae indicate that this portion of Lake Champlain has a moderate to high level of biological activity.

The watershed contains 77 operating dairy farms, averaging 140 ha in size with 100 cows and 50 replacements. Total manure production is approximately 166,000 metric tons annually. Corn is grown for silage on the intensively cultivated cropland and soil erosion rates are as high as 58 metric tons per ha.

Phosphorus is the principal nutrient from nonpoint source pollution in the 57,000 ha watershed. Watershed loadings of 14,000 kg annually represent approximately 13 percent of the total basin's point and nonpoint phosphorus load (112,000 kg) to central Lake Champlain (Bogdon, 1978).

Although agriculture was deemed responsible for 62 percent of the watershed's nonpoint phosphorus, a logical plan of treatment could not be developed without determining the relative contribution of each farm. Toward this end, Soil Conservation Service (SCS) specialists used four computer models to assess the amount of phosphorus generated by each source on individual farms. The five major agricultural sources of phosphorus evaluated were: soil eroded from cropland, livestock concentration areas, field-spread manure, milking center wastewater, and field stacks of manure. After comparing the relative amount of phosphorus loading by each farm, SCS and local authorities designated 52 farms for land treatment priority. In those priority areas the models were used to select the most cost effective treatments.

Phosphorus from eroded soil was calculated with the Phosphorus Reduction Model (PHRED). The basis for this model's soil erosion calculations was the Universal Soil Loss Equation (USLE) (U.S. Dep. Agric. 1978). Soil loss from sheet and rill erosion was quantified field-by-field using USLE's five variables: rainfall, soil erodibility, slope length and steepness, cover and management, and existing treatment practices. A soil's total content of adsorbed phosphorus was established through laboratory analysis of each soil. The total amount of phosphorus from erosion was then determined by the PHRED model as the product of: soil loss per unit area per year, field size, the soil's total phosphorus concentration, an enrichment rate to allow for the finer soil particles in sediment, and a sediment delivery ratio.

The model measured the effectiveness of Best Management Practices (BMP's) through an evaluation of erosion reduction and the corresponding phosphorus levels. PHRED also quantified phosphorus from field-spread manure. For this the model incorporated the following variables: phosphorus needs of the crop grown, the rate and season of manure application, and incorporation of the manure into the soil. The total quantity of manure for a given farm was determined by the number and breed of livestock. The amount of manure available for spreading, however, was based upon a proportioned reduction of this total to reflect pasturing practices. The model applied the available manure seasonally to cropland and hayland at rates identified by the farmer. Phosphorus loss was calculated using mass values in quantities per unit area derived from literature sources (U.S. Dep. Agric. 1979).

For field-spread manure, the PHRED model evaluated treatment by reducing manure application levels to the recommended agronomic rate (the rate calculated to be beneficial for plant growth by meeting a particular soil's fertility requirements.) The model also considers any seasonal variations of application or incorporation due to proper manure storage and utilization. BMP accomplishments were determined by the extent of changes in quantities of manure applied, season of application, and proper incorporation.

Livestock concentration area (LCA) runoff was evaluated with the Barnyard Area Runoff Nutrient Yield program (BARNY). This program utilized methods described by Young et al. (1981).

BARNY determined runoff from an LCA by using the size and hydraulic characteristics of the drainage areas entering the LCA and the seasonal distribution of rainfall events of various size. An average manure pack for each season was also estimated using animal type, amount of daily use, and scraping interval. Seasonal phosphorus runoff was the product of runoff, and the phosphorus concentration determined by the average manure pack. The model also predicted phosphorus reduction when runoff from the LCA passed through a vegetative buffer. The amount of reduction was established by evaluating the slope gradient, slope length, and cover condition of the buffer.

BARNY helped analyze treatment of LCA's with BMP's that would change the drainage area size, animal use, and scraping intervals or increase the buffer efficiency.

Phosphorus contributed by a farm's milkhouse wastewater effluent was predicted with a model similar to that used for LCAs. Water usage within the milkhouse was considered as a factor of both fixed and variable needs (U.S. Dep. Agric. 1975). Those needs considered fixed for each farm did not vary by size or type of system and included such items as cleaning the bulk tank. Variable needs, such as cow preparation and equipment cleaning, were influenced by the type of milking system and herd size. Phosphorus output was calculated as the product of total water usage and an effluent concentration (Regan et al. 1981). The effect of a vegetative buffer was determined with the same equations used in the Barnyard Area Runoff Nutrient Yield Program.

Plan development anticipated milkhouse waste treatment with BMP's that would reduce the amount of effluent, or change the vegetative buffer factors in the model.

The model used to identify the amount of phosphorus contributed by manure stacked in the watershed was based upon information reported by Draper et al. (1979). Phosphorus from this source was predicted using reported levels of runoff and amounts of manure stacked. A distance of travel in overland flow was also considered for linear attenuation of phosphorus as discussed in the study. Treatment in this case assumed complete control with an approved storage system.

The watershed protection plan developed with these four models will reduce biologically available phosphorus from agricultural sources by 51 percent when fully implemented. This reduction will be accomplished by BMP's installed at a cost of 1.3 million dollars, shared equally between the Soil Conservation Service and private landowners. BMP's planned include conservation cropping systems, conservation tillage, contour farming, stripcropping, and animal waste management systems.

Although these four models need further validation, their use during planning of the Lower Winooski River watershed provided three major benefits. First, aggregation of the data by farm enabled planners to specify the major sources of pollution and to set priorities for treatment. Second, treatment areas could be evaluated and the cost efficiency and accomplishments of various alternatives identified for decision makers. Third, such targeting of planned treatment provided for a greater efficiency in the use of Federal expenditures for treating agricultural nonpoint source pollution in the Lower Winooski Watershed.

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