Nonpoint Sources of Pollution to the Great Lakes Basin

Based on the Findings of a Workshop to Assess the Status of Nonpoint Source Pollution Control in the Great Lakes Basin

Toledo, Ohio, September 16-18, 1998

Workgroup on Parties Implementation

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1. BACKGROUND

1998 marked the 20th anniversary of the final reports of the Commission's Pollution From Land Use Activities Reference Group (PLUARG). PLUARG produced a body of work that remains the cornerstone of current thinking about non-point source pollution in the Great Lakes and elsewhere. Twenty years after PLUARG the Workgroup on Parties Implementation sought to assess the status of non-point source pollution control in the Great Lakes basin, particularly progress by the Parties under Annexes 3 and 13 of the Great Lakes Water Quality Agreement. To that end, the Workgroup sponsored a special session at the Great Lakes soil erosion and sediment control conference, held in Toledo, Ohio, September 16-18, 1998. The following report summarizes the findings of that session.

1.1 Session Format

The Workgroup commissioned two major papers from leading experts in urban and agricultural non-point source pollution control. The first of these was from Mr. Tom Schueler, Executive Director of the Center for Watershed Protection, Washington, D.C., on the topic of Source and Controls of Pollutants in Urban Runoff. The second was from Professor Terry Logan, a member of the Environmental Sciences faculty at Ohio State University and a former PLUARG participant. Dr. Logan spoke on the topic "Non-point Sources of Pollutants to the Great Lakes - 20 Years Post PLUARG."

In addition to these two speakers, the session included a panel of four experts: Dr. Trevor Dickinson, Emeritus Professor of Water Resources Engineering, University of Guelph, and a former PLUARG participant; Dr. Roger Brook, Professor of Agricultural Engineering, Michigan State University; Mr. Michael Hunter, Certified Crop Advisor, Bruce AgVise, Ontario; and Mr. Peter Johnson, Soil and Crop Advisor, Ontario Ministry of Agriculture and Food.

The session was attended by about 25 participants, and the breadth of experience within this group contributed markedly to the lively technical discussion during and following the formal presentations.

1.2 Requirements under the Great Lakes Water Quality Agreement

Two annexes of the GLWQA are relevant to the control of non-point sources of pollution. Annex 3, on the Control of Phosphorus, has several key provisions, as follows:

Section 2(c) requires "Reduction to the maximum extent practicable of phosphorus introduced from diffuse sources into Lakes Superior, Michigan, and Huron; and the reduction by 30 percent of phosphorus introduced from diffuse sources into Lakes Ontario and Erie, where necessary to meet the loading allocations to be developed pursuant to paragraph 3 below, or to meet local conditions, whichever is more stringent."

Section 2(e) requires "Maintenance of a viable research program to seek maximum efficiency and effectiveness in the control of phosphorus introductions into the Great Lakes."

Section 4(a) of the Annex Supplement calls for the implementation and evaluation of phosphorus load reduction plans using a staged approach.

Section 5(d) of the Annex Supplement requires the Parties to undertake non-point source programs and measures, including:

(i) "Urban drainage management control programs where feasible consisting of level 1 measures throughout the Great Lakes basin; and level 2 measures where necessary to achieve reductions or where local environmental conditions dictate . . . ; and

(ii) "Agricultural non-point source management programs where feasible consisting of level 1 measures throughout the basin and level 2 measures where necessary to achieve reductions or where local environmental conditions dictate . . . "

Where Level 1 source control options include:

"Agricultural: adoption of management practices such as: animal husbandry control measures, crop residue management, conservation tillage, no-till, winter cover-crops, crop rotation, strip cropping, vegetated buffer strips along stream and ditch banks, and improved fertilizer management practices.

"Urban: adoption of management practices such as: erosion controls, use of natural storage capacities and street cleaning."

and Level 2 source controls include Level 1 plus:

"Agricultural: adoption of intensive practices such as: contour plowing, contour strip cropping, contour diversions, tile outlet-terraces, flow control structures, grassed waterways, sedimentation basins and livestock manure storage facilities.

"Urban: adoption of practices such as: artificial detention and sedimentation of stormwater and runoff and reduction of phosphorus in combined sewer overflows."

Section 5(e) of the Annex Supplement requires the Parties to **"make special efforts to assure that their research activities will be responsive to the Programs and Other Measures described herein."**

Section 5(f) of the Annex Supplement requires that the Parties to **"develop and implement surveillance and monitoring measures to determine the progress of Phosphorus Load Reduction Plans for the Lower Lakes as called for under Section 4 above, and to evaluate efforts taken by the Parties to reduce phosphorus in the Great Lakes basin. These measures will include an inventory of areas treated, watershed modelling and improved measurement of tributary loadings to the Lower Lakes for the purpose of providing improved non-point source loading estimates and the monitoring of mass loadings to the Upper Lakes to maintain or improve the environmental conditions described in Section 3(b)."**

Annex 13, Section 2 of the Agreement, on Pollution from Non-point Sources has the following key provisions:

(a) **"identify land-based activities contributing to water quality problems described in Remedial Action Plans for Areas of Concern, or in Lakewide Management Plans, including but not limited to phosphorus and Critical Pollutants; and**

(b) **"develop and implement watershed management plans, consistent with the objectives and schedules for individual Remedial Action Plans or Lakewide Management Plans, on priority hydrologic units to reduce non-point source inputs."**

Annex 13 further requires in Section 4 that surveillance, surveys and demonstration projects be implemented to determine:

(a) **"non-point source pollutant inputs to and outputs from rivers and shoreline areas sufficient to estimate loadings to the boundary waters of the Great Lakes system; and**

(b) **"the extent of change in land-use and land management practices that significantly affect water quality for the purpose of tracking implementation of remedial measures and estimating associated changes in loadings to the Lakes."**

Furthermore, Section 4 emphasizes the importance of demonstration projects of remedial programs on pilot urban and rural watersheds to advance knowledge and enhance information and education services, including extension services, where applicable.

It was pointed out at the session that progress in these areas was significant through the 1980s but has flagged over the past decade. In part, this may be because other issues, such as concern for persistent toxic organics, became prominent in the environmental agenda and eventually took precedence over issues that were generally believed to have been "solved." Nevertheless, *it became apparent during the workshop that non-point sources of pollution to the Great Lakes basin remain a serious issue, and that phosphorus levels are far from under control.* In view of the fact that non-point sources of pollution are significant in a number of Areas of Concern, and therefore that remedial actions in those areas remain to be developed, the findings of this session also have important implications for the management of Areas of Concern and for Lakewide Management Plans.

The following discussion highlights some of the issues raised in the discussion, and recommends specific actions by the Commission.

1.3 Progress to Date

One of the key points of discussion was that the Great Lakes basin of today is significantly different from the basin of 20 years ago. Indeed, in the opinion of the keynote speakers, these *fundamental changes in the basin may be far more important than the presence or absence of controls in influencing pollution levels.* Two of the most important forces identified were:

- increased urbanization, making a higher proportion of the basin land surface impermeable to rainfall and runoff; and
- global market forces, forcing high efficiency in agriculture and encouraging movement away from smaller family farms to large, intensive operations, especially confined animal feeding operations (CAFOs).

These forces have fundamentally changed the nature and distribution of non-point sources of pollution to the basin over the last 20 years. With increased urbanization, more of the land surface is paved and roofed, and more rainfall is diverted into storm drainage systems. Natural drainage patterns are overridden by constructed systems that are smoother (allowing water to flow faster) and warmer than the undisturbed land surface. As little as 10 percent impervious cover – roughly equivalent to a house and driveway on a one acre lot – can alter stream stability, causing faster flooding and increased bank erosion. The same stream may take decades or centuries to restabilize.

In addition to increased "flashiness" of flows and associated erosion, urban stormwater can create significant water quality impacts. As stormwater passes over city streets and parking lots, it picks up dirt and litter, including animal feces, and washes these pollutants into receiving waters. Although most newer urban development includes stormwater treatment systems, such as retention ponds, many of these are now reaching the end of their useful lives. Most stormwater structures are in any case poorly maintained, so removal efficiencies for many pollutants may be very low. Although lead concentrations in urban stormwater have declined in recent years, in part because of the elimination of lead additives for gasoline, concentrations of zinc, cadmium, copper, PAHs, and total hydrocarbons continue to increase. These materials are of concern because of a variety of human and environmental health issues, both chronic and acute.

Phosphorus and nitrogen, arising primarily from residential and commercial lawn fertilizers, continue to pose eutrophication problems in the urban environment, and available stormwater management technologies are inadequate to remove these pollutants completely. Maximum removal rates for phosphorus and nitrogen may be only about 60 percent and 40 percent, respectively, using typical stormwater treatment methods. Microorganisms, always a matter of concern in urban drainage, have emerged as a important point of concern, both because of their potential impacts on human health and because the biology and pathways of these organisms are poorly known.

In rural areas, economic forces on agriculture have forced a move toward intensive farming, often in large-scale operations quite different from the traditional family farm. Two effects have arisen from this move. First, livestock operations have tended to move towards CAFOs, which produce large volumes of manure and related wastewaters. If not properly managed, these concentrated waste sources can have a dramatic impact on local receiving waters.

A second influence in agricultural portions of the basin has been the gradual implementation of soil conservation practices, such as conservation tillage and no-till, throughout the basin.

Some regions have embraced these practices more enthusiastically than others. Several participants noted that, because of high local acceptance, or topographic, soil, or crop factors, we appear to be approaching the limits of acceptance and/or effectiveness of available soil conservation technology in some areas. *These comments underscored the need for local measures tailored to local needs throughout the basin*. Conservation tillage clearly remains a powerful tool in some parts of the basin, but where it has been fully implemented and non-point source pollution remains a problem, other measures, for instance advanced treatment systems, may be appropriate.

Presentations and comments at the workshop indicated that phosphorus issues are far from resolved in the basin, despite more than a quarter century of effort. Nitrogen levels in the basin have shown little change over the past 20 years, but soil phosphorus levels continue to rise, even though fertilizer use has stabilized. The reason for this is that application rates continue to exceed demand, allowing a buildup of phosphorus in the soil. In some areas, soil phosphorus is so high that it could take 15 or 20 years for levels to return to pre-settlement conditions, even without further addition of phosphorus. This phenomenon is probably tied to the economics of crop production – farmers are unwilling to risk reductions in fertilizer application, and thus in crop yield, so they continue historic over-application practices. Moreover, phosphorus is sometimes used to give crops a "quick start" to help seedlings become established rapidly to insure against damage to crops from extreme weather events.

As in urban systems, microorganisms have emerged as an issue of particular concern, especially following recent *Cryptosporidium* outbreaks that may have arisen from animal wastes.

The full range of pathogens, their biology and pathways, and appropriate control/treatment methods are still largely unknown, but are likely to be important avenues for future investigation. Intensive animal operations are usually located in areas of lower land value, and therefore away from urban areas and the Great Lakes shoreline. They may, however, impact receiving waters through local drainage systems.

In contrast to rising concern about pathogens, pesticide use was viewed by participants as much less problematic than it was even a decade ago, in part because of the advent of new products with very short half-lives and low persistence, and also because of improved pesticide storage, handling, and user training programs.

In addition to known and emerging pollutant sources, participants raised the issue of uncertainties in climate change and weather patterns, and their potential to impact the distribution and abundance of water resources. New technologies, such as "precision agriculture" (discussed below), may help us do the "right thing at the right time" in responding to climate and weather change, but only if those technologies are economically feasible, understood, and used by farm operators.

Although we now have much better general information about the nature and importance of sources, most of this information is derived from inference and not from direct measurement. *In fact, we have few direct measurements of loads, especially the detailed chemistry (for instance of phosphorus species) that may be relevant in assessing the effectiveness of proposed controls.* As governments scale down their monitoring and surveillance efforts, these data are becoming scarcer and older. *Without strong data, we lack proof of cause and effect relationships, and therefore cannot make sound management decisions with confidence.* Computer models of agricultural systems, for instance, too often rely on inadequate data to make predictions that are influential in guiding (possibly erroneous) management decisions. The paucity of good data on non-point source loads and their impacts on environmental decisions has contributed to confusion about appropriate actions and endpoints, and is a major obstacle to further progress on commitments made in the Great Lakes Water Quality Agreement.

1.4 Emerging Technologies

Comments from panelists and participants alike indicated that we are now reasonably well informed about the general characteristics of sources (with the notable exception of microorganisms), and the limits of control technologies. Many of the actions recommended for phosphorus control under Annex 3 have been implemented throughout the basin. But as watersheds develop, populations increase, and pollution sources multiply, it has become difficult even for well-informed water managers to hold the line on non-point source pollution. Level 1 and Level 2 actions identified in Annex 3 apparently are not, in themselves, any longer sufficient for the control of non-point sources. Instead, it will be necessary to develop new technologies *and* to couple those new approaches with existing methods and improved land-use planning.

Emerging technologies for control of non-point source pollution generally take two forms: modification of technologies in use in other industrial or municipal sectors; and optimization of nutrient and soil management through new microprocessor technologies. Control at source was considered by participants to be critical. The following were some of the new technology directions identified by participants.

Urban Systems

In the urban environment, source control implies both reduction of runoff volumes and control of pollution sources. An emerging management approach centres on reduction in the percentage of the land surface that is impervious, through a variety of land-use planning techniques. (Permeable paving, once touted as a promising method of achieving this end, has proved to be much less effective than anticipated, largely because of frost heave and clogging problems.) Examples of promising approaches include planning that incorporates smaller streets and fewer cul-de-sacs in the urban environment. Even a 20 to 30 percent reduction in the impervious cover, coupled with 40-60 percent reduction in nutrient loads (a reduction that should easily be achievable using existing technology) would bring nutrient and sediment loadings back to near presettlement levels. Retrofitting or redesigning older areas will be cumbersome and costly, although these techniques may offer some potential in the long run. Clearly, the preferred approach here is to emphasize better planning for urbanizing areas, to incorporate both structural measures and planned reduction in the percent imperviousness of the land surface.

The key obstacle in the urban environment is therefore not primarily technological but rather institutional. The required linkage between land-use planning and pollution prevention implies a close and ongoing connection between planning and regulatory bodies – a connection that may not be present or even endorsed in all jurisdictions. Furthermore, communities have grown accustomed to wide and numerous streets, and may be reluctant to accept urban design that deviates from familiar patterns. Public education may therefore be an important element of urban non-point source pollution control.

Public education is also an essential component of source controls in the urban environment. In particular, pet feces (controllable through "stoop and scoop" by-laws), storm drain markings (to discourage disposal of wastes) and similar measures may be helpful in reducing inputs from residential areas. The role of lawn watering and lawn fertilization is as yet unclear, but may be significant in some areas.

Rural Systems

Emerging agricultural technologies include onsite drainage (or water table) management, where runoff is held on the site until the storm event has abated and flows can be released safely into receiving waters. (Such approaches would parallel existing technologies used for urban stormwater management.) Riparian zones, used in conjunction with tile drainage sites, may reduce the impacts of agricultural runoff. Both approaches require large land areas, however – a constraint that may limit their utility in some areas. Manure brokering, auctions, and direct sales could provide another method of transferring excess wastes to areas where they can be better utilized. New chemical technologies, borrowed from municipal sewage treatment technology, can assist farmers in immobilizing phosphorus from wash waters and manures, while biological treatment can assist in reducing nitrogen levels. Manure disinfection or other processing, also based on available municipal technologies, could also reduce the impact of animal wastes on receiving waters. Such approaches would, however, require significant education in the agricultural community, and some may entail significant costs, beyond those acceptable by most farmers.

One important new direction in non-point source pollution control relates to nutrient trading, or as it is now better known, nutrient offsets. Under a nutrient offset system, dischargers can "trade" pollutant loads with a designated area, say a watershed. Trading can take place between two point source dischargers, between two non-point source dischargers (e.g. two farms), or between point and non-point source dischargers. The last has been the most fruitful in recent projects in the Tarr-Pamlico basin, South Carolina, and the Bay of Quinte watershed, Ontario. An example trading sequence begins with a point source discharger, such as a sewage treatment plant, deciding that further nutrient reductions are not cost-effective. That discharger then agrees to "buy" the appropriate loading reduction from a non-point source discharger. Normally, this transaction would take place through an impartial broker such as a Soil and Water Conservation Society or Conservation Authority. A fixed per-kilogram price would have been decided among the group of point and non-point source dischargers, and this price would then be paid to the non-point source discharger by the point source discharger, through the intermediary. The non-point source discharger then undertakes on-farm improvements approved by the intermediary. It is the responsibility of the intermediary to collect and disperse funds, and to audit the recipients of funding to make sure that the appropriate work has been done. The primary benefit of point-non-point source offsets is that it is possible to achieve double or triple the pollutant reduction from non-point source controls than from point sources for the same expenditure. Point-non-point source trading may therefore offer a way to achieve cost-efficiency in nutrient reductions, if regulatory challenges can be overcome (see below).

There are several difficulties with offset programs, none insurmountable. One of these is the problem of jurisdiction. Offset programs are best run at a local level, perhaps within a single watershed. But regulatory agencies, whether state/provincial or federal, are often loath to relinquish oversight of discharge permitting. The role of the regulatory agency vis-a-vis the intermediary agency becomes confused and can create obstacles to successful trading. In some jurisdictions, transferring the audit function to a third party agency may create legal complications that a regulator may wish to avoid. More commonly, regulators wish to guarantee discharger performance through permitting, but such a system can be awkward to administer if the trading takes place through, and is audited by, a third-party agency, and when required point source discharge reductions are actually achieved by a different, perhaps distant, party.

A second difficulty is that controls on point sources (for example, sewage treatment plant effluents) may affect different forms of phosphorus than controls on non-point sources. For example, most of the phosphorus in sewage treatment plant effluent is soluble reactive (bioavailable) phosphorus, so reducing total phosphorus in the effluent has an immediate benefit in reducing downstream eutrophication potential. By contrast, almost none of the phosphorus in eroded sediment or construction runoff is bioavailable; instead, it is bound to sediments and would only become available to plants slowly over weeks or months. Controls on these sources would not, therefore, have the same impact on downstream eutrophication.

Participants spent considerable time discussing the potential for "precision agriculture" - that is, selective application of seed, fertilizers, pesticides, and irrigation water using a Global Positioning System (GPS) mounted on the farm equipment. The most widely used facet of the technology is currently yield monitoring, which some of the panelists indicated is "standard equipment" on new harvesting machines. While it is clear that the technology can provide very detailed information about the condition of fields (yield, moisture content, nutrient condition, compaction, etc.) and can automatically adjust practices (fertilizer or pesticide application rate, for example), discussion at the workshop made it clear that our understanding of just what factors are important and how they interact is not yet sufficient to allow optimum use of the technology. Given that the technology is expensive, it is clear that it will not enjoy widespread implementation until it can be demonstrated to be both practical and effective in the field.

Genetic engineering of plants and selective breeding of livestock may eventually allow improved herd health and nutrition, with the result that more of the nutrients contained in food are incorporated into meat and milk, and less emitted as gaseous, solid or liquid wastes. For example, poultry are particularly inefficient at utilizing phosphorus. This necessitates feeding them large amounts of high phosphorus materials to ensure they retain enough phosphorus to be productive. Of course, this results in large volumes of high phosphorus manure. Feed made from plants genetically engineered to make phosphorus more readily available to the poultry could reduce both the volume and the phosphorus concentration in the manure. These approaches have already been demonstrated, for instance in certain highly productive cattle operations. High quality feeds and good herd health may be a simple and achievable measure for controlling nutrient emissions, and indeed are a centrepiece in U.S. EPA's program to control methane emissions from livestock.

1.5 Conclusions

1. **Progress in the control of non-point source pollution was significant through the 1980s but has flagged over the past decade. Phosphorus continues to be a major source of concern in the Great Lakes basin, both because of persistent eutrophication in some areas and because control strategies have been less effective than anticipated. Similarly, soil erosion (leading to high sediment loadings to watercourses) remains a significant problem in some areas. By contrast, nitrogen levels appear to have stabilized, suggesting that that issue is less urgent than control of phosphorus.**

2. **The Great Lakes basin of today is significantly different from the basin of 20 years ago. These fundamental changes in the basin may be far more important than the presence or absence of controls in influencing pollution levels.**

3. **The impacts of urban drainage on receiving waters are significant and must be included in any attempt to address non-point source pollution. Significant improvements in urban drainage impacts may be achievable through modest land-use planning changes coupled with appropriate and well-maintained structural measures such as infiltration trenches and stormwater retention ponds. Jurisdictional issues may, however, be thorny, because effective control of urban non-point sources demands linkages between environmental and planning agencies at several levels of government. These linkages may be entirely absent or complicated by local political or economic forces.**

4. **Knowledge of the sources, biology, and pathways of microorganisms is currently inadequate in both the urban and rural systems. The urgency of this issue has increased in recent years because of drinking water impairments at several locations in the Great Lakes basin, revealing inadequate prediction, control, and treatment capabilities.**

5. **Although trace metals and trace organic chemicals, including PAHs and pesticides, remain of concern in the urban and rural environments, they are relatively minor in mass and impact compared to phosphorus, sediment, and microorganisms.**

6. **We appear to be approaching the limits of acceptance and/or effectiveness of available soil conservation technology in some regions where non-point source pollution is still not adequately controlled. In these areas, more aggressive measures, for instance using emerging technologies drawn from industrial and municipal systems, may be necessary. In all cases, measures must be planned and managed on a local basis, in response to the needs of the local system.**

7. **We cannot rely on existing technologies, however well implemented and maintained, to resolve the nutrient and sediment loads arising from non-point sources of pollution. Both in the urban and in the rural environment, future progress must depend on a combination of technology and land-use planning on a watershed or subwatershed basis.**

8. **In urban systems, the appropriate planning unit may be much smaller than in a largely permeable agricultural watershed. Urban management systems may also have to be based on "sewersheds" – the areas served by individual sewer systems – rather than on natural drainage patterns.**

9. **Farmers need financial incentives to risk new technologies or lower fertilizer and pesticide inputs. Current low food prices and very low producer margins mean that farmers earn only a small fraction of the final product price. If farmers raise prices to reflect additional production costs, they may lose market share in competitive global markets. There is evidence, however, that consumers are willing to pay a higher price for organically grown food, thus offsetting the risk to the farmer.**

10. **Although government regulation has been an effective tool for the control of industrial and municipal point sources, it has been less effective in managing non-point source pollution, in part because of the diffuse nature of sources and the problem of assigning "ownership." Traditionally, farmers have enjoyed the "right to farm," with associated exemptions from many controls that would apply in other sectors. Farm operators are therefore likely to resist government regulation strenuously, arguing that controls must be on a site-by-site basis and developed in the context of local economic and environmental conditions. Economic incentives and education/extension programs have been and are likely to continue to be critical in encouraging progress in control of agricultural non-point sources.**

11. **In some areas, technology development may be proceeding faster than our ability to implement it effectively. Precision agriculture is a good example: the technology is now available and appears powerful, but user education, economic feasibility, and even our basic understanding of agronomy have lagged behind. It is unlikely that the agricultural community will be able to fund the necessary education, economic incentive programs, and agronomic research. This is an area where government support could be instrumental in helping this technology to reach its full potential.**

12. **Existing waste management technologies used in municipal and industrial systems may be transferable to the control of urban and rural non-point source pollution. Although the technologies themselves are clearly proven and effective, the costs of applying them to diffuse sources are as yet unknown.**

13. **The International Joint Commission has an important and central role to play in alerting the Parties and individual Great Lakes jurisdictions to the need for continued action on phosphorus, sediment, and pathogen control. It is clear that obligations under Annex 13 of the Great Lakes Water Quality Agreement cannot be met with the present level of effort. New technologies combined with improved land-use planning will be necessary to meet targets and continue the progress achieved to date.**

2. SOURCES AND CONTROLS OF POLLUTANTS IN URBAN RUNOFF

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2.1 Introduction

The stormwater, or urban nonpoint source, field is relatively new. In fact, the first comprehensive effort to characterize the quality of urban runoff did not take place until the early 1980s with the Nationwide Urban Runoff Program (NURP) study (U.S. EPA 1983). Consequently, there are still many unknowns in the field, including sources of many pollutants and effective methods to reduce pollutant loads in stormwater runoff. At the same time, municipalities began installing stormwater Best Management Practices (BMPs) that focused on improving water quality. Before this point, BMPs in the urban environment primarily focused on flood control.

Over the past 20 years, the stormwater field has advanced significantly, as scientists, engineers and stormwater program managers have learned more about the sources of pollutants in urban stormwater, and techniques that are effective at reducing pollution from these sources. Although a significant amount of research has been conducted to identify sources of pollution, there are still many urban sources of pollutants with sparse evidence linking the pollutant source to actual instream concentrations. Furthermore, while many studies have been conducted to assess the effectiveness of stormwater BMPs, there are many new technologies that have little if any monitoring data.

One of the most critical lessons gained from this experience is that an integrated approach that incorporates programmatic and land use elements as well as structural controls is needed to effectively protect water resources. This integrated approach, conducted at a relatively small subwatershed (2 to 10 square mile drainage area) scale is becoming recognized as an effective method both for reducing pollutants and protecting the habitat of water resources. Pollutant control measures would go beyond the traditional "end of pipe" stormwater controls to include nonstructural solutions such as stream buffers and redirection of new development.

Over the next 20 years, techniques that will help to control pollutant sources include: 1) reducing air pollution; 2) small watershed planning; 3) more targeted BMP selection and design and 4) maintenance and rehabilitation of BMPs constructed over the last 20 years. Finally, research will be needed over the next 20 years to better characterize the sources of pollutants in the urban environment, and means to reduce pollutant loads.

2.2 Key Urban Nonpoint Sources

Some of the most critical pollutants in urban waterways are nutrients, pathogens and sediment. Each pollutant has a different source in the urban environment.

2.2.1 Nutrients

Nutrients (nitrogen and phosphorous) have traditionally been associated with agricultural sources, but the urban environment also has significant sources of nutrients. In order to completely characterize a nutrient source, researchers need information on the source of the inputs (e.g. lawn fertilizer), outputs directly from the source area, and transport to water resources, such as lakes or streams. Three probable sources include: 1) atmospheric deposition and subsequent washoff from impervious surfaces; 2) septic system effluent; and 3) lawn fertilization. Of these three sources, the strongest evidence exists for atmospheric deposition and runoff, and the weakest is for lawn fertilization.

Atmospheric Deposition and Washoff

There is strong evidence that atmospheric deposition is a source of pollutants in stormwater runoff, and that this runoff reaches streams, rivers and other aquatic resources. Sources of airborne pollutants, or atmospheric deposition, in the urban environment include street dust, automobiles, and natural sources such as pollen. Nitrous oxide from burning fossil fuels is a major source of nitrogen. Atmospheric deposition rates of phosphorous on urban land are similar to rural deposition rates, and nitrogen deposition rates are actually lower on urban land because volatilization of nitrogen fertilizers can be significant in rural watersheds (U.S. EPA 1983).

Atmospheric deposition is a much more significant source of pollutants in urban watersheds, however, because runoff rates are significantly higher from urban land. This is because of the increase of impervious cover, in the form of rooftops, roads, sidewalks, and other pavement. As rain falls onto these surfaces, it is immediately converted to runoff, carrying away nutrients deposited on the ground surface. According to the NURP study, atmospheric deposition accounts for approximately 70 to 95 percent of the nitrogen and 20 to 35 percent of the phosphorous in urban runoff (Lugbill 1991). Surface runoff, particularly on urban land, travels directly to waterways, either through overland flow, or in the storm drain system. Thus, the pollutants in urban runoff clearly reach water resources, because there is little opportunity for treatment as runoff travels to the stream, river, lake or estuary.

Septic System Effluent

Septic systems may be a significant source of nutrients in the suburban environment. Nutrient concentrations and loads entering and leaving septic systems are well known, but it is less clear to what extent these pollutants actually reach water bodies. Typical loading rates for each person can be used to characterize inputs to septic system influent. Furthermore, data are available on the efficiencies of various systems (Table 1), and typical effluent characteristics have been derived based on monitoring (Table 2).

Table 1 Effectiveness of Various Septic System Designs

System	Average Effectiveness (%) Total Nitrogen	Total Phosphorous
Conventional System	28	57
Mound System	44	NA
Intermittent Sand Filter	55	80
Recirculating Sand Filter	64	80
Water Separation System	83	30

(Source: Ohrel 1995)

Table 2 Typical Septic System Effluent Concentration

Constituent	Concentration Range (mg/L)
Organic Nitrogen	16-53
Nitrate and Nitrite Nitrogen	0.01-0.17
Total Phosphorous	12-17

(Source: Ohrel 1995)

Groundwater and surface water interactions are not always clearly linked, and the amount of pollutants in subsurface flow that reach surface water depends on the soil characteristics, such as the amount of organic carbon in the soil. In general, phosphorous is not believed to be transported to surface waters because it is tightly bound by the soil. Nitrogen, however, can become mobile if converted to nitrates, and was found to contribute 74 percent of the nitrogen load to Buttermilk Bay, Massachusetts (Horsley and Witten 1994).

Lawn Fertilization

Less is known about the travel pathways of nitrogen and phosphorous from lawn fertilization than from atmospheric deposition or septic systems. Surveys have provided information about how much and what type of fertilizer homeowners apply, but information linking these application rates to water quality data are sparse. According to a comprehensive monitoring study in Wisconsin, lawns have a higher concentration of both dissolved and total phosphorous than any other source (Bannerman et al. 1992). However, the study was unable to conclude that fertilization was necessarily the source of the phosphorous. Even less information is available regarding the transport of nutrients applied on urban lawns to streams, rivers and lakes. Little dry weather monitoring information has been collected to relate the concentrations in urban water bodies due to leaching of nitrogen or phosphorous from lawns (Barth 1995).

2.2.2 Pathogens

Sources of pathogens in urban areas include washoff of non-human bacteria and wastewater discharges from failed septic systems, Combined Sewer Overflows (CSOs), Sanitary Sewer Overflows (SSOs) and illicit connections.

Non-Human Bacteria

Non-human bacteria from dogs, cats, racoons, beavers and other wildlife are a significant source of bacteria in urban runoff. In fact, results of studies of genetic markers indicate that over 95 percent of coliforms found in urban stormwater are from non-human sources, with dogs accounting for the greatest fraction (Schueler 1998). Although these bacteria are from non-human sources, they pose significant human health hazards, because bacterial concentrations often far exceed human health standards. For example, fecal coliform concentrations in urban runoff are approximately 20,000 per 100 ml (Pitt 1998), while the human health standard is only 200 per 100 ml.

Wastewater Discharges

Bacteria concentrations in wastewater discharges from septic systems and combined sewer overflows are generally about two orders of magnitude higher than concentrations in urban runoff (Pitt 1998). However, the importance of these sources varies widely from watershed to watershed. In the Cahaba River in Birmingham, for example, 25 percent of the dry weather flows in the system were found to be from SSO discharges and poorly operating septic tanks. Furthermore, septic tanks have the potential to contaminate subsurface drinking water supplies with pathogens, and most of the groundwater-related health complaints in the United States are from septic-system pathogens (Ohrel 1995).

2.2.3 Sediment

The three most significant sources of sediment in urban streams are channel erosion, construction site erosion, and washoff from impervious surfaces. Of these sources, channel erosion is the most significant in urban watersheds.

Channel Erosion

As urban land is developed, the hydrologic cycle shifts, with an increase in the volume of stormwater runoff, and a decrease in infiltration volumes. This shift leads to higher peak volumes from each storm event, increasing the number of channel forming events. At approximately 10 percent impervious cover, most stream channels become unstable, experiencing significant erosion (Booth and Jackson 1997). San Diego Creek, Southern California, was monitored from the 1930s to the 1980s with urban development occurring over this period. In the 1930s, channel erosion accounted for about one fourth of the total sediment load, and this fraction increased to over two thirds by the 1980s (Trimble 1997).

Construction Sites

Construction sites are the next most significant source of sediment in urban watersheds. Total Suspended Solids (TSS) concentrations from construction sites are significantly higher than from other land uses. Schueler and Lugbill (1990) found that the concentrations in uncontrolled runoff are about 4,100 mg/1 in Piedmont soils of Maryland. While using erosion and sediment control could reduce these concentrations to approximately 280 mg/L, they still far exceed typical urban runoff concentrations of 50 mg/L. Loads from construction vary widely between watersheds, depending on the amount of construction in the watershed. In addition, the amount of sediment transported to larger water bodies depends on the particle size and watershed size.

Urban Runoff

The concentration of sediment in urban runoff is much lower than in construction site runoff, however it is still about twice as high as the concentration from natural areas (e.g. forest). One of the primary sources of this sediment is tire wear on streets. In fact, TSS concentrations from streets are higher than the concentration from any other source in the urban landscape (Bannerman et al. 1992). In addition, atmospheric deposition may represent a significant source of sediment in urban runoff.

2.3 Techniques That Have Reduced Pollutants In Urban Runoff

Stormwater BMPs have been the primary tool to improve the quality of urban runoff. Many of these BMPs have been successful at reducing stormwater runoff concentrations, but proper maintenance and siting are needed to guarantee good removal. Furthermore, there are limitations regarding what BMPs can accomplish even under the best circumstances.

2.3.1 Effectiveness of Various Stormwater BMPs

The BMPs presented in Table 3 have a substantial ability to reduce pollutants in stormwater. In general, BMPs are selected based on their ability to remove total suspended solids. However, performance at removing other contaminants, such as nitrogen or phosphorous, may be a useful selection criterion.

Some other BMPs have high suspected removal rates, but they have not been monitored extensively, either because they are a new technology or because they are difficult to monitor. Two of these BMPs include:

- **Infiltration Trenches:**
  They have a high estimated removal rate, but are difficult to monitor
- **Bioretention:**
  These BMPs have a high estimated removal rate, but are a relatively new technology

2.3.2 Caveats of BMP Effectiveness

Although stormwater BMPS have the potential to reduce pollutant concentrations in urban runoff, there are limits to this effectiveness. First, the performance of BMPs can be severely compromised by poor design and maintenance. Second, BMPs as they have been designed in the past have not been able to prevent channel erosion. Finally, bacteria removal rates are not nearly high enough to meet water quality standards.

Table 3 Selected Pollutant Removal Performance for Stormwater BMPs

	BMP	Median Stormwater Pollutant Removal (percent)					
		TSS	TP	Sol P	TN	Nitrate	Bacteria
Ponds	Wet Pond	77	47	51	30	24	--
	Wet ED Pond	60	58	58	35	42	--
	Overall	67	48	52	31	24	65
Wetlands	Shallow Marsh	84	38	37	24	78	--
	ED Wetland	63	24	32	36	29	--
	Pond/Wetland	72	54	39	13	15	--
	Overall	78	51	39	21	67	77
Sand Filters		87	51	-31	44	-13	55
Swales		81	29	34	--	38	-50

ED = Extended Detention

(Source: Schueler 1996)

Poor Design and Maintenance

Pollutant removal data for BMPs is very variable, at least partially because the design of stormwater BMPs has not been standardized. For example, the treatment volume required varies between municipalities. In general, BMPs that dedicate a larger volume to treating runoff, either through the use of a permanent pool or by detaining stormwater, have higher removal efficiencies. One study compared two ponds of different storage volumes. While the first provided approximately 1.4 acre-feet of storage per impervious acre, the second provided less than 0.1 acre-feet per impervious acre. The larger pond reduced suspended solids concentrations by approximately 92 percent, while the smaller pond had a more modest removal rate of 62 percent (Schueler 1995a). In addition, many BMPs do not incorporate design features that facilitate maintenance. Over time, the BMP performance declines as the volume reserved for treatment becomes filled with sediment. In addition, some BMPs such as infiltration trenches and basins can become clogged if not properly maintained.

Inability to Control Channel Erosion

In the past the two-year storm has been used as the design standard for controlling stream erosion. Recent research, however, indicates that this control is ineffective at reducing channel erosion. A survey of 30 reaches totaling 4.1 miles of channel showed that channel widths increased an average of 1.7 times compared to pre-development channel widths, even with the use of BMPs designed to reduce channel erosion (MacRae 1996). This is because the frequency of the “bankfull,” or approximately two-year storm increases in urban watersheds, and sizing for the less frequent, two-year storm does not account for the storms that cause most of the channel erosion (MacRae and Marsalek 1992).

Bacterial Removal Rates Cannot Meet Water Quality Standards

The ability of stormwater BMPs, to reduce bacteria concentrations varies widely, with some BMPs actually showing negative removal rates (See Table 3). Even the most effective BMPs cannot reduce bacteria rates significantly to meet human health standards. Concentrations of fecal coliform, typically exceed human health standards by a factor of 100 (Section 2-2), and no BMPs have greater than 80 percent removal rates. Although some design features, such as longer detention times, can improve this performance (Schueler 1998), these data suggest that nonstructural options, such as pet waste ordinances, may be more effective at achieving these standards.

2.4 BMPS THAT HAVE NOT WORKED

Several BMPs have not been successful, either because they do not have the capability to remove pollutants, or because they are impractical from a maintenance standpoint. Still, other practices have very little evidence to demonstrate their effectiveness. The BMPs that have shown poor performance include:

- conventional detention
- dry extended detention
- infiltration basins
- porous pavement
- oil/grit separators
- drainage ditches
- straw bales (for erosion and sediment control)
- public education (may work but we have very little evidence)

2.5 NEW TECHNIQUES FOR NONPOINT SOURCE CONTROL

Urban nonpoint source pollution illustrates the difficulty in addressing long-term environmental change at the local level. Development is a gradual process that spans decades and occurs over a wide region of the landscape. It is, however, composed of hundreds of individual development projects completed over a much shorter timespan, which transform just a few acres at a time. Consequently, the true scope of nonpoint source pollution may not be fully manifested at the watershed scale for many years. The challenge for local planners is that they must review and mitigate the impact of each individual development proposal over the long term within a watershed context.

This paper presents an urban watershed protection approach that attempts to provide a coherent framework for effective local nonpoint source reduction throughout the development process. In the past, communities have tried to deal with the complex range of impacts on urban nonpoint sources by adopting an equally complex series of regulations and criteria to govern the development process. However, these measures have often been less effective than anticipated. A major reason for this failure has been the tendency to regulate a single impact at only one stage of development.

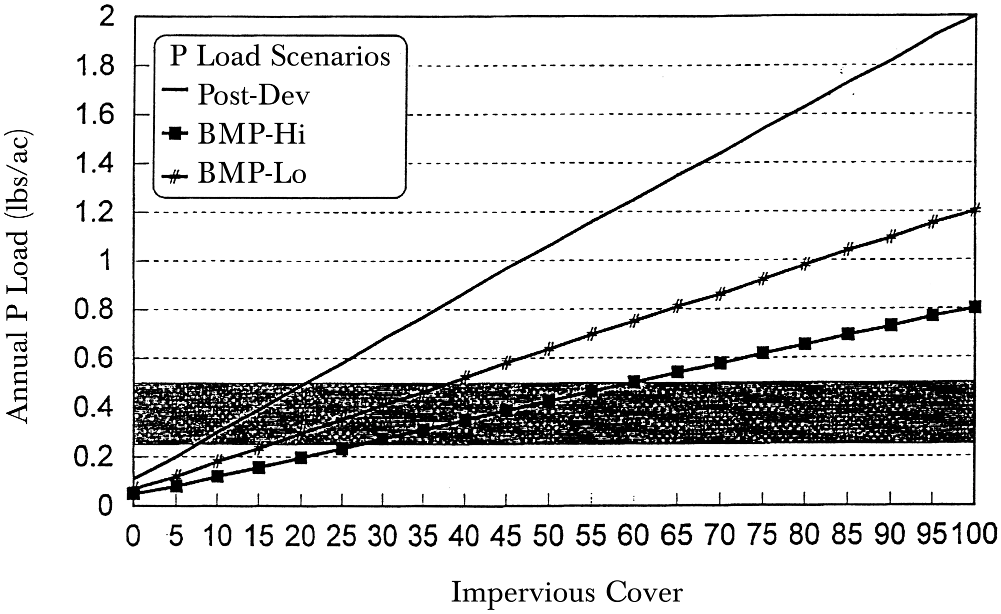

Figure 1 Phosphorus Loading with Increasing Impervious Cover

The gray band indicates typical "background" phosphorus loads from undeveloped watersheds.
Notes: BMH-Hi: 60% removal; BMP-LO: 40% removal (Source: Schueler 1995b}

Until recently, few communities have tried to craft a comprehensive watershed strategy to reduce urban nonpoint sources over the entire development cycle, from broad land use planning to its ultimate realization in the construction of individual development projects. The practice of watershed protection is simply about making choices about what tools to apply, and in what combination. As a result, a watershed manager will generally need to apply some form of all eight tools in every watershed to provide comprehensive watershed protection. The tools, however, are applied in different ways depending what nonpoint source pollutants are being targeted (CWP 1998a).

Tool 1. Watershed Planning

Monitoring and modeling studies have consistently indicated that urban pollutant loads are directly related to watershed imperviousness. Indeed, imperviousness is the key predictive variable in most simulation and empirical models used to estimate pollutant loads (e.g. the Simple Method). The water quality implications of this relationship are highlighted in Figure 1. Consider for a moment a phosphorus limited watershed that has a background phosphorus load of 0.5 lbs./ac/yr. The Simple Method predicts that urban runoff nutrient loads will exceed background loads once watershed imperviousness reaches about 20 to 25 percent. Although phosphorus loads can be reduced using urban BMPs, the upper limit of BMPs removal rates is only about 40 to 60 percent (Figure 1). Therefore, even if effective BMPs are widely applied in a watershed, a threshold is soon crossed beyond which we cannot maintain predevelopment water quality. This reality underscores the need for stronger land use planning, within the context of a watershed plan. Urban nonpoint source pollution is fundamentally determined by the broad land use decisions made by a community. It is therefore essential that the impact of future development on streams be seriously assessed during the zoning or master planning process.

Tool 2. Land Conservation

The second watershed protection tool involves the adoption and enforcement of ordinances to prevent development from occurring in key natural areas, such as streams, wetlands, floodplains, steep slopes, mature forests, critical habitat areas and shorelines. These ordinances need to describe how conservation areas will be delineated at each site and will be protected during the site planning, construction and post-construction stages. In addition, non-regulatory techniques for land conservation may also need to be employed. Some guidance on effective using land conservation tools for urban nonpoint source control can be found in CWP 1998b.

Tool 3. Aquatic Buffers

To fully protect urban watersheds, it is necessary to establish a wide forested buffer adjacent to the stream channel, wetlands and shorelines. A buffer network can be regarded as the right-of-way for a stream, and is an integral element of the stream itself. A forested buffer provides shade, woody debris, leaf litter, streambank protection, and a multitude of other functions and services to the stream.

While urban stream buffers provide many ecological benefits, hydraulic factors often limit their ability to treat all the stormwater runoff produced by an urban watershed. The primary hydraulic factor relates to how flow reaches the stream buffer in urban watersheds. Buffers require the presence of sheet flow to be effective. Once flow concentrates to form a channel, it effectively shortcircuits a buffer. Unfortunately, flow usually concentrates within a very short lateral distance in urban areas. For example, most hydrological design models suggest that sheet flow conditions cannot be maintained once a distance of 150 feet has been reached for pervious areas, and a mere 75 feet for impervious areas.

This constraint sharply reduces the percentage of a watershed that can be effectively treated by a stream buffer. Given typical drainage densities and landforms found in the East Coast, only about 10 or 15 percent of watershed area can be effectively treated by a stream buffer (Schueler 1995b). The remaining watershed runoff is usually delivered to the stream in an open channel or an enclosed storm drain pipe. Consequently, some kind of structural BMP is usually needed to provide water quality control for much of the upstream runoff before it reaches the stream.

Tool 4. Better Site Design

Better site design is a term that describes a fundamentally different approach to the design of residential and commercial development. The approach seeks to accomplish three goals at every development site: to reduce the amount of impervious cover, to increase the amount of land conserved, and to utilize pervious areas of the site for more effective stormwater treatment. To do so, designers scrutinize every aspect of the site plan, from streets, parking spaces, setbacks, lot sizes, driveways and sidewalks to see if they can be made smaller or softer. At the same time, creative grading and drainage techniques are employed to prevent stormwater from concentrating into runoff. Lastly, land "saved" from being paved is then used to conserve forests and stream buffers.

When all of these techniques are applied together, the cumulative benefits can be very impressive. For example, recent studies in Delaware, Maryland and Virginia have demonstrated that better site designs can reduce impervious cover by 25 to 40 percent for a range of residential subdivisions. (CWP 1998b). Other studies have shown better site designs reduce impervious cover by about 15 percent in shopping centers and office parks. Less impervious cover translates directly into smaller pollutant loads. Recent studies have shown that better site designs produce 40 to 65 percent less phosphorus and nitrogen loads than conventional site designs – which is roughly equivalent to what can be removed by a well designed stormwater pond. The same studies have also documented that better site designs cost 5 to 20 percent less to build than conventional site designs.

Tool 5. Erosion and Sediment Control

Perhaps the single most destructive stage in the entire development process is the clearing of vegetative cover and the subsequent grading of the site to achieve a more buildable landscape. The potential impacts to the stream are particularly severe at this stage: trees and topsoil are removed, soils are exposed to erosion, steep slopes are cut, natural topography and drainage are altered, and sensitive areas are often disturbed.

Thus, the goal of the fifth watershed protection tool is to reduce the massive sediment pulse that inevitably occurs during the construction stage, through a combination of clearing restrictions, erosion prevention and sediment controls. Traditionally, many communities have focused on enforcing erosion and sediment control plans at construction sites, primarily through structural practices and temporary seeding. The actual sediment removal capability of many control practices appears to be fairly limited, with most practices achieving TSS removal of 50 to 85 percent, according to recent field research. By contrast, sediment removal rates on the order of 95 to 99 percent are needed to achieve anything resembling a “clear water” discharge.

The value of non-structural practices for erosion control, such as clearing restrictions, construction sequencing, footprinting, and forest conservation, is increasingly recognized. The potential reduction in sediment load from construction phasing can be very impressive; Claytor (1997) computes a 42 percent reduction in off-site sediment loads in a typical subdivision development scenario.

Tool 6. Stormwater Best Management Practices (BMPs)

The sixth watershed protection tool involves the application of urban stormwater BMPs to treat the quality and quantity of runoff generated by impervious surfaces. Stormwater BMPs include ponds, wetlands, filters and infiltration and open channels that are designed to replicate predevelopment stream hydrology and water quality. While many recent advances have been made in stormwater BMP design, most can only partially mitigate the impacts of development on streams. A new design manual for stormwater BMPs has recently been devised by the State of Maryland that surmounts many of these problems (MDE 1998).

Tool 7. Non-Stormwater Discharges

On-site septic systems can be a significant source of nutrients and pathogens, under certain soil, terrain and maintenance conditions. Many Great Lake communities have thousands of septic systems in the ground, and are relying on this method of wastewater disposal in the future. Key urban nonpoint source management issues include what kind of siting and technology criteria need to be applied to new septic systems, and how can existing septic systems be better inspected, maintained or rehabilitated. Apart from public health considerations, septic systems have not received much attention in the. past. Their potential nutrient contribution, however, is increasing being noted in East Coast watersheds such as Tampa Bay and Chesapeake Bay.

Tool 8. Urban Nutrient Education Programs

Unlike agriculture, urban nutrient education programs (UNEP) are still in their infancy, and not much is known about their effectiveness in actually reducing nutrient loads. UNEP programs seek to educate urban and suburban residents to change behaviors that create nutrient loads--primarily from lawn management, septic system maintenance and pet waste. Anecdotal evidence suggests that urban nutrient prevention programs, could be a cost-effective nutrient reduction strategy in developed and developing urban areas. The ultimate effectiveness of any urban nutrient education program is dependent on four factors: (a) how prevalent is the behavior that education programs seek to modify (b) how effective is the education program in getting its message out to the population whose behavior needs to be influenced (c) what is the most effective educational technique to actually change the behavior in question, and (d) what nutrient reductions can be expected if the education program actually succeeds in changing the behavior.

2.6 Recommended Urban Nonpoint Source Strategies for the Coming Decades

Continued growth projected over the next two decades is likely to increase the relative contribution of urban nonpoint source loads in the Great Lakes region. Creative strategies will be needed to address this emerging source. Some recommendations for more effective treatment of urban nonpoint source pollution include:

1. Reduce Atmospheric Deposition of Pollutants Through the Clean Air Act

Since atmospheric deposition is a key source of nitrogen, phosphorus and trace metals that wash off impervious surfaces, continued effort to remove fine particulates from stationary and mobile air pollution sources could have a significant impact on urban nonpoint source loads. The potential benefit of this strategy is illustrated by earlier air pollution control efforts to remove lead from fuels. Runoff monitoring has demonstrated that the introduction of lead free gasoline reduced lead concentrations in urban runoff by a factor of 10 or more. As progressively stricter emissions controls are implemented under the recent Clean Air Act amendments, it is possible that similar reductions in other pollutants could be achieved.

2. Focus Nonpoint Source Management on Smaller Watersheds

Local government has the primary responsibility to implement urban nonpoint source controls on the ground. Consequently, it is increasingly realized that watershed plans need to be conducted on a smaller and local subwatershed scale. These subwatershed plans allow for more targeted selection., location and design of urban BMPs to meet local water resource objectives. The Center has recently developed a handbook to foster more rapid and effective watershed planning at the local level (CWP 1998a).

3. Maintenance and Rehabilitation of BMPs Constructed over the Last 20 years

Many communities have constructed hundreds and even thousands of stormwater detention or water quality BMPs over the last several decades. Many were built using outdated design standards, and do not meet current performance levels for pollutant removal, while others have seen a decline in performance due to poor maintenance or design. These older BMPs represent an enormous environmental investment in land and construction. As they age, these older BMPs will need to be rehabilitated or retrofit to meet or improve pollutant removal.

3. Greater Research on Urban BMPs

Although the last two decades have seen a great deal of research on the pollutant removal capability of urban BMPs, additional research is needed to improve nonpoint source management efforts. Some fruitful areas for research include:

- **modeling and monitoring to determine how to design stormwater BMPs to reduce or prevent downstream channel erosion**

- **research to further track bacterial sources and long -term removal pathways**

- **subwatershed scale evaluations of the effectiveness of BMPs in reducing pollutants and protecting habitat**

- **in situ monitoring within stormwater ponds and wetlands to understand internal nutrient and bacterial cycling in ponds over time.**

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3. NONPOINT SOURCES OF POLLUTANTS TO THE GREAT LAKES: 20 YEARS POST PLUARG

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Introduction

In the 20 years since the Pollution From Land Use Activities Reference Group (PLUARG) made their recommendations to the International Joint Commission (IJC) for reductions in non-point source (NPS) pollution to the Great Lakes, much has changed in the basin, programmatically and as a result of economic and demographic forces. Changes in NPS pollution to the Great Lakes in the last 20 years will be interpreted in light of these stimuli.

3.1 Significant NPS Pollutant Sources to the Great Lakes

Nutrients

Important NPS nutrients to the Great Lakes are organic matter (BOD), nitrogen (N), and phosphorus (P). BOD comes primarily from runoff of livestock manure or land-applied sewage sludges. This is a minor problem in most parts of the basin because of the low overall intensity of animal enterprises, but there is a growing trend for more concentration of animal enterprises and greater opportunity for BOD runoff. In the case of N, loadings to the lakes are a consequence of applications of fertilizer and manure in excess of crop needs. It appears that there has been little change in N use relative to crop needs in the last 20 years, and the increasing trend for adoption of no-till in the basin should have little effect on N loads. Increased numbers of Confined Animal Feeding Operations (CAFOs) could result in local N imbalances, but the impact is more likely to be on P loadings. As a result of the significant implementation of conservation practices (chiefly no-till and chisel plowing) in the basin, there has been a significant reduction in erosion and sediment loads in the last 20 years, and a corresponding reduction in total particulate P. On the other hand, soil test levels of P in basin soils have continued to rise, and this has probably led to no change or an increase in dissolved P loads, although this parameter is difficult to assess over and above temporal trends. The evidence for NPS nutrient load trends is good because of the relatively continuous monitoring of Great Lakes tributaries since 1978.

Toxic Substances

The major source of potentially toxic substances from NPS are the pesticides. The widely used compounds like the herbicides atrazine, alachlor, metolachlor and metribuzin are highly regulated by label under FIFRA and toxicological data suggest that the levels seen in surface waters in the basin pose little danger to human health and aquatic ecosystems. Pesticide monitoring data is particularly good for the Ohio portion of the Lake Erie basin as a result of the efforts of Dr. David Baker at Heidelburg University, and Ohio is the largest contributor to pesticide discharge in the Great Lakes.

Pathogens

Pathogens can enter the Great Lakes from nonpoint sources via discharge from septic tanks, septic tanks bypassed through field drainage tile, from land application of improperly treated municipal sewage sludge, and from manure runoff. Of these sources, none pose particular threats to the Great Lakes because of dieoff mechanisms in fluvial transport and because of the high degree of dilution. The incident in Milwaukee in the early 1990s, in which more than 400,000 people were sickened and as many as 100 died from *Cryptosporidium* in drinking water, does raise questions about pathogens in our surface water supplies, and has heightened public concerns for pathogen exposure. Although the source of this pathogen was never conclusively identified, its source was nonpoint and there is some indication that it may have been from dairy manure. The U.S. Department of Agriculture has concluded that most livestock in the U.S. are infected with this organism. Unlike infectious bacteria like Salmonella and E. coli, *Cryptosporidium* is not readily killed under normal fluvial conditions. The data base on pathogens in tributaries discharging to the Great Lakes is poor. The best data are probably from water and wastewater treatment plants in the basin, but I am not aware of any attempt to organize these data for the Great Lakes. This area certainly needs more attention.

3.2 Successful Techniques for Control of NPS Pollutants

By far the biggest success story in implementing the PLUARG recommendations has been the widespread adoption of conservation tillage in the basin. Adoption has probably reached near maximum achievable levels, although the impacts on sediment and P loads may not as yet have been seen. Introduction of integrated nutrient management, particularly with respect to N and P, has been slow and has only been recently stimulated by concerns for excessive watershed nutrients associated with CAFOs. It is likely that, at best, nutrient management will preserve the status quo in terms of tributary N and P loads. A failure to implement nutrient management could result in small increases in N loadings and large increases in P loadings. One only has to look at the situation in Chesapeake Bay to see the impact of excess manure nutrients from CAFOs.

3.3 Techniques That Did Not Work

There are few NPS control techniques that, if adopted, did not perform as indicated by research. Many Best Management Practices (BMPs) were either not adopted extensively or were predicted to have minimal impact. A good example is reducing the use of P fertilizer and manure on soils already testing in the high to excessive range. Phosphorus fertilizer use in the basin has not changed appreciably in the last 20 years, and P soil test levels continue to rise.

3.4 Emerging Techniques for NPS Pollution Control

Onsite Drainage Treatment

This technique involves the use of storage lagoons and constructed lagoons to treat runoff and tile drainage. This approach is at the field research level, but studies show that nitrate and P reduction levels in excess of 50 percent are attainable. Significant amounts of land are required for these systems, and economic viability will depend on regulatory mandates.

Water Table Management

This technique involves the use of control structures in conjunction with established modern tile drainage systems to hold drainage in the soil profile so as enhance denitrification and pesticide degradation. Results in Ohio and North Carolina have been mixed and reduction efficiencies rarely exceed 25 percent.

Phosphorus Immobilization

Chemical additives or composting can be used to reduce levels of soluble P in animal manures. Chemical additives can also be used to reduce P availability in soils with very high soil test levels. The technology is straightforward and could quickly impact the basin. Adoption by farmers may be difficult since lowering soil test levels is counter to traditional agronomic practice.

Riparian Areas Next to Drainage Ditches and Streams

This is a relatively old technique that is being endorsed by conservation and environmental groups. Efficiency in removing sediment, N and P is highly variable and seldom exceeds 25 percent. This practice has been slow to be adopted in areas with extensive tile drainage because of the perceived need to keep drainage ways open and free of debris.

3.5 Nonpoint Source Pollution Control for the Next Twenty Years

As one looks to the next 20 years in terms of land use in the Great Lakes basin and its impact on NPS pollution, it is necessary to try and predict what the major drivers of land use change might be. Urbanization, particularly along the lakes, will continue to grow as a consequence of improved water quality and rebound from the 1970s economic downturns. Movement of poultry, hog and dairy CAFOs into the basin is likely, based on current U.S. trends, unless individual states and provinces are able to pass legislation to limit their growth. Little major change in crop production is envisioned, so major inputs like fertilizers and pesticides will continue. I sense that there is greater interest today than at any time in the last 20 years to seriously attack the problems of NPS pollution. This is driven by incidences like Milwaukee, the rise of the CAFOs and their attendant problems, and the realization that most of the point sources have already been addressed (at great cost).

Some Emerging (or Maturing) Technologies that Merit Attention Include:

- **Pollution Trading Based on Total Maximum Daily Loads (TMDLs)**

This approach has been discussed and proposed many times, but has never been implemented for NPS pollutants. The TMDL approach is gaining interest as a means of forcing state governments to deal with water quality issues, and the 1978 agreement on P loading reduction allocations to the states and provinces set a precedent for load-based reductions. It is most appropriate for P, a conservative element, and less so for N and pesticides and other toxic organics.

- **Integrated Nutrient Management**

This is another approach that has been widely proposed but not extensively implemented. Policy or regulatory stimuli at the federal or state level could advance use of this methodology, as can the use of computer, GIS, and GPS technology. This approach is most highly suited to P management, but refinements in N fate, transport and availability prediction will increase farmer confidence in this technique. In the case of P, the focus of integrated nutrient management should be on soil test levels; these are easy to monitor, are routinely used by farmers anyway, and are highly correlated with P loadings.

- **Manure Brokering, Auctions, Direct Sales**

For manures like poultry and cattle that are sufficiently dry as to be readily stored, transported and spread, emerging innovations to recycle excess nutrients at CAFOs include brokering (a private enterprise that markets manure from the CAFO to the farmer), auctions (in which manure is sold to the highest bidder, thereby guaranteeing an outlet for excess nutrients), or direct sale or distribution by the CAFO to area farmers.

- **Manure Processing**

For the large CAFOs (those with much greater than 1,000 animal units), there are emerging technologies to treat manure for the purpose of disinfection, nutrient immobilization, physical improvement, or nutrient enhancement. The technologies to achieve these goals are, for the most part, already available from the water, wastewater and chemical industries and only need to be adapted to manures. Their relatively high unit costs will limit their use until regulatory measures mandate their use. Technologies include thermal drying, composting, alkaline stabilization, chemical P immobilization, and chemical nutrient enhancement combined with drying and pelletization.

3.6 NPS Pollution Control for the Next Twenty Years: Recommendations and Unanswered Questions

Recommendations

1. **Move toward TMDL standards for all Great Lakes tributaries. Leave it to state or provincial governments to implement load reductions via pollution trading, incentives, or regulations. The TMDLs would need to address local watershed water quality issues as well as Great Lakes loadings.**

2. **Revisit the 1978 P load reduction goals in terms of current in-lake water quality, NPS and point source loads, and impacts of zebras mussels on phytoplankton productivity and water quality indicators.**

3. **Develop a program to monitor the growth and locations of CAFOs in the basin. This should be coupled with estimates of impacts on tributary pollutant discharges.**

4. **Develop a database on levels of pathogens in tributaries and in the lakes.**

Unanswered Questions

1. **What is the impact of animal manure on transport of pathogens to the Great Lakes, and what is the extent of survival of pathogens during transport to the lake?**

2. **What effect will global change have on weather patterns in the basin and on subsequent fluvial processes?**

3. **How strong a stand will federal and state governments take on regulation of NPS pollution, particularly with respect to the CAFOs?**

3.7 PLUARG Implementation and Its Impact

With the exception of conservation planning and conservation tillage adoption, there has been little significant implementation of PLUARG recommendations. Conservation tillage implementation has had a significant impact on sediment and total P loads, but adoption of this practice may be reaching saturation. The PLUARG recommendations, and the stimulus that the PLUARG program provided the states and provinces, has had the impact of focusing resources in the Great Lakes basin that would not likely have occurred otherwise. A generation of young scientists and managers had their careers launched by PLUARG activities, and this impact is still felt. The greatest loss of momentum occurred, however, because of the lack of monetary investment in implementation of the PLUARG recommendations.

The IJC still has a major role to play in NPS pollution control. Strong recommendations by the IJC to federal, state and provincial governments are timely in light of current public sensitivity to water quality issues. The IJC can also provide a forum to develop unified approaches to NPS control, as it did in the 1970s.

3.8 Conclusions

The PLUARG activities during the 1970s (the research that was conducted, the development of extensive data bases on tributary loadings, and the recommendations that were developed based on large-scale modeling) represented a state-of-knowledge that has remained unchallenged in the intervening 20 years. Where implementation of the recommendations was extensive, as in the case of conservation tillage adoption, the results were positive and predictable. Therefore, one can conclude that the original recommendations are still valid and, if fully implemented, will have the predicted result. However, developments in the last 20 years, particularly the rapid rise of the CAFOs and in-lake effects of the zebra mussel invasion require that these recommendations be reevaluated and altered or augmented as needed. The IJC, as before, can provide a valuable forum for this process.