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ADDRESSING TOTAL PHOSPHORUS IMPAIRMENTS WITH WATER QUALITY TRADING[1]

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ABSTRACT: Water quality trading is a voluntary economic process that provides an opportunity for dischargers to reduce the costs associated with meeting a discharge limitation. Trading can provide a cost effective solution for point sources (i.e., wastewater treatment plants) to meet strict effluent limitations set in response to total maximum daily loads (TMDLs). A successful trading program often depends on first determining the trading suitability of a pollutant for a particular watershed. A simple technical approach has been developed to identify subwatersheds within the Raritan River Basin, New Jersey, where water quality trading could provide a cost effective and scientifically feasible method for addressing total phosphorus impairments. The methodology presented will serve as a model to conduct similar analyses in other watersheds. The Raritan River Basin was divided into 12 subwatershed-based study areas. Point-nonpoint source trading opportunities were examined for each study area by examining the point and nonpoint source total phosphorus loading to impaired water bodies. Of the 12 subwatersheds examined, four had a high potential for implementing a successful trading program. Since instream phosphorus concentrations are closely related to soil erosion, an additional analysis was performed to examine soil erodibility. Recommendations are presented for conducting an economic analysis following the feasibility study.

(KEY TERMS: nonpoint source pollution; nutrients; point source pollution; rivers/streams; surface water; water quality; water quality trading; total maximum daily load.)

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INTRODUCTION

If New Jersey plans to successfully meet its goals to improve and preserve water quality, nutrient trading will have to play a significant role in obtaining cost effective reductions of total phosphorus. As the New Jersey Department of Environmental Protection (NJDEP) moves toward assigning wastewater treatment plants (WWTPs) a total phosphorus effluent limitation of 0.1 mg/l, a potential for point-nonpoint source trading becomes a very attractive alternative to treatment plant upgrades. Stringent effluent limitations are set in response to total maximum daily loads (TMDLs) that calculate the maximum amount of a pollutant that a water body can receive while still meeting water quality standards (USEPA, 1999). To meet new effluent requirements, existing permitted dischargers may have to make significant upgrades to their WWTPs. As an alternative, a point-nonpoint source trading program would allow dischargers to pay for upstream improvements to lands that drain into an impaired water body. By constructing and maintaining stormwater best management practices (BMPs) on these lands, nonpoint sources of pollution can likely be treated at a lower cost than those associated with making infrastructure upgrades to WWTPs.

However, before a successful trading program can be established, the watershed in question must be analyzed with regard to technical feasibility (Horan *et al.,* 2002). This paper describes a simple technical screening tool used to determine a potential for trading in a large watershed by predicting nonpoint source pollutant loadings from land use data. Since

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the development of a trading program requires significant resources (Woodward *et al.,* 2002), an effective screening process is an important precursor. This is especially true when considering that trading programs have resulted in a modest amount of actual trades as of August 2004 (Breetz *et al.,* 2004). A simple screening tool can help limit the number of potentially failed programs from the onset.

Most of the current literature on water quality trading is largely theoretical, making reference to past programs and/or developing models applied hypothetically to watersheds (Jarvie and Solomon, 1998; Woodward *et al.,* 2002; Eheart and Ng, 2004; Hung and Shaw, 2004; Farrow *et al.,* 2005; Horan and Shortle, 2005). Others discuss recent case studies (Horan *et al.,* 2002; Woodward, 2003; Fang *et al.,* 2005).

In general, water quality trading is a voluntary economic process that provides an opportunity for dischargers to reduce the costs associated with meeting a discharge limitation. Trading involves a "buying party" compensating a "selling party" to achieve at least an equivalent, though less costly, pollutant reduction in exchange for credit. A trading policy provides profitable opportunities for parties with low treatment costs to reduce their loading beyond what is required, generate a credit, and sell the credit to parties with higher treatment costs. Ideally, the flexibility of trading produces less expense overall while achieving the desired environmental target (Faeth, 2000). However, experience shows that the savings from water quality trading can be limited by technical and institutional barriers. The major technical barrier is that the number of potential participants is small because, unlike air pollution trading markets, water quality issues are specific to watersheds, resulting in "thin" markets (Woodward, 2003). One solution is ensuring that ample nonpoint sources of pollution are available within a particular watershed before a trading program is attempted. A major institutional barrier is the problem of transaction costs required to develop a trading program that is economically favorable while still maintaining environmental efficacy (Woodward *et al.,* 2002). These costs often include those associated with research, bargaining and decision, and monitoring and enforcement (Stavins, 1995).

In addition to the economic benefits, a point-nonpoint source trading program has the ability to provide ancillary benefits such as wetland restoration and the implementation of other BMPs that improve wildlife habitat and ecological diversity in addition to improving water quality (Kadlec and Knight, 1996). According the U.S. Environmental Protection Agency (USEPA) Water Quality Trading Policy, trading can also preserve existing good water quality by offsetting new or increased discharges of pollutants to unimpaired waters (USEPA, 2003). In addition to the guidance of the Water Quality Trading Policy, lessons learned from past trading programs are valuable in developing new trading policies.

A literature and telephone survey regarding past trading projects was conducted to assist with the analysis of the Raritan River Basin. The survey revealed that before the release of the USEPA's Water Quality Trading Policy in January 2003, there were 37 water quality trading projects in development as of 1999 (King and Kuch, 2003). Of the 37 projects, 10 advanced past the planning stage to actually trading between sources. Of the 37 projects, 20 did not advance past the planning stage successfully because of one or more of the following technical problems: point sources had no economic incentive to trade; project specific regulatory guidance was lacking; no TMDLs were set for the targeted water body; and an insufficient number of nonpoint source candidates were available for trading. The other seven projects lacked adequate information to allow reporting on their status. According to the USEPA, a successful trading program often depends on first determining the trading suitability of a pollutant for a water body. The suitability should be determined by analyzing the following variables: allocations of a pollutant within the water body through a TMDL; fate, transport, and state of the pollutant in multiple segments of the water body; watershed conditions; and the effects of seasonal timing (USEPA, 2004a). In addition, Jarvie and Solomon (1998) explain that a trade should have public support, benefit the community in which it occurs, and pose no additional risk or responsibility for a point source to address a nonpoint source.

Several past trading projects have resulted in viable markets with actual trades. For example, the City of Cumberland's wastewater treatment facility on the Hay River in Wisconsin can trade nutrients with any farm located within a permit specified distance of the facility. During a trade, the city must pay for the implementation and maintenance of the BMPs for three years, after which the farms would be responsible for upkeep. The City of Cumberland must then find a new nonpoint source to trade with for another three years. Over time, this project will result in the participation of several nonpoint sources throughout the targeted watershed (Dale Hanson, Barron County, Wisconsin Soil and Water Conservation Department; July 1, 2004; personal communication). Another successful project involves the Rahr Malting Company of Minnesota, on the Minnesota River, which can exceed its effluent limitations downstream from its outfall by implementing upstream BMPs at a 2:1 conservative ratio for total phosphorus (Jim Klang, Minnesota Pollution Control Agency; June 21, 2004; personal communication). Nonpoint source-point source loading ratios are discussed further in the methods section of this paper when analyzing the Raritan River Basin.

The Raritan River Basin (Figure 1) is where 1.2 million people live. Water provided by the basin is treated for drinking and used for agricultural and industrial processes (NJWSA, 1999). The basin covers approximately 1,100 square miles in Hunterdon, Mercer, Middlesex, Monmouth, Morris, Somerset, and Union Counties and consists of a collection of many watersheds that drain to the Raritan Bay. Major water bodies include the North Branch and South Branch of the Raritan River, the Millstone River, the Green Brook, the Lawrence Brook and the South River, along with their tributaries (Riser, 2004). The basin was identified as a candidate for stormwater management planning in 1999 by the NJDEP as a result of high pollutant loadings. A total of 121 water body segments are impaired for one or more of the following: temperature, dissolved oxygen, total phosphorus, fecal coliform, pH, excessive macrophyte growth, sedimentation, and mercury in fish tissue (NJDEP, 2003a). Currently total phosphorus TMDLs have been adopted for six eutrophic lakes in the Raritan River Basin (NJDEP, 2003c), and a TMDL is being developed for total phosphorus for all the impaired streams within the basin, including the Raritan River.

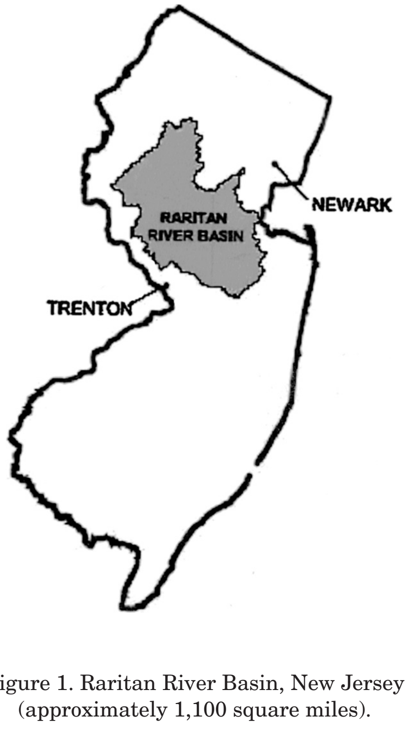

Figure 1. Raritan River Basin, New Jersey (approximately 1,100 square miles).

A TMDL for total phosphorus in the Raritan River Basin leads to effluent caps for point sources (i.e., WWTPs) that will offer incentives for them to participate in a water quality trading project. Ample opportunities for nonpoint source participation exist in agricultural and urban land uses within the Raritan River Basin. The goal of this project was to identify potential water quality trading opportunities within the Raritan River Basin that are scientifically and economically feasible for total phosphorus. Using Geographic Information System (GIS) software, manipulation of existing source data, and technically sound assumptions, the feasibility of conducting successful trading programs between point source dischargers and nearby sources of nonpoint source pollution was determined. The methodology presented here for the Raritan River Basin is intended to serve as a model to conduct similar analyses in other watersheds. These analyses can collectively be considered a screening tool to determine if there is a potential for trading in a particular watershed. Trading is increasingly being promoted as a solution to address water quality problems, although trading is not necessarily appropriate for all watersheds. Thus, a screening tool becomes necessary to avoid a potentially unsuccessful trading effort (with its associated costs).

METHODS

Identifying Potential Subwatersheds for Trading

Available GIS data of the Raritan River Basin and the New Jersey Pollution Discharge Elimination System (NJPDES) permit information were used to identify the location of the point source discharges within the watershed. The GIS data were also used to map physical features within each subwatershed that contains point source discharges. This GIS information was collectively obtained from NJDEP, the U.S. Geological Survey (USGS), and the Natural Resource Conservation Service (NRCS). To determine the potential for point-nonpoint source trading opportunities on a subwatershed scale, several initial considerations were assessed: proximity of a point source discharger to a phosphorus impaired water body (i.e., water bodies that will be required to develop TMDLs); evaluation of land use types suitable for water quality trading of total phosphorus (i.e., adequate nonpoint sources suitable for trading adjacent to the point source); and proximity of suitable land use types to both the point source and the impaired water body to which they discharge.

These initial considerations were essential for identifying baseline characteristics of both point and nonpoint sources. Comparison of point and nonpoint baselines is an important tool for determining eligible candidates for trading (Hennessy, 2001; Horan *et al.,* 2002).

Point sources were evaluated using available data from the NJPDES permitting program and other resources provided by the NJDEP TMDL program. WWTPs that discharge treated effluent to phosphorus impaired water bodies (NJDEP, 2003a) were selected as appropriate candidates for trading. A database containing NJPDES permit information and monthly Discharge Monitoring Reports (DMRs) for each discharge was reviewed to determine the effluent phosphorus loading (NJDEP, 2003b).

One concern in point-nonpoint source water quality trading is the creation of "hot spots" immediately downstream of the point sources. Hot spots can occur when the point sources trade with nonpoint sources that are not in the immediate vicinity of their discharge (NWF, 1999). This creates a situation where the overall load to the stream is reduced but instream receiving water criteria are exceeded immediately downstream of the point source due to the localized loading input from the point source. To minimize the potential for creating hot spots, potential trading opportunities were examined on a subwatershed basis (Horan *et al.,* 2002; Eheart and Ng, 2004). Study areas were therefore delineated according to hydrologic unit code (HUC) subwatersheds that included the point sources and impaired water bodies of interest. Twelve study areas were identified and mapped according to this methodology (Figures 2 and 3).

The next step in the trading feasibility analysis was to calculate the point and nonpoint source loading to the impaired water bodies in each of the 12 study areas. The phosphorus loading from each WWTP was calculated based upon the permitted flow rate and effluent total phosphorus concentrations. Using NJDEP's GIS data, the land uses within the

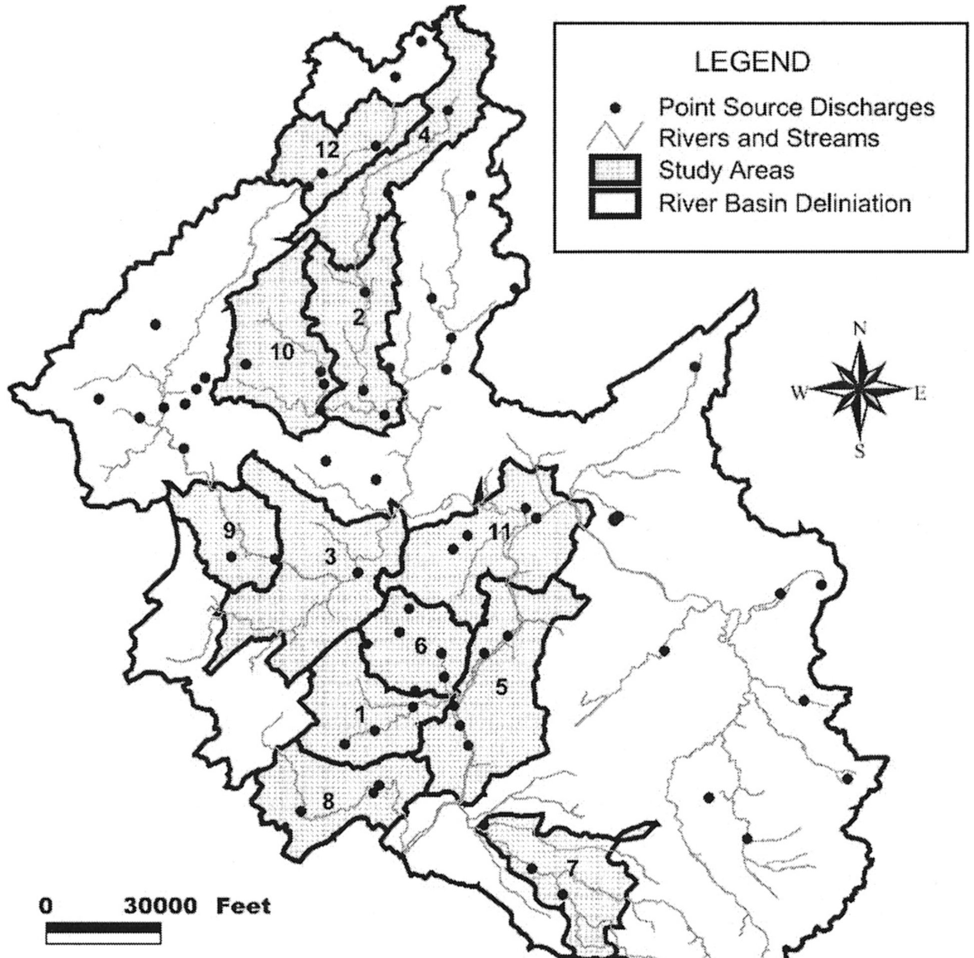

Figure 2. Twelve Study Areas Where Water Quality Trading Opportunities Were Examined (see Table 2 for study area names).

study areas were examined to determine nonpoint source pollutant loads (Figure 4). A summary of land uses and land cover for the 12 study areas is presented in Table 1. The nonpoint source total phosphorus loadings from each land use within the study areas were determined based upon pollutant export coefficients obtained from NJDEP (2004) (Table 2). The NJDEP pollutant export coefficients are based on a database of literature values that includes approximately 4,000 values accompanied by site specific characteristics such as location, soil type, mean annual rainfall, and site imperviousness. The NJDEP used this extensive database to identify export coefficients applicable to New Jersey. It is important to note that some urbanized land uses in these watersheds contain municipal separate storm sewer systems (MS4s). Although MS4s are considered point sources, they are typically modeled as nonpoint sources using aerial loading coefficients for different land uses within them. Therefore, throughout this paper, MS4s are lumped into the nonpoint source loading calculations.

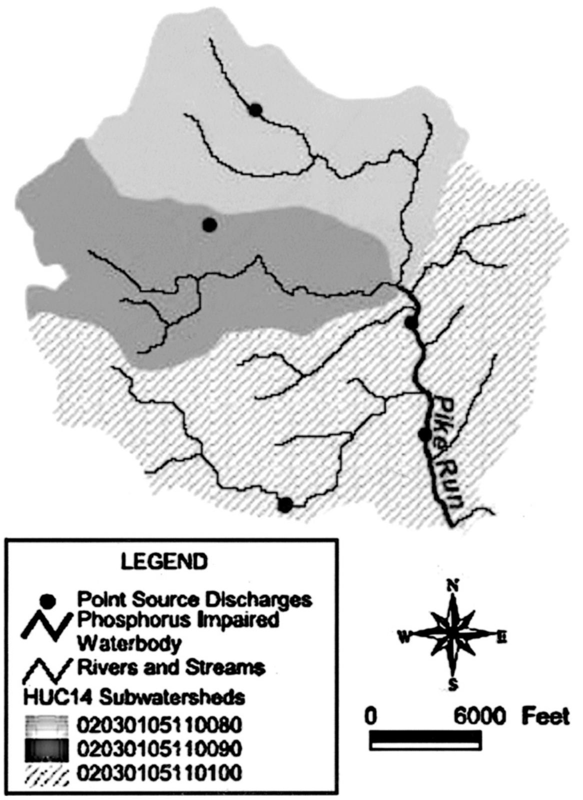

Figure 3. Sample of Study Area – Pike Run, Area 6.

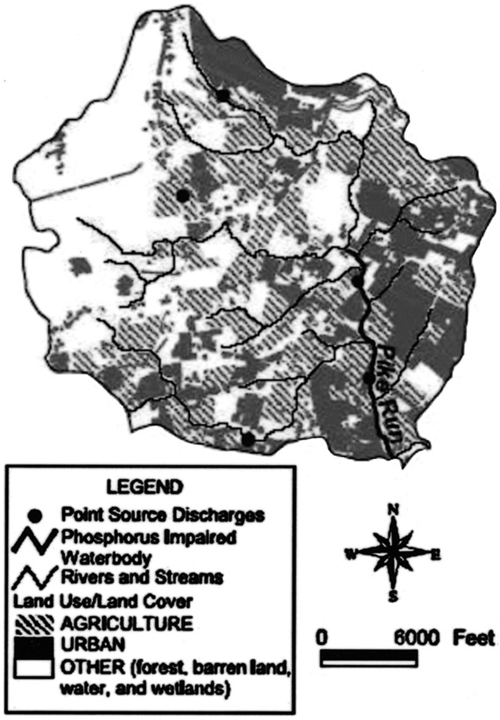

Figure 4. Land Use Map – Pike Run Study Area.

Comparing Point Source Loads to Nonpoint Source Loads for the Study Areas

For each of the 12 study areas, point source total phosphorus loads and nonpoint source loads are presented in Table 2. In many of the study areas, the nonpoint source loadings are significantly higher than the point source loads. This indicates that these watersheds have the potential to trade point source loads for nonpoint source loads.

As discussed earlier, for all point source discharges (i.e., WWTPs) to phosphorus impaired water bodies, NJDEP will require an effluent limitation equivalent to the stream standard, which is 0.1 mg/l for all 12 study areas. Two scenarios for point-nonpoint source trading exist: the WWTPs can trade their entire required load reduction, or the WWTPs can trade a portion of their required load reduction. For the second scenario, a general assumption was made that existing WWTPs can remove phosphorus by chemical precipitation to achieve an effluent concentration of 1.0 mg/l at a reasonable cost. However, substantial capital costs and yearly operation/maintenance costs would be incurred by these facilities if they needed to go beyond 1.0 mg/l. The portion of the point source's phosphorus load that would be ideal to trade with nonpoint sources is the load reduction needed to reduce the effluent concentration from 1.0 mg/l to 0.1 mg/l.

TABLE 1. Land Use/Land Cover (percent) by Study Area.

Study Area	Medium/ High Density Residential	Low Density/ Rural Residential	Commercial	Industrial	Mixed Urban/ Other Urban	Agricultural	Forest, Wetland, Water	Barren Land
1. Beden Brook	1.1	13.5	1.9	0.2	5.4	26.7	50.0	1.2
2. Branchburg-Readington	0.2	8.9	0.6	0.1	5.1	35.5	49.4	0.2
3. Branchburg Township	1.6	14.6	0.8	0.1	4.2	76.0	2.5	0.3
4. Chester-Roxbury	6.3	13.9	1.6	1.6	6.3	11.7	56.9	1.7
5. Millstone River	7.1	17.0	2.6	0.5	6.6	24.8	38.5	2.9
6. Pike Run	0.1	18.6	3.1	0.6	5.8	25.2	42.9	3.7
7. Princeton-East Windsor	6.1	6.0	2.6	8.9	62.0	11.7	2.3	0.6
8. Princeton-Stony Brook	51.1	4.8	19.5	6.5	0.2	9.3	7.1	1.3
9. Raritan Township	50.1	7.4	20.2	8.0	2.8	7.7	3.5	0.4
10. Readington-Clinton	1.2	17.4	1.6	0.3	6.5	24.6	47.6	0.8
11. Somerset-Raritan	31.5	21.6	9.5	10.0	8.3	13.5	3.7	2.0
12. Washington Township	35.4	10.9	24.0	5.5	2.0	11.6	9.4	1.2

TABLE 2. Comparison of Point to Nonpoint Total Phosphorus Loadings for Each Study Area.

Study Area	Size of Study Area (km^2)	Number of Point Sources	Point Source Total Phosphorus Loading (kg/yr)	Nonpoint Source Total Phosphorus Loading (kg/yr)
1. Beden Brook	72.0	3	2,503.4	4,850.8
2. Branchburg-Readington	84.7	3	171.0	5,109.4
3. Branchburg Township	132.9	1	75.8	10,471.4
4. Chester-Roxbury	57.5	2	2,775.6	4,686.6
5. Millstone River	120.7	5	> 22,282.6	9,458.5
6. Pike Run	58.3	6	> 712.6	3,904.1
7. Princeton-East Windsor	75.1	3	7,387.3	7,951.2
8. Princeton-Stony Brook	75.9	3	> 2,130.6	4,030.2
9. Raritan Township	53.1	2	> 9,759.7	4,567.8
10. Readington-Clinton	88.8	4	5,212.8	5,919.0
11. Somerset-Raritan	111.6	3	59,296.0	7,939.8
12. Washington Township	58.5	3	1,367.2	3,316.3

Note: > indicates that effluent concentration data are not available for some of the point source discharges in the study area. Thus, the point source load is assumed to be greater than the load given in the table.

Table 3 shows the required load reductions for each study area for both scenarios. The following three assumptions were made in the calculations for Table 3. For WWTPs that have an effluent concentration between 1.0 mg/l and 0.5 mg/l, an effluent concentration of 1.0 mg/l was assumed to be the permit limitation for total phosphorus. For WWTPs that have an effluent concentration less than 0.5 mg/l, an effluent concentration of 0.5 mg/l was assumed to be the permit limitation for total phosphorus. For WWTPs where effluent concentration data are not available, the effluent total phosphorus concentration was assumed to be 1.0 mg/l. Scenario 1 illustrates the total load reduction from the existing discharge condition (typically greater than 1.0 mg/l) to 0.1 mg/l. Scenario 2 illustrates the load reduction from a discharge condition of 1.0 mg/l to 0.1mg/l or from 0.5 mg/l to 0.1 mg/l.

TABLE 3. Point Source Load Reductions Required to Achieve 0.1 mg/l Effluent Total Phosphorus Concentration From Existing Conditions and Future Discharge Conditions.

Study Area	Scenario 1* (kg/yr)	Scenario 2** (kg/yr)
1. Beden Brook	13,465.4	6,464.6
2. Branchburg-Readington	880.6	880.6
3. Branchburg Township	391.1	391.1
4. Chester-Roxbury	14,263.1	14,263.1
5. Millstone River	> 117,249.3	> 89,831.6
6. Pike Run	>3,501.7	> 2,704.0
7. Princeton-East Windsor	37,568.0	37,568.0
8. Princeton-Stony Brook	> 11,864.8	> 2,173.0
9. Raritan Township	> 52,729.8	> 26,964.5
10. Readington-Clinton	29,044.3	6,485.4
11. Somerset-Raritan	321,675.4	152,064.1
12. Washington Township	6,827.2	6,827.2

*Point source load reduction required to achieve effluent concentrations of 0.1 mg/l from existing discharge conditions, where typical effluent concentrations may be greater than 1.0 mg/l.

**Point source load reduction required to achieve effluent concentrations of 0.1 mg/l from a 1.0 mg/l discharge condition. If the existing discharge condition is between 0 mg/l and 0.5 mg/l, Scenario 2 represents a load reduction from 0.5 mg/l to 0.1 mg/l.

For the 12 study areas, ratios of available nonpoint source loadings to required point source load reductions are presented in Table 4. In three of the study areas (Millstone River, Raritan Township, and Somerset-Raritan), the ratio is less than 1, meaning there are inadequate nonpoint source loads for trading under the two scenarios outlined above. Therefore, these three areas can be eliminated as potential candidates for point-nonpoint source trading. Of the remaining nine study areas, two have very high ratios (Branchburg Township and Branchburg-Readington). Although ample nonpoint sources are available to trade, once the ratios begin to exceed 10, the trades may not lead to significant improvements in water quality. Since the WWTPs comprise only a small portion of the total load to the system, they are also eliminated as potential candidates for trading.

When developing a point-nonpoint source trading program, the regulating authority typically requires the WWTP to purchase more credits from nonpoint sources than are actually required; this is to account for the uncertainty of the removal efficiency of nonpoint source controls and the variability of nonpoint source loadings (Farrow *et al.,* 2005). Typically, a WWTP needs to purchase two to four units of pollutant credits from nonpoint sources for every one unit that it is required to remove as a point source. For the Raritan River Basin analysis, areas with ratios between 4 and 10 (Beden Brook, Pike Run, Princeton-Stony Brook, and Readington-Clinton) were selected as being most appropriate for trading because the trades could result in a greater likelihood of attaining water quality standards in the water body and allow for the WWTPs to purchase additional credits to account for the uncertainty in the nonpoint source controls. A more detailed comparison of land use data, available point source loadings, and nonpoint source loadings was made between agricultural and urban areas. These comparisons are presented in Table 5.

TABLE 4. Ratio of Available Nonpoint Source Load to Point Source Load for Study Areas.

Study Area	Scenario 1*	Scenario 2**
1. Beden Brook	2.1	4.3
2. Branchburg-Readington	33.1	33.1
3. Branchburg Township	153.2	153.2
4. Chester-Roxbury	1.9	1.9
5. Millstone River	0.5	0.6
6. Pike Run	6.4	8.2
7. Princeton-East Windsor	1.2	1.2
8. Princeton-Stony Brook	1.9	9.7
9. Raritan Township	0.5	1.0
10. Readington-Clinton	1.2	5.2
11. Somerset-Raritan	0.1	0.3
12. Washington Township	2.8	2.8

*Ratio of nonpoint source load to the point source load reduction required to achieve effluent concentrations of 0.1 mg/l from existing discharge conditions, where typical effluent concentrations may be greater than 1.0 mg/l.

**Ratio of nonpoint source load to the point source load reduction required to achieve effluent concentrations of 0.1 mg/l from a 1.0 mg/l discharge condition. If the existing discharge condition is between 0 mg/l and 0.5 mg/l, Scenario 2 represents a load reduction from 0.5 mg/l to 0.1 mg/l.

Exploring Additional Criteria

The comparison of point and nonpoint source loadings was the principal method in determining the

TABLE 5. Further Comparison of Land Use and Phosphorus Loading Data.

Study Area	Agriculture (percent)	Total Urban (percent)	Agriculture: Urban Ratio	Percent Imperviousness	Available NPS:PS Load Ratio
1. Beden Brook					
Area	26.7	22.0	1.21	4.22	4.3
Phosphorus loading	60.5	31.1			
6. Pike Run					
Area	25.2	28.3	0.89	5.48	8.2
Phosphorus loading	53.8	37.5			
8. Princeton-Stony Brook					
Area	23.4	28.7	0.81	5.58	9.7
Phosphorus loading	52.5	39.2			
10. Readington-Clinton					
Area	24.6	27.1	0.90	5.43	5.2
Phosphorus loading	55.5	36.7			
2. Branchburg-Readington					
Area	35.50	14.9	2.39	2.34	33.1
Phosphorus loading	74.72	18.2			
3. Branchburg Township					
Area	48.22	23.0	2.10	3.90	153.2
Phosphorus loading	77.09	19.6			
4. Chester-Roxbury					
Area	11.74	29.7	0.39	7.10	1.9
Phosphorus loading	31.39	56.9			
5. Millstone River					
Area	24.77	33.7	0.73	9.24	0.6
Phosphorus loading	47.47	45.7			
7. Princeton-East Windsor					
Area	36.56	38.4	0.95	10.98	1.2
Phosphorus loading	54.22	42.6			
9. Raritan Township					
Area	29.18	40.0	0.73	10.13	1
Phosphorus loading	50.90	45.2			
11. Somerset-Raritan					
Area	17.33	49.6	0.34	16.13	0.3
Phosphorus loading	29.11	65.9			
12. Washington Township					
Area	22.16	26.3	0.84	7.08	2.8
Phosphorus loading	48.69	41.2			

most appropriate candidates for point-nonpoint source trading. However, to further narrow the most appropriate areas for trading, the soil properties of each study area were examined. If the soils in these study areas are highly erodible (i.e., susceptible to detachment by water), phosphorus is more likely to be transported into streams with sediment during storm events. In general, particulate phosphorus is the major portion (75 to 90 percent) of the phosphorus transported in runoff from cultivated land (USDA, 1994). The National Soil Survey Geographic (SSURGO) Database (USDA, 1998) was used to identify regions of highly erodible soils. For each study area, the percentage of highly and potentially highly erodible soils was determined. These percentages are presented in Table 6. In addition, the percentage of highly erodible soils on agricultural lands was determined for each study area. Focusing trading efforts in a watershed with highly erodible soils would yield the most significant benefits for the environment because

TABLE 6. Percent of Erodible Land for Each Study Area.

Study Area	Percent of Potentially Highly Erodible Land	Percent of Highly Erodible Land*	Percent of Highly Erodible Land on Agricultural Lands
1. Beden Brook	51	12	2
6. Pike Run	76	14	2
8. Princeton-Stony Brook	65	5	3
10. Readington-Clinton	59	30	6

*As defined by NRCS.

BMPs can easily address controlling the erosion from various land uses, thereby addressing the phosphorus loading that accompanies soil erosion (McKergow *et al.,* 2003). By targeting agricultural lands in the watershed that are considered to have highly erodible soils, the trading program is more likely to succeed in achieving water quality criteria.

DISCUSSION AND RECOMMENDATIONS

For water quality trading to be effective, a mix of land uses is required where adequate nonpoint sources and point sources are available and willing to trade pollution reduction requirements (USEPA, 2004a). A simplistic method has been presented herein to identify subwatersheds ranging from 10 to 50 square miles in size where water quality trading has a high potential for success. It is clear that trading will not work everywhere but rather should be viewed as one tool in a toolbox for implementing cost effective pollutant reductions to attain water quality criteria. The approximately 1,100 square mile Raritan River Basin was examined to determine subwatersheds where water quality trading could be applied to address phosphorus impairments. Of the 12 subwatersheds that were delineated, four have been determined to have a high potential for implementing a successful trading program. Table 5 was created in an attempt to determine which characteristics possessed by these four study areas made them stand out from the rest of the study areas. The table shows that all of the top four study areas have an agriculture area to urban area ratio of 1 ± 0.2. Additionally, each has an imperviousness percentage of 5 ± 0.8 percent. While other study areas have agriculture:urban ratios within this same range (Princeton-East Windsor and Washington Township), the percent impervious values are higher than 5 ± 0.8 percent. Therefore, we assume that a higher imperviousness percentage relates to a higher population and thus larger capacity WWTPs yielding higher phosphorus loadings. As a rule, the agriculture to urban ratio is the primary indicator of trading appropriateness, and the percent imperviousness is secondary.

The soil erodibility analysis proved to be inconclusive due to the similarities in soil characteristics among the four study areas. As a result, the four study areas could not be further ranked as to their suitability for trading. We expect that the methodology presented will be useful in watersheds with more variability in soil properties.

An economic analysis needs to be conducted to explore the potential cost savings that a point-nonpoint source trading program can provide the WWTPs and the financial incentives that the program can provide to the farmers and municipalities. A general assumption, made early in this analysis, was that all the WWTPs can upgrade to achieve an effluent phosphorus concentration of 1.0 mg/l; however, significant costs would be incurred to achieve the NJDEP required effluent concentration of 0.1 mg/l. Typically, to achieve these higher levels of treatment, a filtration process must be installed. Although filtration systems vary in costs, for a 0.5 to 3.0 million gallon per day (mgd) treatment plant, capital costs can range from $1.7 million to $3 million, with yearly operation/maintenance costs ranging from $70,000 to $100,000 (presentation by E. Enright, P.E., entitled "Phosphorus Control in New Jersey: What Permittees Need to Know," on June 24th, 2003, at the Association of Environmental Authorities Conference). Capital and operation/maintenance costs to upgrade point source discharges need to be further refined.

Costs for nonpoint source controls also need to be developed. The 2002 U.S. Farm Bill (The Farm Security and Rural Investment Act of 2002) does provide funding to farmers to install stormwater BMPs. A BMP cost analysis should be performed to compare the costs associated with WWTP upgrades. BMP cost analysis elements include capital costs; design, permitting, and contingency costs; operation and maintenance costs; land costs or rental fees; and inflation and regional cost adjustments (USEPA, 2004b). It will be important to demonstrate that point-nonpoint source trading can dramatically decrease the financial burden of the point sources and provide funding to owners of agricultural lands to help them become more sustainable.

The next step in this process is to conduct a detailed examination of each of these four subwatersheds and develop trading programs for each. A trading program requires the collaboration of a wide range of experts, including water quality modelers, wastewater treatment plant engineers, environmental policy scientists, and economists. Furthermore, a trading program needs to be developed as a TMDL implementation tool to achieve the load reductions required in the TMDL (Eheart and Ng, 2004). The methodology outlined in this paper can be used by regulators to determine whether there are opportunities to incorporate point-nonpoint source trading into a TMDL implementation plan.

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