POINT-NONPOINT SOURCE WATER QUALITY TRADING: A CASE STUDY IN THE MINNESOTA RIVER BASIN[1]

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ABSTRACT: Contrary to the general trend of only a few actual trades occurring within point-nonpoint source water quality trading programs in the United States, two trading projects in the Minnesota River Basin, created under the provisions of National Pollutant Discharge Elimination System (NPDES) permits, have generated five major trades and numerous smaller ones. In this paper, these two projects are described to illustrate their origins, implementation, and results. It was found that several factors contributed to the relatively high number of trades in these projects, including the offsetting nature of the projects (hence a fixed number of credits that the point sources were required to obtain), readily available information on potential nonpoint source trading partners, and an effectively internal trading scheme used by one of the two projects. It was also found that long term structural pollution control measures, such as streambank stabilization, offered substantial cost savings over point source controls. Estimates of transaction costs showed that the total costs of the trading projects were increased by at least 35 percent after transaction costs were taken into account. Evidence also showed that in addition to pollution reduction, these two trading projects brought other benefits to the watershed, such as helping balance environmental protection and regional economic growth.
(KEY TERMS: nonpoint source pollution; cost effectiveness; phosphorus pollution; erosion; load offsetting; transaction costs; water quality trading.)

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INTRODUCTION

The theory behind market based environmental policies stems from the work by Dales (1968) and Montgomery (1972), which spawned several types of marketable permit systems (e.g., Baumol and Oates, 1988; and Hanley *et al.,* 1997). During the past two decades, marketable permit systems have been used increasingly in the U.S. to achieve cost effectiveness in pollution control. The most prominent example is the U.S. Environmental Protection Agency (USEPA) Acid Rain Program (Title IV of the 1990 Clean Air Act Amendments), in which a system of tradable SO_2 emission allowances is used to reduce the cost of achieving an overall level of SO_2 emissions reduction.

As water quality problems, particularly nutrient pollution, become increasingly linked to nonpoint sources and the marginal cost of further pollution reductions from point sources rises rapidly, watershed-based effluent trading, or water quality trading (USEPA, 2003) between point and nonpoint sources, offers an alternative to the traditional command-and-control approach. Theoretically, this alternative can reduce the discharge of nutrients into the nation's water bodies while lowering the costs by capitalizing on the control cost differentials among and between pollutant sources. A study by Bacon (1992) estimated that the cost of point source reduction could be 65 times higher than nonpoint source reduction. The USEPA (1992) also estimated that substituting tertiary water treatment with reductions in nonpoint source pollution from agriculture would provide a net savings of US$15 billion in capital costs. A more site specific analysis by Faeth (2000) considered policy options for achieving water quality goals in three largely agricultural watersheds in the Upper Midwest. These policy options included stringent point

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source effluent standards, a conventional subsidy program for agricultural best management practices, water quality trading between point and nonpoint sources, and water quality trading coupled with performance-based conservation subsidies. The study concluded that policies with water quality trading had a substantial cost effectiveness (cost of per pound pollutant load reduced) advantage – as much as eight times – over both the point source standards and conventional subsidy program approaches in all three watersheds.

It is therefore not surprising that the concept of using point-nonpoint source water quality trading (WQT) to cost effectively achieve pollution control has been enthusiastically embraced by many economists as well as some regulators. Since the mid-1980s, point-nonpoint source water quality trading has been the subject of experiments in 16 locations in the U.S. (Environomics, 1999). However, these programs have had only limited success, and actual trades have been sparse (Woodward, 2003). Two reasons, among many others, can be cited to partially explain this. First, theoretical estimates of cost savings from point-nonpoint source WQT over conventional technology-based regulations were mostly based on the pure cost differences between pollutant loading control techniques available to point and nonpoint sources and the estimated load reductions that these techniques can achieve. In practice, designing, establishing, operating, and enforcing a water quality trading program all can incur substantial transaction costs (e.g., Malik, 1992; Krutilla, 1999; and Stavins, 1995), greatly diminishing potential efficiency gains and sometimes even resulting in WQT programs that are less cost effective than conventional technology-based direct controls. Second, ethical concerns of the general public (particularly environmentalists) on granting private rights to pollute the environment and the lack of clear authorization of conducting WQT by the Clean Water Act may have led to regulators' placing many restrictions on the transferability of credits (Woodward, 2003), discouraging the market participation of potential trading partners.

Among the experimental WQT programs in the U.S. are the two projects in the Minnesota River Basin in the State of Minnesota. In 1997 and 1999 Minnesota created two point-nonpoint source WQT projects under the legal framework of NPDES permits to offset new point source discharges into the Minnesota River. The Minnesota River Basin encompasses an area in southwestern Minnesota of 38,400 km^2 of which 92 percent is associated with agricultural activities. Contrary to the general trend of few actual trades in trading programs in the U.S., the Minnesota projects had generated, up to the completion of this study (late 2002), five major credit transactions and hundreds of smaller ones. With the continued interest in WQT in the U.S. (Woodward *et al.,* 2002) and the release of USEPA's Final Water Quality Trading Policy in January 2003 (USEPA, 2003), more trading programs are expected to emerge in the U.S. It is therefore important and potentially instructional to study the Minnesota experience, particularly for the reasons behind its relatively high number of trades.

To analyze whether a WQT program is successful, two questions need to be answered in addition to examining the number of trades generated. First, did the program achieve the desired quantity of pollution reduction? And second, was this pollution reduction achieved more cost effectively than with the traditional technology based command and control approach? This paper tries to answer these two questions for the two projects in the Minnesota River Basin. The paper starts with a detailed description of the two projects, providing the reader with an understanding of how the projects came into being, what the specific trading rules were, and how the trades were implemented. A cost effectiveness analysis is then presented to examine whether cost savings in pollution control were realized in the two projects; this summarizes the pollution reduction achieved by each trade and the corresponding cost. Also included is an estimate of the transaction costs incurred in the two projects. Beyond targeted pollutant load reductions, this study also identified other benefits that the two point-nonpoint source WQT projects brought to the watershed. The paper concludes with a discussion of the nature of the two trading projects and what has been learned from the experience.

This paper contributes to the literature primarily in three areas. First, a detailed description of the two trading projects with relatively high number of trades provides the reader an in-depth understanding on the background and regulatory environment in which the two trading projects were designed and implemented and the unique circumstances in which trades were developed and executed. Second, lessons learned from these two trading projects and presented in this paper offer guidance for future WQT programs. Third, although transaction costs in WQT have been much discussed in theories and models, to the authors' knowledge, accounting for these costs in an actual trading project has not yet been attempted. Transaction costs presented in monetary terms in this paper will be valuable for quantitatively understanding the effect of these costs on the efficiency of various WQT programs.

METHODOLOGY

Ten in-person and three telephone interviews were conducted with individuals directly involved in the two trading projects (a key informant approach). Interviewees included: (1) Minnesota Pollution Control Agency (MPCA) staff members administering the projects; (2) management and technical service personnel from the two point sources who were involved in the projects; (3) private technical consultants contracted by the point sources to conduct nonpoint source pollution control design, construction, and trading credit evaluation; (4) a staff member of a local environmental organization who was instrumental in identifying potential nonpoint source trading participants for one of the two trading projects; and (5) a landowner participating in a trade. These interviews provided crucial information regarding the origin and other background information regarding the trading projects. The interviewees also offered their own perspectives on the overall success or failure of the two point-nonpoint source trading projects. Information and data collected through interviews were verified with official documents if available. Cross-verification was conducted if a discrepancy occurred with regard to specific information provided by different interviewees.

Most of the data and facts from which the costs of pollutant load controls were derived were obtained by reviewing verified and archived MPCA documents on the two trading projects. These documents can be broadly classified into two categories: reports submitted by the point sources, and communication letters between MPCA and the point sources. Reports from the point sources included project progress reports, balance sheets of the trust fund established for each project, and technical reports on nonpoint source pollution control measures and quantification of pollution reduction credits. Communication letters mostly were concerned with the request and authorization of pollution reduction credits. They also occasionally dealt with specific issues raised during individual trades.

WATER QUALITY TRADING IN THE MINNESOTA RIVER BASIN

Overview

In 1993 a steering committee was established to assess the suitability of point-nonpoint source WQT in Minnesota. The year long investigation culminated in a policy evaluation report by MPCA in 1997 (Senjem, 1997). The report concluded that "if properly designed and implemented, it (point-nonpoint source WQT) has the potential to promote efficiency, equity and effectiveness while integrating point-source and nonpoint-source projects in the context of basin management" (p. 4). The report recommended that efficiency, equivalence, additionality, and accountability be the four criteria for any point and nonpoint source trading to be considered desirable. The efficiency criterion is the economic basis for trading. A trade should be pursued only when one source can reduce its pollutant emissions at a substantially lower cost than another source. In the case of point-nonpoint source trading, this means that nonpoint sources should be able to reduce water pollutant discharge more cost effectively than point sources.

Equivalency refers to the physical interchangeability of point and nonpoint source discharges of the targeted pollutant. There are two key differences in physical characteristics between point and nonpoint source discharges: dependency on weather conditions and impact on the water quality of receiving water bodies. While point sources such as municipal wastewater treatment plants generally have a steady and easily measurable end-of-pipe discharge, nonpoint sources such as agricultural fields contribute pollutant loadings to receiving water bodies mostly during runoff events. The second difference has to do with the chemical composition of point and nonpoint source discharges and the timing of these discharges. For example, a point source load of 100 kg of phosphorus – mostly in dissolved form – discharging directly into a lake during the summer has quite a different effect on the nutrient balance of the lake than a nonpoint source load of 100 kg phosphorus – mostly bound on sediment particles – entering the same lake in late fall from agricultural fields many miles upstream of the lake. Another important difference between pollutant discharges from point sources and nonpoint sources involves the methods used to quantify discharges. Point source discharges usually can be measured end-of-pipe, but it is difficult to monitor nonpoint source discharges due to their diffuse nature. Simple models based on empirical calculations (e.g., the Revised Universal Soil Loss Equation) can be used in lieu of expensive, on-site monitoring programs. However, without adequate monitoring, the applicability and accuracy of these models may become a major point of dispute in a trading program. Although equivalence is largely a technical issue, it has important implications in point-nonpoint source WQT in terms of meeting environmental goals. Many scientific uncertainties still remain in quantifying the equivalence between point and nonpoint source loadings. Examples of these uncertainties include the unpredictability of weather conditions, the verifiability of nonpoint source load models, and the lack of knowledge on the long term water quality impact on receiving water bodies.

The additionality criterion requires that nonpoint source load reductions credited to a point source in a point-nonpoint source trade "would not have occurred otherwise, in the absence of a point-nonpoint trading" (Senjem, 1997, p. 5). Accountability refers to measures necessary to ensure that trading projects satisfy the criteria of equivalence and additionality and that all other requirements – for example, the timely completion and appropriate maintenance of pollution control measures that generate trading credits – are effectively enforced.

Although the criteria are based on sound principles, it should be recognized that in practice it is difficult to meet all four simultaneously. For example, one can partially compensate for scientific uncertainties on the equivalence of discharges from different sources by using approaches such as zoning and by applying trading ratios greater than one, where a trading ratio specifies how many units of pollutant reduction a source must purchase to compensate for one unit of required load reduction. However, defining zones, identifying appropriate trading ratios, and enforcing both can impose a large cost on the regulatory authority in the form of a substantial information requirement and increased administrative expenses (Tietenberg, 2001). In addition, high trading ratios diminish economic efficiency of point-nonpoint source trading by increasing the relative cost of nonpoint source pollution controls. The additionality criterion could preclude some potential trading participants and result in a thin market. Accountability is necessary to ensure that the environmental goals of trading projects are met. Nevertheless, a high degree of accountability achieved by regulatory means, such as inspections and legal actions, will increase program costs.

Common Features of the Trading Projects

Based on the findings of the 1993 steering committee, MPCA negotiated with the Rahr Malting Company (hereinafter Rahr) in 1997 and the Southern Minnesota Beet Sugar Cooperative (SMBSC) in 1999 to implement point-nonpoint source trading in the Minnesota River Basin under the provisions of the NPDES permits issued to these two point sources. Both projects were "offset trading" that required the full compensation of new point source loadings to the Minnesota River. The pollutants being traded were essentially nutrients (phosphorus and nitrogen). The two point sources bore the burden of identifying nonpoint source trading partners and ensuring the proper functioning of pollution control measures implemented on the properties of nonpoint sources by the point sources themselves or by the nonpoint sources to generate credits. Credit eligible nonpoint source pollution reduction practices were either agricultural best management practices (BMPs) or instream erosion controls. They were prescribed in the NPDES permits and included soil erosion control, cattle exclusion, rotational grazing with cattle exclusion, critical area set-asides, constructed wetland treatment systems, alternative surface tile inlets, and cover cropping. Credit evaluation procedures also were detailed in the permits for each of these BMPs and control measures.

A mandatory trust fund was established by the permittee (the point source) that was devoted to the trading project to achieve required nutrient load reductions. The trust fund is a unique feature of the Minnesota trading projects compared with other WQT projects in the nation. The NPDES permit specified the minimum amount of the trust fund. The reason for such a fund was apparently to assure the financial viability of the trading project. The permittee was obligated to make up any shortfalls. A trust fund board, composed of at least one local watershed manager, one government representative, and a representative of one local water protection nongovernmental organization, was responsible for managing the trust fund and approving trades.

Both trading projects employed a trading ratio equal or greater than 2:1 – two units of nonpoint source pollutant load reduction traded for one unit of point source load increase. The trading ratios were used to serve two purposes: to account for uncertainties in converting nonpoint source loading into point source loading (see discussion in previous section) and to provide additional environmental benefits to the river by providing extra pollutant load reductions. The actual trading ratio used in each project was a result of negotiation among the permittee, MPCA, and public participants.

In terms of accountability, annual load reduction goals were outlined in the permit, and every potential trade had to be approved and verified by MPCA, which also had the authority to revoke previously approved tradable credits based on inspection results. Annual reports were required on the operation and effectiveness of the pollution control practices used to generate credits, and the format and content of the annual reports were specified in the permit. In an apparent effort to provide the permittee some flexibility in complying with the credit requirement, the permittee was given the option of meeting its total credit requirement in several stages with specific and progressive stage targets. In addition, the permittee was awarded a specific portion of the total potential credits at the completion of each phase of a particular trade. Specifically, the permittee received 45 percent of the total credits when an appropriate contractual agreement was reached for a specific pollution control measure. Another 45 percent of the total credits was granted at the completion of construction and implementation work, while the remaining 10 percent was granted after the vegetation establishment criterion was satisfied.

Rahr Malting Company

The five-year Rahr project started in early 1997 (MPCA, 1997). The primary reasons for creating the project were: the establishment of an oxygen demand total maximum daily load (TMDL) by the USEPA and MPCA in 1988 for the Minnesota River below River Mile 25 (near Shakopee, Minnesota), and Rahr's intention to build its own wastewater treatment plant (WWTP) in order to expand its production while reducing wastewater treatment costs. Because all the available point source waste load allocation of the TMDL had already been distributed to existing point sources on the river, no new loading could enter the river without violating the TMDL. Before construction of its own treatment facilities, Rahr routed its wastewater to one of the point sources on the river, the Blue Lake municipal WWTP. Unable to buy part of the Blue Lake WWTP's waste load allocation, Rahr eventually agreed to offset all its projected $CBOD_5$ (five-day carbonaceous biochemical oxygen demand) load of 150 pounds per day (68 kg/day) with $CBOD_5$ reduction credits it would buy from nonpoint sources implementing pollution control measures. Rahr also agreed to provide a US$250,000 trust fund to financially guarantee the realization of the trades.

The Rahr trading project is unique in that $CBOD_5$, a measure of the result of nutrient pollution, not the nutrients (phosphorus and nitrogen) themselves, was the traded pollutant specified in the permit. This added some uncertainty when nutrient loading was converted to $CBOD_5$. Based on evidence presented by Van Nieuwenhuyse and Jones (1996), MPCA and Rahr agreed upon $CBOD_5$ conversion ratios of 1:8 for phosphorus (i.e., for every unit of phosphorus load reduction, eight units of $CBOD_5$ would be credited) and 1:4 (1:1 upstream of the TMDL zone) for nitrogen, respectively. A 2:1 trading ratio was used to account for other uncertainties.

During the five years of project implementation, Rahr was able to achieve the credit requirement through four trades with nonpoint sources. The control measures included two river flood scoured area set-asides coupled with vegetation restoration (one on the Cottonwood River and the other on the Minnesota River main stem, both near New Ulm, Minnesota), one streambank erosion control and stabilization (Rush River near Henderson, Minnesota), and one livestock exclusion plus streambank erosion control (Eight Mile Creek, New Ulm). In the first two trades, farmland was converted back to its original floodplain status and native grasses and trees were planted to stabilize the soil and prevent future flood scouring. The other two trades used structural work and bioengineering methods to stabilize eroding riverbanks. Phosphorus and nitrogen reduction credits were generated for reduced sediment and soil loss from the trade sites, because phosphorus and nitrogen contained in sediment and soil are sources of $CBOD_5$.

Southern Minnesota Beet Sugar Cooperative

The second point-nonpoint source trading project was conducted under an NPDES permit issued to SMBSC in 1999 for its planned WWTP (MPCA, 1999). Similar to the Rahr case, SMBSC intended to build a new WWTP as part of developments to modernize its sugar beet slicing process and expand its production scale. However, the new plant would have to discharge its effluent (1.75 million gallons per day or 6,620 cubic meters per day) into a nearby stream that eventually flows into the Minnesota River. The permit required SMBSC to trade with nonpoint sources to completely offset the projected 4,982 pounds of phosphorus per year (2,260 kg/yr) discharged from the new WWTP.

The trading ratio was set at 2.6:1. The permit specifically defined the trading ratio as follows: 1.0 for the basic load offsetting, 0.6 for "engineering safety factor reflecting potential site-to-site variations," and 1.0 for water quality improvement (MPCA, 1999, Attachment, p. 1). With this trading ratio, the trading requirement was translated into a total of 12,954 credits (12,954 pounds of phosphorus per year, or 5,875 kg/yr) that would have to be purchased from nonpoint sources if the WWTP was to reach its full permitted annual phosphorus discharge limit. The trust fund mandated for this project was US$300,000.

For the first three years, SMBSC was able to meet credit requirements mainly by contracting with its cooperative member sugar beet growers to adopt spring cover cropping as an erosion control BMP. Typical practices for sugar beet spring cover cropping involve planting wheat or oats when or just before the sugar beets are planted (late April to early May). The cover crop emerges from the ground earlier than the beets and provides the field with some vegetative cover at a time when the potential for soil erosion from major rain events is particularly high. Three to four weeks after beet emergence, the first application of post-emergence herbicide is used to kill the cover crop. The remainder of the cover crop is killed two weeks later. To SMBSC, spring cover cropping was the easiest and most economical way to obtain phosphorus credits because the cooperative had a large base of sugar beet growers (about 600) who were willing to help the cooperative meet its environmental obligations. During the two-year period of 2000 and 2001, 367 parcels of land were contracted to plant spring cover crops, involving 164 landowners and 35,839 acres (14,515 hectares) of sugar beet farmland.

Monitoring and Enforcement

The MPCA maintained environmental accountability on the trading projects through two primary ways. First, MPCA required detailed technical and management reports both before and after each trade. Among the items required in the reports were engineering plans and specifications for structural work, operation and maintenance plans for the project, and labeled photographs from all trade sites before and after the implementation of pollution control measures. Second, MPCA staff members also inspected trade sites periodically based on the nature of the pollution control measures, weather conditions that could affect the functioning of the measures, and some specific site sampling schemes.

Although compliance with permit provisions by the point sources was generally satisfactory, no systematic, on-site monitoring was conducted to verify the pollution reduction effectiveness of nonpoint source loading control measures used to generate credits. Such monitoring would be an expensive undertaking as it would involve intensive instrumentation and labor inputs. For the two trading projects in the Minnesota River Basin, due to their relatively small scale of trading (in terms of both quantity and duration), it was not practical to require such monitoring.

COST EFFECTIVENESS ANALYSIS

Rahr Malting Company

A breakdown of the calculated credits generated by each trade and the associated cost (Table 1) shows that the two river flood scoured area set-asides, coupled with vegetation restoration on the Cottonwood and Minnesota Rivers, were the most cost effective trades. Using the phosphorus:$CBOD_5$ ratio of 1:8, the equivalent phosphorus reduction cost for the two river sites was US$4.90/kg over the five years of the project period. The Rush River bank stabilization was a close second. Although the Eight Mile Creek trade had the highest cost, it was still an acceptable US$5.82/kg. However, when additional maintenance costs due to flood damage (about US$79,000, Table 1) were included, the overall cost of phosphorus reduction rose to US$6.77/kg for the four trades.

It is not possible to compare these numbers to the costs resulting from the "what-if" situation where the point source (Rahr) reduced its WWTP discharge by 150 pounds (68 kg) of $CBOD_5$ per day. This is because the total offset requirement called for Rahr's WWTP to treat its wastewater until zero pollutant discharge was reached. Nevertheless, this cost can be contrasted with the cost that most small municipal WWTPs having a designed flow comparable with Rahr's permitted discharge rate would face in meeting a 1 mg/l total phosphorus effluent limit. This limit is considered necessary for significant water quality improvement to occur in most Minnesota waterways in the situation where only point sources are required to make all the necessary phosphorus load reductions (Senjem, 1997; Faeth, 2000). According to Senjem (1997), to achieve this 1 mg/l phosphorus limit, these municipal WWTPs, depending on the influent phosphorus concentration, would have to spend US$9 to US$40 per kilogram of phosphorus removed on capital and operation costs, based on a 20-year investment life and an 8 percent annual interest rate. Compared to these costs, nonpoint source control activities such as those employed in the Rahr trading project can offer substantial savings.

From a societal point of view, as long as these sediment load reduction structures are in place and function as designed, they will continue to lower phosphorus levels in the Minnesota River. If a structural life of 10 years and an 8 percent discount rate are assumed (Senjem, 1997), the cost of $CBOD_5$ reduction would be only US$0.64/kg. With the 1:8 phosphorus to $CBOD_5$ conversion ratio, the cost of phosphorus reduction rises to US$5.05/kg (average over all trades; Table 1). If the structural life of Rahr's nonpoint source controls can be extended to 20 years, which is likely, according to field experts, these numbers become US$0.44/kg for $CBOD_5$ and US$3.44/kg for phosphorus. Clearly, nonpoint source control measures employed in Rahr's trades are much more cost effective than those commonly used in municipal WWTPs, especially when long term cost effectiveness is considered.

TABLE 1. Cost Analysis of the Rahr Water Quality Trading Project (1997 to 2002).†

Costs to Rahr	Cottonwood and Minnesota Rivers‡	Eight Mile Creek	Rush River	Sum	Average (per trade)
Credit Generated (per day)	100.7	14.8	98.7	214.2	53.6
$CBOD_5$ Removed (kg in five years)	166,692	24,499	163,381	354,571	88,643
P§ Removed (kg in five years)	20,836	3,063	20,423	44,322	11,080
Cost (US$)	102,000	17,810	101,122	300,044¶	75,011
Cost Per Credit (US$)	1,013	1,203	1,025	–	1,401
$CBOD_5$ Removal Cost (US$/kg)	0.62	0.73	0.62	–	0.84
P Removal Cost (US$/kg)	4.90	5.82	4.96	–	6.77
Social Costs (10-year)††					
Cost (US$, annualized)	15,201	2,654	15,070	44,715¶	11,179
$CBOD_5$ Removal Cost (US$/kg)	0.46	0.55	0.46	–	0.64
P Removal Cost (US$/kg)	3.64	4.34	3.68	–	5.05
Social Costs (20-year)††					
Cost (US$, annualized)	10,389	1,814	10,299	30,560¶	7,640
$CBOD_5$ Removal Cost (US$/kg)	0.31	0.37	0.31	–	0.44
P Removal Cost (US$/kg)	2.49	2.95	2.51	–	3.44

†Data Source: Letters between the Rahr Malting Company and MPCA (James Klang, MPCA, December 21, 2001, personal communication).
‡Two trades are combined here, the Cottonwood and the Minnesota River sites, both of which were located near New Ulm and were flood scoured area set-aside plus vegetation restoration. Separate cost numbers were not available to this study.
§Phosphorus.
¶Also includes additional expenditures totaling about US$79,112, resulting mostly from a failed trade, miscellaneous post-construction site maintenance (US$29,112), and structural repairing due to flood damage (estimated at about US$50,000).
††Assuming an 8 percent discount rate.

Southern Minnesota Beet Sugar Cooperative

Each year during the period 2000 through 2001, SMBSC contracted with about 100 farmers for 7,258 hectares of sugar beet spring cover cropping (Table 2). The SMBSC compensated the growers at a rate of US$4.94/ha (US$2/acre). These acres of spring cover cropping generated an average of 5,765 credits per year (i.e., 5,765 pounds, or 2,615 kg, of phosphorus load reduction per year) as computed by the credit calculation procedures specified in the permit. The annual cost of phosphorus load reduction thus was US$13.72/kg to SMBSC (Table 2). However, it actually cost growers about US$14.82/ha (US$6/acre) to implement the cover cropping practice. As a result, the actual cost of reducing phosphorus load by applying sugar beet spring cover cropping was US$41.12/kg. This cost is as high as most municipal WWTPs, with a design flow of 1 million to 2 million gallons (3,790 to 7,580 m^3) per day, would have to pay to meet the 1 mg/l total phosphorus effluent limit (US$9 to US$40/kg).

From the perspective of society, the above analysis suggests that trading with farmers practicing sugar beet spring cover cropping does not result in cost savings in phosphorus pollution control. Nevertheless, there were benefits not directly related to pollution control that could lend some support to this control measure. For example, sugar beet growers were willing to plant a spring cover crop because it also can protect emerging sugar beet plants from wind damage. Although no quantitative research has been done on the agronomic and farm-level economic benefits of spring cover cropping for sugar beet production, empirical and anecdotal evidence has demonstrated these benefits. This is reflected in the increasing acceptance of cover cropping among sugar beet growers in the Minnesota River Basin.

To diversify its credit sources, SMBSC initiated a trade using cattle exclusion plus streambank stabilization to generate credits in the second year of the trading project. However, this trade was halted when the construction phase was about to start because of a dispute between the landowner and SMBSC on a cattle crossing design change. Although the trade finally occurred after much effort, the dispute resulted in a delay of the construction of a key pollution control structure and the deferral of SMBSC fulfilling the requirement for credits in that year. This trade was not included in the cost effectiveness analysis of this article because it was completed after the conclusion of the study leading to this article. Consequently, no specific data were collected on this trade.

TABLE 2. Cost Analysis of the SMBSC Water Quality Trading Project (2000 to 2001).†

	2000	2001	Average
Total Acreage (ha)‡	7,366	7,149	7,258
Payment Made By SMBSC (US$/ha)	4.94	4.94	4.94
Total Payment by SMBSC (US$)	36,376	35,302	35,839
Credits Generated (kg)	2,403	2,826	2,615
Credits Per Hectare (kg/ha)	0.33	0.40	0.36
P removal Cost (US$/kg)	15.15	12.48	13.72
Cost to Growers (US$/ha)§	14.82	14.82	14.82
Total Cost to Growers (US$)	109,128	105,906	107,517
Actual P Removal Cost (US$/kg)	45.42	37.46	41.12

†Data Source: Communication letters between the Southern Minnesota Beet Sugar Cooperative and MPCA (James Klang, MPCA, December 21, 2001, personal communication).
‡Sugar beet spring cover crop planted.
§Expert estimate.

Transaction Costs

Transaction costs occurred at every stage of the trading projects. These costs included time spent on permit negotiation, searching for trading partners, administrative expenditures, mandated communications between the permittee and MPCA, and MPCA staff time on credit verification, post-project site inspection, and routine project management. It was difficult to distinguish and capture every cost associated with a transaction. Given MPCA's regulatory role and the full responsibility that the two point sources had in making trades happen and ensuring the proper functioning of nonpoint load control measures, MPCA and the point sources were the parties who bore most of the transaction costs. Therefore, the transaction cost analysis focuses on expenditures incurred by these two parties.

To facilitate analysis, each trading project was divided into two phases: the permitting phase and the implementation phase. The permitting phase refers to the period that started with the initial permit negotiation and ended at the issuance of the final permit. The implementation phase refers to the period when trades took place and credit requirements were fulfilled with the implementation of pollution control measures. Engineering, material, and consulting service costs during the implementation phase, most of which were covered by the trust fund and accounted for in the cost analysis conducted above, were not considered transaction costs. In each phase, staff time spent by the point source and MPCA were estimated by respective staff members, and median salary rates were used to calculate the personnel cost. Due to SMBSC's unwillingness to disclose relevant information and the ongoing nature of the project, only transaction costs associated with the Rahr project were estimated. Nevertheless, cursory accounting of potential transaction costs associated with the SMBSC project is provided here based on a general examination of the project.

Table 3 presents a breakdown of the major transaction costs incurred during the Rahr project. The numbers point to two major findings. First, the permitting phase was very costly to both the point source and MPCA (the regulatory agency). Second, the regulatory agency spent much more time than the point source in the trading project in both phases. It took about two years to complete the permitting process for the project. As the state's first attempt at point-nonpoint source trading, the Rahr project was a new experience for everyone involved in negotiating trading-related permit provisions. The length of the permitting process thus was not a total surprise. Of the estimated US$105,032 in total transaction costs, 65 percent occurred before any actual trade took place. The Rahr project clearly benefited from the small number (four) of trades needed to obtain all required credits. The "outside help" item identified in Table 3 refers to a well connected and respected activist from a local environmental organization who helped identify nonpoint source trading sites and build initial contacts with the landowners. Two (the Minnesota River and the Cottonwood River sites) out of the four trades were brought into the project in this manner. The cost associated with his service was the compensation he received from his organization for the time he spent on the trading project. Of the other two trades, one was introduced to Rahr by a regional hydrologist from the Minnesota Department of Natural Resources and the other by a member of the local chapter of a nationwide environmental organization. Trading opportunities quickly surfaced for Rahr through word of mouth and newspaper stories about the trading project, which effectively reduced transaction costs for Rahr in the area of searching for trading partners.

The other important finding shown in Table 3 is that MPCA's share of the total transaction cost was 81 percent, or US$85,095. There are probably two reasons for this. During the permitting phase, in addition

TABLE 3. Transaction Cost Analysis of the Rahr Water Quality Trading Project.

		Time (hr)	Rate ($/hr)†	Number of Personnel	Sum ($)
		Permitting Phase			
Rahr	Consultants	30	200	2	12,000
	Company Staff	30	75	2	4,500
	Subtotal	**120**	**–**	**4**	**16,500**
MPCA‡	Staff (engineer)	1,387	24	1	33,301
	Staff (permit writer)	347	24	1	8,325
	Staff (supervisory)	347	29	1	10,168
	Subtotal	**2,080**	**–**	**3**	**51,794**
	Phase Total	***2,200***	**–**	***7***	***68,294***
		Implementation Phase			
Rahr	Company Staff	35	63	1	2,188
	Subtotal	**35**	**–**	**1**	**2,188**
MPCA	Staff (engineer)	1,387	24	1	33,301
	Subtotal	**1,387**	**–**	**1**	**33,301**
Outside Help	Citizens Group	45	17	1	750
	Subtotal	**45**	**–**	**1**	**750**
Nonpoint Sources	Landowner	–	–	–	500§
	Subtotal	**–**	**–**	**–**	**500**
	Phase Total	***427***	**–**	***3***	***36,738***
	Grand Total (US$)	**3,667**	–	10	**105,032**

†Median values.
‡(1) MPCA staff salary rate based on median levels for different staff categories; (2) fringe benefits not included; (3) A full time MPCA staff member is assumed to work 40 x 52 = 2,080 hours per year.
§Legal fee for contract proof reading.

to negotiating with the point source, MPCA also was responsible for designing the overall structure of trading and other administrative activities necessary for developing an NPDES permit. During the implementation phase, when Rahr reduced its transaction costs with a low volume of trades and readily available nonpoint source trading partners, MPCA's administration, monitoring, and enforcement burdens were not reduced correspondingly. As a result, MPCA spent more staff time on the project than the permittee.

The cost effectiveness analyses conducted in the previous sections did not include transaction costs. Values for pollution reduction costs were basically engineering costs to implement pollution control measures, including material and designing. These engineering costs were counted as trust fund expenditures in both trading projects. As expected, when transaction costs were added, the project's cost effectiveness noticeably declined. In the Rahr case, adding the total transaction cost to the cost effectiveness analysis elevated the total cost of the project to US$405,076, a 35 percent increase over the originally calculated cost (Table 1) over the five-year project period. The cost of phosphorus reduction rose to US$9.11/kg. (The US$500 legal fee spent by one of the nonpoint sources and the US$750 listed as "outside help" in Table 3 were not included when per kilogram pollutant reduction costs were calculated. These costs did not apply to all four trades and were insignificant compared to the total transaction cost.) The 20-year annualized cost became US$4.63/kg. Compared to Senjem's (1997) municipal WWTPs phosphorus reduction cost estimates of (US$9 to US$40/kg), however, these numbers are still very competitive and indicate potentially sizable cost savings for point-nonpoint source pollution trades of a similar nature.

The SMBSC permit required about a year and a half to finalize, half a year less than the Rahr permit, likely reflecting the experience that MPCA gained from Rahr. The permitting process for the SMBSC project was essentially the same as that for Rahr. Therefore, it can be assumed that roughly the same amount of staff time occurred in the SMBSC project during the permitting phase as that in the Rahr project, except that a half-year's time was saved. A rough accounting based on the Rahr numbers (Table 3) are as follows: cost saved from the 0.5 year reduction during permitting phase was US$68,294 x (0.5/2) = US$17,073.

The different types of trades that the two projects used to obtain credits, however, resulted in different sources of transaction costs (or cost savings) during the implementation phases of the two projects. SMBSC, a cooperative with a large member base, traded with its farmer members for the first three years of the project by contracting with them to practice spring cover cropping. Many sources of transaction costs, such as searching for trade sites, collecting site specific information, and negotiating prices, were avoided because of the working relationship between the farmers and the cooperative management. For example, the permit required photographs to be taken to record cover crop planting and managing at each trade site. This seemed to be a potential source of significant cost. However, visits to farm sites by the cooperative's agronomists had been conducted routinely for sugar beet planting advice before the trading project. It took the agronomists only a few extra minutes during a field visit to take the required photographs for the trading project. As a result, these types of transaction costs were minimized. In essence, credit exchanging between SMBSC and sugar beet farmers resembled an internal emission credit trading scheme where offsets for new emissions from a plant are obtained by reducing emissions from other sources in the same plant. This is much like the netting policy in USEPA's Emission Trading Project in 1974 (Hahn, 1989). There were no actual external trading partners, and thus transaction costs were lower.

Another effect of the cover cropping trades on transaction costs went in the opposite direction. The large number of trades (367 in total for 2000 and 2001 alone) and the strict site-by-site credit verification process required more time by MPCA staff for site visits, credit auditing, and other necessary administrative work. The MPCA staff members estimated that time spent by them on the SMBSC project during the implementation phase would be three times more than that in the Rahr project when the current permit expired in early 2004. Overall, although internal trading resulted in low transaction costs to the point source, the total transaction cost of the SMBSC project is expected to be higher than the Rahr project because of the substantially higher staff time that MPCA invested in the former.

Although the magnitude of the total transaction cost cannot be accurately estimated at this point, two facts led to the conclusion that SMBSC's trading provided no advantage over phosphorus controls applicable to small to medium-size municipal WWTPs. First, the above analysis of cost effectiveness indicated a high per kilogram phosphorus reduction cost (US$41.12) for cover cropping. Second, analysis of Rahr's transaction costs indicated that a large share of the total transaction cost accrued to MPCA. With an increase in MPCA staff time in the SMBSC project, the total transaction cost for the SMBSC project is estimated to be higher than that for the Rahr project. Therefore, the phosphorus reduction cost for cover cropping, with transaction costs included, will likely exceed US$55/kg (assuming a 35 percent increase of pollutant reduction costs due to transaction costs based on the data in Table 3).

Other Economic and Social Benefits of Trading

From a societal point of view, the two trading projects may have produced economic and social benefits other than cost savings in pollution control. First, WQT provided the necessary solution through which the two NPDES permittees were able to build their own WWTP to lower production cost (Rahr) or to expand production scale (SMBSC) during a time in which domestic and international competition created difficulties for the two large local employers. Rahr's Shakopee facility is the largest producer of malt at a single site in the world, and SMBSC employs approximately 260 year-round workers and 460 seasonal workers in the local labor market with an annual payroll of more than US$10 million. Although regional economic impacts brought by the two trading projects were not quantified in this study, they were clearly positive, local, pecuniary externalities that were important for the local economy.

Second, the trading projects provided much needed funds for nonpoint sources to implement pollution controls. This is best illustrated by the Rush River and the Eight Mile Creek trades in the Rahr project. Since 1988, the landowners at these project sites had been in search of financial aid to control river bank erosion that was so severe at times that it threatened to cut the banks deep into the adjacent land and destroy nearby houses and barns. Until the trading project was developed, the owners could not raise sufficient funds for effective bank stabilization to solve the problem. After the installation of bioengineered bank stabilization structures on the sites, there has been "no problem," as one of the owners commented.

Third, environmental benefits brought by WQT were not limited to water quality protection and improvement. Before the operation of its new WWTP, SMBSC stored its production wastewater in ponds and spray irrigated the detained wastewater during spring. Pond storing not only limited production but also caused an odor problem that was a major nuisance in the area. The trading project in effect reduced air pollution, a welcome positive externality. Rahr's floodplain restoration trading sites, with the protection and planting of native vegetation, have created habitat for wildlife. Such ecological benefits reflect an important difference between end-of-pipe point source control measures and nonpoint source management schemes, as the latter can generate many ancillary environmental and ecological benefits. Point-nonpoint source WQT, therefore, has the potential to be an environmentally beneficial policy alternative in pollution control.

Finally, involving farmers, environmental groups, and local watershed officials in the trading projects brought the unregulated nonpoint sources into the spotlight. This likely had positive effects on public awareness of both the nonpoint source pollution problem and the opportunity of using trading to introduce nonpoint source pollution controls. In addition, Rahr donated the Cottonwood and Minnesota River sites, which were basically restored wetlands, to the City of New Ulm and a local environmental organization, respectively, to be used as park space and an environmental education site.

It should be noted here that in spite of the many co-benefits, there may be some negative externalities resulting from WQT. For example, herbicides used in the sugar beet spring cover cropping practice may enter nearby waterways and cause unexpected environmental consequences. Although not specifically studied here due to the lack of relevant data, such potential negative externalities should be carefully considered in the design and evaluation of future trading projects.

DISCUSSION

From the beginning, Minnesota tied its point-nonpoint source WQT to the NPDES permitting framework, as recommended by Taff and Senjem (1996) and the USEPA's 1996 framework (USEPA, 1996). This legal arrangement was well suited to the two projects, as both involved trading between a single point source and multiple nonpoint sources. The NPDES permit trading framework offers many advantages, the most significant of which is a higher level of environmental accountability through the control and oversight by regulatory agencies. The MPCA achieved control and oversight by prescribing credit eligible nonpoint source load control measures and maintaining the authority to certify credits.

However, because of the legal framework of NPDES permits and the offsetting nature of both projects, the point sources did not have the flexibility to choose between implementing in-plant control measures and purchasing reduction credits from nonpoint sources. They had to obtain a fixed amount of credits every year during the five-year permit period and were responsible for assuring the proper functioning of nonpoint source control measures prescribed by the permit. In essence, these Minnesota River Basin trades were the result of offsetting projects created to compensate for loads from new point sources (Woodward *et al.,* 2002), which is not a traditionally defined market based pollution control mechanism. As pointed out by Shabman *et al.* (2002), true market based trading necessitates a high degree of shifting management responsibility of pollution control decisions from the regulator to the discharger. The trading framework used in the two Minnesota River Basin projects did not have this characteristic.

On the other hand, the legal obligation of the two point sources to obtain a fixed number of credits apparently contributed to the number of trades realized in these two projects. While point sources in other trading programs can avoid trading by improving their wastewater treatment through new technology or better facility management such as the Wisconsin Fox River BOD trading (Hahn, 1989), the Tar-Pamlico River nitrogen trading (Randall and Taylor, 2000), and the Lake Dillon phosphorus trading (Woodward, 2003) – trading was the only option for the two point sources in the Minnesota River Basin to comply with their NPDES provisions. Consequently, the point sources were actively engaged in searching for trading opportunities and carrying out trades. In addition, internal trading between SMBSC and its cooperative farmers and information on potential nonpoint source trading partners provided by local sources to Rahr all helped the projects achieving the required number of credits, and hence a good number of trades.

Another difference between the NPDES permit based trading framework and a true credit trading market involves what the "sellers" in the market actually produced. Under contracts, sugar beet farmers and other nonpoint sources received payments to conduct certain farming practices or allow the point sources to work on their property to install pollution control structures. They were not, however, obligated by the contracts to generate a fixed amount of pollution reduction credits, the article of trade in the market. In a sense, the point sources were both the buyers and the producers of credits, and the nonpoint sources were only subcontractors or resource suppliers in the credit generating process.

Coupled with the fact that nonpoint sources involved in the two trading projects were not regulated, the NPDES permit based WQT framework has some important implications for the continued success of these two trading projects and similar ones in the future. First, as estimated in this article, high transaction costs were involved in the two trading projects. As a result, some of the theoretically predicted cost savings from such emissions trading programs were not realized or were substantially diminished. The analysis indicated that cover cropping in the SMBSC case did not provide pollution reduction cost savings to society. In the Rahr case, if locating high credit yielding trades in the basin becomes more difficult in the future, Rahr will likely be faced with higher transaction costs in finding and negotiating with nonpoint source trading partners.

Because of the offset nature of the two trading projects studied here, transaction cost analyses on traditionally defined marketable emissions permits such as those examined by Malik (1992) and Stavins (1995) do not apply directly. Nevertheless, findings from this study confirmed some general conclusions from their work. For example, in his analysis of transaction costs in tradable permit systems, Stavins (1995, p. 144) concluded that "transaction costs increase the aggregate costs of control indirectly by reducing total trading volume and directly by adding the total costs of control." Although total trading volume was fixed in both projects in the Minnesota River Basin due to their offsetting nature, transaction costs raised the total cost of the projects by more than 35 percent. Stavins (1995, p. 145) also pointed out that the government authority should "avoid creating regulatory barriers (such as requirements for government preapproval of trades) that drive up transaction costs and discourage trading." However, it is seen here in the two trading projects that preapproval of trades was a central if not the most emphasized component of the NPDES permit trading framework. As these were offset projects and the first ever such new policy trials in the state, MPCA was more concerned with the environmental accountability of the projects than with realizing efficiency gains. Better control and oversight came at the expense of higher personnel costs for the regulatory agency. Therefore, it was not surprising that the overall transaction costs were high, and MPCA shouldered much of these costs.

In his analysis comparing the social costs of pollution control with uniform standards and marketable permits, Malik (1992) concluded that when enforcement costs were high, it cost more to achieve the same level of pollution control using incentive based policies such as marketable permits. Transaction cost analysis of the SMBSC project showed that higher trade volume brought higher transaction costs to the regulator due to the greater administrative work in pre-approving trades and the increased number of sites to monitor after trading took place. As a result, the overall phosphorus load reduction cost in the SMBSC trades was not lower than a point source as indicated with similar size municipal wastewater treatment facilities.

Krutilla (1999) conceptualized and outlined transaction costs in three stages of the policy process of pollution control: (1) choosing a particular policy; (2) administratively implementing the structure of the policy; and (3) operating, monitoring, and enforcing the policy. He also pointed out that there were few studies in the literature examining the transaction costs of the second stage of the process and that empirical evidence suggested the possibility of high-cost implementation. The transaction cost analysis contained herein included the NPDES permitting phase of the two projects, which corresponds to Krutilla's second stage of the policy process. The result that the permitting process accounted for 65 percent of the total transaction cost in the Rahr project provides some real case evidence for Krutilla's proposition.

Another implication of the NPDES permit based WQT framework on the operation of such programs is the potential for nonpoint sources to manipulate the supply of credits and hence the credit price. Because there was only one buyer (the point source) and numerous potential sellers (nonpoint sources) in both trading projects studied here, the buyer should have had some market power and thus might have been able to use it to manipulate the credit price. However, because unregulated nonpoint sources participated in the market only on a voluntary basis and practically possessed all possible credits, they in fact were more likely to influence the price than the buyer by limiting credit supply. In theory, nonpoint sources could exit the market at any time. On the other hand, point sources had to rely on trading to meet their regulatory obligations, and finding nonpoint source trading partners was not guaranteed. The difficulties encountered by the point source in the trade using cattle exclusion plus streambank stabilization in the SMBSC project are instructive in that regard. It was evident that an important reason behind the dispute and delay of the trade was that the landowner did not have any legal obligation to install pollution control measures on his property. Consequently, he did not need the trade as much as his counterparts in the Rahr trades since he saw no imminent threaten to his property from streambank erosion.

Finally, the NPDES permit based trading framework may prevent the realization of an important benefit of performance based approaches to pollution control such as WQT – the potential for the regulated to innovate in pollution control technology, including pollutant load monitoring methods (Randall and Taylor, 2000). This is because the NPDES trading framework prescribed both a limited number of credit eligible pollution reduction measures and corresponding pollution reduction quantification methods. In essence, this was still a technology based, not a performance based, approach (Baumol and Oates, 1988). As a result, both point and nonpoint sources had few incentives to innovate.

CONCLUSIONS

In summary, the following conclusions can be drawn from this study. First, the two trading projects in the Minnesota River Basin cannot be regarded as truly market based pollution trading because of their new source offsetting nature and restrictions placed on the point sources in choosing control measures to meet load reduction requirements. Second, several factors contributed to the relatively high number of trades generated in these two trading projects, including, (paradoxically) the offsetting nature of the projects (hence a fixed number of credits that the point sources were required to obtain to comply with trading provisions in their NPDES permits), readily available information on potential nonpoint source trading partners, and an effectively internal trading scheme used by one of the two projects.

Third, in terms of cost effectiveness in reducing pollutant loading to the environment, long term structural nonpoint source pollution control measures such as streambank stabilization were substantially more cost effective than further treating point source wastewater. This was true even after transaction costs were added to the total cost. This finding suggests that point-nonpoint source trading, when implemented with properly selected nonpoint source load reduction techniques, can indeed generate significant cost savings in pollution control, as predicted by theoretical studies. Fourth, it was found that transaction costs increased the total cost of the projects by at least 35 percent. In the Rahr project, 65 percent of the total transaction cost occurred during the permitting phase, and 81 percent of the total transaction cost was borne by the regulatory agency, mostly on ensuring the environmental accountability of the trades. Finally, this study found that in addition to cost savings in pollution control, offsetting trading projects brought other social benefits to the watershed, including a balancing of environmental protection and regional economic growth. Such benefits suggest that it may well be appropriate to look beyond cost effectiveness when WQT programs are designed to solve environmental issues in particular social and economical settings.

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