Pollution Trading to Offset New Pollutant Loadings
-- A Case Study in the Minnesota River Basin

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INTRODUCTION

Economic theories on using market-based approaches to achieve cost-effectiveness in pollution control have seen increasing applications in environmental policies in the United States during the past two decades. As water quality problems become increasingly linked to nonpoint sources and the marginal cost of further pollution reductions from point sources rises rapidly, watershed-based effluent trading between point and nonpoint sources offers an alternative. This alternative can reduce the discharge of nutrients into the nation's water bodies and lower the costs compared to the traditional command-and-control approach. A study by Bacon (1992) estimated that the cost of point source reduction could be 65 times higher than nonpoint source reduction. The EPA (1992) also estimated that substituting tertiary water treatment with reductions in nonpoint pollution from agriculture would provide a net savings of $15 billion in capital costs.

To achieve the desired environmental outcome while obtaining the full potential of cost minimizing through pollution trading, there are several issues that need to be considered. First of all, pollution trading depends heavily for its effectiveness on the development of a smoothly functioning market in permits. High transaction costs, market imperfections, and strategy behavior can all pose significant obstacles to the performances of a permits market (Cropper and Oates, 1992). Second, even if a smoothly functioning market is present, the exchangeability of permits among different sources is impeded by the variability in environmental impacts of emissions from different sources (spatial differentiation) and the scientific uncertainty in quantifying emissions. The latter is especially evident in point-nonpoint source pollution trading where it is necessary to substitute nonpoint source pollution load reductions for point source load reductions. Finally, there are substantial resource requirements and technical difficulties in quantifying and monitoring nonpoint source pollution reductions.

In Minnesota, starting in 1997, two point-nonpoint source pollution trading projects were created in the legal framework of National Pollution Discharge Elimination System (NPDES) permits to offset new point source discharges into the Minnesota River (Figure 1). As of 2001, five major credit transactions and hundreds of smaller registered transactions have taken place in

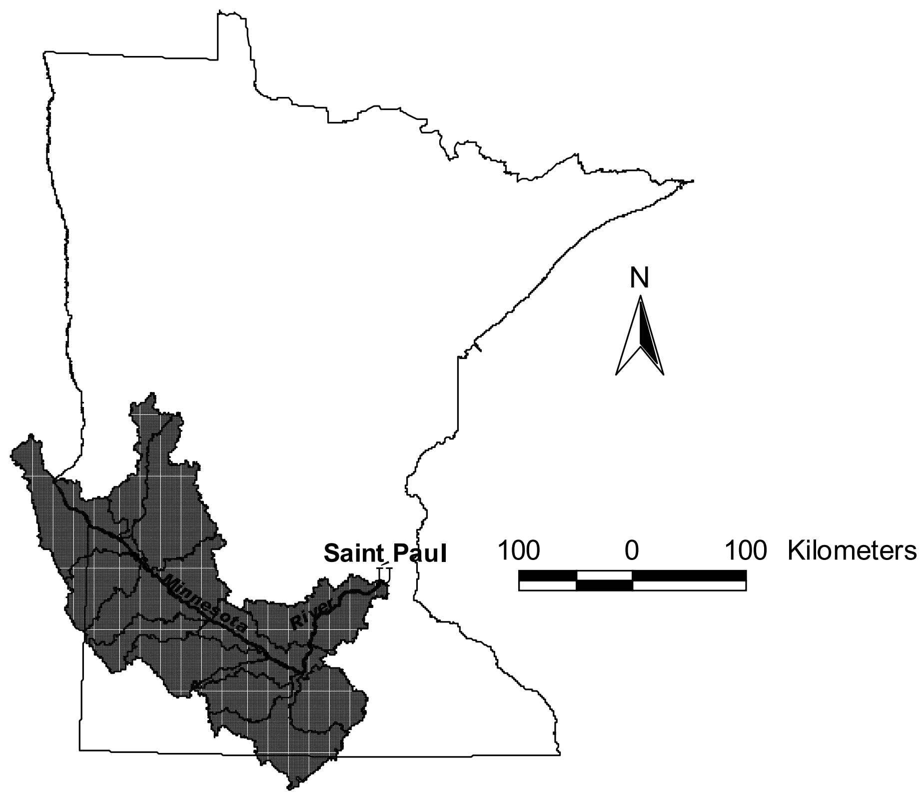

Figure 1: The Minnesota River Basin

the two projects. Among the current and past water pollution trading projects in the U.S., the two Minnesota projects have unquestionably generated the most trading activity. This paper provides a detailed overview of these two projects and tries to answer the question: have these two projects been cost-effective and environmentally beneficial?

Specific objectives of this paper include: (1) to provide an in-depth examination of the two point-nonpoint source trading projects in the Minnesota River Basin, (2) to conduct cost-effectiveness analysis of the nonpoint source loading reduction practices used in the two projects for trading, (3) to evaluate the role of scientific uncertainty played in these two projects, and (4) to look for other social benefits that such offsetting pollution trading efforts can offer to a watershed.

METHODOLOGY

Data and Information

Ten in-person and three telephone interviews were conducted with individuals directly involved in the two projects. Interviewees included: (1) Minnesota Pollution Control Agency (MPCA) staff members administering the projects, (2) employees providing management and technical services for the two point sources, (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 partners for Rahr (one point source), and (5) a landowner participating in a trade with Rahr. These interviews provided crucial information regarding the origin and background of the trading projects. They also offered the perspectives of the trading implementers on the overall successes and failures of the two point-nonpoint source trading projects.

Most of the information from which phosphorus pollution reduction costs were derived was obtained by reviewing documents on the two trading projects archived by the MPCA. These documents can be broadly classified into two categories: reports submitted by the point sources, and communication letters between the MPCA and the point sources. Reports included project progress reports, balance statements of the abatement trust fund, and technical reports on nonpoint source pollution control measures and the quantification of tradable phosphorus reduction credits. Communication letters were mostly concerned with the request and authorization of phosphorus reduction credits. They also occasionally dealt with specific issues rising from individual trades.

ADAPT

A biophysical modeling approach was used to evaluate the role scientific uncertainty played in these two point-nonpoint source trading projects. Among the seven credit-eligible nonpoint source pollution control practices (including 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), cover cropping is probably the most difficult one to be quantified with regard to its effectiveness in reducing pollution. Currently, the Revised Universal Soil Loss Equation (RUSLE) is used to calculate the effect of cover cropping on soil eroded from the field (MPCA, 1999). RUSLE is a soil erosion model designed to predict long-term average annual soil loss (Renard et al., 1996). In phosphorus trading projects, more precise yearly results will give the regulators and the credit buyers much needed certainty during trade transactions. In this study, we used the Agricultural Drainage And Pesticide Transport (ADAPT) model to accomplish this. ADAPT is a field-scale water management simulation model (Chung et al., 1992). ADAPT differs from RUSLE in that it improves the capability to predict soil losses in two ways. First, ADAPT has a hydrology component that permits the use of fundamentally based erosion equations to describe the soil detachment, transport, and deposition processes.

Second, ADAPT has an algorithm that accounts for the sediment transport capacity of surface runoff. In contrast, if the calculated value from RUSLE exceeds transport capacity, only the capacity-allowed amount of sediment leaves the field.

For ADAPT input files, soils data were extracted from the MUUF (MAP Unit Use File), a PC-based, U.S. Department of Agriculture, Natural Resource Conservation Service soil database. Climatic data were obtained on-line (http://climate.umn.edu/hidradius/radius.asp) from the National Weather Service Cooperative project database. Tillage practices, fertilizer applications, crop rotation systems, and planting/harvest dates were acquired from the MPCA trading project documents and interviews with experts involved in the trading projects.

For the purpose of this study, eight fields participating in the SMBSC trading project were chosen based on their geographic locations. These fields were included in the project in 2000 with a spring cover crop for sugar beets. Sugar beet farms in the basin have a typical three-year corn-sugar beet-soybean crop rotation system. To have a more complete picture of the erosion control performance of spring cover cropping, a six-year two rotation system (corn-sugar beet-soybean–corn-sugar beet-soybean, 1996-2001) was simulated in ADAPT. In addition, Minnesota suffered a damaging flood season in the spring of 1997. A two rotation system that included 1997 would enable one to observe and compare the impact of extreme climatic events and also to test the sensitivity of the ADAPT model to extreme climatic conditions.

POLLUTION TRADING IN THE MINNESOTA RIVER BASIN

Overview

In 1993, a steering committee was established to assess the suitability of point-nonpoint source pollution trading in Minnesota. The year-long investigation culminated in a policy evaluation report by the MPCA in 1997 (Senjem, 1997). The report concluded that "if properly designed and implemented, it (point-nonpoint source pollution trading) has the potential to promote efficiency, equity and effectiveness while integrating point- and nonpoint-source projects in the context of basin management." The report recommended efficiency, equivalence, additionality, and accountability to 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 pollution trading project should be pursued only when one source can reduce pollutant emissions at lower cost than another. In the case of point-nonpoint source trading, this means that nonpoint sources should be able to reduce water pollutant loading more cost-effectively than point sources.

Equivalency refers to the physical interchangeability of point and nonpoint source emissions or loadings of the targeted pollutant. For example, a load of 100 pounds of phosphorus entering a lake in summer from a point source discharging directly into the lake has quite a different effect on the eutrophic status of the lake than a 100 pound load of phosphorus entering the lake in late fall from several nonpoint sources 50 miles upstream of the lake. Although equivalence is largely a technical issue, it has important implications in point-nonpoint source pollution trading when it comes to meeting environmental goals. Unfortunately, there are still many scientific uncertainties in quantifying the equivalence between point and nonpoint source loadings.

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)." Accountability refers to measures necessary to ensure that trading projects satisfy the criteria of equivalence and additionality, and all other requirements[1] are effectively enforced.

While the four criteria are sound principles and should be followed, it should also be recognized that in practice it is difficult to meet the four criteria simultaneously. Achieving equivalence, additionality, and accountability in trading often comes at the expense of reduced efficiency. Scientific uncertainties on the equivalence of loadings from different sources can be partially compensated with zoning and applying trading ratios[2] greater than one. However, defining zones, finding suitable trading ratios, and enforcing them can pose a large cost on the regulatory authority in the form of a substantial information requirement and increased administrative expense. In addition, high trading ratios diminish economic efficiency of point-nonpoint source trading by implicitly increasing the cost of nonpoint source pollution controls. The additionality criterion could preclude many potential trading partners and result in a thin market situation. Accountability is necessary to ensure the environmental goals of trading projects are met. Nevertheless, a high degree of accountability achieved by regulatory means, such as inspections and legal actions, increase costs.

Common Features of the Trading

Based on the findings of the 1993 steering committee, the MPCA negotiated with the Rahr Malting Company (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 the two point sources. Both projects were offset

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[1] For example, the timely completion and appropriate maintenance of pollution control measures that generate trading credits.
[2] A trading ratio specifies how many units of pollutant reduction a source must purchase to receive credit for one unit of load reduction.

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 pollutant reduction measures. Credit-eligible nonpoint source pollution reduction practices are either agricultural or in-stream nonpoint source controls. Trading credit evaluation procedures were detailed in the permit for each of these remedial practices.

A mandatory trust fund was set up by the permittee, devoted to the trading project to achieve the required nutrient load reductions. The trust fund is a unique feature of the Minnesota trading projects in comparison to other water pollution trading projects in the nation, in that the permit specifies the minimum amount of the trust fund required in each of the projects. 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 one local water resources organization representative, 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 reduction trading for one unit of point source reduction. The trading ratios were used to serve three purposes: (1) to assure equivalence of load reduction from difference sources, (2) to account for uncertainties in converting nonpoint source loads into point source loads, and (3) to provide additional environmental benefits to the river by providing extra pollutant loading reductions. The actual trading ratio used in each of the two projects was a result of negotiation among the permittee, the MPCA, and public participants.

In terms of accountability, every potential trade had to be verified by the MPCA and annual reduction goals were outlined in the permit for the permittee to achieve. The MPCA had the right to revoke previously approved tradable credits based on inspection results. Annual reports on the operation and effectiveness of the remedial practices were required, and the format of the reports was 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 to meet its total load reduction requirement in several stages with specific and progressive stage targets. In addition, the permittee was awarded a specific portion of the total potential credit amount at each stage of a particular trade. Specifically, 45% of the total credits was granted when appropriate contractual agreements were reached, another 45% of the total credits for the completion of construction and implementation work, and the remaining 10% for achieving the vegetation establishment criteria.

Rahr Malting Company

The five-year Rahr project started in early 1997. The primary reasons for creating the project were: (1) the total minimum daily load (TMDL) established by the U.S. Environmental Protection Agency (EPA) and the MPCA in 1988 for oxygen demand at the Minnesota River below river mile 25 (near Shakopee, Minnesota), and (2) the Rahr's intention to build its own wastewater treatment plant (WWTP) to expand its production while reducing wastewater treatment costs. However, all the point source waste load allocations had already been distributed to existing point sources on the river. Rahr's processing wastewater was discharged to and treated at one of these point sources (the Blue Lake municipal WWTP) before the construction of its own treatment facility. Unsuccessful in its attempt to buy part of the Blue Lake WWTP's waste load allocation, Rahr eventually agreed to offset all its projected $CBOD_5$ (5 day carbonaceous biochemical oxygen demand) load to the river with the $CBOD_5$ reduction credits it would buy from nonpoint sources implementing pollution control measures. Rahr also agreed to provide a $250,000 trust fund to financially guarantee the realization of the trades.

The Rahr trading project is unique in that $CBOD_5$, the result of nutrient pollution, not the nutrients (phosphorus and nitrogen) themselves, was the traded pollutant. Based on scientific evidence presented by Van Nieuwenhuyse and Jones (1996), the MPCA and the permittee 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, to account for credits generated by the reduction of nutrient loadings to the river. A 2:1 trading ratio was used to account for the uncertainties.

During the five years of implementation, Rahr was able to achieve the credit requirement through four trades with nonpoint sources. The control measures employed included two river flood scoured area set-asides coupled with vegetation restoration (one on the Cottonwood River and the other on the Minnesota River, both near New Ulm, MN), one stream bank erosion control and stabilization (Rush River near Henderson, MN), and one livestock exclusion plus stream bank erosion control (Eight Mile Creek, New Ulm). The first two trades converted farmland back to its original floodplain status and planted native grasses and trees to stabilize the soil and prevent flood scouring. The other two trades used structural work and bioengineering methods to stabilize eroding riverbanks. Phosphorus and nitrogen reduction credits were generated from reduced sediment and soil loss[3] from the trade sites.

Southern Minnesota Beet Sugar Cooperative

The second point-nonpoint source trading project has been done under an NPDES permit issued to SMBSC in 1999 for its planned WWTP (MPCA, 1999). Similar to the Rahr case, SMBSC

[3] Phosphorus and nitrogen contained in sediment and soil, together with sediment, are sources of $CBOD_5$.

intended to build a new WWTP as part of its development 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) to a nearby stream, which eventually flows to the Minnesota River. Previously, SMBSC stored its wastewater in ponds during its processing season (September to April) and spray-irrigated the water to its 500 acres of alfalfa/grassland during May to August. The permit required SMBSC to trade with nonpoint sources to offset all its projected 4,982 lb phosphorus/yr (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). With this trading ratio, the trading requirement is translated into a total of 12,954 credits (12,954 lb phosphorus/yr or 5,876 kg/yr) that would have to be purchased from nonpoint sources to meet the requirement if the WWTP reaches its permitted annual phosphorus emission limit. The trust fund mandated for this project was $300,000.

For the first three years, SMBSC was able to meet credit requirements mainly by contracting its cooperative member sugar beet farmers to adopt spring cover cropping as an erosion control best management practice (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 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, the sugar beet 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 2000-2001, 367 parcels of land were contracted to plant spring cover crops, involving 164 landowners and 35,839 acres of sugar beet farmland.

Monitoring and Enforcement

There are primarily two ways through which the MPCA maintained the accountability of the trading projects. The first one is the detailed technical and management reports required by the MPCA prior to and after the transaction of each trade. Among the requirements in the reports are engineering plans and specifications for structural practices, operation and maintenance plans for the project, and detailed labeled photographs of the project site before and after the implementation of pollution control measures. MPCA staff members also inspected the project sites periodically based on the nature of the pollution control measures, weather conditions that may affect the functioning of the measures, and some specific inspection schemes.

Although compliance with permit provisions by the point sources has been satisfactory, no systematic monitoring aimed to identify and/or verify the pollution reduction effectiveness of the nonpoint source pollution loading control measures used in trading has been performed. 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 time), it is not likely that such monitoring would take place any time soon. Furthermore, the results from such monitoring can not be totally relied on to make unambiguous conclusions due to the high temporal and spatial variability of the actual effectiveness of nonpoint source controls in pollution reduction. Only a comprehensive and long-term monitoring project can yield the necessary information leading to definite conclusions.

COST-EFFECTIVENESS ANALYSIS

Rahr Malting Company

A breakdown of the calculated credits generated by each trade and associated costs (Table 1) shows that the river flood scoured area set-asides coupled with vegetation restoration on the Cottonwood and the Minnesota Rivers were the most cost-effective trades. Using the phosphorus:$CBOD_5$ ratio of 1:8, the phosphorus reduction cost for the two river sites was \$4.44 per pound during the five years of the NPDES permit duration. The Rush River bank stabilization was a close second. Although the Eight Mile Creek trade cost the most, it was still an acceptable \$5.28/lb. However, when additional maintenance costs (about \$79,000, Table 4-1) were considered, the overall cost of phosphorus reduction rose to \$6.14/lb. It is not possible to compare these numbers to the costs resulting from the "what-if" situation where the point source (Rahr) had reduced 150 pounds of $CBOD_5$ from its WWTP discharge. This is because the total offset requirement would call for Rahr's WWTP to treat its wastewater until zero pollutant discharge was reached. Nevertheless, we can contrast this number to the price that most municipal WWTPs with a designed flow comparable with Rahr's permitted discharge rate of 1.5 million gallons per day would have to pay to meet a 1 mg/L total phosphorus effluent limit. This limit has been considered necessary for significant water quality improvement in most waterways in Minnesota if only point sources were to bear the burden of all the necessary phosphorus load reductions (Faeth, 2000; Senjem, 1997). According to Senjem (1997), to

Table 1. Trade cost analysis of the Rahr trading project (1997-2002).

Costs to Rahr	Cottonwood & Minnesota R. ‡	Eight Mile Creek	Rush River	Total	Average (per trade)
Credit generated (per day) †	100.7	14.8	98.7	214.2	53.6
$CBOD_5$ removed (lb in 5 years)	367,555	54,020	360,255	781,830	195,458
P§ removed (lb in 5 years)	45,944	6,753	45,032	97,729	24,432
Cost ($) †	102,000	17,810	101,122	300,044 ¶	75,011
Cost per credit ($)	1,013	1,203	1,025	--	1,401
Cost per lb $CBOD_5$ removed ($/lb)	0.56	0.66	0.56	--	0.77
Cost per lb P removed ($/lb)	4.44	5.28	4.49	--	6.14
Social costs (10-year) ††					
Cost ($, annualized)	15,201	2,654	15,070	44,715 ¶	11,179
Cost per lb $CBOD_5$ removed ($/lb)	0.21	0.25	0.21	--	0.29
Cost per lb P removed ($/lb)	1.65	1.97	1.67	--	2.29
Social costs (20-year) ††					
Cost ($, annualized)	10,389	1,814	10,299	30,560 ¶	7,640
Cost per lb $CBOD_5$ removed ($/lb)	0.14	0.17	0.14	--	0.20
Cost per lb P removed ($/lb)	1.13	1.34	1.14	--	1.56

† Source: communication letters between Rahr Malting Company and the MPCA.
‡ Two trades are combined here, the Cottonwood and the Minnesota River sites, both of which are located near New Ulm and are flood scoured area set-asides and vegetation restoration. Separate cost numbers were not sought after in this study.
§ Phosphorus (phosphorus contents of eroding soils were analyzed for the conversion of soil loss reduction to phosphorus loss reduction).
¶ Also includes additional expenditures totaled at about $79,112, resulting mostly from a failed trade and miscellaneous post-construction site maintenance ($29,112), and structural repairing due to flood damages (estimated at about $50,000).
†† Assuming an 8% discount rate.

achieve this 1 mg/L phosphorus limit (depending on the influent phosphorus concentration), these municipal WWTPs would have to spend $4-18 per pound of phosphorus removed on capital and operation costs, based on a 20 year investment life and an 8% annual interest rate. Compared to these values, nonpoint source control activities such as those carried out in the Rahr trading projects can result in substantial savings in most cases.

From a societal point of view, as long as the phosphorus load reduction structures are in place and function as designed, they will continue to contribute to maintaining a lower phosphorus level in the Minnesota River. If we assume a structure lifetime of 10 years and an 8% discount rate (Senjem, 1997), costs of $CBOD_5$ reduction would be only $0.29/lb. With the 1:8 phosphorus to $CBOD_5$ conversion ratio, costs of phosphorus reduction rise to $2.29/lb (Table 1). If the structure life of Rahr's nonpoint source controls can be extended to 20 years—which is very likely according to field experts, these numbers become $0.20/lb for $CBOD_5$ and $1.56/lb for phosphorus. Compared with municipal WWTPs costs, nonpoint source control measures employed in Rahr's trades clearly are cost-effective when long-term social cost-effectiveness is considered.

Southern Minnesota Beet Sugar Cooperative

Each year during the period of 2000-2001, SMBSC contracted on average with about 100 farmers for 17,920 acres of sugar beet spring cover cropping (Table 2). SMBSC compensated the growers at a rate of $2/acre. These acres of spring cover cropping generated an average of 5,765 credits per year (i.e., 5,765 lbs of phosphorus load reduction per year) computed by the credit calculation procedures specified in the permit. Therefore, the annual cost of phosphorus load reduction was $6.22/lb to SMBSC (Table 2). However, it actually cost growers about $6/acre to implement the cover crop. As a result, the actual cost of reducing phosphorus load by practicing sugar beet spring cover cropping was $18.65/lb. This is as high as most municipal WWTPs with a design flow around 1-2 million gallons per day would have to pay to meet a 1 mg/L total phosphorus effluent limit ($4-18/lb).

Table 2. Cost analysis of SMBSC's sugar beet spring cover cropping trades.

	2000	2001	Average
Acreage (acre) †	18,188	17,651	17,920
Payment made by SMBSC ($/acre)	2.00	2.00	2.00
Total payment by SMBSC ($)	36,376	35,302	35,839
Credits generated (lb P) †	5,298	6,232	5,765
Credits per acre	0.29	0.35	0.32
Cost per lb P ($/lb)	6.87	5.66	6.22
Cost to growers ($/acre) ‡	6.00	6.00	6.00
Total cost to growers ($)	109,128	105,906	107,517
Actual cost per lb P ($/lb)	20.60	16.99	18.65

† Source: communication letters between Southern Minnesota Beet Sugar Cooperative and the MPCA.
‡ Expert estimate, not inflation adjusted.

From the perspective of society, the above analysis suggests that trading with farmers practicing sugar beet spring cover cropping does not result in cost saving in phosphorus pollution control. Nevertheless, there are other benefits not related to pollution control that may lend some support to this control measure. For example, sugar beet growers are willing to adopt spring cover crop because it also protects emerging sugar beet plants from wind damage. Although no quantitative research has been done on exactly what the agronomic and farm-level economic benefits of spring cover cropping are to sugar beet production, empirical and anecdotal evidence have demonstrated these benefits, and acceptance of cover cropping is increasing among sugar beet growers.

Transaction Costs

Transaction costs occurred at every stage of trading. These costs included time spent on permit negotiation, searching for trading partners, administrative expenditures, mandated communications between the permittee and government authorities, and MPCA staff time on credits verification, post-project site inspection, and routine project management. It is difficult to distinguish and capture each and every cost associated with a transaction. Given MPCA's regulatory role and the full responsibility that the two point sources had in making trading happen and function properly in controlling pollution, MPCA and the point sources were the primary parties who incurred most of the transaction costs. Therefore, the transaction cost analysis focuses on expenditures incurred by these three parties but were not included in the previous sections.

To facilitate analysis, trading 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 where trades took place and credit requirements were fulfilled with implementation of pollution reduction measures. Engineering, material, and consulting costs during the implementation phase, most of which were covered by the trust fund, were not considered transaction costs. In each phase, staff time spent by the point source and the MPCA were estimated by respective staff members and median salary rates were used to obtain the cost. Due to SMBSC's unwillingness to disclose relevant information and the on-going nature of the project, only transaction costs associated with the Rahr project was estimated and is presented in the next section. However, an approximate account of potential transaction costs associated with the SMBSC project is also provided 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 pointed to two remarkable findings. First, the permitting phase was very costly to both the point source and the MPCA (the regulatory agency). Second, the regulatory

Table 3. Transaction cost analysis of Rahr's trading.

		Time (hr)	Rate ($/hr) †	Number of personnel	Total ($)
Permitting Phase					
Rahr	Consultants	30	200	2	12,000
	Company staff	30	75	2	4,500
	Sub Total	**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
	Sub Total	**2,080**	**--**	**3**	**51,794**
	Phase Total	***2,200***	***--***	***7***	***68,294***
Implementation Phase					
Rahr	Company staff	35	63	1	2,188
	Sub Total	**35**	**--**	**1**	**2,188**
MPCA	Staff (engineer)	1,387	24	1	33,301
	Sub Total	**1,387**	**--**	**1**	**33,301**
Outside help	Citizens group	45	17	1	750
	Sub Total	**45**	**--**	**1**	**750**
Nonpoint sources	Landowner	--	--	--	500 §
	Sub Total	**--**	**--**	**--**	**500**
	Phase Total	***427***	***--***	***3***	***36,738***
	Grand Total ($)	**3,667**	--	10	**105,032**

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

agency spent much more time than the point source on transactions of the trading project in both phases. The permitting process for the project took about two years to complete. As the state's first point-nonpoint source trading project, it was a new experience for everyone involved in negotiating the trading related permit provisions. Therefore, the length of the permitting process was not a total surprise. Of the estimated $105,032 total transaction cost, 65% occurred before any actual trade took place. The Rahr project clearly benefited from the small number (four) of trades that it needed to obtain all the required pollution reduction 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 potential project sites and build initial contacts with landowners. Two out of the four trades (the Minnesota River and the Cottonwood River sites) 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 American Waters (a nation-wide 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 terms of information searching for trading partners.

The other noteworthy finding from Table 3 is the MPCA share of the total transaction cost was at 81% of $85,095. There are probably two reasons for this. During the permitting phase, besides negotiating with the point source, MPCA was also 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 burden were not reduced correspondingly. As a result, MPCA spent more staff time on the project than the point source.

The cost-effectiveness analyses conducted in the previous section did not include transaction costs. Figures for pollution reduction costs were basically engineering costs for construction work to implement the pollution control measures, including material and designing. Trust funds spent in both trading projects were counted against these engineering costs. Including transaction costs would inevitably lower the project's cost-effectiveness. In the Rahr case, adding the total transaction cost to the cost-effectiveness analysis increased the total cost of the project to \$405,076, a 35% increase over the original calculated cost (\$300,044, Table 1) over the five-year project period. The cost of $CBOD_5$ reduction[4] increased to \$1.03/lb and phosphorus to \$8.26/lb. The twenty-year annualized costs became \$0.26 and \$2.10/lb, respectively. These numbers represent a 34.6% increase from the corresponding values calculated without transaction costs in the previous section. Compared to Senjem's (1997) municipal WWTPs phosphorus reduction cost estimates (\$4-18/lb), however, these numbers are still very competitive and indicate potentially sizable cost-savings for point-nonpoint source pollution trades of similar nature.

The SMBSC permit took about one and a half years to finalize, half a year less than the Rahr permit, apparently due to the experience that the MPCA staff gained from the latter. As an NPDES permit, the permitting process for the SMBSC was essentially the same as the one for Rahr. Therefore, it can be assumed that the same amount of transaction costs occurred in the Rahr project during the permitting phase as occurred in the SMBSC project, except that half a year's time was saved. The different types of trades that the two projects used to obtain credits, however, resulted in some different sources of transaction costs (or cost-savings) during the implementation phase of the two projects.

[4] When per pound pollutant reduction costs were calculated, the \$500 legal fee spent by one of the nonpoint sources and the \$750 listed as "outside help" in Table 3 were not included. They did not apply to all the four trades and they are insignificant compared to the total transaction cost.

SMBSC, a cooperative with a 600 farmer-member base, traded with its farmer members for the first three years of the project period by contracting with them to practice sugar beet spring cover cropping. Many sources of transaction costs, such as trade searching, information collection, and bargaining 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 each parcel's planting and cover crop management. This seemed to be a potential source of significant transaction cost. However, visits to the farmers by the cooperative's agronomists had been conducted routinely for sugar beet planting advice before the trading project started. It took the agronomists only a few extra minutes during their field visits to take the required photographs for the trading project. Therefore, these types of transaction costs were minimized. In essence, credit exchanges between SMBSC and the sugar beet farmers practicing cover cropping is a kind of internal credit trading that offsets new loadings from the plant by reducing emissions from other sources in the same plant. This is much like the netting policy in EPA's Emission Trading Project in 1974 (Hahn, 1989). There were no actual external trading partners and thus lower transaction costs.

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 trade-by-trade credit verification process required more time by MPCA staff for site visits, credit auditing, and other necessary administrative work. It is estimated that MPCA staff time spent on the SMBSC project during the implementation phase will have been three times more than that in the Rahr project when the current permit expires. 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 the MPCA invested in the former.[5]

The magnitude of the total transaction cost cannot be accurately estimated at this point as the project is still in its fourth year of implementation. One full year remains in the permit and information on transaction costs incurred by the point source is not readily available. However, two facts lead us to conclude that SMBSC's trading provided no advantage over phosphorus controls applicable to small-to-medium sized municipal WWTPs. First, the cost-effectiveness analysis from the previous section indicated an already high per pound phosphorus reduction cost for cover cropping. Second, because of Rahr's transaction cost, a large share of which accrued to MPCA, and the increased 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, when the transaction costs are included, will very likely exceed $24/lb.[6]

Scientific Uncertainties

The above analysis indicates that the most cost-effective nonpoint source pollution control methods are long-term structural measures coupled with bioengineering techniques, such as the three bank stabilization/flood scouring area set-asides and re-vegetation sites in the Rahr trading project. The advantages of these measures lie not only in the higher pollution reduction they can achieve with low investment but also in the greater scientific certainty they can offer when

[5] A rough accounting based on the Rahr numbers (Table 3) are as follows:

Cost saved from the 0.5 year reduced during permitting phase: $68,294 × (0.5/2) = $17,073

Cost increased from more MPCA staff time: $33,301 × (3 - 1) = $66,602

Net increase: $66,602 - $17,073 = $49,528

[6] Assuming a 30% increase of pollutant reduction cost due to transaction costs based on the Rahr numbers in section 4.3.1, we have: $18.65/lb × (1+30%) = $24.24/lb

pollution reduction is estimated. The reason for the latter advantage is the long lifetime of the structures used in these measures and the equally long timeframe involved in the pollution reduction estimation process. For example, the credits calculation procedure for the Rush River bank stabilization project was based on seven aerial photographs taken from 1964 to 1999 at the project site on the river. Average bank recession rate was estimated over this time span of 36 years that included both high and low flow periods, and average flow years. The lifetime of the bank stabilization structure is expected to be the same as the trees planted. The “J” hooks put in the river to deflect flow energy are also expected to withstand designed events. Even after catastrophic flood events, they still can continue to be self-sustaining when properly repaired and maintained. As the lifetime of the structures gets closer to the time span used to estimate the bank recession, we will gain more certainty on the value of the credits estimated for the control measure.

The sugar beet spring cover cropping, on the other hand, has the potential to invoke more controversy in terms of its pollution reduction efficiency evaluation used in trading. The RUSLE method, used in evaluating the trades, was designed for estimating long-term soil loss potential while the cover cropping practice and subsequent pollution reduction was credited in the trading project on an annual basis. The variation of weather conditions (mostly timing and intensity of precipitation) from year to year can directly affect phosphorus loadings from agricultural fields. Using the ADAPT model, which takes into account daily weather conditions, we simulated the effects of cover cropping on phosphorus loss potential from eight land parcels receiving credits from the SMBSC trading project in 2000. Results (Table 4) indicate that for the crop rotation years of 1999-2001 that

Table 4. Comparison of ADAPT and RUSLE credit (equivalent of reduced phosphorus loading in pounds) calculations for sugar beet spring cover cropping.

Township Name	Land Parcel Area (acres)	Tillage Residue System	RUSLE Credits 1999-2001† (/acre)	ADAPT Credits 1999-2001 (/acre)	ADAPT Credits 1996-1998 ‡ (/acre)	ADAPT Credits Average (/acre)
Bashaw	80	Low	0.18	0.002	0.064	0.033
Bernadotte	35	Low	0.30	0.113	0.164	0.138
Crooks	155	High	0.16	0.024	0.102	0.063
Granite Falls	120	High	0.28	0.000	0.726	0.363
Norfolk	90	Low	0.39	0.000	0.215	0.108
St. Johns	87.7	Low	0.53	0.057	0.256	0.156
Three Lakes	50	High	0.05	0.000	0.036	0.018
Wood Lake	115	High	0.23	0.000	0.434	0.214
Average	*91.6*	--	*0.27*	*0.025*	*0.250*	*0.137*

† Sugar beets and cover cropping planting year 2000; values quoted from report submitted to the MPCA by the point source.
‡ Sugar beets and cover cropping planting year 1997.

included 2000 as the sugar beet planting year, RUSLE invariably yielded higher per acre credit values than ADAPT in all eight cases. However, when sugar beet spring cover cropping was simulated for the crop rotation period of 1996-1998, the two models yielded much closer values, with the two means being only 0.02 units apart. ADAPT even produced higher credit values for two of the eight fields (Granite Falls and Wood Lake) than the RUSLE did. The below-average spring flood conditions in 2000 and the catastrophic spring flood of 1997 explained the difference. The short time period that the cover crops stay in the field and their relative small impact after they are killed make the effectiveness of this practice very sensitive to weather conditions. Extreme weather conditions in 1997 caused cover cropping to display its full potential of reducing sediment and associated phosphorus losses to streams while low runoff in the spring of 2000 rendered this practice almost ineffective. Averaging the ADAPT results from the two rotation periods yielded a per-acre credit value of 0.137 for the eight sample fields, a little over half of the RUSLE average value (0.27/acre, Table 4).

During permit negotiations, the trading ratio was a very contentious issue, as expected. However, when scientific uncertainties are encountered, an appropriate trading ratio can indeed help provide some assurance in environmental accountability of point-nonpoint source trades. If we apply the 2.6:1 trading ratio to the RUSLE average credit value of 0.27 per acre for the eight fields, actual phosphorus reduction applied to offsetting SMBSC's point source phosphorus loading becomes 0.104 per acre, lower than the average value estimated by ADAPT over the two crop rotation periods (0.137 per acre). If we assume that the ADAPT results reflect or are at least closer to the real phosphorus reductions achieved by cover cropping, the trading ratio in effect assured that the environment did not suffer from the trading no matter what credit evaluation methods were used.

Although using ADAPT directly in the trading project for credit evaluation would make the project more environmentally accountable, ADAPT requires not only a higher level of technical expertise than RUSLE but also much more time. To evaluate the phosphorus load from the same land parcel, the workload for ADAPT is at least 5 times more than that for RUSLE. This would substantially increase the cost of a trading project that needs to evaluate credit potential for hundreds of land parcels. A more practical approach would be to use ADAPT to statistically develop a trading ratio during the project design phase based on the potential over- or under-prediction of phosphorus loads by RUSLE. Such an investment would be worthwhile considering the benefits it can bring to other similar projects in the future.

Other Social Benefits of Trading

From a societal point of view, the two trading projects may have produced social benefits other than cost savings. First, the trading projects provided much needed funds for nonpoint sources to implement pollution control measures. This is best illustrated by the Rush River and the Eight Mile Creek trades in the Rahr project. Since 1988, the land owners at the project sites had been in desperate search for financial aid to control river bank erosion because the erosion 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 project came along, the owners could not raise sufficient funds for effective bank stabilization work to solve the problem. Now, two and four years after the installation of bioengineered bank stabilization structures on the sites, there has been "no problem," as one of the owners commented.

Second, pollution trading provided the necessary solution through which the two NPDES permittees were able to (1) build their own WWTP to lower production cost (Rahr) or (2) expand production scale (SMBSC) during a time in which domestic and international competition has created difficult times 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 190-300 workers in the local labor market with an annual payroll of over $6 million.

Third, environmental benefits brought by pollution trading are 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 retained waste water during spring. Pond-storing not only limited the production scale but also caused an odor problem that once was a major environmental nuisance in Renville County. Therefore, point-nonpoint source trading also reduced air pollution. In addition, the Rahr's floodplain restoration projects with the protection and planting of native vegetation created habitat for wildlife.

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 the public awareness of both the nonpoint source pollution problems and the opportunity of using trading to introduce nonpoint source pollution controls. In addition, Rahr donated the Cottonwood and Minnesota River sites, which are basically restored wetlands, to the city of New Ulm and a local environmental organization (the Coalition for a Clean Minnesota River), respectively, to be used as park and an environmental education site.

DISCUSSION AND CONCLUSIONS

Nature of Offset Projects

From the very beginning, Minnesota has tied its point-nonpoint source pollution trading to the National Pollutant Discharge Elimination System (NPDES), as recommended by Taff and Senjem (1996) and the U.S. EPA's 1996 framework (EPA, 1996). This legal arrangement is well suited to the two projects evaluated: both are trading between a single point source and multiple nonpoint sources. An NPDES permit offers many advantages. The most significant one is probably a higher level of environmental accountability through the control and oversight by MPCA. MPCA achieved this control and oversight by prescribing credit-eligible nonpoint source 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, point sources did not have the flexibility to choose between implementing in-plant control measures and purchasing necessary reductions from nonpoint credits. They had to buy, and were responsible for assuring the proper functioning of nonpoint source control measures prescribed by the permits. In essence, what we had in the Minnesota River Basin were offsetting projects created to compensate for loads from new point sources, which is not a traditional market-based pollution control mechanism. As pointed out by Shabman et al. (2002), a true market-based trading project necessitates a high degree of shifting management responsibility of pollution control decisions from the regulator to the discharger. The trading scheme used in the two projects in the Minnesota River did not have this characteristic. The program design coupled with the fact that most nonpoint sources are not regulated can cause the following three negative effects. First, because nonpoint sources have low incentives to innovate and there are high transaction costs involved in trading, theoretically predicted cost savings from emission trading may not be realized or may be realized to only a small extent of the full potential. The analysis indicated that cover cropping did not provide any pollution reduction cost-savings to the society. When Rahr's good fortune of finding high credit-yielding trading opportunities in the basin runs out in the future, it is very likely that Rahr will also suffer from high pollution control investment costs and high transaction costs in finding and negotiating with nonpoint source trading partners.

Second, high transaction costs, particularly administrative costs of the regulatory agency in such a trading scheme, cannot easily be avoided. As discussed above, the regulatory agency shouldered much of the total transaction costs in both of the trading projects. Better control and oversight for environmental accountability came at the expense of higher staff costs. In addition, higher trade volume brought higher transaction costs to the regulator due to the increased number of sites to monitor and greater administrative work. In true market-based trading, higher trade volume usually means lower transaction costs per trade because of the introduction of secondary market activities such as brokerage services.

Conclusions

The two trading projects in the Minnesota River Basin cannot be regarded as truly market-based pollution rights trading due to their new source offsetting nature and the restrictions that the point sources faced in choosing different control options to meet pollution reduction requirements. In terms of cost-effectiveness in reducing pollutant loads to the environment, long-term structural pollution control measures, such as stream bank stabilization, were more cost-effective than investing in small- to mid-sized municipal waste water treatment plants even after transaction costs were added to the total cost. It was found that transaction costs increased the total cost of the projects by at least 35%. In the Rahr project, 65% of the total transaction cost occurred during the permitting phase while 81% of the total transaction cost was carried by the regulatory agency.

Scientific uncertainties in credit evaluation procedures have the potential to compromise the environmental benefits expected from point-nonpoint source trading projects. However, with the help of advanced scientific tools, properly defined trading ratios can take these scientific uncertainties into account and provide assurance for the environmental accountability of point-nonpoint source trading. Long-term structural controls not only were more cost-effective in pollution reduction but also offered greater scientific certainty in estimating pollution reduction. The reason for the latter advantage is the long life of the structures used in these measures and the equally long timeframe involved in the pollution reduction estimation process.

It was also found that besides cost savings in pollution reduction, offsetting trading projects also brought some other social benefits to the watershed, including balancing environmental protection and economic growth and providing funds for nonpoint sources pollution control measures.

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