JOURNAL OF THE AMERICAN WATER RESOURCES ASSOCIATION

Vol. 48, No. 1 AMERICAN WATER RESOURCES ASSOCIATION February 2012

AN EX POST EVALUATION OF OHIO'S GREAT MIAMI WATER QUALITY TRADING PROGRAM[1]

David A. Newburn and Richard T. Woodward[2]

ABSTRACT: Market-based approaches to address water quality problems have resulted in only limited success, especially in trading programs involving both point and nonpoint sources. We analyze one of the largest point-nonpoint trading programs – the Great Miami Trading Program in Ohio, administered by the Miami Conservancy District (MCD). Our evaluation focuses on the economic and institutional aspects of the program, including cost effectiveness, efficiency of bidding, transaction costs, trading ratios, and innovation. We use a unique dataset consisting of all bids from agricultural nonpoint sources and interviews of soil and water conservation district (SWCD) agents in the watershed. We find that the MCD's reliance on county-level SWCD offices to recruit and advise farmers has been essential to achieve relatively high rates of farmer participation. Additionally, the MCD is able to partly free ride on the administrative costs that SWCD offices receive to assist federal conservation programs, which is helpful to lower costs for a fledgling trading program. However, the involvement of SWCD offices reduced the potential cost savings from the reverse auction structure because some agents were able to learn about the threshold price over the six rounds of bidding and help farmers bid strategically. Overall, the program structure serves as an effective model for future trading programs in other regions that seek to involve agricultural nonpoint sources.

(KEY TERMS: water quality economics; water policy; environmental trading; watershed management; best management practices.)

Newburn, David A. and Richard T. Woodward, 2011. An Ex Post Evaluation of Ohio's Great Miami Water Quality Trading Program. *Journal of the American Water Resources Association* (JAWRA) 48(1): 156–169. DOI: 10.1111/j.1752-1688.2011.00601.x

INTRODUCTION

Market-based approaches are increasingly being used to address issues of environmental quality. The United States Environmental Protection Agency (USEPA) started down the path toward market-based instruments to reduce air pollution in the 1970s and by the 1990s the number and scope of such programs was expanding rapidly. The national SO_2 program, started in 1990, has proven that a program can work in textbook-like fashion (Stavins, 1998). A market-based approach to address water pollution, commonly called water quality trading (WQT), has been promoted for decades and was even the primary example used in Dales (1968) that first proposed the idea of transferable discharge permits. In the prototypical WQT program, a municipal wastewater treatment

[1]Paper No. JAWRA-10-0197-P of the *Journal of the American Water Resources Association* (JAWRA). Received November 10, 2010; accepted August 3, 2011. **Discussions are open until six months from print publication.**

[2]Respectively, Assistant Professor and Professor, Department of Agricultural Economics, Texas A&M University, 2124 TAMU, College Station, Texas 77843-2124 (E-Mail/Newburn: danewburn@ag.tamu.edu).

plant (WWTP) offsets a legal requirement to reduce its pollution load by purchasing credits from farmers who adopt nutrient-reducing practices such as conservation tillage. When reducing pollution from agricultural conservation practices is less expensive than similar reductions at a WWTP, then trading has the potential to greatly reduce the cost of achieving the pollution reductions in total maximum daily load (TMDL) requirements under the Clean Water Act that are increasingly being mandated within the United States (U.S.). The USEPA (2001) estimated that allowing trading between point and nonpoint sources could reduce the cost of implementing TMDLs nationally by $140-235 million annually.

While trading programs in air pollutants have expanded and led to robust markets, WQT programs have been slow to be established and market activity has been limited despite substantial agency efforts at local, state, and national levels. Breetz *et al.* (2004) conducted a comprehensive survey of WQT programs in the U.S. in 2004 that analyzed 46 trading initiatives and state-level policies and found that most of these efforts generated few, if any, trades. In 2008, the EPA compiled information on 37 trading programs and found that about a third of these programs reported no trades. When trading did occur in 24 programs, it typically resulted in only a few trades (USEPA, 2008, Trading Program Information, http://www.epa.gov/owow/watershed/trading/tradingprograminfo.xls, *accessed* November 2010).

There have been a number of critiques of WQT, that have provided a range of explanations given for the limited success of WQT programs (Hoag and Hughes-Popp, 1997; Jarvie and Solomon, 1998; King and Kuch, 2003; King, 2005; Shabman and Stephenson, 2007; Morgan and Wolverton, 2008; Stephenson and Shabman, 2011). Ribaudo and Gottlieb (2011) provide a recent summary of both supply- and demand-side factors that have created barriers for effective trading. Among the issues that are most frequently noted as creating barriers for WQT is the fact that existing WQT programs often incorporate high distortionary trading ratios that require buyers to purchase more pollution reductions than they would need to offset internally without trading, or have high transaction costs that reduce the gains from trading between buyer and seller. Both of these factors reduce the value of trading (e.g., Hahn and Hester, 1989; Horan *et al.*, 2004). The difficulty in monitoring nonpoint source loads, which are often believed to be the low cost sources of abatement, has also created obstacles to the success of these programs. First, such sources can usually not be regulated directly. Second, the credibility of a trade depends on how accurate pollution reductions can be measured or estimated. Additionally, as TMDLs must pass through a highly litigious process, failure to establish credible bounds on the total nutrient load may also limit demand (King, 2005; Ribaudo and Gottlieb, 2011) and, according to Morgan and Wolverton (2008), has been a significant reason why even established programs have failed to generate many trades.

In this paper, we conduct an ex post evaluation of the Great Miami Trading Program (GMTP) located in the Ohio River Basin and administered by the Miami Conservancy District (MCD). The GMTP is one of the most successful WQT programs to date in several dimensions: the program has resulted in significant demand for pollution credits from WWTPs, these sources have purchased credits from nonpoint sources, and the program has led to the implementation of a large number and diverse array of agricultural best management practices (BMPs) to reduce pollution in the watershed. We utilize the framework proposed by Tietenberg and Johnstone (2004) for the ex post evaluation of a tradable rights program. Specifically, our evaluation focuses on the following economic and institutional aspects of the Tietenberg and Johnstone framework: cost effectiveness, efficiency of bidding, transaction costs, trading ratios, and innovation in practices proposed. These criteria are particularly appropriate for an economic evaluation of a trading program since the incentives for cost effectiveness and innovation are the advantages of a market-based approach that are most frequently noted in favor of a tradable emissions system (Tietenberg, 2006).

We utilize two primary data sources. First, we use the complete set of farmer bid applications submitted to the MCD, including both accepted and rejected applications. Each application has the proposed practice, farmer bid, estimated nutrient reductions, length of contract, round of bidding, and other information. Second, we conducted semistructured interviews in June 2009 of the extension agents in soil and water conservation district (SWCD) offices for all 10 of the participating counties in the watershed. A standardized survey was administered in field visits to each SWCD office in June 2009 and included closed-end questions on topics, including: size of SWCD office staff, amount of training received from MCD staff about the GMTP, program dissemination and recruitment methods, factors influencing bidding behavior, and attitudinal questions about the GMTP program design. The interviews also included open-ended discussion to understand more details on how the program actually functioned. The SWCD agents play an important role in the GMTP because they serve as intermediaries between the MCD and farmers.

The remainder of this paper is organized as follows. In the next section, we provide an overview of important features of the GMTP. The following section presents our ex post evaluation of the GMTP, focusing on the cost effectiveness, bidding behavior, and the role of institutions that were critical to program success. Finally, we provide concluding remarks and lessons learned from the GMTP that may help researchers and policy makers develop more effective WQT programs in other regions facing TMDL requirements.

BACKGROUND AND INSTITUTIONAL DESIGN OF THE GMTP

The Great Miami River Watershed is located primarily in southwestern Ohio and covers an area of nearly 4,000 square miles (Figure 1). The watershed area is dominated by agricultural uses (70% of land area) particularly for row-crop production in corn, soybeans, and wheat. Typical livestock operations include swine, beef cattle, and dairy. In 2002, the watershed included over 1,000 farmers with gross annual farm revenues in excess of $1.2 billion (National Agricultural Statistics Service, 2004). The watershed has a total population of 1.5 million people and more than 75% reside in urban areas, including the cities of Dayton, Troy, Hamilton, and the upper portion of Cincinnati. The watershed includes over 1,000 stream miles and over 40% of these stream miles do not meet federal standards for attaining aquatic life (MCD, 2005). The condition of the Great Miami River Watershed also affects receiving water bodies downstream, including the Ohio and Mississippi Rivers and the Gulf of Mexico.

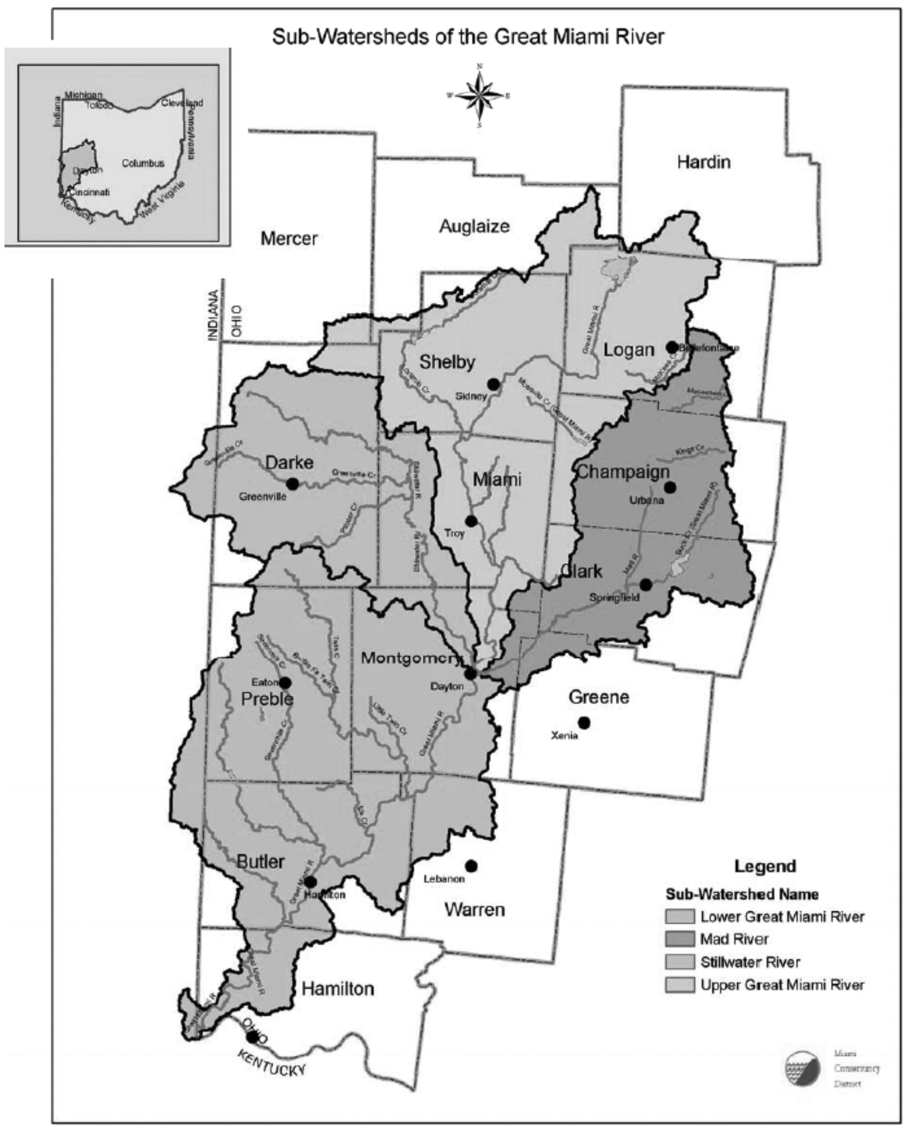

FIGURE 1. Map of the Great Miami River Watershed. Source: MCD (2005).

In 2004, the Ohio EPA anticipated scheduling of TMDLs and implementation of instream nutrient criteria for nitrogen and phosphorus in nearly all subwatersheds in the Great Miami River Watershed. The MCD is a regional water management agency authorized and founded by the State of Ohio in 1915 for flood control and later expanded so that their responsibilities included solving water quality and other watershed management issues. The District began to explore the potential of WQT as a more cost-effective approach to address the new requirements. The MCD's interest coincided with a USEPA (2003) report on guidance for the development of WQT programs. Kieser & Associates (2004) conducted a preliminary economic analysis on WQT for the MCD and estimated that the cost of nutrient reductions from agricultural BMPs on average may be more than 30 times less expensive than from municipal WWTPs. While there are 314 point sources in the watershed, the large municipal WWTPs are the dominant dischargers, including seven point sources with over 10 million gallons per day (Kieser & Associates, 2004). This economic analysis served as a major impetus for demand from WWTPs for the trading program.

The GMTP became fully operational in 2006 and was initiated using a $1 million U.S. Department of Agricultural Natural Resource Conservation Service (USDA-NRCS) grant and contributions from WWTPs to pay farmers to implement load reducing BMPs. It was expected that the nutrient criteria and TMDLs would act as the driver for demand from WWTPs for credits. However, as is true nationally, finalization of the nutrient criteria and TMDLs in Ohio has been delayed for a range of scientific reasons (Miltner, 2010) and legal challenges (MacCurdy, 2011). Of the sub watersheds included in the GMTP, the TMDLs for the Stillwater and Mad watersheds were completed in 2009 and 2010, though numerical nutrient criteria are still not being imposed for sources in those watersheds. Needless to say, this has eliminated the direct demand for credits (Selman *et al.*, 2009).

Despite the absence of a binding obligation on the point sources, WWTPs' contributions to the program by 2010 exceeded $1.2 million. Five separate entities have contributed, with one representing three cities and another that has four plants and inter-plant trading options. During rounds 1-6, contributions from these sources were based on the each entity's contribution to the total of the design discharge flows relative to the loading from all participating entities (Dusty Hall, MCD, July 7, 2011, personal communication). Over half of the plants' contributions have been allocated to funding load reducing projects, with the balance used to support administrative and water quality monitoring costs. Credits purchased to date have *not* been used to offset the WWTPs' pollution reduction requirements since binding nutrient requirements have not yet been imposed. Instead, plants have been willing to purchase credits in advance of a reduction obligation since by doing so they lock in favorable trading ratios for early participation, and this would have great value once the nutrient criteria and TMDLs are finalized (Dusty Hall, MCD, April 1, 2011, personal communication). It is not anticipated that nutrient criteria or TMDLs will impose a binding cap on loads from the agricultural sector. Rather, the GMTP uses a "baseline-and-credit" approach in which a farmer who voluntarily implements a new or expanded conservation practice generates credits equal to the reduction in nutrient loads relative to their current practices.

On the demand side, nutrient limits are to be included in the National Pollutant Discharge Elimination System (NPDES) permits for WWTPs when the nutrient criteria and TMDL requirements are finalized. The WWTPs will be allowed to offset their load reduction requirements by purchasing credits from the GMTP (MCD, 2005). A WWTP can only purchase credits from agricultural sources that are located upstream of the treatment plant's discharge point. The number of credits needed to offset each pound of loading depends on a trading ratio, which varies depending on whether a WWTP is an "Investor," that is, they participate in the program before the regulations are finalized. WWTPs that are Investors can use a trading ratio of one credit purchased in place of a one pound reduction when discharging into attaining waters, or two credits purchased for each pound reduction when discharging into impaired waters. A WWTP that does not participate until after the regulations are in place is called a "Contributor" and must purchase two or three credits when discharging into attaining and impaired waters, respectively. A portion of the credits that are generated by "Contributors" are added to an insurance pool that can be drawn on if projects fail in the future. WWTPs do not have a binding obligation to reduce or offset their loads prior to finalization of the nutrient regulations. However, those "Investor" WWTPs that purchase credits early at lower trading ratios are securing reduced obligations for credits that they may need to submit after regulations are implemented. This has been the principal driver for credit demand to date (Dusty Hall, MCD, October 19, 2010, personal communication).

On the supply side, any farmer in the watershed is eligible to apply for funding under the GMTP. A farmer who applies, works with his/her SWCD to submit a bid stating the dollar amount requested and proposed practice changes. The proposed practice must be newly adopted and cannot receive funding from any federal or state cost-share programs. However, unlike in some WQT programs, there is no requirement that farmers implement a minimum set of baseline practices before practice changes are eligible to generate credits. In preparing the applications, farmers receive assistance from a county-level SWCD agent to calculate the number of credits that the proposed BMP generates using a standardized Spreadsheet Tool for Estimating Pollutant Load (STEPL, Ohio Department of Natural Resources [ODNR], Division of Soil and Water Resources, n.d.). The STEPL worksheet for many of the 17 field-based practice types is based primarily on the factors in the universal soil loss equation, such as cover type, slope, and soil erodibility. The livestock management worksheets cover manure management and treatment of milkhouse water. They are based primarily on the following factors: proximity of manure to a waterway, percentage of surface that is paved, animal weight and number, and the proposed management technology. The worksheets consider the distance from the nearest waterway, but there are no adjustments made for a farm's location within the watershed. The worksheet is authorized for load calculations in the trading program by the ODNR and is based on a spreadsheet developed by USEPA Region 5.

All farmers must submit their applications to the GMTP through their county-level SWCD office. The SWCD office is allowed to include the costs in the farmer's bid application for the SWCD agent time related to assistance and annual inspections. To calculate credits, the SWCD agent enters both actual and proposed practices into the STEPL worksheet. The total number of credits is calculated as the sum of the annual nitrogen and phosphorus load reductions in pounds estimated by STEPL, multiplied by the contract length in years. Hence, nutrient reductions in nitrogen and phosphorus are fungible in the current formulation to calculate credits. The contract length for project duration varies by conservation practice. Most conservation practices have a contract length of up to 5 or 10 years, while those involving livestock management infrastructure projects were allowed to be up to 20 years in length. Applications are evaluated to determine if they satisfy the eligibility criteria and are then ranked based on the lowest total cost per pound of nutrient reduction. Although the application asks whether the proposed practices will generate ancillary benefits (e.g., improved habitat, enhanced canopy), they are only considered in funding decisions in the event of a tie bid. To date, all funding decisions have been based only on the price per pound of nutrient reduction over the contract period of the project. Hence, the bidding is a type of *reverse auction* in that the MCD asks the farmers and SWCDs to state their requested bid amount and then sets the maximum acceptable bid after the round of bidding is finished.

After the nutrient criteria and TMDLs in the watershed are finalized, GMTP credits will be used by WWTPs to offset pollution reduction obligations. Projects must be installed before they can generate credits and annual monitoring of the practices by the SWCD offices is required. Two safeguards are in place to minimize the chance that failed projects will result in compliance issues for the NPDES permit holders. First, "a Management Practice Contingency Plan assures a timely and coordinated response to the failure of a management practice" (MCD, 2005). Second, an insurance pool of credits, which is generated through trading ratios as discussed in more detail below, can be used in the event of failed agricultural projects. Buyers, therefore, face minimal risk that their compliance will be jeopardized by BMP failures. This feature means that buyers have very low risk when buying credits from any source – all credits are essentially uniform. This should lead to a reduction in the program's transaction costs (Woodward *et al.*, 2002).

Two institutions have played critical roles in the functioning of the GMTP. First, the GMTP has benefited greatly from the influential and inspired leadership of the MCD managers. During the process of formulating the GMTP, they organized over 100 meetings with stakeholders. This collaborative approach led to widespread support from diverse stakeholders including agricultural producers, the Ohio Farm Bureau, municipalities, SWCD offices, regulatory agencies, and local watershed groups. Additionally, the MCD serves as a clearinghouse for all transactions between participating WWTPs, SWCDs, and farmers. Hence, transaction costs to market participants are reduced, which can greatly improve the program efficiency (Woodward *et al.*, 2002). The MCD has several other roles, including: issuing the requests for BMP proposals once or twice per year depending on funding, maintaining data on credits, managing an insurance pool of additional credits, and supervising the collection of water quality monitoring data (MCD, 2005).

The second key institution has been the SWCD offices. The MCD relies on the SWCD offices in each county rather than attempting to recruit farmers on its own. The SWCD agents help promote the program, assist farmers in the completion of project applications, distribute funds to accepted projects, and then oversee the implementation and monitoring of the funded projects. The SWCD agents already have similar responsibilities in the federal conservation programs administered by the USDA, including the Conservation Reserve Program (CRP) and

Environmental Quality Incentives Program (EQIP). They also are "socially embedded" agents with existing networks of relationships that can reduce the historic mistrust between farmers and urban groups, such as the MCD and municipal WWTPs, thereby facilitating transactions in WQT programs (Breetz *et al.*, 2005; Mariola, 2009).

EX POST EVALUATION OF THE GMTP

Bid Applications for Agricultural BMPs

Table 1 summarizes the bid applications by proposed practice type that farmers submitted to the MCD through the first six rounds of bidding. A total of 160 eligible applications were submitted as of the sixth round of bidding in 2009, and the MCD funded 100 projects for agricultural BMPs (63% acceptance rate). Over $1.3 million, about two-thirds of which has come from the WWTPs either directly or with matching support from the EPA and USDA, has been allocated to the funded practices, providing an estimated 808,845 pounds of nutrient reductions. There were an additional 60 applications (not included in Table 1) that the MCD ruled ineligible for various reasons, including projects already funded by federal conservation programs, not using an approved STEPL module for calculating nutrient reductions, missing information, or withdrawn by the farmer. These 60 ineligible applications are not considered in the analysis below.

Table 1 demonstrates the substantial diversity of practice types submitted to the MCD. This table actually understates the diversity in the practice types because some applications involve multiple practices on multiple fields. In fact, 11% of the applications used two or more unique practices sufficiently different to require separate STEPL worksheets. As the farmer's bid is submitted as a single application in these cases, some aggregation is required for our analysis and we determined the dominant practice as that which is estimated to generate the most nutrient reductions.

The majority of bid applications in Table 1 are field-based practices, including 49 applications for conservation tillage and 55 applications for cover crops. However, these two field-based practices only represent 21 and 8% of the total funded nutrient reduction, respectively. Meanwhile, the program has funded 12 applications for livestock management (e.g., manure storage pond or structure), and these projects represent 58% of the total funded nutrient reductions. The majority of these funded livestock projects were located in Darke County (10 out of 12 livestock projects), with the remaining 2 livestock projects in Logan and Mercer Counties. The average project size for livestock management practices is approximately six times larger than average size of all other practice types (Table 1). One reason is that the contract length for livestock projects is on average 15.8 years, which is three times longer than the average project. This is logical given the large fixed costs for manure management projects, relative to much shorter contract lengths for cover crops that are more easily reversible.

When compared to the other WQT programs in the U.S., the GMTP has been an unprecedented success in the diversity of agricultural BMPs funded (Ribaudo and Gottlieb, 2011). To our knowledge, all WQT programs that have led to trades involving agricultural nonpoint sources have generated trades from a single practice type. For example, a single practice was pursued in the Southern Minnesota Beet Sugar Cooperative Permit, the program with the largest number of trades (Ribaudo and Gottlieb, 2011) and the Rahr Malting Company, one of the earliest significant

TABLE 1. Bid Applications by Practice Type.

			Approved Projects			
Practice Type	**Bids Submitted**	**Approved Projects**	**Total Nutrient Reductions (Pounds)**	**Nutrient Reductions per Project (Pounds)**	**Min. and Max. Bid ($/lb)**	**Contract Length (Years)**
Bank stabilization	7	5	39,466	789	1.69-1.75	10.0
Cover crops	55	47	67,342	1,030	0.36-2.00	1.3
Filter strips	2	0	NA	NA	NA	NA
Grass waterways	14	9	36,224	458	1.24-2.00	9.4
Fertilizer management	10	0	NA	NA	NA	NA
Hayfield establishment	11	9	26,357	358	1.12-1.60	8.6
Livestock management	12	12	467,768	2,435	1.20-1.99	15.8
Conservation tillage	49	18	171,689	1,350	0.58-2.00	5.6
Total	160	100	808,845	1,142	0.36-2.00	5.6

programs (Breetz *et al.*, 2004). Other programs still under development, such as the Lower Boise River program, are designed to allow a range of different practices, but this potential has not yet been realized (Morgan and Wolverton, 2008). The implication for economic efficiency is that when a trading program focuses narrowly on a single BMP to reduce pollution, it suggests that other cost-effective opportunities may be left unexploited. Hence, it is a positive sign that the GMTP has been able to create a program with greater variety in the proposed and funded practice types.

Innovation in the GMTP

One of the most attractive features of tradable rights programs is the potential that such programs might create incentives for individuals and firms to find innovative ways to achieve environmental goals at lower cost. Given the wide variety of BMPs that affect nutrient loads, there seems to be potential for innovation. This philosophy is stated explicitly in the GMTP's operations manual:

> The Trading Program does not recommend specific activities that generate credits but instead relies on agricultural producers, local soil and water conservation professionals, and members of community-based watershed organizations to identify projects that accomplish a desired nutrient reduction. (MCD, 2005, p. 9)

In reality, however, the prospects for innovation are somewhat constrained. As an SWCD agent explained during our interviews, "They told us to think out of the box, but there was no way to step out of the box." The "box" in this case is the STEPL module used to estimate the reduction in pollution load. A proposed practice type is eligible for the GMTP only after the ODNR has approved the STEPL module for this practice. These modules are only developed for widely used practice types with available data to support the model to estimate nutrient reductions.

That being said, the ODNR has reacted to pressure from farmers and SWCD agents to develop new STEPL modules. An approved STEPL module was introduced for livestock manure management starting in round 2 and for cover crops starting in round 6. These new modules are important for the GMTP because the livestock management BMPs represent the largest number of total pounds reduced and the cover crop BMPs represent the largest number of applications (Table 1). Although there has been some degree of innovation in the GMTP, the current process does not encourage farmers to experiment and explore new management options to reduce loads outside of those approved by the ODNR. Because the process must rely on agency specialists from the ODNR, innovation is slow and imperfect. This acts as a critical barrier to innovation, where some potential low-cost practices are not allowed to sell pollution credits until a STEPL module is developed for those practices.

Cost Effectiveness

In this section, we evaluate the GMTP use of a reverse auction structure to improve cost effectiveness for bids on proposed agricultural BMPs (i.e., supply side of the WQT market). By cost effectiveness, we refer to an assessment on the degree to which actual farmer bids in the reverse auction structure are lower than would be achieved under a simple fixed price structure. In a reverse auction, when a farmer submits a bid that is higher than their opportunity costs, they will gain additional rents from the program; however, a higher bid also has a lower likelihood of acceptance. In theory, a reverse auction can increase the cost effectiveness of the program by creating incentives for farmers to reveal their reservation price, that is, the lowest price they would willingly accept to compensate them for implementing the practice (Latacz-Lohmann and Van der Hamsvoort, 1997).

We calculate a cost-savings (CS) metric as the percent savings for round j in the program relative to a fixed price

$$\mathrm{CS}_j = \frac{p_j - b_{ij}}{p_j} \times 100\% \qquad (1)$$

where p_j is the maximum allowable price for bids accepted in round j and b_{ij} is the bid amount requested by farmer i in round j. Table 2 shows the CS metric as percent savings by round number in the program. In round 1, the reverse auction provided an average of 32% savings relative to a fixed price. However, the percent savings decreased in latter rounds of bidding and was only 14% in round 6.

TABLE 2. Cost Savings by Round Number.

Round Number	Bid Applications	% Accepted	CS Metric (% savings)
1	19	63	32
2	62	24	24
3	9	89	28
4	18	78	19
5	2	50	1
6	50	100	14
Total	160	63	19

Figure 2 presents the smoothed frequency distributions of bids in each round. It should be noted that round 5 is omitted because there were only two bids due to a relatively short time window to submit bids in this round. The frequency distributions of bidding were relatively dispersed in rounds 1 and 2 (Figure 2). After round 2, however, the bid distribution became more concentrated into a narrow band just below the threshold for the maximum price at $2 per pound set by the MCD. This convergence of the bidding behavior increased over time. In fact, all of the 50 applications submitted in round 6 were accepted. This is further evidence that, in the latter rounds, the participating counties have learned how to bid strategically to get the most possible money from the program while still having their bids accepted. This indicates that the MCD is purchasing nonpoint offset credits at an increased cost over time. As the MCD serves as a clearinghouse for all transactions between farmers and WWTPs, the higher cost of credits has somewhat reduced program efficiency.

A major reason for the decline in effectiveness of the reverse auction is that the MCD did not vary the maximum price paid between rounds. The effectiveness of the reverse auction relies on some degree of uncertainty about the threshold price to create an incentive for lower bids. Some SWCD agents were able to learn over subsequent rounds because of the lack of variation in the MCD decision process. As a result, over the six rounds of bidding, the program has begun to perform increasingly like a fixed price program. This observed effect of learning that occurred due to a lack of variation in the threshold price is a fundamental concern with administering a reverse auction. Latacz-Lohmann and Van der Hamsvoort (1997) report similar behavior in CRP auctions, "By the ninth signup, the majority of the bids were almost exactly equal to the bid caps" (p. 415).

Efficiency of Bidding

In this section, we attempt to evaluate the extent to which the GMTP has been able to obtain the most efficient bids, that is, those that offer the greatest nutrient reductions at the lowest possible cost. Table 3 shows the bid applications and percent funded by county and round number. Fifteen counties have at least some portion of their land area within the Great Miami River Watershed (Figure 1). Fourteen of the counties have land area above the most downstream participating WWTP and therefore are

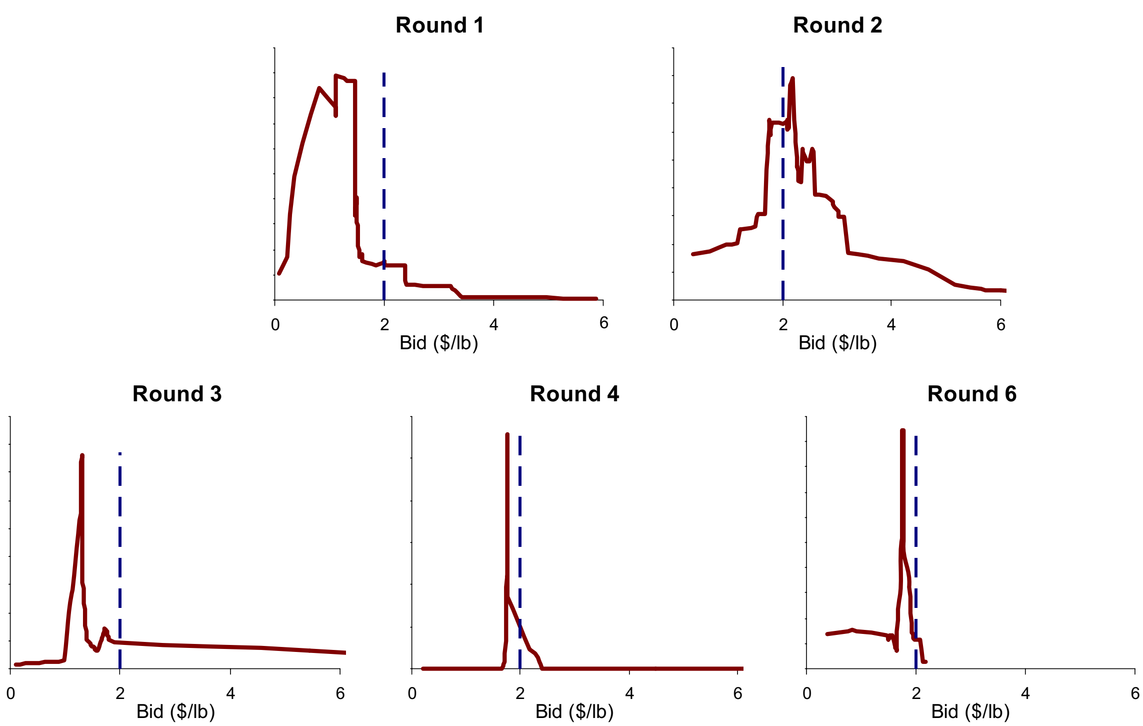

FIGURE 2. Probability Density Functions of Bids by Round. The scale on the horizontal axes is the bid in dollars per pound of nutrient reduction. Round 5 is not included here because only two bids were submitted. The vertical dashed line indicates the $2 threshold above which no bids were accepted. Each probability density function (pdf) was estimated by first developing the cumulative density function (cdf) using linear interpolation from the discrete cdf in the data. The approximate pdf was then obtained at 100 points using discrete derivatives. Finally, moving averaging was used to smooth the pdf in each figure.

TABLE 3. Bid Applications and Percent Accepted by County and Round Number.

County	Round 1	Round 2	Round 3	Round 4	Round 5	Round 6	Total
Butler	1 (0)	2 (50)			1 (0)		4 (25)
Clark				5 (40)			5 (40)
Darke	7 (100)	2 (100)	6 (100)	5 (100)	1 (100)	16 (100)	37 (100)
Logan	1 (100)					3 (100)	4 (100)
Mercer		1 (100)				9 (100)	10 (100)
Miami	1 (100)		1 (100)	4 (100)		1 (100)	7 (100)
Montgomery	2 (100)						2 (100)
Preble		54 (15)					54 (15)
Shelby	4 (0)	3 (67)	2 (50)	4 (100)		21 (100)	34 (85)
Warren	3 (33)						3 (33)
Total	19 (63)	62 (24)	9 (89)	18 (78)	2 (50)	50 (100)	160 (63)

Note: Five of the 15 eligible counties (Auglaize, Champaign, Hamilton, Hardin, and Greene) did not submit any applications.

eligible to submit bids for those farmers inside the watershed boundaries. The applications are highly concentrated in three counties – Darke, Preble, and Shelby – that comprise 125 out of the 160 applications (78% of all proposals). Darke and Shelby Counties both had a high rate of acceptance. Darke County has participated in all six rounds to date and had all 37 bids accepted. Shelby County had only moderate success in the first three rounds, but thereafter had all their bids accepted. Meanwhile, Preble County submitted 54 eligible bids in round 2, but only 8 of these were funded and submitted no bids after round 2.

Table 3 also shows that some counties submitted a small number of applications during the six rounds of bidding, despite having substantial land area within the watershed. In our interviews with SWCD agents, we found that some counties, such as Clark and Warren Counties, that had a low rate of acceptance in their first attempt of bidding largely decided to not promote or participate in the program in later rounds. Similar to Preble County, these SWCD agents said that there was a small amount awarded to the SWCD office and their farmers relative to the considerable effort to formulate the bid applications. Other counties had a high acceptance rate but few bid applications, such as Logan, Miami, and Montgomery Counties. These SWCD agents said that they knew approximately the amount the MCD would pay; however, most BMPs for their farmers would not be competitive or federal conservation programs paid more than the GMTP. There were no bids submitted by five of the fifteen eligible counties – Auglaize, Champaign, Greene, Hamilton, and Hardin. This is primarily explained by the fact that all except Champaign have a minor portion of their land area within the watershed boundary (Figure 1). For Champaign County, the SWCD office has only one SWCD agent who mentioned already being overcommitted with assisting on the large federal conservation programs.

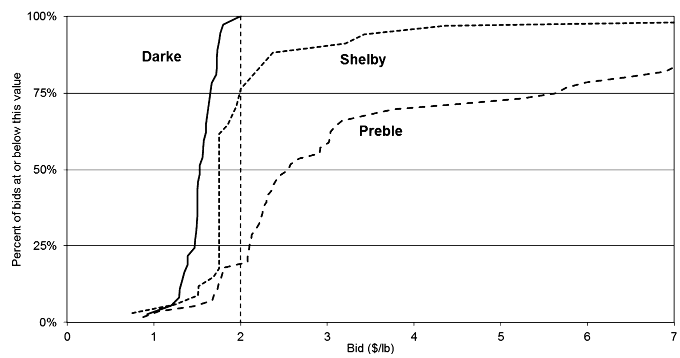

FIGURE 3. Cumulative Distributions of Bids for Three Most Active Counties. The vertical dashed line indicates the $2 threshold above which no bids were accepted.

Figure 3 presents the cumulative density functions for the bid amounts in the three most active counties that submitted the largest number of bids. The shape of these distributions suggests that bidding differed across the three counties. We performed the Kolmogorov-Smirnov (KS) test, using Stata statistical software (version 11) (StataCorp LP, College Station, Texas), to assess whether the bid distributions are statistically different based on pairwise comparisons between counties. The KS test is a nonparametric method to determine whether two sets of data (the bid amount in this case) are drawn from the same distribution. For example, we test the hypothesis that the 54 bids from Preble County are drawn from the same distribution as the 34 bids from Shelby County. This hypothesis can be rejected at the 1% level. Similarly, the bid distributions for Darke and Shelby Counties are significantly different at the 1% level.

One reason for the observed variation in the bid distributions is that the county SWCD offices used different approaches to recruit and advise farmers on bidding strategies. The SWCD agents in Darke County worked individually with each farmer to suggest bid options that met the farmer's economic needs and provided information from previous rounds on the range of bids that were likely to be accepted. In contrast, the SWCD office in Preble County mentioned the GMTP in their newsletter to farmers that included a menu of practice types and corresponding recommended bid rates on a *per acre* cost basis; however, this strategy neglects to consider how the pollution reductions calculated with the STEPL worksheet varies between different farms. Hence, the bids from Preble County are widely dispersed and had a low rate of acceptance, whereas the bids from Darke County are distributed tightly below the threshold price set at $2 per pound (Figure 3 and Table 3). The SWCD agents in Shelby County worked individually with each farmer, similar to the strategy used in Darke County. However, Shelby County took a longer time to learn the range of bids that would be accepted. Shelby County only had 3 out of 9 bids accepted in the first three rounds of bidding, and then had all 25 bids accepted in rounds 4 and 6 (Table 3).

In sum, there has been an increase in strategic bidding by a few successful counties. Some SWCD offices have stopped participating in the program which is problematic because it suggests that some potentially cost-effective practices in those counties are not being implemented. Hence, the reliance on SWCD agents has been critical to encourage participation, but it also can act as a barrier between the MCD and potential farmer participants. Farmers are highly unlikely to participate if they are located in a county in which the SWCD office decides not to promote the program and recruit farmers.

Transaction Costs for Search and Bargaining

Transaction costs have been recognized as an important issue for WQT programs since the earliest programs were formulated. For example, Hahn and Hester (1989) found that transaction costs were the primary reason for the failure of the WQT program on the Fox River in Wisconsin. The USEPA also emphasizes the importance of keeping transaction costs low in their WQT policy guidelines (USEPA, 2003).

The institutional design of the GMTP is relatively effective in reducing transaction costs for search and bargaining. As the MCD serves as a clearinghouse, this lowers the bargaining costs since there are no direct contractual agreements between the WWTPs and participating farmers. Hence, these buyers and sellers do not need to incur the costs of searching for trading partners (Woodward *et al.*, 2002). Furthermore, there is no bargaining in a reverse auction structure on the supply side of the WQT market. An eligible farmer's proposal is either accepted or rejected based solely on the bid.

Additionally, the MCD primarily relies on the county-level SWCD offices to disseminate information and recruit potential participants. Without the involvement of the SWCD offices, it would have been very costly for the MCD to identify farmers who would be suitable potential applicants. The SCWD offices varied substantially in the approaches used to search for willing farmers. But regardless of how the information was exchanged, SWCD offices already have similar duties to assist and monitor practices funded by the large federal conservation programs in the Farm Bill. Hence, the expansion of their responsibilities to encompass participation in the GMTP did not amount to a significant change in their job responsibilities.

An innovative feature of the GMTP is that the SWCD office can explicitly include the costs of assistance and monitoring within the farmer bid application to the MCD. Table 4 summarizes the SWCD costs allocated to both initial assistance and monitoring and the amount paid to the farmer for funded projects in the participating counties. Overall, the GMTP has allocated $52,700 to SWCD offices to provide initial assistance that compensates for the SWCD agent's time spent to design and implement the BMP, calculate the nutrient reductions, and provide other advice for preparing the bid application. This amount represents only about 3.9% of the over $1.3 million total expenditures in the GMTP. Hence, these SWCD costs are unlikely to create a significant barrier to market efficiency.

There is substantial variation between counties in both the amount and percentage allocated to SWCD costs (Table 4). Darke County received the vast majority of the funds allocated to SWCD costs because it has the largest number of funded projects, including several major livestock projects. The other SWCD offices each received <$2,000 for initial assistance. Two relatively successful counties – Shelby and Mercer – actually included no costs for the SWCD office. In our interviews, these SWCD agents explained that any increase in the overall bid amount would reduce the chance that the farmer application would be funded. Hence, they were more concerned with helping their local farmers get accepted than to charge the full costs of their assistance.

The GMTP has typically paid a minor amount relative to the budget for SWCD offices. Table 4 shows the number of employees on staff in each participating SWCD office, which serves as a proxy for the size of the SWCD budget. To put this into perspective, the MCD application lists a billable rate of $25 per hour for SWCD agent time. Therefore, the SWCD offices,

TABLE 4. Total Program Funds for Initial Assistance, Monitoring, and Farmer Payments in Participating Counties.

County	Funded Projects	SWCD Initial Assistance Cost ($)	SWCD Monitoring Cost ($)	Farmer Payments ($)	Total Funds ($)	Number of SWCD Staff[1]
Butler	1	350	0	18,000	18,350	3
Clark	2	400	1,000	15,909	17,309	4.5
Darke	37	46,475	11,128	790,149	847,752	7
Logan	4	1,650	150	20,833	22,633	4.5
Mercer	10	0	0	23,927	23,927	5.5
Miami	6	1,125	625	57,085	58,835	5
Montgomery	2	1,900	100	15,855	17,855	6.5
Preble	8	800	1,000	20,329	22,129	5
Shelby	29	0	0	262,164	262,164	7
Warren	1	0	0	45,260	45,260	3
Total	100	52,700	14,003	1,269,511	1,336,214	51

[1]Soil and water conservation district (SWCD) staff numbers were gathered during in-person interviews in June 2009. All other values are from the bid data provided to the authors by the Miami Conservancy District.

except Darke County, received funds from the GMTP that would provide compensation for less than two weeks of an SWCD agent's expenses over the four-year period spanning 2006-2009 for the six rounds of bidding. Rather, the SWCD offices receive their primary funding from the county government with state-level matching funds to provide assistance for other programs, particularly the federal conservation programs in the Farm Bill administered by the USDA-NRCS.

In sum, the GMTP has been able to exploit the existing network of relationships and institutional infrastructure (e.g., staff, office buildings, vehicles) that assist in the federal conservation programs. This has importantly lowered the transaction costs during the incubation stage of the program. As SWCD offices are commonly found throughout the U.S., this type of relationship with SWCD offices provides a model that may be replicated by fledgling WQT programs in other regions.

Transaction Costs for Monitoring and Enforcement

The cost of monitoring farmer compliance is another type of transaction cost needed for WQT programs, and the GMTP requires that annual inspection reports be filed that document the "generation and status of water quality credits" (MCD, 2005). Again, SWCD agents keep monitoring and enforcement costs relatively low. As the agents have ongoing relationships with the farmers and monitor practices funded by the larger federal conservation programs, it allows them to easily monitor the BMPs installed under the GMTP as well. SWCD agents are also more likely to become aware of farmers who have failed practices or are not in compliance with their contract because they drive through the county and visit with farmers on a regular basis. Finally, since in the end MCD makes payments to the SWCD offices, the board of supervisors for these offices accepts some responsibility for ensuring that credits are actually delivered. In those instances to date where farmers have been found to be not complying with the terms of the contract, the SWCD offices have found ways to either generate the necessary credits on the farm, or SWCDs or farmers have returned funds for credits that were not delivered (Dusty Hall, MCD, April 1, 2010, personal communication). In contrast, monitoring would be more difficult and expensive for the MCD managers who are located in the City of Dayton and only periodically make trips to the counties that participate in the program.

Table 4 shows the GMTP funds paid to SWCD offices for the annual inspections to monitor funded projects. The overall amount dedicated to monitoring was $14,003, representing just over 1.0% of total GMTP funds. The SWCD offices, except for Darke County, received $1,000 or less for the annual inspections. Hence, the transaction costs for monitoring are even smaller than those provided for initial assistance and, thus, do not pose a significant barrier to market efficiency.

Trading Ratios

Similar to transaction costs, trading ratios can create a wedge between buyers and sellers that diminishes market efficiency. Numerous studies have explored issues with trading ratios in WQT programs (e.g., Montgomery, 1972; Malik *et al.*, 1993; Horan, 2001). Montgomery (1972) demonstrates that trading ratios should consider the extent to which pollutants are dispersed and diffused between the point where they are emitted and the point of environmental impact. Malik *et al.* (1993) analyzed how trading ratios should take into account the spatial and temporal uncertainty of the actual pollution reductions achieved. An interesting but somewhat counterintuitive result that comes out of this literature is that the optimal trading ratio should be <1:1, that is, for each credit purchased on average, less than one credit reduction would be required (Shortle and Horan, 2008). The reason behind this result is that if decision makers are risk averse, then the optimal trading ratio should be designed to encourage the purchase of nonpoint offsets to reduce the overall uncertainty in the water quality. Finally, García *et al.* (2011) have argued for trading ratios that incorporate the pulse nature of loading from nonpoint sources and find that the trading ratios should be >1:1.

The trading ratios defined in the GMTP do not address any of these theoretical considerations. Rather, the trading ratios are designed to create two types of incentives. First, the program sets a lower trading ratio for WWTPs that purchase credits prior to the finalization of the TMDL to stimulate early participation in this fledgling market. This incentive has been the principal driver for WWTPs to participate during the pilot phase of the program. Second, the trading ratios are higher when the WWTP discharges into an impaired stream, thereby requiring the WWTP to provide greater nutrient reductions upstream from nonattaining water bodies where water quality improvements are needed most. A portion of the surplus credits created through higher trading ratios >1:1 are used as an insurance pool. Furthermore, the MCD used the funding from the $1 million USDA-NRCS grant, a portion of which was used to support administrative expenses and a portion was used to fund projects and generate credits from agricultural sources which are held in the insurance pool. This reduces the risk of enforcement on the participating WWTPs that may occur as a result of the failure of funded agricultural practices (MCD, 2005). These surplus credits also increase the likelihood that the GMTP will lead to a net reduction in loading in the watershed.

CONCLUSION AND IMPLICATIONS FOR WQT PROGRAMS

Our evaluation of the GMTP provides salient findings and lessons learned that are relevant to help foster the creation of WQT programs in other regions. The GMTP has been quite successful in developing both supply and ensuring funding for agricultural pollution abatement projects compared to other WQT programs. An important factor is that the institutional design relies critically on the MCD acting as a clearinghouse so that WWTPs are not required to search and bargain with potential farmers as trading partners. Hence, transaction costs are lower than many other WQT programs because WWTPs do not need to identify potential farmers or even identify a reputable broker or aggregator.

The GMTP has achieved a large number of farmer bid applications and a wide variety of BMPs funded. There are two main reasons why the reliance on SWCD offices to recruit and advise farmers has been essential to achieve relatively high rates of farmer participation. First, the SWCD agents have longstanding relationships with local farmers and the expertise to know which farmers and practice types are likely to be competitive in the program. The SWCD agents help overcome the historic mistrust between farmers and urban parties (e.g., municipal WWTPs, MCD), thereby lowering the transactions cost needed for market efficiency. As program funds are being administered through the SWCD offices, the GMTP appears similar to the more familiar federal conservation programs and, thus, farmers are more likely to overcome their reluctance to participate.

Second, the GMTP is able to partly free ride on the administrative costs that SWCD offices receive to assist in the federal conservation programs. The SWCD offices are allowed to include administrative costs within the application for assistance and monitoring, which is an innovative feature of the GMTP. However, this amount has compensated at most for time of the SWCD agent. Hence, the MCD only paid a small amount per funded project rather than the costs to establish an office and hire staff in each participating county, which would be prohibitively expensive for a fledgling WQT program. We believe that the prominent role of the SWCD offices in the institutional design of the GMTP has enormous potential to be replicated in future WQT programs in other regions. WQT program administrators, however, will likely vary in the types of responsibilities they wish to allocate to the SWCD offices according to local circumstances (Breetz and Fisher-Vanden, 2007).

Nonetheless, the involvement of SWCD offices poses several issues which require further attention. A reverse auction structure is used in the GMTP in an attempt to reveal the farmer's reservation price to adopt BMPs. However, SWCD agents are likely to learn more quickly than individual farmers about the narrow range of bids accepted in the reverse auction because they receive feedback from prior rounds while assisting farmers and discuss this information with other SWCD agents. Farmers are able to learn bidding strategies directly from the SWCD agent and other farmers to a lesser degree, but repeated bidding by the same farmer was surprisingly rare in the program. This suggests an inherent tradeoff in that the SWCD office is critical for effectively recruiting local farmers but also can reduce cost effectiveness due to their advice on bidding strategies.

Another issue is that the SWCD office can create a barrier between the WQT program and potential farmers in certain circumstances. Some SWCD offices chose not to recruit farmers into the program either because they were overcommitted with their primary duties assisting in the federal conservation programs or because they became frustrated with the trading program after limited success in the early rounds of bidding. In these situations, the SWCD office does not reduce transaction costs, but rather imposes a barrier to trading because farmers in their county are unlikely to be aware of the program without SWCD promotion even though some farmers may be competitive.

Our evaluation of the GMTP has not addressed the program's effect on regional water quality, which has not yet been systematically studied given the relatively minor role that the trading program has had on nutrient management in the watershed to date. Nonetheless, based on our ex post evaluation of the GMTP, we find that the program serves as an effective model for future WQT programs. Moreover, the program continues to be operational, with rounds of bidding occurring in both 2010 and 2011. The institutional design has resulted in active participation and relatively low transaction costs. Overall, we find that the program may represent a turning point in the history of WQT to a future with more vibrant point-nonpoint trading where gains from trade may be substantial.

ACKNOWLEDGMENTS

This article was developed under a STAR Research Assistance Agreement No. RD-83367401-0 awarded by the U.S. Environmental Protection Agency. It has not been formally reviewed by the EPA. The views expressed in this document are solely those of the authors and the EPA does not endorse any products or commercial services mentioned in this publication. The research also benefited from Texas AgriLife Research with support from the Cooperative State Research, Education & Extension Service, Hatch Project TEX8604. We acknowledge many helpful discussions with Dusty Hall, Sarah Hippensteel, Brent Sohngen, Jim Ramey, and the SWCD agents and farmers throughout the Great Miami River Watershed. Research assistance was provided by Sergio Colin Castillo and Mariano Mezzatesta and editorial assistance was provided by Michele Zinn.

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