

# Establishing a Clearinghouse to Reduce Impediments to Water Quality Trading

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**Abstract.** Pennsylvania adopted a water quality trading program to reduce Chesapeake Bay nutrient pollution. It is the first such program to provide regulated point sources the option of purchasing nutrient reduction credits via arms-length market transactions to achieve mitigation requirements. After the program initially experienced limited trading, the Pennsylvania Infrastructure Investment Authority designed a nutrient credit clearinghouse to reduce some of the transaction costs and risks that impeded market activity. We review the clearinghouse functionality, examine initial results of its implementation, and evaluate its effectiveness. Nutrient credit auctions conducted by the clearinghouse revealed that the clearinghouse provided benefits for participants seeking to buy credits and that purchasing credits could be a least-cost compliance alternative for many regulated point sources. To our knowledge, this is the first clearinghouse to successfully administer a nutrient credit auction on behalf of regulated point sources seeking to comply with a discharge permit.

## 1. Introduction

Pennsylvania's Department of Environmental Protection implemented an innovative water quality trading (WQT) program to reduce Chesapeake Bay nutrient pollution originating in the Potomac and Susquehanna River watersheds. The program provides regulated "point" sources, which are predominantly wastewater treatment plants, the flexibility to either upgrade their facility and/or purchase verified credits from other parties, including "non-point" source agricultural operations that undertake eligible pollution mitigation practices. Pennsylvania's WQT program is of economic significance due to its scale and the ecological importance of the Chesapeake Bay.

Pennsylvania's WQT program is unique because regulated point sources have to execute arms-length market transactions to purchase credits, as opposed to administratively-determined fees or other type of non-market program structure. Regulated point

sources must assess the cost-effectiveness of upgrading their treatment facility relative to a credit purchase over a multi-year time horizon to comply at least-cost. This implies that, if they are to purchase nutrient credits, they prefer forward contracts that establish the price they will pay for a specified quantity of credits for multiple successive future years. However, bilateral transactions, which result in a customized contract between a buyer and seller, can entail high transaction costs due to search, negotiation, and enforcement costs. Thus, the ability of regulated point sources to achieve least-cost compliance through trading depends critically on their ability to ascertain the costs of purchasing credits and to assure the performance of credit seller's contractual commitments.

Almost all of the largest regulated point sources elected to upgrade their facility instead of purchasing credits in the early stages of Pennsylvania's WQT program. This occurred, in part, because the WQT program design and institutional characteris-

tics of regulated point sources combined to introduce high transaction costs and risks for those who might otherwise purchase credits to achieve compliance. As a consequence, WQT program stakeholders requested that the Pennsylvania Infrastructure Investment Authority (PENNVEST), a state financing authority for municipal water projects, serve as a financial intermediary in the market as a "clearinghouse" by interposing itself as a buyer to sellers of nutrient credits and vice versa. In response to this interest, PENNVEST, with assistance from the Chicago Climate Exchange (CCX), designed and implemented a nutrient credit clearinghouse during 2009 and 2010. PENNVEST's clearinghouse is intended to reduce impediments to trade nutrient credits by absorbing some of the transaction costs and risks that market participants confront.

The objective of this paper is to describe and evaluate the development of the clearinghouse. While reverse auctions to finance agricultural best management practices that improve water quality have been conducted<sup>1</sup>, this institution is, to our knowledge, the first clearinghouse to successfully administer a nutrient credit auction on behalf of regulated point sources seeking to comply with a discharge permit. We found that the auctions administered by the clearinghouse demonstrated that purchasing nutrient credits can be a least-cost compliance method for many regulated point sources. We show that the clearinghouse's design was effective because some market participants seeking to purchase credits bought credits from PENNVEST instead of bilaterally. Also, in the clearinghouse's first year, it successfully managed a default by a forward contract seller by procuring replacement credits in order to fulfill its commitments to deliver credits to a contracted purchaser. We further describe that the process of establishing the clearinghouse focused greater attention on long-term modifications to the trading program that could induce greater market activity. PENNVEST may try to improve the clearinghouse's performance in future years by modifying the calendar schedule of market auctions and refining eligibility criteria for sellers to participate in forward-contract auctions.

The remainder of this paper is organized as follows. First, we describe Pennsylvania's WQT

program. Second, we examine the transaction risks and costs that deterred regulated point sources from purchasing nutrient credits. Third, we describe the development of the clearinghouse, clearinghouse structure, and market activity to-date. Fourth, we discuss the impact of the clearinghouse on the functionality of the state's WQT program. We conclude by identifying topics for further research.

## 2. Pennsylvania's nutrient trading program

### 2.1. Overview of water quality trading programs

The U.S. Clean Water Act has historically regulated discharges from point sources by mandating technology standards. This "command-and-control" approach can fail to capture differences in abatement costs that may exist among potential mitigation options. This can result in an inefficient use of funds by taxpayers and ratepayers that pay the compliance costs of municipal authorities that operate regulated treatment plants, which can reduce public willingness to maintain pollution limits or demand further reductions.

A WQT program includes any program where a point source can comply with an effluent limit by financing, compensating, or implementing off-site pollution reduction projects. Non-point agricultural sources of nutrient runoff are not subject to discharge limits even though they are a major contributor to pollution loads in many watersheds, including the Chesapeake Bay (e.g., Manale et al., 2011). If non-point pollution sources are not allowed to provide mitigation services to watershed-wide pollution reduction objectives, then greater abatement costs may be realized. Further, the process of defining, quantifying, and verifying agricultural best management practices (BMPs) can have additional benefits in other contexts, including environmental markets for other ecosystem services (e.g., greenhouse gas mitigation) or incentive-based financing schemes.

WQT programs have proliferated in recent years in attempts by regulators to reduce the costs of improving water quality (Breetz et al., 2004; Morgan and Wolverton, 2005; Selman et al., 2009). Various forms of WQT programs have been established, but few trades have occurred. One reason trades are difficult to execute is because the local geographic scope of the watersheds reduce the number of market participants and heterogeneity of pollution control costs, both of which reduce the potential gains

<sup>1</sup> Reverse auctions have been conducted in Pennsylvania's Conestoga watershed (Selman et al., 2008), Ohio's Great Miami River watershed (Selman et al., 2009; Stephenson and Shabman, 2011), and Kansas (Smith, Nejadhashemi, and Leatherman, 2009). In these instances, federal government grants and/or local donations provided funds to compensate farmers.

from trade. High transaction costs also arise from programmatic design features<sup>2</sup>, and we discuss in a subsequent section how this has impacted Pennsylvania's WQT market. Most WQT programs are not designed for open market or "arms-length" credit transactions that economists associate with the concept of trading (e.g., Connecticut DEP, 2010), and some do not even involve any transfer of funds (Breetz et al., 2004; Morgan and Wolverton, 2005; Shortle and Horan, 2008).

WQT programs that engage agricultural non-point source projects face additional challenges. Eligible non-point source projects are typically issued less than one credit pound for every estimated pound of pollution reduced, which reduces their cost-effectiveness (e.g., Malik, Letson, and Crutchfield, 1993; Horan, 2001; Horan and Shortle, 2005). Other obstacles with engaging agriculture include outreach and communication (Breetz et al., 2005); unenforced, ambiguous, or competing regulatory policies (King, 2005; Ribaudo and Gottlieb, 2011); and cumbersome non-point source credit validation procedures (Schary and Fisher-Vanden, 2004).

## 2.2. Pennsylvania's nutrient trading program

The Chesapeake Bay is the largest freshwater estuary in the United States and was once an ecosystem rich with marine life, although its natural ecology has suffered from centuries of anthropogenic damage (e.g., Jackson, 2001). Even though the Bay is not located within Pennsylvania, the state lies within its watershed and is responsible for 44% of the nitrogen (N), 24% of the phosphorus (P), and 32% of the sediment that reaches the Bay (USEPA, 2010). Pennsylvania's Chesapeake Bay point source polluters, which are predominately wastewater treatment plants in the Potomac and Susquehanna River watersheds, contribute 12% of Pennsylvania's Chesapeake Bay nitrogen loadings (USEPA, 2010).

Pennsylvania's WQT program was introduced in December 2004 and imposes annual nutrient effluent limits for the 184 largest publicly-owned treatment works (POTW) facilities in the state's Chesapeake Bay watershed. These POTWs were each issued a National Pollution Discharge Elimination System (NPDES) permit that establishes annual absolute discharge levels using nitrogen and phosphorous

concentration targets. POTWs can comply with their NPDES permit by upgrading their facility and/or by purchasing credits. Credits can be issued to point sources that reduce discharges to levels beyond permitted requirements and to eligible non-point source projects that reduce runoff, such as manure management, streamside buffer strip plantings, and conservation tillage of cropland.

The 64 largest POTWs, which constitute approximately 85% of point source runoff, were classified as "Phase 1" facilities and were required to comply with their NPDES permit beginning with the October 1, 2010 - September 30, 2011 compliance year. Smaller POTWs are scheduled to begin complying with their permit in either 2013 or 2014. In addition, all new or expanded point source nutrient discharges, such as those arising from a new housing development, are required to offset new loads through the annual purchase of credits in an amount equal to the incremental discharge. Pennsylvania's WQT program is intended to serve a critical role in the state's ability to reduce nutrient pollution according to targets established in the Environmental Protection Agency's Chesapeake Bay Total Maximum Daily Load (Pennsylvania DEP, 2011).

Pennsylvania's Department of Environmental Protection (DEP) administers both the point source permitting and the credit generation processes. Prospective credit sellers first must "certify" their credits with DEP by having their project conceptually approved. This requires submitting a proposal that documents the practices, quantification methodology, and verification procedures to be employed. After a project is certified (i.e., deemed eligible), credits are issued when DEP subsequently reviews and approves a verification report. Regulated point sources need to procure all of their credits for compliance within two months after the compliance year ends.

To-date, many certified non-point source projects involve transporting manure and applying it on nutrient-deficient soils outside the Bay's watershed. Red Barn Trading Company and Chesapeake Nutrient Management, brokers that help poultry operators sell their manure, also became nutrient credit aggregators as a service to their clients. We see in Table 1 and 2 that these two manure brokers have been among the market's most active sellers of nutrient credits.

<sup>2</sup> Challenges to executing transactions in WQT programs are well-documented. Relevant articles include Stavins (1995); King (2005); Abdalla et al. (2007); Shortle and Horan (2008); Olmstead (2010); Smith, Peterson, and Leatherman (2010); Ribaudo and Gottlieb (2011); Stephenson and Shabman (2011); and Horan and Shortle (2011).

**Table 1.** Forward contract transactions in Pennsylvania's nutrient credit market.

Buyer	Seller	Date of Agreement	N Credits (lbs/yr)	N Price (\$/lb/yr)	P Credits (lbs/yr)	P Price (\$/lb/yr)
Dunn Lake	Red Barn Trading Company, LLC	17-Oct-06	223	\$9.00	3	\$4.00
Hamm Equities LLC	Red Barn Trading Company, LLC	2-Feb-07	1,592	\$9.00	73	\$4.00
Mount Joy Borough Authority	Brubaker Farms	26-Feb-07	8,432	\$4.50		
Fairview Township, York County	Red Barn Trading Company, LLC	10-Apr-08	20,000	\$5 to \$7.56		
Tamarack Mobile Home Park	Chesapeake Nutrient Management, LLC	28-Apr-08			21.5	\$4.50
Quail Creek Homeowner's Association	Chesapeake Nutrient Management, LLC	14-Jul-08	538		40	
Airy View Heights	Red Barn Trading Company, LLC	20-Feb-09	635	\$10.00	48	\$5.00
His Camps, Inc. (Camp Iroquoiana)	Red Barn Trading Company, LLC	17-Mar-09	8	\$15.00	11	\$10.00
PPL EnergyPlus, LLC	Red Barn Trading Company, LLC	8-Jul-10	Up to 57,000			
PPL EnergyPlus, LLC	PENNVEST	29-Oct-10	21,000	\$3.04		
PENNVEST	Lycoming County	29-Oct-10	9,153	\$3.04		
PENNVEST	ElectroCell	29-Oct-10	12	\$3.04		
PENNVEST	City of Lancaster	29-Oct-10	11,835	\$3.04		
PPL EnergyPlus, LLC	PENNVEST	5-Nov-10	41,000	\$2.75		
PENNVEST	Lycoming County	5-Nov-10	3,722	\$2.75		
PENNVEST	Elizabethtown Borough	5-Nov-10	7,369	\$2.75		
PENNVEST	City of Lancaster	5-Nov-10	29,909	\$2.75		
Mt. Hope Nazarene Retirement Community	Red Barn Trading Company, LLC	8-Dec-10	546	\$15.00	53	\$10.00
PPL EnergyPlus, LLC	PENNVEST	21-Mar-12	10,000	\$4.00		
Lycoming County	PENNVEST	21-Mar-12	45,224	\$4.00		
PENNVEST	Chesapeake Nutrient Management, LLC	21-Mar-12	50,000	\$4.00		
PENNVEST	Red Barn Trading Company, LLC	21-Mar-12	5,224	\$4.00		
PPL EnergyPlus, LLC	PENNVEST	21-Mar-12	30,000	\$2.98		
PENNVEST	Gettysburg Energy and Nutrient Recovery Facility, LLC	21-Mar-12	30,000	\$2.98		

Source: Pennsylvania Department of Environmental Protection

**Table 2.** Spot market transactions in Pennsylvania’s nutrient credit market.

Buyer	Seller	Date of Agreement	N Credits (lbs)	N Price (\$/lb)	P Credits (lbs)	P Price (\$/lb)
PENNVEST	Red Barn Trading Company, LLC	19-Sep-11	41,744	\$2.75 - \$3.04		
Clearfield Municipal Authority	Red Barn Trading Company, LLC	26-Sep-11	40,000	\$4.50		
Municipal Authority of the Town of Bloomsburg	Mercuria Energy America, Inc.	14-Oct-11	34,271			
City of Harrisburg	Northwestern Lancaster County Authority	18-Oct-11	8,749	\$3.10		
University Area Joint Sewer Authority	Mercuria Energy America, Inc.	21-Oct-11	20,918		2,520	
Milton Regional Sewer Authority	Chesapeake Nutrient Management, LLC	24-Oct-11	10,000			
City of Harrisburg	The Borough of Elizabethtown	28-Oct-11	21,993	\$3.10		
City of Harrisburg	Red Barn Trading Company, LLC	31-Oct-11	12,460	\$4.80	2,180	
Borough of Wellsboro	Red Barn Trading Company, LLC	2-Nov-11	12,721	\$5.50		
PENNVEST	Lycoming County	2-Nov-11	5,059	\$3.10	238	\$4.73
PENNVEST	ElectroCell	2-Nov-11	500	\$3.10	462	\$4.73
PENNVEST	The Borough of Elizabethtown	2-Nov-11	15,290	\$3.10		
PENNVEST	Mercuria Energy America, Inc.	2-Nov-11	10	\$3.10		
City of Harrisburg	PENNVEST	2-Nov-11	20,859	\$3.10		
Mountaintop Area Joint Sanitary Authority	PENNVEST	2-Nov-11			700	\$4.73
City of Harrisburg	Lancaster Area Sewer Authority	7-Nov-11	5,260	\$2.50		
Ekland Borough	ElectroCell	8-Nov-11	1,722	\$5.75		
Williamstown Borough Authority	Chesapeake Nutrient Management, LLC	14-Nov-11			523	
Mountaintop Area Joint Sanitary Authority	Berwick Area Sewer Authority	16-Nov-11			389	\$1.50
Westfield Borough	ElectroCell	17-Nov-11			429	\$6.00
City of Lancaster	Lancaster Area Sewer Authority	17-Nov-11	18,283			
Municipal Authority of the Town of Bloomsburg	Mercuria Energy America, Inc.	23-Nov-11			13	
Borough of Highspire	Mercuria Energy America, Inc.	28-Nov-11			558	

Source: Pennsylvania Department of Environmental Protection

### 3. Transaction costs and risks in Pennsylvania's WQT market

As with other WQT programs, engaging agricultural non-point source projects in credit trading is also challenging in Pennsylvania. DEP applies three different discounts in credit calculations for non-point source projects and has not developed standardized quantification and verification protocols for smaller farms that wish to undertake BMPs for credits. However, since Pennsylvania's WQT program was the first designed for market-based credit transactions, we focus on two additional deterrents that combined to present unique challenges to executing transactions and catalyzed stakeholder interest in establishing a clearinghouse.

First, Pennsylvania's WQT program has multiple disaggregated credit markets. This reduces the number of potential participants within each market, which exacerbates the challenges of executing a trade. Pennsylvania's WQT program rules stipulate that credits cannot be traded across Pennsylvania's two Chesapeake Bay watersheds (Susquehanna and Potomac Rivers). Also, credits are non-fungible for the two types of nutrients (nitrogen and phosphorus), which differs from greenhouse gas trading programs that convert various greenhouse gases into carbon dioxide equivalent units.

Most critically, credits that are unused for compliance in the compliance year in which they are issued cannot be "banked", or used for compliance in a subsequent compliance year. Credit banking is typical in most air emissions trading programs (e.g., Tietenberg, 2006). This implies that unused credits expire worthless at the conclusion of each compliance year. The practical effect of disallowing credit banking is to severely restrict the time frame for "spot market" credit transactions, which occur when the transfers of payment from buyer to seller and credit ownership from seller to buyer are immediate. This is because credits are not issued until annual verification occurs, which is near the end of the compliance year for many projects.

The absence of a reliable spot market increases the perceived compliance risk of a credit purchase for POTWs. If they are to buy credits, many POTWs prefer forward contracts for the delivery of credits for multiple successive years at an established price, as this allows long-term compliance planning and is akin to the length of time that an investment in a facility upgrade would be effective. However, if a forward contract seller defaults on credit delivery commitments, this failure may not be realized until

near the end of the compliance year. Phase 1 POTWs were concerned about the feasibility of purchasing replacement credits in the spot market since they had to make compliance decisions prior to the trading program's first compliance year and could not observe how this spot market would function in practice. Further, Pennsylvania's WQT program does not absolve regulated point sources from the obligation to acquire credits to comply with their NPDES permit if a credit seller defaults on a forward contract.

A second challenge in Pennsylvania's WQT program arises from high transaction costs that POTWs experience in conducting arms-length market transactions. POTWs initially must assess whether purchasing nutrient credits is synergistic with other environmental regulations. In the mid-to-late 2000s, this included a subjective assessment of whether nutrient trading would be allowed under a future TMDL, an assessment of whether purchasing nutrient credits would be sufficient to comply with local streamflow nutrient requirements that may be more stringent than Chesapeake Bay requirements, and whether plant upgrades may be required to comply with regulations for non-nutrient pollutants (PMAA, 2007). Further, in contrast to electric utilities regulated in air emission markets, most POTWs had no experience with commodity trading. POTWs perceived upgrading as a less risky way to comply even though an upgrade entails maintenance costs and equipment performance risk (PMAA, 2007; Pennsylvania Legislative Budget and Finance Committee and Metcalf & Eddy, 2008).

It also may take a POTW several years to execute a contract to purchase credits. POTWs in Pennsylvania are typically operated either by a municipality or municipal authority, have a local service area, and have limited staffing. A decision on how to proceed with a compliance strategy may require multiple public meetings of the governing body and hiring an engineering firm to assist with determining compliance costs under various options. If a POTW decides to purchase credits to comply with its permit, the POTW may be legally required to solicit offers to sell credits through a tedious competitive procurement process involving the issuance of a request-for-proposals (RFP). After sellers are identified, the POTW would then be required to sign and enforce individual contracts with each credit supplier.

Property developers seeking to build new housing projects also need to purchase nutrient credits. They confront different types of transaction risk

relative to POTWs, although their nutrient credit purchases are for smaller quantities. Developers need to demonstrate that a contract is in place to buy credits in order for their NPDES permit application to be approved, which is required for their development to proceed, but do not want to purchase credits if it is not approved. In addition, Pennsylvania's WQT program does not have a procedure for developers to transfer the future obligation of nutrient credit purchases, so the number of years into the future for which they must purchase nutrient credits is indeterminate.

## 4. Clearinghouse implementation

### 4.1. Clearinghouse rationale and development

Regulated point sources in Pennsylvania believed there would be significant advantages in having PENNVEST serve as an intermediary to absorb some of the transaction costs and risks they confronted. First, a POTW may not be required to undergo a costly competitive procurement process if it purchased credits from another government agency such as PENNVEST. Second, a POTW would be able to execute one nutrient credit purchase contract with PENNVEST, as opposed to multiple, if their credit purchase was sufficiently large such that it entailed multiple credit sellers. Given PENNVEST's longstanding role in disbursing loan and grant funds to local public water projects, POTWs already had familiarity and experience in contracting with PENNVEST. Third, PENNVEST would manage the nutrient credit delivery risk and contract enforcement responsibilities. Fourth, POTWs could be assured that the costs of buying credits are minimized if PENNVEST identifies sellers through a competitive auction.

PENNVEST believed that fostering success in the Pennsylvania WQT program was consistent with its broader public policy objectives. PENNVEST concluded, after discussions with DEP and stakeholders, that a critical reason for the failure of the nutrient credit market to mature was the transaction risks facing potential participants, and that there was no other entity willing or able to mitigate that risk at the time. While the clearing structure would place PENNVEST as a financial intermediary in the market, PENNVEST would have no role with the administration of the nutrient trading program, which would continue to be independently overseen by DEP.

By early 2009, when PENNVEST began to formally evaluate developing a clearinghouse, most

Phase 1 POTWs had already committed to upgrading their facilities in lieu of a credit purchase. Table 1 shows that only eight forward contract credit transactions had occurred by early 2009 and that six of those were executed by housing developers for credit purchases of modest quantities. However, the pioneering trades that occurred in the early program years included the first POTW to non-point source bilaterally negotiated forward contracts undertaken by both Mount Joy Borough Authority and Fairview Township.

Nonetheless, there was still interest in designing a clearinghouse for smaller POTWs subject to permit requirements beginning in 2013 or 2014, housing developers, and Phase 1 POTWs that may need to buy credits in future years. PENNVEST, in coordination with DEP and CCX, worked with a diverse group of stakeholders for two years to develop the framework wherein PENNVEST would clear nutrient credit transactions. These stakeholders included government officials, municipalities, municipal authorities, developers, conservation districts, agricultural organizations, manure brokers, and environmental organizations. The outreach process was advanced through numerous stakeholder meetings, results from a detailed questionnaire mailed to market participants, and an open-participation mock auction.

### 4.2. Clearinghouse structure

The term "clearinghouse" is used in the WQT literature to describe programs in which point sources make payments into a fund at a predetermined per-unit fee, and a state agency uses these funds to finance pollution mitigation projects (Woodward and Kaiser, 2002; Breetz et al., 2004; Morgan and Wolverton, 2005; Selman et al., 2009). These agencies typically assume responsibility for contracting and enforcement of credit generation from funded projects, and, in contrast to Pennsylvania's program, may adopt indemnification clauses that absolve point sources of regulatory liability after the appropriate fee is paid (Breetz et al., 2004).

A similarly structured institution could not be developed in Pennsylvania's WQT program because the program is designed for transactions with market-determined prices. Here we refer to PENNVEST's "clearinghouse" in a context that is analogous with how clearinghouses are operated in support of commodity futures exchanges. In this framework, the credit price and quantity at which transactions occur is determined through a competitive auction rather than being administratively

determined. A single auction in this structure could have multiple buyers and sellers. If the resulting supply and demand curves from the auction intersect, then winning buyers and sellers become contractually committed to buy or sell the number of credits they successfully bid or offered at the auction's market-clearing price.

PENNVEST's clearinghouse will host quarterly forward-contract auctions for the future delivery of credits for multiple successive years. These contracts may be desirable for regulated point sources that are seeking long-term assurances for the delivery of credits at a predetermined price. PENNVEST developed eligibility standards for entities to participate in forward contract auctions to reduce the financial risk that it assumes as a clearinghouse (PENNVEST, 2012). For example, municipalities purchasing credits in a forward contract auction have to make a future revenue pledge, pay for the credits up-front in full, or provide another type of acceptable collateral to be eligible. Sellers must provide evidence that DEP has certified their project(s) and aggregators must provide copies of agreements that they have in place with individual farmers.

PENNVEST will also host annual spot market auctions at the end of each compliance year for credits that already exist. This auction allows regulated point sources to procure credits to comply with annual permit requirements, and PENNVEST could, if needed, procure replacement credits through these auctions. In addition to auctions, PENNVEST allows prospective buyers and sellers that have agreed on a credit price and quantity to interpose PENNVEST as the central counterparty to clear the transaction. PENNVEST has also established a streamlined process for housing developers to buy credits customized to address the particular permitting procedures they must follow.

For simplicity, auctions are administered as single-round, uniform-price, and sealed-bid auctions. The auction rules stipulate tie-breaking procedures and a method for determining the market-clearing price. PENNVEST relies upon a third-party auction service provider to both assist with auction administration and to uphold the auction's integrity. PENNVEST does not view prices or quantities submitted by any auction participant until after the auction is completed.

The clearinghouse assumes enforcement responsibility and counterparty default risk by interposing itself to become the buyer to every winning auction seller and vice versa. When a forward contract expires, buyers make payment and sellers transfer

ownership of nutrient credits to PENNVEST. PENNVEST then transfers payments to sellers and ownership of credits to buyers. If a forward contract buyer that uses the clearinghouse defaults, PENNVEST remains obligated to purchase the credits from all contracted sellers. If a forward contract seller defaults, PENNVEST remains contractually committed to deliver a specific quantity of credits at the contracted price to forward contract buyers, even if it means PENNVEST has to purchase replacement credits at a price higher than the defaulted contracted price.

If a seller default occurs, PENNVEST's first option to obtain replacement credits is to purchase credits from another seller at the same price. There has been an excess potential supply of credits in the market, as the number of credits certified by DEP – almost 4.5 million pounds of nitrogen credits per year as of January 27, 2012 – is approximately two orders of magnitude larger than the number of credits PENNVEST is obligated, after the first compliance year, to purchase through forward contracts. However, finding another seller is easier to do when it is earlier in the compliance year, as many projects that are certified may not be implemented or undergo verification if the project owner does not have a forward contract in place to sell the credits and credits cannot be banked for future years. PENNVEST also has direct access to replacement credits. This is because PENNVEST finances nutrient credit projects directly and owns a portion of the credits that those projects generate. PENNVEST further can utilize \$50 million in the Environmental Protection Agency's Clean Water State Revolving Fund to purchase credits if a seller default occurs (Marchetti, 2011).

### 4.3. Clearinghouse market activity

At the conclusion of the two year outreach period, CCX administered PENNVEST's first nutrient credit auction on October 28 and 29, 2010. This was, to our knowledge, the first nutrient credit auction conducted in a compliance-based WQT market. As a result, PENNVEST entered into matched forward contracts to buy and sell 21,000 pounds of Susquehanna nitrogen credits per year for three consecutive years at a price of \$3.04 per credit. CCX administered a second auction on November 4 and 5, 2010 for one-year forward contracts that resulted in PENNVEST contracting to buy and sell 41,000 pounds of Susquehanna nitrogen credits at \$2.75 per credit. PPL EnergyPlus – an energy company with experience trading in air emissions markets – was the sole purchaser of credits in the first two forward

contract auctions. In both auctions the aggregate quantity of credits offered for sale significantly exceeded the aggregate bid quantity. The diversity of organizations that were successful sellers in the forward contract auctions demonstrated the importance of fostering competition among nutrient pollution mitigation sources. Winning auction sellers included the Lycoming County government that aggregated credits on behalf of resident farmers that undertook agricultural BMPs, a private company that installed a manure treatment technology on a farm, and two POTWs that DEP certified to reduce nutrient discharges below permitted levels.

There was a high demand for credits at the conclusion of the nutrient trading program's first compliance year due to wet weather, which increases discharges. This resulted in a spike in spot market trading activity, as indicated in Table 2. One of the winning sellers in the 2010 forward contract auctions defaulted on their delivery of 2011 compliance year credits to PENNVEST. As a result, PENNVEST purchased 41,744 replacement credits from Red Barn Trading Company at the 2010 forward contract auction prices. In addition, Markit administered a spot market auction on PENNVEST's behalf on November 2, 2011 for the immediate delivery of 2011 compliance year credits. As a consequence of this spot market auction, PENNVEST purchased 20,859 Susquehanna nitrogen credits at \$3.10 per credit and 700 Susquehanna phosphorus credits at \$4.73 per credit that they concurrently sold to two POTWs. Winning spot market auction sellers comprised some of the same organizations that were successful in the 2010 forward contract auctions.

Markit administered PENNVEST's first 2012 forward contract auction on March 21, 2012. At its conclusion, PENNVEST entered into offsetting forward contracts to sell 55,224 Susquehanna nitrogen credits at \$4.00 per credit for the 2012 compliance year to PPL EnergyPlus and Lycoming County that PENNVEST will purchase from two manure brokers. PENNVEST also entered into offsetting forward contracts to sell 30,000 Susquehanna nitrogen credits per year at \$2.98 per credit for the 2013, 2014, and 2015 compliance years to PPL EnergyPlus that PENNVEST will buy from Gettysburg Energy and Nutrient Recovery Facility.

## 5. Discussion

The benefits that PENNVEST's clearinghouse provides were sufficiently advantageous that some regulated point sources elected to buy credits

through PENNVEST instead of executing bilateral trades. However, regulated point sources that need credits at the end of the compliance year may be compelled to buy credits directly from sellers if they participate in PENNVEST's spot market auction but win less than the full quantity of credits they need for compliance. In future years, it may be beneficial for PENNVEST to conduct spot market auctions earlier in the compliance year. Because the first compliance year was wet and there was performance failure with some of the new nutrient reduction technology, many POTWs needed to buy credits (Chiaruttini, 2011). Some POTWs chose to buy credits directly from sellers in advance of PENNVEST's November 2 spot market auction. POTWs could not know *a priori* if they would have the time necessary to acquire credits if they waited for PENNVEST's auction but failed to purchase as many credits as they needed through the auction, as they were required to have completed all credit purchases less than one month after the November 2 auction. Table 2 shows that, disregarding PENNVEST's purchase of replacement credits, only 10% of the nitrogen credits transacted in the spot market at the end of the first compliance year occurred through PENNVEST's spot market auction.

We cannot conclude at this early stage if PENNVEST's clearinghouse induced purchases of nutrient credits that otherwise would not have occurred due to the multitude of factors that regulated point sources must evaluate when considering their optimal compliance strategy. Whether the clearinghouse induces credit purchases in the future will depend upon how effectively PENNVEST adapts the clearinghouse functionality, if necessary, to satisfy and accommodate the needs of market participants. One of PENNVEST's biggest challenges entails designing contracts that mimic the long-term compliance assurance a plant upgrade provides for POTWs. For example, a POTW may prefer a twenty-year forward contract for nutrient credits whereas many sellers are unwilling to commit to a contract of this length.

One way that PENNVEST's clearinghouse may induce future purchases is through its demonstration that purchasing nutrient credits was a cost-effective means of compliance for POTWs. In a 2008 survey, 68% of POTWs had a perception that prices for nitrogen credits were at least \$7 per pound, over 40% said they would not be willing to pay greater than \$3 per pound for credits, and between 75% and 85% had nitrogen compliance upgrade costs greater than \$5 per pound (Pennsylvania Legislative Budget

and Finance Committee and Metcalf & Eddy, 2008). Thus, significant cost savings could have been realized to many POTWs through credit purchases instead of upgrades, and more POTWs would likely have purchased credits had they known credits would be available at realized auction prices of approximately \$3 per pound for nitrogen.

A critical test was successfully passed in the clearinghouse's first year when a seller default occurred and PENNVEST procured replacement credits at the same price. This meant that PENNVEST did not default on its commitment to deliver credits to PPL EnergyPlus. A failure would have placed PPL EnergyPlus at risk of program non-compliance, and PENNVEST would have incurred a financial loss if they acquired replacement credits at a higher transaction price than originally contracted with PPL. The confidence of market participants in the feasibility of purchasing credits through PENNVEST could have been impaired if PENNVEST had not achieved this result. The default also signals that PENNVEST may need to reexamine the eligibility criteria for sellers to participate in future forward contract auctions.

Another benefit of establishing PENNVEST's clearinghouse is that it focused greater attention on long-term improvements to the WQT program, including evaluating whether credit banking could be allowed on a limited basis. In addition, through the stakeholder outreach sessions, PENNVEST helped develop and publicly post a contact information database for market participants to make it easier for them to contact and trade directly with each other.

#### 4. Conclusion

Evaluating the effectiveness of PENNVEST's clearinghouse can inform whether the clearing and auction systems should be replicated in other WQT programs or incentive-based financing schemes. On the positive side, the auctions administered by the clearinghouse demonstrated that purchasing nutrient credits is a cost-effective compliance method, the design of the clearinghouse proved effective as its benefits were advantageous to some credit purchasers, the procedures for procuring replacement credits were successfully executed after a contracted seller defaulted, and establishing the clearinghouse increased stakeholder focus on potential long-term program modifications that could induce greater market activity. To improve clearinghouse performance in future years, PENNVEST may modify the timing of spot market auctions and revise eligibility

criteria for prospective sellers in forward-contract auctions.

Establishing PENNVEST's clearinghouse also helped identify future research topics. One such topic is to examine the costs and benefits of introducing credit banking in WQT programs. While implementing credit banking would enhance market liquidity, it could also exacerbate the ecological damages associated with pollution spikes. The implications of assigning regulated point sources compliance liability if a credit seller defaults also merits more systematic research. This was a significant obstacle to purchasing credits both in Pennsylvania and elsewhere (Abdalla et al., 2007; Horan and Shortle, 2011; Ribaudo and Gottlieb, 2011), although others have recommended assigning compliance liability to the buyer (Schary and Fisher-Vanden, 2004), and liability is not applied consistently across WQT programs in the U.S. (Breetz et al., 2004). Finally, a distinguishing feature of Pennsylvania's WQT program is that it allows prices to be determined through market-based transactions. The auction administration and dissemination of market-clearing prices advances the goal of procuring credits from the most cost-effective mitigation sources, although it entails high transaction costs. Further research could evaluate the merits of establishing a WQT program using market-based transactions, with explicit consideration of the types of transaction costs WQT programs entail (e.g., Smith, Peterson, and Leatherman, 2010), relative to alternative designs with lower transaction costs.

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