Transaction costs of nonpoint source water quality credits: Implications for trading programs in the Chesapeake Bay watershed

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Contents

Executive Summary

Many of the Chesapeake Bay states have developed nutrient trading programs to provide compliance options to regulated point sources. These programs offer cost effective compliance options to regulated sources if the sum of the nutrient abatement costs and nutrient credit transaction costs are less than on-site regulatory compliance costs. Most economic analyzes, however, either assume administrative or "transaction" costs associated with nutrient trading programs are low relative to transformation costs, or omit consideration of transaction costs altogether. This research focuses on the estimation of transaction costs associated with nutrient trading programs, with a special emphasis on the provision of nonpoint source nutrient credits from agricultural sources.

While the professional literature on transaction costs is massive, relatively little empirical research has been conducted into the cost to design and implement water quality trading programs or the cost to secure enhanced water quality services from agricultural sources. Empirical research that has been conducted finds large variation in the level of transaction costs. Studies estimate that program administration costs that provide agricultural conservation services may be less than 1% of to more than 100% of total nonpoint source abatement costs.

Using data from a variety of sources, this study estimates the transaction costs associated with creation, certification, and verification of agricultural nonpoint source credits. The Virginia nutrient credit trading program is used as a case study to identify how these costs might change with program expansion.

Currently, over 1600 permanent P credits have been certified for use in Virginia, mostly through land development projects. These credits are being sold to meet on-site water quality criteria for land development activities. The transaction costs to both program administrators and credit providers are low and not considered a barrier to market activity. Based on best available evidence, the administrative costs of creating credits using management and structural BMPs will be significantly more costly on a per project basis than the activities involved in land conversions (the dominant credit generating practice in Virginia). It is estimated that it may be 2 to 3 time more costly to plan for working land BMPs than for land conversion an retirement. Furthermore, given dynamic and changing farm conditions and limited BMP lifespans, these costs are relatively frequent and recurring. However, while higher, costs need to be compared to the relative value created in terms of nutrient reductions. In some situations, these costs might be quite modest relative to overall possible nutrient credit prices.

The verification (compliance monitoring) protocols can be a significant costs for credits generated from working agricultural lands. Several programs require annual site visits to verify the existence and performance of credit generating practices. The cost of providing annual "boots on the ground" verification is estimated at around $500 - $750 per visit per year. Significant reductions in transaction costs could be achieved through alternative verification processes. For instance, in our

analysis monitoring costs were reduced 67% by allowing interim remote self-reporting of BMP status for 4 out of 5 years, and by 80% if all monitoring is undertaken remotely. Remote sensing technologies offer opportunities for dramatic reductions in verification costs. These results suggest an important cost/risk tradeoff between verification cost and compliance certainty for program designers to consider. Little is currently known about the efficacy of alternative verification regimes to deter noncompliance and to identify instances of noncompliance. The cost of corrective measures, and/or credit cancelation for noncompliant contracts was not estimated.

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Part I: Overview

Introduction

Landowners and farmers have long participated in voluntary incentive schemes to enhance and protect environmental quality. Federal and state agencies administer many of these programs, working closely with landowners to develop contracts to implement best management practices (BMPs) to improve the environment. Water quality credit trading programs may provide additional landowner conservation incentives. Like conventional incentive programs, landowners can participate in water quality trading (WQT) by contracting to provide incremental environmental services. Because WQT programs have emerged to provide regulated dischargers with additional compliance options to meet specific numeric pollutant control requirements, they contain different administrative structures, contractual conditions, and verification standards.

Numerous studies state that the costs of controlling land-based water pollutants via agricultural conservation practices are only a fraction of the cost of other control measures, suggesting that regulated entities would benefit from participating in trading and thus be willing to pay farmers and landowners for nutrient reduction credits (services).[1] In making such assessments, however, many studies only compare the *transformation costs*[2] of alternative policies; that is the installation and maintenance costs of pollutant control measures used to achieve an environmental objective (Krutilla and Krause, 2010). Most economic analyzes either assume administrative or "transaction" costs associated with implementing trading programs are low relative to transformation costs, or omit consideration of transaction costs altogether (Vatn, Kvakkestad & Rørstad 2002). Broadly speaking, the total cost of a policy consists of *transformation costs* plus *transaction costs*. The level of transaction costs has direct implications on the costs and incentives for public agencies tasked with administering the program, farmers and landowners' participation in credit generating activities, and regulated entities' willingness to enter into a nonpoint source (NPS) credit trade.

Most states within the Chesapeake Bay watershed are developing or have implemented nutrient trading programs to help regulated sources maintain compliance with discharge control requirements. Each state program is designed to allow agricultural producers and landowners to contribute and participate through the supply of nonpoint source credits/offsets. States across the U.S are designing and/or experimenting with a variety of processes and protocols to quantify and certify agricultural nonpoint reductions into credits/offsets that can be used for compliance. To date, very little is known about costs to administer and participate in these programs.

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[1] E.g.: Jones et al (2010) suggest that water quality trading in the Chesapeake Bay watershed has the potential to "reduce nitrogen removal costs for some in the wastewater sector by as much as 60 percent" (p2). EPA (2001) suggests 7%-13% of costs to point source discharges could be saved under its "More Cost-Effective TMDL Program" scenario which includes PS-NPS trading compared to the "Moderately Cost-effective TMDL Program" scenario, which does not (p33). Woodward et al (2002) also cite another EPA study's (EPA: 1994) estimates of the prospective benefits of WQT: "The EPA (1994) found that trading would reduce the costs of completing President Clinton's Clean Water Initiative by between $0.65 and $7.5 billion, with a majority of the savings resulting from trades between point and nonpoint sources."

[2] Also referred to as *abatement costs*, *production costs* and *compliance costs* (Ofei-Mensah & Bennet, 2013; Marshall, 2013).

This study aims to assemble the available evidence in order to provide insight into the nature and level of some of the transaction costs currently incurred in WQT or environmental service programs. Particular attention is focused on providing insights into the provision of environmental services for agricultural producers and landowners. We analyze which actors bear which costs, and where costs are greatest in the credit generation and transfer processes that involve the provision of environmental service enhancements from agriculture.

The paper is organized as follows: Part II provides a definition of transaction costs for the ensuing analysis and a comprehensive conceptual framework for analyzing the full range of transaction costs of environmental service trading programs, of which water quality trading programs are one variant. This framework provides a consistent basis for measuring and analyzing the transaction costs associated with water quality trading programs, which will assist researchers and policy makers in assessing the transaction costs of water quality credit trading. Part III presents empirical evidence from the existing literature on the nature and level of transaction costs incurred in voluntary agri-based water quality trading and related conservation programs. The literature provides relevant benchmarks regarding the overall level of transaction costs as well as insights into various situational and policy factors that might explain observed differences in costs across programs. Part IV examines cost implications of expansion of nutrient trading activities for Virginia. Information and insights are derived from existing from Natural Resources Conservation Service (NRCS) conservation programs and water quality trading programs in Oregon and the Ohio River Basin. Part V provides a summary of findings and recommendations from this study.

Part II: Definitions and conceptual framework

In order to consider the full cost of water quality trading programs and their alternatives, it is necessary to specify what is meant by transaction costs. Considerable variation in the definition and classification in the term exists within both the conceptual and empirical literature. This section provides a conceptual framework that can be applied to various approaches to the costs to administer water quality trading programs. The framework has been designed to serve two purposes:

(1) Provide a consistent basis for quantifying and analyzing the transaction costs of designing, implementing, and maintaining the infrastructure necessary to support provisioning of environmental and conservation services within the context of water quality trading programs (& incentive programs in general); and

(2) Provides a basis for consistently summarizing the empirical literature and comparing transaction cost estimates across studies, thus enabling comparison of administrative costs between different water quality management programs, including water quality trading programs.

2.1 What are transaction costs?

The term "transaction costs"[3] has been defined in many and varied ways since economists coined the term in the 1930s. In efforts to explain when economic activity is organized by markets or

[3] Krutilla and Krause (2010) point out that 'the terms "transaction cost", "transaction costs", and "transactions costs" appear to be used synonymously in the literature', with "transactions-cost" also occasionally appearing (p266, footnote 3). In this paper we use the term "transactions costs" as a general term to denote the various costs of the environmental

within a firm, Coase described transaction costs as the "cost of using the price mechanism" (Coase, 1937). Since Coase, an enormous literature has been developed around the term and has been applied to a wide ranging set of topics, including environmental policy.[4] A review of this literature is beyond the scope of this report. Rather, this literature is used to identify how transaction and administrative costs influence environmental policy effectiveness.

While a variety of definitions exist, Lai (1994) describes transaction costs broadly as "all costs other than" transformation (production) costs.[5] This definition acknowledges that "transaction" costs extend beyond the costs of negotiating, executing, and enforcing an exchange. Transaction costs would also include the costs to the organization of controlling and monitoring resource use.

The transaction cost literature also acknowledges that transaction costs occur within a "nested" or hierarchical set of rules and institutions, where each subsequent level operates within the norms or constraints set out by the previous level (Williamson, 1998). A variety of formal rules (regulatory, statutory, constitutional, judicial, etc.) and informal norms define the range and conditions that structure decision-making by defining and clarifying what actions can and cannot, and may or may not, be pursued. There are costs (search, negotiation, legal) incurred in the establishment and revision of the rules themselves and many researchers classify these costs as transaction costs. The costs of establishing the legal foundations and regulatory programs associated with environmental protection are often a critical focus area within the environmental policy literature.

For this study, we adopt a broad definition of transaction costs to include both the cost of developing trading program rules and the costs involved in program and trade implementation. Thus transaction costs include the cost of developing and implementing new regulatory and statutory rules for program operation, investigating trade and compliance alternatives, identifying and selecting participants, entering into contracts and making payments, monitoring compliance, and taking enforcement actions. This definition derives from similar definitions found in the environmental and conservation policy literature (McCann and Easter, 2000; Classen, Cattaneo & Johansson 2008; McCann et al 2005). At this general level, note that this definition does not distinguish who pays the transaction costs. Costs at each level of decision-making will be incurred by both government and the private sector. How the costs are distributed is partly a function of

policies analyzed, and "transaction cost" to refer to a specific cost associated with a particular activity (for example, the negotiation costs of a specific transaction between a credit seller and purchaser).

[4] In the environmental economics field, researchers generally take either a property rights approach or an institutional approach to defining the boundaries of what are considered relevant transactions costs, or some synthesis of the two. In the former approach, the transactions costs boundary is defined as the costs incurred in creating and maintaining a specific set of non-attenuated property rights (Allen, 1991). "Non-attenuated" property rights have the characteristics of being clearly defined both with respect to ownership and with respect to the rights conferred, enforceable (and enforced), and tradeable (Randall: 1975). The institutional approach is broader than the property rights approach in that it acknowledges that policies may be concerned with other institutions than property rights (Marshall 2013).

[5] Additional example definitions of transactions costs from proponents of the institutional approach to defining transactions costs include: (1) "the costs of the resources used to: define, establish, maintain, use and change institutions and organizations; and define the problems that these institutions and organizations are intended to solve" (Marshall, 2013); (2) "transaction costs refer to the resources required to: i) address collective action challenges... ii) "define, establish, maintain, use and change institutions and organizations and define the problems that these institutions and organizations are intended to solve" and...iii) "define, establish, transfer and maintain property rights" (Garrick, Whitten & Coggan, 2013).

program rules. Also, this perspective allows us to consider what additional costs and benefits water quality trading programs involve over and above those already occurring in conventional programs.

2.2 Conceptual framework

We develop a conceptual framework for classifying transaction costs with specific application to water quality trading programs. The framework describes transaction costs from policy development and rule making through to implementation, monitoring and enforcement. This method of organizing the conceptual framework draws on previous work by McCann and Easter (2000), McCann et al (2005), and Krutilla & Krause (2010).

The framework (Diagram 1) comprises two sections. The **color shaded boxes** identify general processes that occur at various stages of water quality trading program implementation: legislation, regulatory design, and program implementation.[6] Broad categories of activities that occur at each stage are also identified. While used to describe water quality trading, this framework could also be used to describe many incentive-based water quality programs (practice subsidies, payment for performance) within a variety of participant configurations (e.g. trading programs, government administrative purchase, etc.).

The **white boxes** provide detail specific to a particular type of program, and thus would differ depending on the program being analyzed. The white boxes identify specific activities needed to administer a water quality program and for which costs would be incurred. In the diagram below, the white boxes are tailored to a trading program that has buyers (credit providers), sellers, and an independent regulator (e.g. state agency), and which provides for the possibility of third-party participation (e.g. third party verifiers).

The framework is designed to encompass all relevant transaction costs regardless of who bears the cost. This allows for consideration of whether policy changes reduce total transaction costs or shift costs between parties (i.e. total costs in the framework are the same as before but borne by different actors). The way that transaction costs are 'experienced' by different actors will depend on the specific program (Coggan, Whitten and Bennet 2010). Table 1 provides a list of examples found in the literature of the transaction costs that might arise at each stage and how these costs might be experienced by different trading program participants.

(1) <u>Legislative environment</u>:

This first level comprises transaction costs incurred during the development of authorizing and/or enabling legislation to support a trading program (note: this could occur within the existing legal framework). Examples of these transaction costs include staff time in setting overall program goals and developing suitable legislation; participating in the legislative process; costs of public consultation; (potential) costs of legal challenges to the legislation, etc. (see Table 1). New or

[6] Note, this framework considers on the costs that are incremental to water quality trading programs but not the transactions costs of pre-existing or over-arching institutions. For example, in considering the transactions costs of Virginia's water quality trading program, the costs of designing the Chesapeake Bay TMDL fall outside the boundary of trading program costs, as do the costs of establishing and running the Virginia Department of Environmental Quality (VADEQ). Although these institutions form part of the underpinnings of Virginia's trading program, they exist independently of it. Similarly, where existing cost share programs are used as part of the credit generating process (e.g. to reach baseline), the cost of developing such programs (e.g. EQIP , CREP etc.) is not included. In contrast, cost of regulation or legislation specifically related to water quality trading in Virginia falls inside the boundary, as do costs of the specific VADEQ staff who administer the trading program

specific authorizing or enabling legislation is not necessarily required before the commencement of a program if existing legislation is viewed as sufficient to accommodate the program without alterations. However, specific legislation can be beneficial in that it may improve the certainty and stability of the program and ultimately decrease the transaction and transformation costs incurred at the implementation stage (Mank: 1998).

Authorizing legislation vests administrative agencies with the explicit authority to administer and enforce the program. Authorizing legislation may also establish general programmatic goals. For example, authorizing legislation for a trading program may focus on either incentivizing farmers to voluntarily adopt conservation practices or providing compliance options to point source permit holders to offset new growth. Private participants may also attempt to influence legislation in ways that establishes priorities and provide bounds on regulatory rule making that advances specific private interests/goals.

Where relevant, authorization may clarify how water quality trading programs interact with other existing sets of statutory or administrative rules and programs. For example, statutory changes may clarify or create opportunities for the newly-authorized trading program to operate consistently with existing legislation and programs. An example of where this has occurred is the creation of the 'general watershed permit' in Virginia which allows wastewater treatment plants (WWTP) to trade nitrogen and phosphorous consistently with the requirements of the Clean Water Act without continual changes to individual Virginia Pollutant Discharge Elimination System (VPDES) permits (Pomeroy, Evans, & Leeth 2005). Similar legislation authorized general permits for the nitrogen point source control program in Connecticut. Enabling legislation includes measures such as appropriations and funding for transaction costs (e.g. agency administrative costs) or to pay for services (e.g. cost share funding).

(2) Regulatory design:

At this level the operational rules, processes, and expectations for program implementation are established. Transaction costs incurred at this level are costs of developing rules and operational procedures relating to 1) rules and procedures for defining the service provision, 2) defining rules of allocation, contracting and exchange of services, and 3) monitoring and enforcement policies. These rules will, to a significant degree, also determine what costs will be incurred by program participants during implementation.

Unlike markets for typical goods and services, water quality trading programs require government to define the commodity (the service) to be exchanged or contracted. Defining the commodity involves numerous elements including defining existing discharge allocations[7] and baselines, quantification of service provision, identification of conditions when the commodity may be created, and certification that the incremental service has been provided (white boxes in Diagram 1 under "Defining the Commodity"). The complexity and level of costs incurred is related to the type of trading program being designed. For example, defining nonpoint source credits typically

[7] We note that discharge allocations are generally defined prior to the implementation of a water quality trading program. Where this is the case, transactions costs incurred in defining discharge allocations should not be counted as part of the costs of the WQT program, because they are required independently of the program.

requires more time and effort than point sources and has been a central focal point in the design of many trading programs.

Administrative agencies also devise rules that structure exchange and enforcement. Transaction costs are incurred in defining when and under what conditions trades can be used for compliance, what contractual arrangements will be used for compliance, and how information on credit prices and availability will be conveyed. Finally, rules and processes must be defined that establish compliance monitoring and systems of penalties for noncompliance as these relate to trading program implementation.

(3) Implementation / program operation:

This level comprises what are typically considered "market transaction costs" (McCann et al: 2005), but generalized to allow for water quality trading and the contracting for pollutant control services. These transaction costs relate to a specific instance of service provision. Transaction costs are incurred (1) when the service is provided ("creating the commodity"), (2) when the benefits arising are transferred from the service provider to another party ("market transaction"), and (3) during monitoring and enforcement of contracts.

It is important to appreciate that the sets of rules of a program (their structure and content), captured in the "legislative environment" and "regulatory design" levels, shape implementation costs (both transformation and transaction costs). Costs incurred in the implementation phase may have as their root cause rule requirement(s) which are not easily altered once the program has commenced. This has implications for what features of a program are able to be altered or "designed' in any efforts to lower transaction costs (McCann: 2013).

Summary

In this study we use this conceptual framework to structure the investigation of the transaction costs associated with water quality trading programs. We focus particular attention on the transaction costs and activities associated with defining, verifying, certifying, and monitoring nonpoint source credits generated by agricultural operations. Most states in the Chesapeake Bay region incorporate agricultural nonpoint sources within several compliance programs for regulated sources, but to date states have had limited experience with large scale implementation of this aspect of their programs.

In Part III, we present evidence on transaction costs for the components of the conceptual framework from the available literature. We focus on research into the transaction costs of agricultural operations participating in a variety of environmental trading programs and more generally in payment for ecosystem services programs. In Part IV, we concentrate our focus on the implementation stage to explore the magnitude of transaction costs that are currently experienced in Chesapeake Bay water quality trading programs, as well as what those costs might be in the future. In presenting new quantitative data, we focus on the transaction costs specific to the supply of agricultural nonpoint source credits – that is, on costs incurred in defining, certifying, and monitoring the nonpoint source credits. There are many additional costs to consider on the buyer side, which can be very complex depending on program rules and market structure. These costs are described qualitatively and included in the conceptual framework; however, gathering and analyzing quantitative data for the buyer side of existing water quality trading programs is beyond the ability of the current effort. The possible costs of agricultural nonpoint source credit generation are explored with application to Virginia's programs.

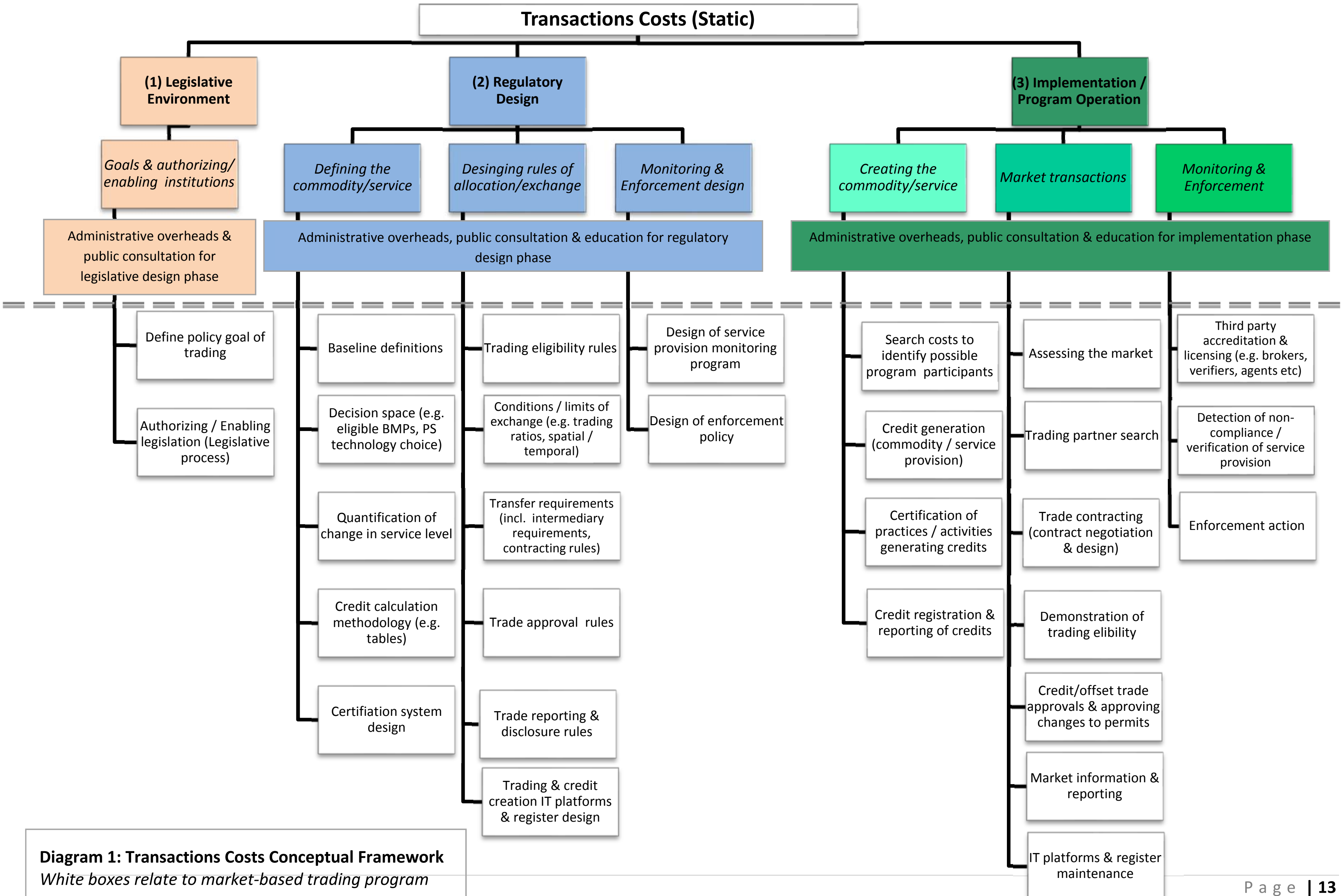

Diagram 1: Transactions Costs Conceptual Framework
White boxes relate to market-based trading program

Table 1: Static transaction costs and experience of transaction costs by participants in a trading program

<table>
<tr><th rowspan="2"></th><th rowspan="2"></th><th rowspan="2">Activity</th><th rowspan="2">Activity description</th><th colspan="3">Transaction costs* as experienced by:</th></tr>
<tr><th>Regulator</th><th>Seller</th><th>Buyer</th></tr>
<tr><td rowspan="3">(1)</td><td colspan="2">Administrative overheads & public consultation</td><td>Co-ordination between relevant government agencies & legislature
Consultation about legislation with potential market participants and the public</td><td>• Co-ordination within regulator
• Co-ordination between agencies
• Co-ordination between regulator and legislature
• Public consultation</td><td colspan="2" rowspan="3">• Participation in legislative process (e.g. participation in public consultation, lobbying)
• Investment in understanding the authorizing/enabling legislation
• Potential costs of participating in legal challenge to authorizing/enabling legislation
• Opportunity cost of waiting for clear legislative environment and/or the impact of legislative uncertainty on decision making</td></tr>
<tr><td rowspan="2">Goals & authorizing / enabling institutions</td><td>Define policy goal</td><td>Establish the goal of the trading program (e.g. to improve cost-effectiveness of PS reductions vs. to provide funding for NPS reductions)</td><td rowspan="2">• Investigate policy options for trading program; select desired goal; assess need for authorizing/enabling legislation to support achievement of goal
• Provide assistance to legislature in drafting legislative instrument
• Information dissemination (e.g. publication of authorizing/enabling legislation on departmental website and briefing potential market participants
• Potential costs of legal challenge to legislation (e.g. due to perceived inconsistencies with existing legislation)</td></tr>
<tr><td>Authorizing / enabling legislation</td><td>Provision of legal support that authorizes / enables the regulator to establish the trading program</td></tr>
<tr><td rowspan="5">(2)</td><td colspan="2">Administrative overheads, public consultation & education</td><td>Co-ordination between relevant government agencies & legislature

Ongoing education of market participants

Continuing public disclosure and consultation about rule development</td><td>• Co-ordination within regulator
• Co-ordination between agencies
• Public consultation
• Information dissemination
• Education programs re: credit & trading program design (e.g. user guides, how to generate credits, how the trading system works); regulatory requirements; monitoring & enforcement policy design</td><td colspan="2">• Participate in consultation processes
• Participate in education programs re: credit & trading program design
• Locate & read educational material</td></tr>
<tr><td rowspan="4">Defining the commodity</td><td>Baseline definitions</td><td>Specification of requirements credit-generating entity must achieve prior to credit generation</td><td rowspan="4">• Research & analysis of credit policy alternatives & their consequences
• Rule-making process:
o Research to quantify reductions achieved by baseline and credit-generating service provision (e.g. credit-generating BMPs), possibly involving trials, modelling, consultation etc.
o Development of quantification protocols
o Policy regarding translation of changes produced by service provision into credits
o Credit certification policy (incl. decisions regarding involvement of third parties –e.g. verifiers)
• Preparation for implementation: Investment in IT systems to support credit generation; hiring & training staff</td><td colspan="2" rowspan="4">• Investment in understanding the credit generation system (e.g., learning relevant IT applications)
• Opportunity cost of waiting for clear regulatory environment and clarity of decision space</td></tr>
<tr><td>Decision space</td><td>Specification of choice set of trading program participants with respect to: (1) credit-generation (e.g. eligible BMPs for NPS credits) and (2) market participation (e.g. PS eligible to trade with NPS only to offset growth; PS technology requirements)</td></tr>
<tr><td>Quantification of change in service level</td><td>Methodology for quantifying change in service level (e.g. load reduction) that will provide the basis for credit generation (e.g. modelling load reductions beyond baselines for NPS BMPs)</td></tr>
<tr><td>Credit calculation methodology</td><td>Methodology for translating change in service level into credits (e.g. credit tables)</td></tr>
</table>

		Certification system design*	Methodology for certifying all requirements for credit generation have been met		
...(2)	**Designing of Allocation and exchange rules**	*Trading eligibility rules*	Rules governing eligibility to participate in the market (e.g. PS may participate in NPS trading if technology standards are met and PS credits are not available)	• Research & analysis of trading policy alternatives & their consequences • Rule-making process (trading policy design): o Cost of designing trading policy to be consistent with existing legislation (e.g. creating a 'general permit' that allows PS to trade without costly alterations to individual permits) o Measures to ensure trading outside the cap does not result in cap being breached (i.e. measures to address leakage) o Measures to address uncertainty of equality between different types of reductions (e.g. trading ratios to address uncertainty) o Measures relating to additionality of reductions achieved outside of cap o Rules relating to conducting trade (matching of buyers & sellers; contracting requirements; post-trade reporting requirements) o Rules relating to approval of trade • Preparation for implementation: Investment in IT systems to support trading; hiring & training staff	• Investment in understanding the credit trading system (e.g. learning relevant IT applications) • Opportunity cost of waiting for clear regulatory environment and/or the impact of regulatory uncertainty about trading program parameters on decision making
		Conditions / limits of exchange	Rules governing the pairing of buyers and sellers (e.g. trading zones, no banking of credits, trading ratios)		
		Transfer requirements	Rules governing the transaction between buyer and seller (e.g. seller must use a broker; contract must report price; rules relating to ability of contract to transfer PS compliance risk; brokers must disclose conflict of interest)		
		Trade approval rules	Rules governing requirements for trade to be approved (e.g. required forms) and rules governing regulator's decision to approve trade (e.g. rules for when regulator can reject a proposed trade; rules requiring regulator to provide reasons for trade rejection)		
		Trade reporting & disclosure rules	Rules governing post-transaction reporting and market disclosure (e.g. price must be reported to regulator; number of credits traded to be made publically available)		
		IT platforms & register design	Design of IT systems to support 'arm's length' transaction (e.g. online trading platforms or credit auction design) and design of system for recording credit ownership & ownership transfers		
	Monitoring & enforcement design	*Design of service provision monitoring program*	System for ongoing verification of credit-generating entity to ensure service provision & credit generation requirements continue to be met	• Design of monitoring regime (e.g. number of site visits required per period; specification of required evidence of compliance to be provided by credit-generating entity) • Design of enforcement regime (e.g. penalties for non-compliance; design of appeals processes & dispute resolution mechanisms if needed)	
		Design of enforcement policy	Procedure for notifying entity of non-compliance and levying penalties to enforce compliance		

(3)	*Administrative overheads, public consultation & education*		Co-ordination between relevant government agencies & legislature Ongoing education of market participants Continuing public disclosure and consultation about ongoing program status Internal evaluations of progress with trading and assessment re: required rule changes	• Co-ordinate within regulator and with other agencies (e.g. EPA) & participate in compliance programs if applicable (e.g. demonstrate consistency of program outcomes with CWA) • Report to legislature • Education programs (e.g. education for new entrants, market updates) & publication of educational material • Information dissemination (e.g. credits traded, reductions achieved) • Consultation about trading program status / performance • Evaluate trading program performance and recommend changes† (e.g. to facilitate new technologies / entrants; changing trading ratios) • Public consultation on required changes • Implement required changes	• Participate in consultation processes • Participate in education programs re: credit & trading program operation • Locate & read educational material • Participate in public consultation about changes to trading program • Determine consequences of changes • Adapt behavior in light of changes	
	Creating the commodity	*Search costs to identify possible program participants*	Administrator outreach / search to identify and approach possible program participants (including via use of third parties such as local environmental groups)	• Search costs to identify potential participants / sites • Approving and contracting for funding – e.g. funding for baseline practices, cost share for credit generating practices (where trading system rules allow) • Other contracting costs: contracting with third party verifiers or technical assistance providers, aggregators, service providers • Assistance with creation of plans for service provision to generate credits • Reviewing, ranking and approving submitted documentation • Creating and registering issued credits • Publishing registered credits • Investment in training relevant third parties (e.g. verifiers, land planners) involved in credit generation processes • Contracting costs for cost-shared practices (e.g. to meet baseline)	• Participating in outreach activities / scoping studies to identify what credit-generating activities to implement • Applications and / or contracting for service provision (e.g. for cost-share funding for baseline practices; contracts with service providers, etc) • Creation of plans for service provision to generate credits, including for meeting baseline (possibly using the assistance of a third party) • Hire relevant licensed third parties • Contracting costs for cost-shared practices (e.g. to meet baseline) • Documentation of baseline requirements & service provision for credit generation • Submit documentation to regulator & apply for credits	• Investment in understanding the credit trading system (e.g. reading published material, participating in education programs, learning relevant IT applications)
		Credit generation (commodity / service provision)	Contracting for service provision (including applications for funding if relevant – e.g. to achieve baseline); Documentation of service provision; calculation of number of credits generated; applications for credit generation by generating entity			
		*Certification of credit generating practices / activities ***	Certification by regulator (or deputized third party) that all requirements to generate credits have been met (including baseline practices / activities if applicable)			
		Credit registration & reporting	Documentation and public disclosure of credit generation and status (e.g. 'released' credits)			

…(3)	**Market transactions**	*Assessing the market*	Potential market participants gather information to assess whether to enter the market	• Release registered credits for trade & publicize availability of credits • Review and approving submitted documentation relating to trading eligibility • Trade approvals (including providing reasons for trade if trade is rejected) • Alter permits to reflect trade • Record changes of ownership • Report market information • Maintain IT support system for trading • Investment in training third parties (e.g. brokers) • involved in trading processes	• Hire third parties • Demonstrate to regulator that trading eligibility requirements (including baselines) are met • Trading partner search (possibly via an intermediary) • Negotiate contract • Legal fees for contract review • Submit trade application to regulator • Appeal trade rejection (if necessary) • Opportunity cost of holding excess credits because of market uncertainty or lack of demand caused by regulatory setting	• Assess desirability of entering the market • Hire third parties – e.g. to negotiate with trading partner • Demonstrate to regulator that trading eligibility requirements are met • Trading partner search • Negotiate contract (possibly including measures for financial compensation in case of permit non-compliance caused by credit generator) • Legal fees for contract review • Submit trade application to regulator • Apply to regulator to have purchased credits / offsets added to permit • Appeal trade rejection (if necessary)
		Trading partner search	Buyer & seller matching (possibly via a third party – e.g. seller uses a broker)			
		Trade contracting (contract negotiation & design)	Negotiation of terms of exchange between buyer and seller (possibly via a third party); legal consultation re: contracting			
		Demonstration of trading eligibility	Potential market participants' demonstration to regulator of eligibility to participate in trades (e.g. PS purchasing offsets for new growth have met all requirements)			
		Credit trade approvals & approving permit changes	Approval of trade by regulator, including changes to permits (e.g. PS NPDES permits) required to give effect to trade			
		Market information & reporting	Public / market disclosure re: credit availability and market activity (e.g. aggregate price reporting; reporting of credits generated)			
		IT platforms & register maintenance	Ongoing maintenance to IT systems that support credit generation and trading			
	Monitoring & Enforcement	*Third party accreditation & licensing*	Regulator accreditation & licensing of third parties (e.g. nutrient management planners, brokers, verifiers etc.)	• Initial accreditation / licensing of eligible third parties • Monitoring program (e.g. carrying out site visits for credit verification; auditing evidence provided by regulated parties, incl. third parties) • Enforcement actions: Notification of failure to comply, fines, etc.		
		*Detection of non-compliance / verification** of service provision*	Monitoring of service provision to ensure compliance requirements are met Monitoring of third parties to ensure third party requirements are met		Comply with monitoring requirements (e.g. site visits, submitting evidence for credit verification)	Comply with monitoring requirements (e.g. submitting permit compliance plans)

		Enforcement action	After detection of non-compliance, implementing the enforcement policy (e.g. notification of non-compliance, levying of penalties)	• Legal challenges to regulator enforcement decisions / actions Adjudication / participation in trading disputes	• Fines, legal costs of enforcement action • Legal challenges to regulator enforcement decisions / actions • Legal challenges to trading contracts (i.e. trade disputes)

*****Transaction costs for all categories include: opportunity cost of time spent doing the relevant activity; wage costs of staff time spent; overheads to support staff time spent. Related costs such as travel costs (e.g. for site inspections) or specific fees (e.g. legal fees, payments to research consultants) may also be incurred depending on specific decisions made (for example, the regulator could conduct research in-house or via research consultants).

****** The use of the terms **certification** and **verification** varies in the literature and across trading programs. Here, certification refers to the initial checks that are part of the credit generation process; verification refers to the ongoing process of monitoring the credit-generating entity and practices to ensure that requirements continue to be met after credits have been created. **†** Large structural changes to trading programs (e.g. expanding the program scope to include interstate trading) are likely to have additional significant costs (e.g. may require changes to enabling legislation; may require significant re-training of staff and learning costs for market participants). Such costs are "**dynamic**" and are excluded here.

Part III: Existing empirical evidence

In this section we examine existing evidence on the size and incidence of transaction costs and the various factors which influence those costs. Primary empirical data are difficult to come by. We therefore look beyond water quality studies and use the wider literature on transaction costs for environmental service provision from agriculture and forestry to glean insight that is relevant for WQT programs.

An extensive examination of empirical studies in the literature was conducted (for a detailed summary see Table A1 in the Appendix). From these studies, we identified 20 studies which empirically estimate the level of transaction costs relative to total costs for environmental programs and markets involving agriculture and / or forestry (Table 3 below). Although few studies focus directly on water quality, a suite of OECD studies in the mid-2000s examined what they termed "policy-related transaction costs".[8] These studies look broadly across "agri-environmental schemes", and a range of practices are analyzed such as land retirement, organic farming and conservation measures on livestock farms. Several empirical papers are also available for conservation and organic cost-share programs, water quantity markets and carbon / greenhouse gas (GHG) emissions.

This literature tends to focus on the 'implementation' stage (stage 3 in the conceptual framework), but empirical studies exhibit a great deal of variation in methods and definitions, which makes comparisons across studies challenging. First, researchers employ various categories and definitions of transaction costs. Second, empirical studies may only estimate transaction costs for specific parties involved in the program (public agencies, private service providers, buyers, etc.). Finally, studies differ in how transaction costs are estimated. Some researchers use a 'top down' approach, wherein official budgets, usually at the level of an agency or program as a whole, are obtained, and costs are allocated to specific programs or categories of transaction costs. While such studies cover a large range of costs, the aggregate nature of budget data makes analysis of sensitivity to costs to different policy features and designs challenging. Other studies use a 'bottom up' approach which usually involves developing a conceptual framework or taxonomy of transaction costs, and then directly obtaining data via surveys and / or interviews with program administrators, participants (e.g. farmers) and possibly third parties on specific administrative tasks and activities. A detailed description of data-gathering methods is given in the Appendix (Table A2). Finally, some studies do not directly seek to measure transaction costs, but estimate costs as a 'residual' by subtracting transformation costs from total program costs or by measuring price differentials across different trading regions.

With these caveats, the available literature was analyzed to provide insight into a number of issues related to the transaction costs of water quality trading programs and more generally the transaction costs of providing agri-based environmental services. We look at several issues

[8] Papers using the OECD definition of policy-related transactions costs: Mann (2005); OECD (2001, 2005a, 2005b, 2005c, 2007) ; Ollikainen et al (2008). The definition originally came from Mann (2000).

including the overall size of transaction costs, where transaction costs are incurred through the implementation process, and what factors might explain the magnitude of costs.

3.1 Transaction costs: how large are they?

The starting point for consideration of transaction costs in water quality trading programs is to question whether they are economically relevant. If transaction costs amount to only a trivial proportion of the total costs of a program or policy, not much information is lost by failing to account for them and they will not have much of an impact on policy design or implementation. A related question is how the transaction costs of a particular program compare to other programs. A relative comparison of transaction costs makes it possible to "benchmark" program costs to better understand whether a program's costs are reasonable.

To date there are very few studies available that assess transaction costs of water quality trading programs, so benchmarking only in relation to WQT programs is not currently feasible. As far as we are aware, only two studies, Fang et al (2005) and Newburn & Woodward (2012) – assess the level of transaction costs compared to total costs for water quality trading programs. A summary of the results from these studies is presented below.

Fang et al (2005) examine water quality trading programs in the Minnesota River Basin for two point sources – the Rahr Malting Company and the Southern Minnesota Sugar Beet Cooperative (SMSBC), but only present concrete estimates of transaction case for the Rahr case.

Table 1: transaction costs estimates by actor & phase, Rahr Water Quality Trading project, 1997 - 2002:

	Cost ($)
Total Transformation Costs	$300,044
Transaction costs:	
Permitting phase	**$68,294**
Rahr	$16,500
MPCA	$51,794
Implementation phase	**$36,739**
Rahr	$2,188
MPCA	$33,301
Other (citizen's group)	$750
Nonpoint sources	$500
All phases	**$105,033**
Rahr	$18,688
MPCA	$85,095
Other (citizen's group)	$750
Nonpoint sources	$500
TOTAL COSTS	$405,077

Source: adapted from Fang et al (2005), Tables 1 & 3.

The Rahr Malting Company trading program commenced in 1997 and was aimed at establishing an oxygen demand TMDL. The Minnesota Pollution Control Agency (MPCA) allowed the Rahr Malting Company ("Rahr") to build its own wastewater treatment plant (WWTP) despite having no available wasteload allocation (WLA) to distribute to the new plant (as PS WLAs had already been fully distributed and Rahr was unable to purchase WLA).The MPCA negotiated to allow the Rahr Malting Company Rahr to offset projected loads of CBOD5 (five-day carbonaceous biochemical oxygen demand) from the new plant by purchasing credits from agricultural nonpoint sources (NPS). Rahr achieved this via four NPS trades over the 5 year project period. Credits were generated from a combination of land conversion (farmland reconversion to native floodplain) and streambank erosion control measures.

The authors estimated costs of the program without and with transaction costs, and found a 35% increase over the five year project period when transaction costs were included. Estimated costs are reproduced in Table 1. The estimated costs were derived primarily from estimates of MCPA and permittee staff time commitments and wages (a 'bottom up' approach). Note that this trade was a first time case of a point source permit containing a nonpoint source offset condition in Minnesota. As such, some of the permitting costs would include activities described in the conceptual framework as "regulatory design" as well as implementation related transaction costs. If the Rahr case is used as a precedent, the staff costs of establishing offset permit conditions might be expected to decrease for future permit modifications.

Newburn & Woodward (2012) assess the Great Miami Trading Program (GMTP) in Ohio, a pilot WQT program administered by the Miami Conservancy District (MCD). The GMTP became 'fully operational' in 2006. Originally it was anticipated that nutrient criteria and TMDLs in Ohio would drive point source demand for credits, but finalization of the TMDLs was delayed due to scientific reasons and legal challenges. Nevertheless, five separate WWTP point sources contributed to the program, purchasing credits in advance of reduction obligations under the expectation that advanced credits would provide more favorable future terms of trade.

The focus of the GMTP is on the solicitation and generation of agricultural nonpoint source credits. The GMTP relies on local Soil and Water Conservation District (SWCD) staff to identify and work with agricultural producers to install best management practices (BMPs) that are additional to current practices. A loading model converts proposed practices into phosphorus loading estimates. Farmers submit applications to be funded which are ranked by MCD according to cost-effectiveness (lowest total cost per pound of nutrient reduction). As of 2009, 160 applications for agricultural credit-generating projects had been submitted, 100 of which had been approved. Credit-generating projects are monitored by SWCD agents who report to MCD.

Newburn and Woodward (2012) provide a partial picture of transaction costs. Transaction costs estimates only include payments made from MCD to the SWCDs for initial SWCD staff assistance to the farmer and SWCD monitoring costs. These estimates are reported in Table 2 for the 10 participating counties. Moreover, the authors find that MCD has essentially been able to 'free ride' by using Soil & Water Conservation District (SWCD) staff to identify and work with landowners to get the contracts for environmental services that generate credits in place. Costs of SWCD that are not reimbursed by MCD are not included in the transaction costs analysis. Furthermore MCD costs of administering the auction, recording of credits, program oversight/coordination, and remediation costs for noncompliant actors were not reported. Furthermore, the costs do not include buyer-related costs. To date, the point sources have not used credits for regulatory compliance, thus estimates do not include costs associated with permitting and credit exchange.

Consequently, the transaction costs reported are likely to underestimate the true costs of administering the trading program, and moreover do not include any measure of the transaction costs incurred by program participants (e.g. landholders, permittees). These caveats notwithstanding, Newburn & Woodward report that total transaction costs of SWCD initial assistance plus monitoring are 5% of total program costs. However, results at the county level show some variation in this figure, as proportional transaction costs varied from 0% (Mercer and others) to 12% (Montgomery County). It is important to note in these estimates that counties reporting "zero" transaction costs in fact incurred costs but did not seek to recover them. The authors report that SWCD agents in these cases "were more concerned with helping their local farmers get accepted than to charge the full costs of their assistance" (p. 165). The authors also report that

SWCD agents and farmers in some counties elected not to participate after the initial auction due to low award amounts relative to the "considerable effort to formulate bid applications."

Table 2: SWCD initial assistance and monitoring transaction costs (recovered), Great Miami Trading Program

County	No. Funded Projects	SWCD Initial Assistance Cost ($)	SWCD Monitoring Cost ($)	Farmer Payments ($)	Total Funds ($)	Number of SWCD Staff	*Initial assistance % of total funds*	*Monitoring Costs % of total funds*
Butler	1	350	0	18,000	18,350	3	*1.9%*	*0%*
Clark	2	400	1,000	15,909	17,309	4.5	*2.3%*	*6%*
Darke	37	46,475	11,128	790,149	847,752	7	*5.5%*	*1%*
Logan	4	1,650	150	20,833	22,633	4.5	*7.3%*	*1%*
Mercer	10	0	0	23,927	23,927	5.5	*0.0%*	*0%*
Miami	6	1,125	625	57,085	58,835	5	*1.9%*	*1%*
Montgomery	2	1,900	100	15,855	17,855	6.5	*10.6%*	*1%*
Preble	8	800	1,000	20,329	22,129	5	*3.6%*	*5%*
Shelby	29	0	0	262,164	262,164	7	*0.0%*	*0%*
Warren	1	0	0	45,260	45,260	3	*0.0%*	*0%*
Total	**100**	**52,700**	**14,003**	**1,269,511**	**1,336,214**	**51**	***3.9%*** †	***1.1%*** †

† Calculated for aggregate (total) figures. Source: adapted from Table 4, Newburn & Woodward (2012)

Size of transaction costs: evidence from beyond water quality trading

Given the paucity of data on WQT programs, we need to go beyond water quality trading to provide an adequate benchmark for transaction costs. Studies measuring transaction costs for other types of environmental programs for agricultural operators are useful in that such programs often have elements that are similar to those of water quality trading programs.

Table 3 summarizes studies that estimated transaction costs of agri-based environmental improvement or resource management programs. The studies relate to a broad spectrum of environmental markets / programs: air pollution programs (1 study), water quantity programs (5), conservation programs (6), organic programs (2), water quality programs (3), and 3 studies which compare multiple program types. Table 3 also reports available estimates of total transaction costs, generally where costs can be expressed either as a proportion of prices paid (for water quantity trading programs), or as a proportion of program expenditures or compensation payments transferred (all other programs).

A plethora of approaches were used in these papers to estimate transaction costs, making cross comparisons challenging. We have therefore used the conceptual framework developed in section 2 to analyze these works and to identify commonalities that exist. In Table 3 we note the section(s) of the framework each study focuses on, although it should be acknowledged that seeking to situate diverse studies within a coherent conceptual framework is an inherently uncertain exercise (Rørstad et al 2007). The Appendix (Table A1) provides description of the transaction cost categories or framework actually used in each of the studies.

Our categorization highlights the emphasis that has to date been placed on certain components of the conceptual framework; almost all studies which empirically estimate transaction costs do not include the full range of transaction costs. The transaction costs most commonly estimated are associated with the implementation stage (creating the commodity (or service), transacting the service, monitoring and enforcement). Studies of water quantity trading between consumptive users are even more narrowly focused: in these cases, analyzes focus almost exclusively on "market transaction". Most studies do not attempt to measure enactment costs or initial allocation / establishment of property rights systems that enable trading (Krutilla and Krause: 2010), although various studies do acknowledge these cost components exist.

Immediately evident in Table 3 is the broad range of percentage estimates; from as low as 0.1% of reported total costs to 244% (i.e. transaction costs substantially exceed transformation costs for the program). Clearly, one explanation for this variation is differences in what costs (see Table 3, column 4) and which actors (Table 3, column 2) were included in each analysis. Apart from these differences in accounting techniques, however, there are underlying reasons why transaction costs should differ across programs. Several of these reasons are discussed in the following sections.

Several of the studies include programs with close parallels with water quality trading programs involving agricultural nonpoint source credits. For example, many conservation programs, including WQT programs, use land conversion and protection. Antinori and Sathaye (2007) estimated the transaction costs to private market participants to implement forest preservation projects for greenhouse gas mitigation. The authors report private transaction costs range from 13 to 38% of total project costs. On the other hand, estimated ongoing public costs to administer the U.S. Conservation Reserve Program (CRP) range from 1 to4% (Classen et al 2008, OCED 2005). Some other research has examined the private and public costs to develop and implement voluntary contracts for conservation activities between farmers and government agencies (e.g. cost share/ financial incentive programs). Such programs encompass many of the same activities required to generate contracts to supply agricultural nonpoint source credits. Using program level data from the mid-1990s, McCann and Easter (2000) estimate that NRCS technical assistance and administration costs represent nearly 40% of total program costs (cost share assistance). Several studies of European agricultural conservation programs estimate public and/or private transaction costs and find many instances of transaction costs accounting for 5% to 50% of total program costs, with the occasional program exceeding 100% (Falconer and Whitby (2000); Mann (2005); Ollikainen et al (2008); Rørstad, Vatn and Kvakkestad (2007)).

Table 3: Summary of Empirical Transaction Cost Literature Involving to Agri-based Environmental Services

			Framework components					Actors included			
		Programs / services evaluated	(1) Legislative environment	(2) Regulatory Design	(3i) Creating the commodity	(3ii) Market transactions	(3iii) Monitoring & Enforcement	(Public) Administrator	Private program participants[10]	Third parties	**Transaction Costs (TC) estimates, expressed in percentage form[9]**
Air pollution	Antinori & Sathaye (2007) Various countries	41 greenhouse gas (GHG) projects[11]			✓	✓	✓		✓		(Mean of 5 forest preservation projects, mature market) W/o insurance: Mean TC: 13%; Min: 8%; Max: 18% W/ insurance: Mean TC: 21%; Min: 13%; Max: 38%
Water (quantity)	Brown et al (1992) US (New Mexico)	Water rights markets				✓			✓		Mean TC as % of Mean price per acre foot: 13%
	Challen (2000) Australia	Permanent water entitlement market				✓			✓		TCs as % of price per unit traded: Total TCs: 3%-25% Administrative fees and charges: 3% - 12% Commissions paid to agents: 5% Costs of residual imperfect information: 0%-8%
	Colby (1990) US (CO, Utah, New Mexico & Nevada)	Water right transfers				✓			✓	✓	Mean TC across all states as % of Mean price per acre foot: 6% Mean $ spent per protest filed: $7052 (range: $750-$24,400)
	Garrick & Aylward (2012) US, Columbia R. Basin	Columbia Basin Water Transactions Program; acquisitions of water for environmental flows	✓	✓	✓			✓			Mean TCs as % of mean price per discounted unit of water recovered, by sub-basin[12]: Min: 13%, Max: 244%

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[9] Percentage TCs are $TC / $unit price of water for water quantity programs; for all other programs, percentage TCs are $TC / $transfers. What counts as a 'transfer' depends on the study in question; generally, transfers are total compensation payments made. See Appendix Table A2 for a detailed description of percentage measures used.

[10] E.g. farmers / landholders, regulated entities such as point sources, etc.

[11] (26 with complete data): included different types of energy efficiency, forestry, renewable energy, fuel switching, and landfill gas projects; we generally only include data from the forestry projects, as other projects do not involve agriculture / forestry.

[12] Calculated by dividing TCs ($/Cubic feet per second) by average water costs ($/CFS) from Table 4 in Garrick & Aylward (2012).

	Hearne & Easter (1995) Chile	Water allocation markets			✓			✓		TC % of price per unit of water traded: Elqui valley: Buyers: 21%; Sellers: 2% Limarí valley: Buyers: 5%; Sellers: 2%
Conservation programs	Classen, Cattaneo & Johansson (2008) US	Conservation Reserve Program (CRP)	✓	✓	✓	✓	✓			USDA FSA reported conservation-related salaries & expenses: $15.5 million, around 1% of $1,850 million total CRP expenditures ($1850 million).
	Falconer & Saunders (2002) UK	3 types of management agreements for conservation activities on sites of special scientific interest[13]		✓	✓	✓	✓	✓	✓	Mean TC as % of total compensation costs, per agreement, over agreement life-cycle: All agreements: 21.4% -'Under seal': 16.6% -'Under hand': 27.8% -WES: 112.6%
	Groth (2008) Germany	2 conservation auctions, for 3 types of grassland BMPs		✓				✓		Estimated TC; 1st auction; 2nd auction: -Grassland I: 9%; 5% -Grassland II: 7%; 3% -Grassland III: 4%; 2%
	McCann & Easter (2000) US	2 NRCS programs: technical assistance and cost-sharing for conservation programs	✓	✓	✓		✓			Total public administrator TC (NRCS + Non-NRCS): $12.52 per acre; 38% of total conservation costs
	Mann (2005) Switzerland	Agricultural cross-compliance[14] programs					✓	✓		TCs as % of transfers: -Extensive Grassland: 5% -Low-intensity grassland: 11% -Litter-meadow: 7% -Hedges: 14% -Mixed fallow land: 3% -Rotational fallow land: 4% -Arable field margin: 113% -High-stem trees: 13%
	OECD (2005a) US	Conservation Reserve Program (CRP); Farm Service Agency (FSA); National Resources Conservation Services (NRCS)	✓	✓			✓			Start-up costs (1st year of CRP): -FSA: 23% -NRCS: 87% Ongoing costs: -FSA: 3-4% -NRCS: 0.4-4%

[13] (1) Wildlife Enhancement Scheme (WES) - standardized agreements; (2) "Under hand" - individualized agreements, less formal, short-term agreements; (3) "Under seal" - individualized agreements, more formal, longer-term.

[14] Cross-compliance is "[t]he practice of granting public payments to farmers only if they comply with certain environmental standards" (Mann (2000), p471).

Organic programs	Sinabell (1998) [15] Austria	Organic aid schemes				✓	✓		✓		Farmer's cost-to-premium ratio: 4.89%
	Skuras (1998) [16] Greece (Thessaly)	Nitrate reduction schemes			✓			✓	✓		Consultant - cultivation plan: 1-2% of total subsidization Costs of applications borne by farmers: 3.7% of compensation payments received
Water (quality)	Fang, Easter & Brezonik (2005) USA (Minnesota R. Basin)	Rahr Malting Company water quality trading project (trading N and P)[17]		✓	✓	✓	✓	✓	✓	✓	TCs for the project as a whole increased total costs by 35%.
	McCann & Easter (1999) US (Minnesota R. Basin)	(1) tax on phosphate fertilizers (2) educational programs re: BMPs (3) requirement for conservational tillage on all cropland (4) permanent conservation easement program ("RIM")	✓	✓	✓		✓	✓			Total TC except research to achieve policy objective over a 10-year time horizon: Extension: $3,109,000 Tillage: $7,851,000 RIM: $9,371,000 Fertilizer tax: $935,000 Assumed fringe benefits of 28%, discount rate 5%
	Newburn & Woodward (2012) US, Ohio	Great Miami Water Quality Trading Program			✓			✓			Initial assistance: 1%; Monitoring: 3.9%
Multiple agricult	Falconer & Whitby (2000) EU member states	[18]37 AES schemes from EU member states participating in the STEWPOL survey[19].		✓	✓		✓	✓			TCs as per cent of compensation paid (expenditure weighted): Austria: 8.8%; Belgium: 63.4%; France: 87.1%; Germany: 12.3%; Greece: 8.6%; Italy: 6.6%; Sweden: 11.3%; UK: 47.9%

[15] Cited in Falconer (2000); original paper not available.

[16] Cited in Falconer (2000); original paper not available.

[17] The 'Regulatory design' activities accounted for by Fang et al (2005) were negotiations between administrator (MPCA) and permittee (Rahr), which included determining what the MPCA would consider acceptable in terms of 'trading' with the nonpoint sources.

[18] Types of schemes included are: Suasion & Advice; Regulation; Market mechanisms; Tradeable permit schemes; Voluntary management agreements; Public purchase of land

[10] The project "Market effects of countryside stewardship policies", also called the "STEWPOL" project, commenced in 1996 and provides detailed data including information about transactions costs of various agri-environmental schemes in eight EU Member States.

Ollikainen et al (2008) Finland	Agri-environmental programs	✓	✓	✓		All forms of agri-environmental support: 2.78% *Basic measures* (total): 1.46% *Additional measures* (total): 6.69% - more accurate fertilization: 9.81% - plant cover in winter & reduced tillage: 8.04% - additional measures on livestock farms: 3.70% *Special measures* (total): 33.06% - buffer zones: 42.83% - traditional biotopes: 28.77%
Rørstad, Vatn & Kvakkestad (2007) Norway	1. Tax on fertilizers 2. Tax on pesticides 3. Price support for home-refined dairy 4. Acreage payments 5. Livestock payments 6. Subsidy for reduced tillage 7. Organic farming - acreage 8. Organic farming - conversion 9. Preserving cattle breeds 10. Special landscape ventures 11. Investment support for environmental measures	✓	✓	✓	✓	TCs (% of payments / tax revenue): 1: 0.1% 2: 1.1% 3: 12.3% 4: 0.9% 5: 2.1% 6: 5.9% 7: 19.8% 8: 29.3% 9: 66.3% 10: 46.6% 11: 21.8%

3.2 Which components of transaction costs are most important?

A deeper understanding of transaction costs requires not only assessing overall levels (absolute or relative to total program costs), but also examining where in the framework transaction costs are greatest. In order to best consider this question, we focus on studies of programs involving agricultural / forestry practices that provide estimates for all actors. This avoids the question of cost shifting: for example, in one program, a cost may be borne by the program administrator, while in another the cost is still incurred, but by a private actor. We also focus on implementation, rather than regulatory program design.

Many studies focus only on private *or* public actors as their focus; only a few of the studies discussed previously estimate transaction costs for *both* public and private actors and also provide a breakdown. Table 4 provides the proportion of estimated transaction costs occurring in the categories used in selected studies.

We did not find any studies of agri-environmental programs that addressed search and information costs associated with implementing agricultural environmental service projects (e.g. disseminating information on program options, evaluating service options, etc) . However, Ofei-Mensah & Bennett (2013), who assess 3 programs to ameliorate GHG emissions in the Australian transport sector, estimate these costs constitute 65-85% of start-up costs. This is an important result because it puts into perspective how much measures which do not include these costs could underestimate the true size of transaction costs. Although the contribution of search and information costs to total transaction costs declined in the ongoing (implementation) phase, they still constituted the largest and second largest source, respectively, of costs for the Fuel Label Program (42%) and the Fuel Efficiency Program (32%).

For the Rahr Water Quality Trading Program, the initial permitting phase for the point-source buyer involved in the program constituted the majority of costs. The authors point out that this was because the administrator had to work out the overall structure of trading despite only one point source participating in the trade (Fang, Easter & Brezonik: 2005); this circumstance essentially loads many of the costs in the rule design phase onto a small number of trades, driving up transaction costs as a proportion of total costs for these trades (but possibly in the future resulting in lower transaction costs for future trades as this work has already been done).

For programs described in Antinori & Sathaye (2007) (greenhouse emissions reductions forestry projects) and McCann & Easter (1999) (Reinvest in Minnesota "RIM" conservation easement program), monitoring costs constitute the greatest proportion of total transaction costs. For the conservation programs analyzed in Falconer & Saunders (2002), monitoring is not as important, and for these programs implementation is where most of the transaction costs occur.

Table4 Distribution of transaction costs by TC categories

Antinori & Sathaye (2007)

Transaction costs for project developer: percentages per TC category (mean of 11 forestry projects)

Nascent Market	**100%**	**Mature Market**	**100%**
Search	3.8%	Search	2.8%
Feasibility	19.9%	Feasibility	18.2%
Negotiation	15.4%	Negotiation	10.0%
Insurance	23.7%	Insurance	31.8%
Monitoring & verification	35.1%	Monitoring & verification	36.5%
Regulation	1.6%	Regulation	1.0%

Fang, Easter & Brezonik (2005)

TCs by TC category (%)

Permitting phase	65%
Implementation phase	35%
Total	100%

Falconer & Saunders (2002)

TCs by TC category and actor (%)

	English Nature (administrator)	Farmer	Land agent	Total
Meeting	11%	8%	16%	13%
Site visit	11%	8%	16%	13%
Internal files, letters, payments & computer entries	43%	9%	18%	29%
External letters	9%	68%	39%	29%
Payments	3%	0%	0%	2%
Letters to other agencies	8%	0%	0%	4%
Management agreement	15%	6%	11%	12%
Total	100%	100%	100%	100%

McCann & Easter (1999)

Mean administrator transaction cost (in FTEs) per TC category and project type

	Education (extension)	Conservation Tillage (MPCA)	RIM[a] (BWSR, SWCDs)	P fertilizer tax (MDA)
Total info costs over 4 years	*22.13*	*19*	*22.087*	*12.275*
Time to design and implement program	14.33	16	16.28	0.895
Time administering program once set up (per year)	5.25	2	0.048	1
Time spent in monitoring (per year)	0.475	0.0305	6.45	0.5
Time spent with prosecution-enforcement-litigation (per year)	0	2	0.095	0.15
Lobbying overall *(assume this is over life of project)*	0.12	5.5	0.21	4

[a] Permanent conservation easement program: "Monitoring consists of yearly inspections for the first five years and then once every three years. If a violation is noted, there is a discovery phase." (p408)

Costs of 'Market Transactions'

Some studies focus specifically on the costs incurred to conduct an exchange (costs faced by buyers and sellers in the "market" component of the conceptual framework). While the literature concerning environmental markets is limited on this subject, researchers studying for water *quantity* trading programs have focused more attention on this component of transaction costs. Brown et al (1992) report that transaction costs of trading water rights in New Mexico amount to 13% of the total price paid, Challen (2000) estimates the costs of trading permanent water entitlements in South Australia range from 3 to 25% of the average entitlement price per megalitre, and Hearne & Easter (1995) provide a similar range of 7% to 23% for water trading in Chile. Accordingly, it appears from the available data that a reasonable benchmark is that transaction costs in the "market transactions" component of the conceptual framework to buyers and sellers of water (quantity) rights constitute around 5-25% of the price paid. However, where administrator transaction costs are not fully recovered by administrative fees charged to buyers and sellers, this benchmark would not adequately reflect costs of market administrators; therefore the benchmark should be conceived as a lower bound for the component as a whole.

In terms of relating these results to water quality trading, note that the above benchmark does not include costs of demonstrating eligibility to participate in the trading program; also not included are costs incurred in water quality trading programs relating to altering point source compliance permits (e.g. NPDES permits in the US case) to reflect trades. This is because these activities generally have no counterpart in a water quantity trading program.

The form and administration of NPDES permits however have frequently been identified as having significant consequences on transaction costs (Shabman et al 2002; Woodward and Keiser 2002; Industrial Economics 2008). All trades under the Clean Water Act involve use and modification of permits. Although costs are not directly quantified, researchers have noted costs of trades can be significantly influenced by permit type (general vs individual). The use of discharger associations has also been cited as an organizational structure that facilitates information sharing and coordination between groups of regulated dischargers. Furthermore, permit holders sometimes express concerns about the time and legal risks involved in amending permits to reflect trade activity. The legal risks associated with individual permit modifications arise from a number of CWA requirements (public consultation, anti-backsliding, etc) and the exposure to third party lawsuits.

Trading program maturity

Many studies on transaction costs assume costs will fall over time as learning occurs for both administrator and scheme participants, and 'adaptive management' tends to streamline application and approval processes. Several studies show this result overall for a variety of existing programs (see for example Falconer & Whitby (2000), Falconer, Dupraz & Whitby (2001), Challen (2000), Garrick, Whitten & Coggan (2013), Groth (2008)).

However, Antinori & Sathaye (2007) study changes in components of transaction costs for projects which were intended to produce credits in 'nascent' versus 'mature' emissions trading markets. While their results for overall transaction costs supports the notion that transaction costs fall over time, they find that costs for some components actually increase as the markets mature (Table 5). In particular, insurance costs and regulatory costs increased substantially as compliance standards became stricter or more rigid (e.g. because projects moved from a "pilot phase" to being used to generate credits for regulatory compliance). In addition to this, the authors note that lower numbers of attractive or eligible projects may put upward pressure on transaction costs as markets mature via increased search and approval costs.

Table5: Changes to transaction costs as emission trading projects mature

Mean % change in $TC per category (nascent to mature market)	average change	min change	max change
Search	-35.04%	-84%	78%
Feasibility	-29.11%	-84%	131%
Negotiation	-25.67%	-85%	186%
Insurance	70.01%	-100%	100%
Monitoring &Verification	-25.64%	-70%	112%
Regulation	47.76%	0%	127%
Difference in total TCs: Mature: Nascent	-23.13%	-70%	49%

Source: authors calculations based on data in Antinori & Sathaye (2007), Appendix E.

3.3 Transaction costs, uncertainty, and trust

Although difficult to quantify, uncertainty is often a significant opportunity cost of entering into an exchange. Risk and uncertainty originate from a number of sources, including market risks associated with changing prices and market conditions. Uncertainty may also arise from unknown or unfamiliar outcomes of a contractual arrangement. Several studies in the literature found that increases in landowner trust in program administrators increased program participation and reduced transaction costs; or, conversely, that low levels of trust acted a barrier to program implementation and contributed to higher transaction costs for both administrator and program participants.

Breetz et al (2004) noted in their analysis of the Kalamazoo River Water Quality Demonstration Project (MI) that encouraging participation in the program was a challenge for the administrator because farmers "did not trust regulators, were afraid of being targeted as polluters, and were reluctant to make voluntary changes that might later become required" (p 168). The project's Steering Committee combatted this by partnering with NRCS to provide a "trusted contact" for farmers (p167).The strategy of partnering with local agencies and environmental groups has also been used in other programs: in the Rogue Basin temperature trading program (Oregon), the Freshwater Trust, which implements projects generating temperature credits, seeks to work via local groups to minimize its search costs (*pers. comm.* Alex Johnson, Freshwater Trust, 2014). Similarly, EPRI makes use of Soil and Water Conservation District (SWCD) staff in the Ohio Basin WQT program because SWCD agents already have a working relationship with farmers, and hence help to lower search, contracting, and monitoring costs for the program (*pers. comm.* Jessica Fox, EPRI, 2014).

Mettepenningen et al (2007) found that a higher level of farmer trust in the administrator was associated with lower participant transaction costs, particularly in the search (i.e. finding information about the program) and contracting stages; this finding is similar to Ducos and Dupraz (2007), who found that distrust in government and "uncertainty stemming from the opacity of public decisions" negatively affect the probability of a farmer participating in an agri-environmental contract (p7).

However, Mettepenningen, Beckmann & Eggers (2011) caution that "trust is a complex issue" (p647). In their study of perceptions of what causes public (administrative) transaction costs for a range of agri-environmental schemes in EU member states, they found a *positive* relationship between farmer trust in public administrators and transaction costs for the design phase of programs. They theorize that "trust may enable transactions which are not possible without it" (p647); or, in other words, the positive relationship may be attributable to a dynamic where the administrator can implement a more complex program (which comes with higher transaction costs in the design phase) *because* it enjoys a high level of trust.

3.4 Transaction costs incidence

Although as noted above the question of *who bears the transaction costs* can vary from program to program as costs are shifted, it is nonetheless useful to consider. In some cases, shifting activities or costs from one actor to another may result in net savings – for example because one actor can perform a task more efficiently. In section 4.3 we discuss the outsourcing of initial search costs from program administrators to local entities ranging from SWCD agents to local environmental groups. This is a method that has been used in several WQT programs in an effort to reduce administrator costs and streamline upfront costs (i.e. prior to applications for credit-generating practices being submitted).

Also, at times policy-makers may be interested in the incidence of transaction costs for a particular actor. For example, concerns have been raised by Ducos & Dupraz (2006) and others that program participation is low because farmer/landholder transaction costs form a barrier to entry.

Table 6 shows available data on transaction costs incidence from selected studies. It is clear that public agencies often bear the bulk of transaction costs in many agri-based environmental enhancement programs, but which agency (and at what level: national, regional, county etc) incurs the most costs varies from program to program. Also, programs with lower transaction costs overall (measured as a percentage of total costs) tend to have a higher proportion of costs borne by the farmer (program participant). This perhaps suggests that efforts to lower transaction costs should be concentrated on the administrator's side of the program.

Table 6: Transaction costs incidence

Paper	Actors for whom TCs were measured	Transaction cost incidence (% of total TCs borne by actor)		
		Administration level	*Organic conversion %*	*Reduced tillage %*
Vatn, Kvakkestad & Rørstad (2002)	Public administrators and & program participants (farmers, farm product wholesalers)	Ministry of Agriculture	0%	1%
		Norwegian Agricultural Authority	46%	3%
		Agricultural Inspection Service	0%	NA
		Debio (organic certifier)	33%	NA
		County agricultural authority	2%	10%
		Local agricultural authority	13%	44%
		Farmers, transactions with the state	1%	43%
		Farmers, transactions with Debio	4%	0%
		Total	100%	100%
		Total TCs as % of subsidies paid	*29.04%*	*6.81%*

Falconer & Saunders (2002)	Public administrator: English Nature (EN); participating farmers / landowners	Average public administrator (EN) share of total negotiation TCs, all agreement types: 70%		
Fang, Easter & Brezonik (2005)	Public administrator: Minnesota Pollution Control Agency (MPCA) and the regulated point source (Rahr); citizen's groups and nonpoint sources	*Incidence of TCs by phase and in total:*		
		Permitting phase		100%
			Rahr	24%
			MPCA	76%
		Implementation phase		100%
			Rahr	6%
			MPCA	91%
			Other (citizen's group)	2%
			Nonpoint sources	1%
		All phases		100%
			Rahr	18%
			MPCA	81%
			Other (citizen's group)	1%
			Nonpoint sources	0%
			Total TCs as % of transformation costs	35%
Ollikainen et al (2008)	Public administrators (doesn't include participant TCs)	*Incidence of public TCs among public agencies:*		
			Agri-environmental support	CAP, LFA and national support
		Ministry of Ag. & Forestry	19%	73%
		Ministry of the Environment	0%	0%
		Rural Departments	45%	11%
		Environment Centers	23%	0%
		Municipal Authorities	13%	16%

3.5 Explanatory Factors Influencing Transaction Costs

The conceptual framework highlights that transaction costs occur at multiple levels and spread widely through the water quality credit development and exchange process. However, special attention and challenges face agriculture in the area of what is defined in Part II as credit definition (rule making) and credit creation and monitoring (implementation stage). Agricultural operations are complex and fluid with multiple sources of nutrients, production processes, and cropping systems. Multiple avenues exist for improving environmental outcomes and translating management actions into quantifiable service load changes is challenging. Verification of multiple and widespread practices that singularly produce relatively small individual reductions add to the cost of creating agricultural nonpoint source credits. Mettepenningen, Beckmann & Eggers (2011) find that the complexity of the agri-environmental scheme (AES) is considered by program administrators (and other survey respondents) to be the most important factor in determining the AES design costs.

It is clear that commodity complexity is a multi-faceted concept (see Figure 1). In the context of WQT programs involving nonpoint sources, we distinguish three key axes along which complexity can vary and consequently impact transaction costs:

- The complexity of "defining the commodity";
- The complexity of creating the commodity; and

- The complexity of measuring & monitoring the commodity.

These are by no means the only dimensions along which one can consider the effect of complexity, but they incorporate many of the elements particularly important for programs that involve agricultural nonpoint sources.

Figure 1: Axes of commodity complexity in water quality trading programs

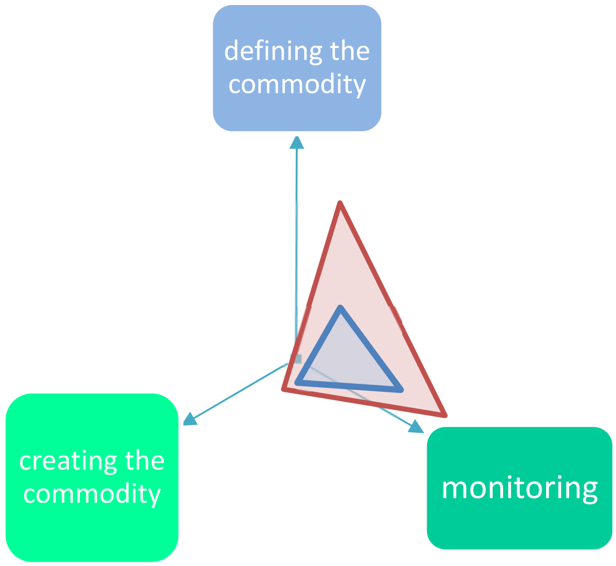


Figure 1: Moving outwards on any axis indicates increasing complexity for the relevant axis. The blue triangle represents low complexity on all three axes, indicating low overall complexity and associated low transaction costs. An example of this kind of commodity is a water quality credit generated using land conversion, without public funding. The red triangle represents a commodity with similar complexity on the "defining the commodity" axis, but greater complexity – and accordingly higher transaction costs – in the areas of commodity creation and measurement / monitoring. An example of this kind of commodity could be an enhanced riparian buffer with baseline practices of riparian buffer and livestock exclusion fences.

Before discussing each of these axes, it is important to recognize that although, as we argue, increasing complexity increases transaction costs, there are several reasons why increased complexity may be desirable.

The first and most important reason is that in many cases a trade-off exists between transformation costs and transaction costs. In fact, this trade-off lies at the heart of WQT programs which allow for nonpoint participation. Involving NPS may come at a relatively high cost in terms of transaction costs, as program administrators must grapple with many issues such as eligible BMPs, modelling NPS load reductions, trading ratios to account for differences in uncertainty between types of sources (equivalency), monitoring of credit-generating activities, dealing with a higher number and higher diversity of program participants, etc. In effect, quantification, certification, verification, and enforcement standards established in the regulatory program are being transferred to a sector with numerous diffuse sources that typically does not face these costs or face requirements typical of a regulatory program. These represent incremental transaction costs that must be covered with by PS-NPS program participants. For PS-NPS WQT programs to work, therefore, it must be the case that transformation costs of achieving load reduction goals are significantly less when NPS actors are involved; indeed, there must be enough 'gain' in the form of lower abatement costs to outweigh the potential for increased transactions and perceived risk and uncertainty for the program to be effective (compared to a PS-PS trading scheme, for example).

The second reason is that increasing complexity on one axis may allow for reduced complexity (and hence costs) on another. This concept is discussed further below, but, to demonstrate, consider the inherent uncertainties in accurately measuring load reductions associated with a particular BMP. In a WQT program, this uncertainty may be dealt with by increasing the complexity of the specification of standards for implementing that BMP, such that implementation of the BMP becomes more homogeneous. This is an example of trading off decreased complexity on the measuring/monitoring complexity axis with increased complexity on the 'defining the commodity' axis.

Complexity in 'defining the commodity'

Complexity in defining the commodity affects transaction costs in the design phase of a WQT program. Regulators and program administrators must agree on the precise specifications for what "counts" as a credit.

For NPS credits, the difficulty of measuring actual loads means that credits are generally based on modelled rather than directly measured loads (Woodward 2003). Thus, the building of models in the 'design' phase[20] to estimate credits generated are transaction costs, the size of which depends on how elaborate and precise the models are. Higher precision may yield higher certainty about reductions achieved at a particular site, but it comes at a higher cost. To date, we have only limited data on the size of transaction costs in the design phase of WQT programs and how they are affected by complexity. One source of data is the Ohio River Basin trading program administered by the Electric Power Research Institute (EPRI). This program uses a complex model which cost EPRI over $1 million to develop (*pers. comm.* Jessica Fox, EPRI: 2014) to estimate edge-of-field loads and various attenuation coefficients which account for differences in location between buyer and seller, and address uncertainty (Keller et al: 2014). World Resources Institute estimates the cost to develop Chesapeake Bay Nutrient Tracking Tool to be $600,000 (WRI: 2014). How modelling costs would vary if complexity was reduced is an area that would benefit from further study.

As the number of allowable credit-generating practices increases, so too the number of decisions that need to be made in the design phase. Program administrators must decide for each practice (and possibly for variations of practices) how the practice translates into credits. The number and heterogeneity of allowable practices will also affect the complexity required in designing documentation: e.g. of application forms, standard trade contract templates, monitoring & verification forms, etc.

Complexity in 'creating the commodity'

After the commodity has been defined, the process of creating the commodity can also involve different levels of complexity. Credits that are nominally equal may involve significantly different transaction costs (as well as transformation costs) in the "creating the commodity" phase because of differences in the way the credit was generated. For example, in the Virginia nutrient trading program, nitrogen term credits can be[21] generated from a variety of agricultural management practices including early cover crops, 15% nitrogen reduction on corn and continuous no-till (non-management options are also available). These practices all must be implemented on an annual basis; however transaction costs involved with installing the BMP and verifying credit creation may

[20] Also note that the complexity of modelling may impact transactions costs in the 'implementation' phase, as more complex models may take longer to use or require more training.
[21] We note that this has yet to occur in practice.

vary widely. In addition, the use of relatively sophisticated site-specific procedures to calculate credits generate higher search and information costs to credit suppliers than programs with standardized default values for approved practices.

Another key source of complexity along this axis – and additional transaction costs – is the *number of activities* used to generate a particular credit. For example, credit generation involving a simple land conversion is administratively simpler than generation using several structural BMPs, vegetative, or agricultural management practices because only one activity is involved. Likewise, transaction costs are expected to be higher where installation of baseline practices is required prior to credit generation, as for each credit-generating BMP, transaction costs are incurred also for the required baseline practices. Note, however, that as additional practices are added transaction costs are not expected to increase linearly because of scale economies of contracting for several "stacked" practices rather than contracting for each individually.

Where credit generation involves external funding (e.g. public cost share for installation of baseline practices), administrative transaction costs in the 'creating the commodity' stage may increase because of the additional administrative requirements of applications and contracting to secure funding, over and above the transaction costs accrued in creating the commodity using private funding only. This generally occurs because availability of public funding is limited, and so agencies generally use a ranking system to determine which applications will be funded (generally less than 100 percent of applications). External funding is used in many existing trading programs which allow public funding of BMPs to achieve baselines and in selected cases where public funding can be used for credit-generating practices. Although data is not available for transaction costs relating to the use of public subsidization of BMPs in water quality trading schemes, studies of transaction costs of conservation programs, organic programs and other publically-funded agri-environmental schemes show indicative costs.

More complex eligibility criteria can similarly increase participant transaction costs. Participants in conventional cost-share programs typically do not face complex eligibility tests to participate in these programs.[22] This is an important point of difference with WQT programs which place pre-requisites, baselines or cross-compliance restrictions on potential program / market participants. Costs for participants arising from eligibility criteria such as learning eligibility rules, self-assessing and demonstrating eligibility are not insignificant (this is particularly true for programs involving regulatory compliance rather than "stewardship credits").

Complexity in 'monitoring the commodity'

All WQT programs currently include verification or certification at the time of credit generation, as well as subsequent monitoring to ensure practices generating an ongoing stream of credits continue to meet required standards. Generally, the more difficult it is to measure whether a credit has been generated successfully and to monitor it 'ex post' (i.e. after the initial verification), the

[22] For example, although there are eligibility criteria in NRCS programs, eligibility is generally assessed by NRCS staff rather than the landholder; participants may be required to provide some documentation but do not need to learn about the eligibility requirements by themselves (pers. comm. Hunter Musser, NRCS District Conservationist, 2014).

higher the transaction costs. Land conversion to forest is perhaps the simplest credit-generating practice to verify and monitor. According to Virginia Department of Environmental Quality (VADEQ) staff, this type practice can be easily verified by a short site visit at or shortly after planting, and in subsequent monitoring periods remote sensing technologies can be used to monitor the site in a matter of minutes (*pers. comm*. Allan Brockenbrough VADEQ 2014). In contrast, verification and monitoring of agricultural management practices may require proofs that a farmer has completed a particular schedule of activities correctly (e.g. all fertilizer applications have adhered to approved rates).

Monitoring and enforcement also requires addressing questions such as how often will credit-generating BMPs be monitored and for how many years and whether the program administrator staff conduct on-site visits or outsource to a third-party verifier. As demonstrated in the literature, the monitoring regime is a key area for generating transaction costs. The draft report of the Chesapeake Bay Program Partnership Water Quality Goal Implementation Team's BMP Verification Committee (2014, p220) has noted that in developing monitoring and verification regimes "[it] is important to balance the need for quality assurance with the imperative of lowering transaction costs to encourage market participation."

Part IV: Transaction costs of nutrient trading program in Virginia

In this section we consider the transaction cost implications of expanding nonpoint source credit trading activity in Virginia. We consider possible expansion of the Virginia program in terms of both the type (working lands BMPs versus land conversion) and number of credit generating projects (focused at program implementation). Where relevant, we also draw on supplementary data and information from similar WQT programs in other states. A 'bottom-up' approach to assessing transaction costs is taken here: costs estimates are provided for specific activities undertaken, rather than parsing out transaction costs from estimated organizational budgets. It should be noted that program fixed costs (e.g. overheads for managing staff) are difficult to ascertain using the 'bottom-up' approach and that accordingly the estimates presented here do not constitute a measure of transaction costs in their entirety.

4.1 Nonpoint Nutrient Credit Trading in Virginia

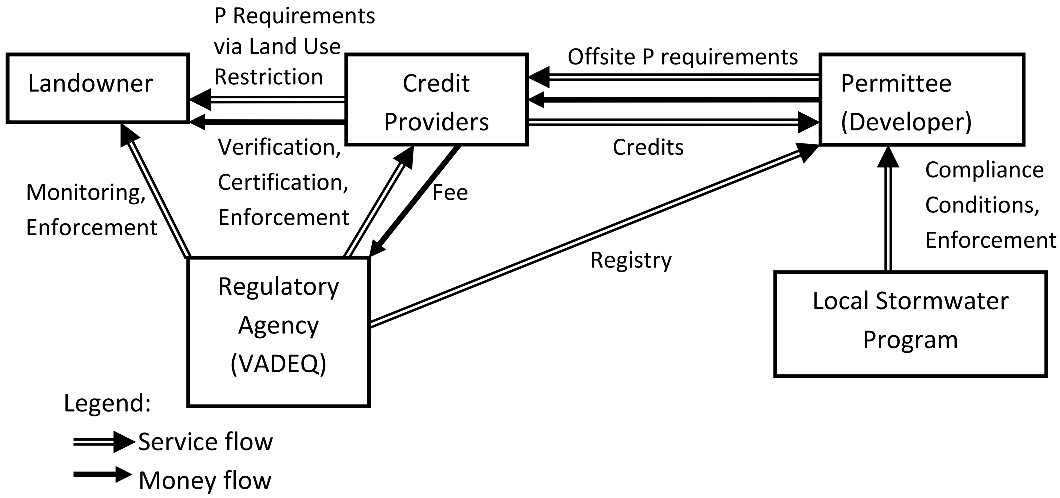
The Virginia nutrient trading program serves the regulatory compliance needs of several regulated source sectors, including regulated National Pollutant Discharge Elimination System (NPDES) municipal and industrial point sources and land developers. Virginia DEQ is authorized to expand trading options to other sectors including the municipal stormwater permittees. Virginia nutrient trading was officially authorized by the General Assembly in 2005 to support efforts to cap nutrient discharges from major point sources. Since that time, Virginia has made considerable effort (incurring substantial upfront transaction costs) in developing the legal and regulatory structure for nutrient trading (see Appendix, Table A3).

Municipal and industrial point sources cooperate to schedule and plan wastewater treatment investments and use trading within the point source program (aided by an association of point sources, the Virginia Nutrient Credit Exchange Association, Inc.) to maintain compliance with point source wasteload allocations. New and expanding point sources have yet to utilize agricultural nonpoint source credits. To date nonpoint source credit sales demand has come exclusively from the development community. In Virginia, developers with land disturbance of a certain size must meet specific water quality criteria, defined as a per acre phosphorus load (construction activities under the Virginia Stormwater Management Program (VSMP)). The Virginia program allows developers opportunities to meet some or all (depending on project size) of these phosphorus control requirements offsite through the purchase of permanent credits. Permanent credits are distinguished from fixed "term" credits by the duration over which they generate credits.[23]

[23] ***Permanent credits/offsets*** are perpetual and are generated by permanent reductions in loads. In Virginia, land conversion (e.g. conversion of working lands or degraded riparian areas to forest) is the key non-point source activity that generates permanent credits, although other practices such as stormwater ponds have been used in at least one trade to date. Permanent credits are purchased as **offsets** by developers whose land disturbing activities create permanent new nutrient loads (measure by P) from new construction. Unlike other trading programs that involve an NPDES permit holder, trades involving developers in Virginia includes a transfer of legal responsibility for nutrient control from the credit buyer (developer) to the seller (landowner). ***Fixed term credits/offsets*** are not perpetual, and are generated by an activity that either ceases after a specified period (e.g. an annual cover crop) or whose benefits are accounted over a finite period. A regulated source with an active permit can use fixed term credits / offsets to assist in maintaining compliance. Purchased credits may not be banked and are only useful for the regulatory period (calendar year) in which they are generated. An

Figure 2 shows the general process and entities involved in the Virginia credit trading option under the VSMP construction program. In this figure, attention is focused on the credit-generating side of program implementation, and although it includes market transactions with the developer and local stormwater program, it is simplified for purpose of exposition. As shown, Virginia DEQ is responsible for verification, certification, and long term monitoring/enforcement of generated credits.

Figure 2: Credit Generation and Transfer Process: Virginia (permanent) Phosphorus Credits



The 'credit providers' is the party responsible for generating and marketing credits.[24] Water quality trading programs in the Chesapeake Bay have developed around the use of a credit supplier who is *not* the landowner. Currently in the Virginia program a relatively small number of firms, who generally have extensive experience in contracting for wetland offsets, act as 'credit providers'. Accordingly, we define the principal actors in a trading program as:

- Landowner / farmer
- Regulatory agency
- Credit provider
- Credit buyer

Additional actors are involved in many trading programs; we label these 'third parties'. Examples of third parties are:

- Program administrator (where this differs from the regulatory agency)
- Verifiers contracted by the program administrator
- Local groups (e.g. farmer associations, environmental groups)
- Market intermediaries (e.g. brokers who are not also credit providers; credit exchanges)

NPDES permit holder cannot transfer legal liability to the credit seller; if the credit-generating activity fails to produce the credited reductions, the purchaser is still liable for their individual control obligations.

[24] This is a significant divergence from the literature: the landowner, credit purchaser (permittee) and regulator / administrator are viewed as the principal parties in the literature, and hence a credit supplier would be viewed as a third party.

In Virginia, credit providers (suppliers) are private actors who identify willing landowners to install nutrient reducing practices. These credit providers incur the search and administrative costs necessary to certify credits through VADEQ rather than the landowner; the landowner can be thought of as an 'input supplier' who is contracted by the credit provider. Under proposed credit certification regulations, credit providers also pay fees to DEQ to partially compensate DEQ for the certification process (9VAC25-900-210 and 220).

To date, VADEQ has approved 15 nonpoint source credit projects that produce a total of 1,637 permanent phosphorus credits (DEQ registry as of 8/22/2014). All projects, with the exception of one, are land conversion projects (the other involves an urban wetpond).

Currently overall transaction costs for nutrient nonpoint source trading in Virginia are relatively low (see next sections for further discussion on specific transaction costs components). The levels of transaction costs experienced to date are likely due, in part, to the type of activities generating credits currently being credited: simple land conversions. Land conversion projects are straight-forward to plan and evaluate, as Virginia provides clear and uncomplicated procedures to quantify credits and typically do not involve the implementation and consideration of baseline practices. Verification and monitoring is straight-forward and can be done remotely. In contrast, if credits were to be generated using management, vegetative, and/or structural practices, the procedures will become more complex and involved. This does not mean that total program costs will necessarily be lower if credits are only generated via land conversion: the "transformation costs" associated with land conversion may be significantly higher because of land costs.

In the following sections we examine available evidence on current transaction costs and then consider how transaction costs associated with credit creation and monitoring costs might change for expansion of trading into other agricultural nonpoint source credit generating activities.

Data gathering methods

We interviewed a range of public agency staff who currently administer water quality trading or payments for environmental services programs, and several other parties who provide specific services for these programs.

Organizations contacted are as follows:

- Natural Resources Conservation Services (NRCS) (Federal financial assistance programs):
    - Richmond office
    - District Conservationist, Virginia Area II, Christiansburg office
- Willamette Partnership (Oregon temperature credit trading program)
- Freshwater Trust (Oregon temperature credit trading program credit provider)
- Electrical Power Research Institute (EPRI) (Ohio Basin nutrient credit trading program)
- Water Stewardship Inc.
- World Resources International (WRI) (who also provided data from the Maryland Department of Agriculture)
- Private Credit Supplier: Aaron Revere, Falling Springs LLC (private credit provider in Virginia).

Interviewees generally remarked on the paucity of available data on transaction costs of administering their programs. In the case of EPRI and Willamette Partnership, studies are currently being undertaken to obtain better data; however estimates were not yet available or were not obtainable due to privacy concerns.

Quantitative data was also generally not available on program participant transaction costs (e.g. farmer, landholder, point source / credit purchaser). Administrative agencies typically reported their own costs in hours, and may have specified estimates of costs of third parties where these were used for verification or to assist in the application process. Where third parties were used as part of the credit trading process (i.e. in the 'market transactions' component), cost estimates were not provided by program administrators; however, some information was gleaned via interviews with these third parties.

Quantitative data was typically provided for variable costs rather than for the program as a whole. The principal reason for this is that sources viewed transaction costs from a 'bottom up' perspective; in making estimates they typically considered costs to complete a representative contract or project. When questioned about fixed costs such as program design, registry costs or staff overheads (e.g. management), most sources could not provide quantitative data.

In the analyses below, we consider each component of the conceptual framework as it relates to agricultural nonpoint credit creation. Some sources provided data for multiple components, while others provided data relating to a specific component (e.g. NRCS provided data on the 'creating the commodity' component, while Willamette Partnership data relates to the 'monitoring and enforcement' component).Where available, we sought both quantitative and qualitative data; however it should be noted that many interviewees were unable to provide quantitative estimates, or could only provide partial or high level estimates.

4.2 Implementation costs (I): Credit Creation

In the Virginia trading program credit providers currently contract with landowners to implement nutrient-reducing conservation practices that generate credits. The necessary steps for the service provider are (1) contracting with the landowner regarding access to and preservation of the credit-generating site (2) tree planting and (3) providing requisite paperwork to DEQ to verify that planting has been done correctly (*pers. comm.* Aaron Revere, Falling Springs LLC, 2014). Quantitative data on transaction costs incurred in these steps was not available; however, the credit provider (broker) we interviewed commented that cost and time to move projects through the process is straightforward and the costs are modest compared to those incurred in other environmental service markets.

The program administrator must verify installation of the credit-generating practice(s) and certify credit creation. Partial information on the current transaction costs of these steps incurred by the Virginia Department of Environmental Quality (DEQ) is available.[25] Virginia DEQ provided data for staff time spent in site visits for verification / certification of five agricultural land conversion

[25] Quantitative data on the costs borne by landowners, credit providers and permittees are not available for the Virginia program.

projects which have generated credits (Table 7).[26] Site visits occur as part of the credit verification and certification process (i.e. not for ex post monitoring). Total staff hours spent on site visits ranged from 6 hours to 17 hours and on average 2 visits occurred for each project. Using assumptions provided by Virginia DEQ of staff wages and overhead costs, this equates into costs ranging from $294 to $790 per project, which are relatively small costs. Note that these estimates relate to site visits only and do not account for accompanying time spent reviewing project plans (e.g. to process paperwork relating to the site visit), unplanned trips, registry management, and compliance monitoring. Thus these costs under estimate the costs involved. In fact Virginia proposes credit certification fees higher than these estimated costs under 9 VAC 25-900 . Regardless of the specific cost involved, DEQ does not consider these costs and activities problematic or large.

Table 7: VADEQ: Staff costs for site visits, permanent phosphorus credits

Project	Culpeper	Stone Tavern	Elk Run	Swinging Bridge	Layne	**Average**
Travel time (hours per round trip)	3	6	3	5.5	1	**3.7**
Site Acres	80	38	135	35	51	**67.8**
No. P credits generated	87	20	109	17	66	**59.8**
No. Credits per acre	1.08	0.53	0.81	0.49	1.29	**0.84**
Hours per visit	2.5	2	4	2	2	**2.5**
No. visits	2	2	2	2 - 3	2	**2**
Total site visit hours	10.5	16	10	14 - 17	6	**10.625**
Hours per credit [a]	0.12	0.8	0.09	0.82	0.09	**0.384**
Staff Cost ($ per credit) [b]	$5.93	$39.52	$4.45	$40.51	$4.45	**$18.97**
Staff Cost ($ per project) [c]	$516	$790	$485	$689	$294	**$555**

[a] Total hours / No. P credits generated. [b] Based on $38 per hour + 30% Admin ($49.40). [c] generated by multiplying staff cost (hrs per credit) * No. credits generated.
Source: Virginia DEQ

Future transaction costs of credit creation in the Virginia Program

We assume that in the future the credit provider will continue to be the primary credit generator and also the credit seller in the market for the Virginia trading program. As credit provision moves beyond creation of permanent credits via land conversion, transaction costs are expected to increase.

Due to the fact that all existing credits are permanent credits, no data was available from Virginia DEQ on transaction costs relating to creation of term credits. However, the broker interviewed commented that he was unlikely to move into provision of agricultural term credits partly because he expected administration and coordination costs to be significantly higher (*pers. comm.* Aaron Revere, Falling Springs LLC, 2014).

To assess possible transaction costs of term credits for creating agricultural nutrient credits, we generated estimates based on the NRCS's extensive experience in contracting for the installation of best management practices. We obtained detailed information about conservation planning activities from the NRCS District Conservationist for Area II, which is based in Christiansburg and services western Virginia (NRCS 2014). While the data generated reflect NRCS experience in one NRCS field office, these interviews with the Field Office provided detailed insight into elements of

[26] As noted previously, in Virginia we thus far only have evidence of the permanent credits (generated via land conversion) being traded from NPS.

conservation planning that are similar those needed to generate nutrient credits. The steps NRCS uses for conservation planning and contracting are considered similar to the general activities required to generate nutrient credits (or to form part of a baseline suite of practices the enabled additional practices to generate credits). This conclusion is supported by evidence provided by EPRI for the Ohio Basin Water Quality Trading Program. In this program there are some cases where projects are submitted to EPRI that have already been through most stages of the NRCS or Soil & Water Conservation District (SWCD) technical and financial assistance programs; for example projects that did not succeed in obtaining limited available funding (*pers. comm*. Jessica Fox, EPRI, 2014).[27] Furthermore, NRCS field office information on resource requirements for conservation planning was corroborated with the experience of private conservation consultant and secondary data sources. The field staff described the various steps in the contracting process and provided estimates (measured in hours of agency staff time) on the following activities:

- *Inception*: initial prep time and meetings with landholders / farmers to discuss potential conservation activities; initial site visit;
- *Planning and application*: natural resource concerns on the site are identified; Conservation Plan and conservation activities are chosen (this may include interim sit visits by NRCS staff); cost estimates are made; application paperwork is submitted
- *Approval*: NRCS staff review application, check eligibility and rank application processes, approvals;
- *Contracting*: successful applicants are notified, large contracts (>$150,000) are sent for NRCS Regional approval, contracts are developed and signed, funding avenue (e.g. electronic banking) is determined;
- *Implementation*: pre-construction meeting / site visit; engineering designs developed (if needed), follow-up and spot checking of contracted item implementation
- *Certification*: final "checkout" and signoff of practice installation for each contracted item.

Although typically a project contracted through NRCS would not be eligible to generate credits because federal funding has been received, these steps would be similar to the activities required of a credit provider working with an agricultural producer.

NRCS staff noted that time commitments can vary substantially between contracts depending on the type and complexity of the practice(s) being installed. Staff provided time estimates required to complete every step of the planning and contracting process for 3 representative contract types. Note that, in the view of the District Conservationist, administrator transaction costs are a function of the type of planning and contract being considered rather than the specific funding pool or program under which the contract would be administered. Hence, the estimates relate to contracts under several federal programs, such as the Conservation Reserve Program (CRP), the Conservation Reserve Enhancement Program (CREP)[28] or the Environmental Quality Incentives Program (EQIP). The 3 types of contracts are:

[27] The EPRI program is currently generating "stewardship" credits (e.g. credits not used for regulatory compliance).

[28] Note, however, that contracting for CREP is handled by the FSA.

1. *Simple contract*: (a) 'high tunnels'[29]; and (b) forestry land conversion + forest management plan: typically 1 – 2 items per contract.
2. *Moderate contract*: Fencing livestock away from streams and providing alternative watering facilities. May also involve invasive species control plan: typically a low number of items (2-4) per contract.
3. *Complex contract:* Animal waste management facilities on an intensive dairy farm: requires several engineering practices to be installed, such as heavy use area protection where feeding occurs and animal waste storage structures. May also involve rotational grazing plan. Typically more items are included in a contract (e.g. up to 8 – 10).

In terms of potential ability to generate credits, the NRCS *simple* contract type (b) best corresponds to the generation of permanent credits; this project type involves land conversion from agriculture to forest. The NRCS *moderate* and *complex* contract types, and *simple* contract (a) (hoop house construction) all relate to fixed term projects that, if used for credit generation, would produce fixed-term credits.[30]

Generally, a range of hours for each task was provided (low and high) in order to better reflect the heterogeneity of NRCS staff experiences in administering these programs and variation in site conditions. Estimates were provided for each item on the NRCS Virginia Contracting Checklist. According to the District Conservationist, the Checklist is used for every contract that is successfully completed. We grouped these items into broader 'tasks' that are consistent with our conceptual framework. Table 8 presents estimated staff hours per contract for each of these tasks. Note that travel time to and from sites was accounted for separately, as site visits are not specifically accounted for in the Contracting Checklist (although estimates for time actually spent on farm are included in the task time estimates. According to the District Conservationist, in general, one visit occurred during inception, several more over the course of the planning & application, approval and contracting stages, one or more during implementation and one or more for certification depending on whether contract items were completed at the same time or not. It was estimated that a minimum of four site visits occur for the simple contracts that progress smoothly, and that the number of visits rises with the complexity of the planning contracting and if any problems are encountered during planning or practice implementation (e.g. a landowner requires encouragement to complete contracted items according to schedule).

[29] "High tunnels (also known as hoop houses) are structures that modify the growing climate, allowing for tender, sensitive, and specialty crops like certain varieties of vegetables, herbs, berries, and others to grow where they otherwise may not… High tunnels can lengthen the timeframe for local marketing of produce, which increases sustainability while lowering energy and transportation inputs." (NRCS, date NA (website))

[30] Structural (engineering) practices often have an assumed lifespan of 25 years while fencing and pipelines, have a 20 year lifespan. Agronomic and tillage practices have a 1 year lifespan but may be contracted to be supplied over a period of consecutive years (e.g. 5 years). Some vegetative practices have useful lives longer than a year

Table 8: NRCS data: administrator 'creating the commodity' transaction costs (hrs per contract [a])

	Simple contract			Moderate contract			Complex contract		
Task	Low	High	Average [e]	Low	High	Average [e]	Low	High	Average [e]
Inception	1.5	2	1.75	1.5	2	1.75	1.5	2	1.75
Planning & Application	5.5	7.9	6.7	7.8	11.5	9.7	12.8	17.8	15.3
Approval	3.7	5.3	4.5	3.9	5.5	4.7	4.4	7.0	5.7
Contracting	5.2	6.75	6	8.25	11.9	10.1	13	17.6	15.3
Implementation	1.0	1.5	1.3	12.0	16.0	14.0	22.0	29.0	25.5
Certification [b]	0.3	1	0.65	0.5	0.5	0.5	2.0	3.0	2.5
TOTAL HOURS (excl. travel time) [c]	**17.1**	**24.45**	**20.9**	**34.0**	**47.4**	**40.7**	**55.8**	**76.3**	**66.0**
Average travel time per site visit (round trip)	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
Average number of site visits per completed contract [d]	*4*	*4*	*4*	*4*	*8*	*6*	*4*	*10*	*7*
TOTAL HOURS (incl. travel time)	**21.1**	**28.45**	**24.9**	**38**	**55.4**	**46.7**	**59.8**	**86.3**	**73**

[a] Estimates are for *first-time participants*: the District Conservationist noted that there are often efficiencies for repeat contracts, typically because participant is familiar with the program and NRCS staff are familiar with the conservation concerns of the land in question. [b] Certification hours are *per item*, per contract. [c] Estimates exclude travel time for site visits (i.e. only time actually spent on farm is counted). [d] Data on the number of site visits per contract were given over the life of the contract rather than for each stage. Generally, one visit occurred during inception, several more over the course of the planning & application, approval and contracting stages, one or more during implementation and one or more for certification depending on whether contract items were completed at the same time or not. [e] Average = simple mean of *low* and *high* estimates.
Source: Hunter Musser, NRCS District Conservationist (Virginia, Area II)

For each contract type, the bulk of staff time is spent on three tasks: planning & filing applications, contracting (which occurs once applications are approved), and implementation. These tasks are also where the greatest differences across contract types appear.

For a simple contract, the total administrator time ranges from 17 to 24 hours (or 21 to 28 hours including average travel time & number of site visits). The most time-consuming task for a simple contract is planning and application. The District Conservationist noted that all applications require the formation of a comprehensive plan to deal with all conservation concerns on the land involved in the application, regardless of whether the eventual contract addresses all of these concerns. Indeed, many contracts do not address all resource concerns at once, typically because program participants prefer to apply conservation incrementally in stages.

Implementation transaction costs for the simple contract are typically quite low, because technical assistance needs are low (or not required), and there are no engineering structures that require more sophisticated planning. Similarly, certification is a simple task that generally takes around 20 minutes per item.

A significant increase in staff hours is required to administer a moderate contract compared to a simple contract. The 'low' estimate for a moderate contract is around 10 hours higher than the 'high' estimate for the simple contract, and on average 41 hours are needed per moderate contract. Differences occur because of the number and complexity of items included in the contract. Where, for example, the simple contract involves a single item (e.g. tree planting), a moderate contract typically involves 2 – 4 items. Agency staff typically conduct more site visits during the planning stage for a moderate contact, to settle the precise details of each item with the landholder. In the contracting stage, costs increase because each item must be specifically spelled out in the contract, and details such as a timeline for implementing each item may also be included. In the implementation stage, a moderate level of technical assistance may be required (e.g. livestock watering facilities require the approval of an NRCS engineer and must be completed to specified standards). Because of the increased complexity per item, certification of each item also takes longer on average than for the simple contract.

A further substantial increase in hours occurs in the move from a moderate to a complex contract. The largest driver of this increase is the need for substantial technical assistance in designing and constructing the engineering practices included in the contract (e.g. livestock waste storage structures). These contracts usually require the input not only of the NRCS District Conservationist, but also a NRCS soil scientist and / or NRCS engineer.[31]

Thus far only the individual cost components and the sum total for a single contract have been considered. In reality, the situation is more complex than simply summing up the cost component estimates and multiplying by the total number of contracts. Factors such as the ongoing nature of contracting (i.e. not all contracts commence at the same time) and that not all project 'inceptions' ultimately result in a completed contract and conservation 'on the ground'. Projects can fail at a number of stages in the process.

According to NRCS district staff, around 75 to 80 per cent of farmers who contact NRCS staff about possibly applying for a conservation program actually submit an application. Further, of the submitted applications, only around 40 to 45% of projects are actually approved for funding, because ultimately there are only a limited amount of available funds. Under the Chesapeake Bay Watershed Program, 48.5% of all applications were approved (Stubbs 2013). Finally, a small number of projects fail at the implementation stage – they can either be 'cancelled' (which occurs when a landowner has failed to implement the project item(s) but before they receive any funding) or 'terminated' (occurs where full implementation has not occurred but at least some funding has been received; in this case NRCS may attempt to recover funding). NRCS data for Virginia indicates that 6% of contracts (weighted average of 2013 Farm Bill programs) were cancelled or terminated in 2013 (Source: *pers. comm.* Patrick Vincent, NRCS Virginia). All in all, these attrition rates imply that for every contract successfully implemented, approximately 2 inceptions occur that ultimately do not result in successful contracts. This result was corroborated by a private conservation provider in Virginia.

[31] In some cases a third party 'technical service provider' may be used instead of the official NRCS staff; this typically occurs where engineering practice items have been adapted from NRCS standards, or for nutrient management (due to a lack of NRCS capacity to design nutrient management plans; in Virginia this service is provided by the Virginia Department of Conservation and Recreation). Note, however, that the relevant NRCS staff member is still required to oversee and 'signoff' on items where a technical service provider has been employed. Conservation Activity Plans (CAPs) are another example of third party vendors (certified TSPs) provide part of the conservation planning aspects that may lead to an EQIP contract.

Estimates of the transaction costs of generating credits from working land BMPs were constructed based on the information on attrition rates and time estimates. We constructed a timeline for accounting for transaction costs across all stages of credit development using a spreadsheet model. The model traces out the timeline for developing a set of contracts with specified inputs that include hourly time requirements, attrition rate, assumptions about unit staff costs and a discount rate. Assumptions in the model can be varied to see how they affect transaction costs estimates.

To illustrate how transaction costs of credit generation vary with contract type, we first assume one hundred hypothetical contracts will be successfully implemented over a 4 year period (see Table 10) in which contracting takes place over 2 years and implementation takes place over 2 years (note that this does not include ex-post monitoring of the practice after installation is complete). Assuming NRCS experience would be similar to a credit provider, the time commitment for each contract is show in Table 10. Reasonable attrition rates estimates were derived based on NRCS estimates, cross-referenced with private service provider information. The derived required project numbers at each stage were as follows: 295 inceptions; 236 submissions, 106 contracts offered and 6 cancellations / terminations; 100 successfully completed projects (see Table 9). We assume a $75 per unit cost of each hour spent (which includes fringe/overhead to be consistent with a private service provider). The total present value cost discounted at 5% of conducting those 100 contracts are summed The distributions are given in table x and an example of how this table should be read is as follows: relative to the year 0 when the first project is certified as successfully completed, 50% of project inceptions occurred in year t-2, and 50% occurred in year t-1. Assumptions and inputs into the timeline are provided in tables 9 and 10; results are given in table 11.

Table 9: Inputs: Assumptions re: attrition rates, hourly wage and discount rate; all contract types

No. contracts completed [c]	100
% of inceptions submitting application [a]	80%
% of applications approved [a]	45%
% of contracted projects cancelled or terminated [c]	6%
No. inceptions (per 100 contracts completed)	295
No. applications submitted	236
No. inceptions not submitting application	59
No. applications not approved	130
No. contracts made	106
No. contracts cancelled	6
Hourly wage assumption ($/hr) [c]	75
Discount rate [c]	0.05

[a] estimates supplied by NRCS District Conservationist; [b] weighted average of cancellations + terminations % of contracts 2013 for Farm Bill Programs in Virginia [c] assumption (NB: wage assumption *not reflective* of NRCS wages)

Table 10: Inputs: hours per contract type per stage and assumptions re: time distribution of activities [c]

Project stage	Inception [a]	Planning & Application [a]	Approval [a]	Contracting [a]	Implementation [a]	Certification [a]	Cancellation & Termination [b]	Credit registration & reporting [b]
	hours per contract							
Simple - Average	1.8	6.7	4.5	6.0	1.3	0.3	2.5	1
Moderate - Average	1.8	9.7	4.7	10.1	14.0	0.5	2.5	1
Complex - Average	1.8	15.3	5.7	15.3	25.5	2.5	2.5	1
	% of contracts achieving stage in each year [a]							
Year t-2	50%	50%	50%	50%	50%	0%	0%	
Year t-1	50%	50%	50%	50%	50%	0%	0%	
Year t = 0	0%	0%	0%	0%	0%	100%	100%	50%
Year t+1								50%

[a] estimates supplied by NRCS District Conservationist; [b] assumption; [c] travel costs to and from site visits not included.

Table 11 shows the cost estimate to successfully complete three different classes of conservation contracts. The contracting costs vary significantly due to the complexity of the conservation activity. Simple contracts (land conversion is one example) cost more than $2,800 to complete after accounting for "false starts" as per the attrition rates ($280,000 for 100 successful contracts). Complex contracts, however, are more than 2.5 times more costly to complete (approximately $7,600 per successful contract, accounting for "false starts"). Attrition rates account for a significant portion of these costs. Project attrition can increase costs by 40 % (complex contracts) to 64% (simple contract). The reason the difference is smaller as contract complexity increases is that a proportionally higher share of costs accrue in the "implementation" stage for more complex contracts than for simple contracts: these costs are avoided if the project fails for whatever reason to proceed through contracting to the implementation stage.

Table11: Results: Costs Estimates to develop conservation contracts [c]

Stage of project	Inception	Planning & Application	Approval	Contracting	Implementation	Certification of practice / activity	Cancellation & Termination	Credit registration & reporting	**TOTAL**
Simple contract									
Hours per stage per single project	1.8	6.7	4.5	6.0	1.3	0.3	2.5	1.0	**23.9**
Cost per stage per single project ($NPV)	141	541	162	481	101	22	188	73	**1,709**
Cost per 1 completed project ($NPV)	417	1,280	383	512	107	22	12	73	**2,806**
Cost per 100 completed projects ($NPV) [d]	41,743	128,011	38,284	51,165	10,734	2,188	1,197	7,321	**280,643**
Costs for 100 completed projects only ($NPV) [e]	14,126	54,149	16,194	48,095	10,090	2,188	18,750	7,321	170,913
Moderate contract									
Hours per stage per single project	1.8	9.7	4.7	10.1	14.0	0.5	2.5	1.0	**44.2**
Cost per stage per single project ($NPV)	141	780	171	814	1,130	38	188	73	**3,335**
Cost per 1 completed project ($NPV)	417	1,845	404	866	1,202	38	12	73	**4,656**
Cost per 100 completed projects ($NPV) [d]	41,743	184,464	40,431	86,587	120,219	3,750	1,197	7,321	**485,712**
Costs for 100 completed projects only ($NPV) [e]	14,126	78,028	38,005	81,391	113,006	3,750	0	7,321	**335,627**
Complex contract									
Hours per stage per single project	1.8	15.3	5.7	15.3	25.5	2.5	2.5	1.0	**69.5**
Cost per stage per single project ($NPV)	141	1,234	207	1,234	2,058	188	188	73	**5,324**
Cost per 1 completed project ($NPV)	417	2,918	490	1,313	2,190	188	12	73	**7,601**
Cost per 100 completed projects ($NPV) [d]	41,743	291,802	49,018	131,311	218,971	18,750	1,197	7,321	**760,114**
Costs for 100 completed projects only ($NPV) [e]	14,126	123,432	46,077	123,432	205,833	18,750	0	7,321	**538,972**

[c] travel costs to and from site visits not included [d] This estimate includes the costs of "false starts". [e] This estimate shows costs relating only to completed projects; costs of projects that were not completed ("false starts") are not included.

The costs estimated using the timeline approach are broadly consistent with costs cited by another conservation organization operating in Virginia, whose estimates cannot be provided due to confidentiality restrictions. The hours estimates are also fairly similar to figures provided by Falconer and Saunders (2002) for administration of conservation contracts at specific sites in England: they report that the typical contract requires 24 hours of administrator staff time.[32]

The above analysis suggests that generation of term credits could involve considerably higher transaction costs than is currently the case for permanent credits in the Virginia WQT program.

[32] Falconer & Saunders (2002) report the following estimates in Table 4: Typical hours for: computerized entry: 1; Meeting: 3; Site visit: 3; Internal file notes: 1.36; Internal letter: 1.63; Internal payment: 1; Internal solicitor's letter: 1.63; External letter: 1.19; External solicitor's letter: 1.19; Payments: 0.83; Letter to other agencies: 2; Management agreement: 4.

However, there are additional costs to generate credits that would be experienced by a private credit provider over and above what is currently experienced by NRCS staff. Firstly, NRCS field staff typically have extensive networks of contacts to locate prospective applicants and area farmers and landowners may have broad familiarity with long-established cost share (FSA) and financial assistance (NRCS) programs. A private credit generator may face higher costs in the "inception" stage compared to hourly estimates used above because these conditions may not apply to the same degree.

Secondly, in contracting with a landowner a private credit provider must consider whether a particular project can generate credits that can be sold at a profit (or break-even at least) in the market. This consideration will likely include calculation of the expected number of credits generated from a project (e.g. via use of look-up tables in the Virginia program) and an assessment of the probability that a credit can be sold (as credits currently cannot be 'banked'). Such additional calculation / assessment requirements produce additional transaction costs (time costs) for the credit provider beyond what would be incurred by NRCS staff.

Thirdly, NRCS staff use fairly standard contracts with pre-constructed legal appendices covering cancellations, terminations, operation and maintenance requirements, etc. that attach to all contracts. As such, the NRCS contracting costs described above may be quite low compared to contracting costs in water quality trading programs which used individualized contracts, or if contracts require permanent annotations to land titles (e.g. an easement may be required to generate a permanent credit from a land conversion project).

Transaction costs per credit generated

Thus far we have assessed transaction costs on a per project basis. Another metric that is of interest is how transaction costs vary on a *per credit* basis. This will depend on the number and type of credits generated from a project and the length of time a given project generates credits. Falconer and Saunders (2002) provide some insight on this matter. They studied how transaction costs varied across contract types for conservation projects in England. They found that although more formal 'under seal' contracts (typically 15–20 year term but sometimes as long as perpetuity, and requiring a formal deed change) had higher transaction costs per acre under contract than the less formal 'under hand' contracts (typically 3 – 6 years, deed change not required) which are used for situations that are lower-risk or less contentious. However, costs for a third type of contract – a new type of standardized contract under the Wildlife Enhancement Scheme (WES) – had higher transaction costs than the 'under seal' contracts even though the contracts were typically less formal and less long-lived. The authors concluded that although the legal formality of the contract is a factor in determining the transaction costs of contracting, also important is the complexity of the project being contracted for. In this case, WES agreements aimed at "encouraging positive management of conservation resources, whereas 'under seal' and 'under hand' agreements aim primarily at maintaining the resource" (p164).

Number of items/projects being contracted to produce credits

Because credits created to date in Virginia have been generated from agricultural land conversion, only one 'practice' is being used per particular parcel of credits; there are no baselines practices to be implemented by participating nonpoint sources. This simplifies the process considerably compared to the case where several practices are used in the generation of a parcel of credits, especially considering some programs allow funding from sources such as NRCS for baseline practices, essentially adding on an 'upfront' entire process of applications, contracting and implementation for baseline practices.

We note that whether one or more practices are used to generate credits is partly a function of trading program design, and partly dependent on the specific credit-generating practices used. For land conversion programs, implementation of baseline practices is not required for the simple reason that calculations of load reductions gained via land conversion assume the full suite of relevant baseline practices applicable to the current land use have been implemented prior to the land conversion. The setting of baselines is about both the distribution of responsibility for water quality improvements and the desired level of certainty that water quality improvements are indeed occurring. Thus, some programs (e.g. EPRI) have a time-based baseline, which merely seeks to ensure new BMPs are "additional" to what was currently on the landscape. In other cases (e.g. Maryland WQT, and Virginia for non-land conversion credits), land must be in accordance with the relevant Chesapeake Bay TMDL Watershed Implementation Plan requirements before credits can be generated. These requirements mean that landowners must take at least some responsibility for reductions prior to being eligible to participate in trading.

4.3 Implementation costs (II): 'market transactions'

Quantitative transaction costs data relating to current 'market transactions' was not available for Virginia, and in general is difficult to obtain. However, qualitative evidence suggests that trading partner search and contracting in the Virginia WQT program are relatively simple tasks because credits are traded from credit aggregators to permittees (*pers. comm.* Aaron Revere, Falling Springs LLC, 2014). This evidence fits with estimates in the literature which indicate that market transaction costs typically constitute only a small proportion of total program costs (see discussion in Part III).

Future transaction costs of 'market transactions' in the Virginia Program

To envisage how transaction costs of "market transactions" may change in the future, we consider two dimensions of change:

- The number of buyers and/or sellers may increase; and
- The type of buyers may change (e.g. if fixed term credits are generated and NPDES permit holders enter the market to purchase them).

As the number of market participants grows, demands on the credit registry will increase. Currently the Virginia credit register is a simple spreadsheet maintained by Virginia DEQ. The summary is readily accessible by the public, but lack details of the credit-generating projects are not as accessible as other trading registries. Demand for more sophisticated registry functions such as public access to project certification and verification information and the ability to conduct interstate or inter-program trades may emerge over time.

If the market expands to providing fixed term credits for use in compliance with ongoing permits, the needs of new market participants (NPDES permit holders) will differ from those of current buyers (developers). Unlike the case with developers, NPDES permit holders are not able to transfer compliance liability to credit suppliers in the event of a trade. Thus, the perceived risk of using credits to achieve compliance is likely to be higher for permit holders than for developers. Concerns about market liquidity and the possibility of credit failure may increase the demand for an intermediary such as a credit aggregator or public purchaser-reseller of credits who can assist with supply-demand matching and (b) new / different contracting provisions aimed at mitigating risk of credit failure for the permittee (e.g. by specifying that seller must reimburse buyer for costs if permit requirements are not met due to credit failure). The nature and conditions of permits also will influence transaction costs. Land developers face a term permit associated with the land development activity. Municipal and industrial point sources hold 5 year permits for discharge activities (subject to continued renewal). For individual NPDES permits, there will be constant and ongoing costs of managing permit administration and negotiation costs associated with credit purchases. The procedures with contracting with credit suppliers will be important to program success.

The above discussion points a likely increase in the demand for various market intermediaries, such as credit exchanges and third party providers of registry services. There is a wealth of discussion in the wider literature on transaction costs on the benefits (or otherwise) of using third parties to reduce market transaction costs borne by principal trading parties (see, for example Coggan et al 2013, McCann 2013, Vatn 2010). Coggan et al (2013) point out that there are numerous forms of intermediaries, which may each provide a different function in the market (or non-market program). Two key functions provided by intermediaries are provision of information and mitigating principal trading party risk (buyer and / or seller).

In a study of the use of a 'clearinghouse' to match buyers and sellers in the Pennsylvania nutrient trading program, O'Hara, Walsh & Marchetti (2012) note that, without a coordinating third party present, point sources face significant transaction costs in using NPS credits for compliance purposes due to various risks. For example, the authors noted that at the beginning of the program point sources had to assess for themselves whether purchasing credits was compliance with other environmental regulations. Also, since credit 'banking' was not permitted under the program rules and contracting was time-consuming, point sources were often in the position of having to contract *prior* to verified service provision, which opened them up to the risk of seller default leading to non-compliance. On the seller side, nonpoint sources face the risk of being left with a credit that has no market value if there is not sufficient demand for credits in the year in which credits are generated.

The authors argue that the 'clearinghouse' was developed in order to mitigate these risks, although they concede that it is not possible to determine yet whether the clearinghouse successfully "induced purchases of nutrient credits that otherwise would not have occurred" (p147). The clearinghouse operated by purchasing credits from sellers and on-selling them to point sources, using auctions in both instances. In this manner, the intermediary (PENNVEST) absorbed part of the market risks faced by buyers and sellers, and also provided a clear trading partner for each and market information, thereby reducing search costs for market participants. The authors report that for the first compliance year of the Pennsylvania trading program, 10% of the nitrogen credits transacted in the spot market occurred via PENNVEST's spot market auction.

Two points from this study are important for the present discussion: firstly, market risks for nonpoint source sellers and point sources considering purchasing credits for compliance purposes may have the potential to give rise to transaction costs that prevent gains from differences in transformation costs between nonpoint and point sources being realized (Shortle 2013); but, secondly, it may be that there are solutions available to mitigate risk that may not be too costly to implement. In the Pennsylvania case, although actual data on the costs of running the clearinghouse are not available, it appears that incremental costs associated with the clearinghouse may not be large because the clearinghouse is run by the Pennsylvania Infrastructure Investment Authority (PENNVEST). PENNVEST was already well-established prior to the Pennsylvania trading program creation.

4.4 Implementation costs (III): 'monitoring / verification & enforcement'

Monitoring costs emerged as a key component of total transaction costs for the WQT programs studied. Differences in the level and frequency of monitoring activities caused substantial differences in transaction costs.

The water quality trading program administrators appear to make use of two distinct levels or 'types' of monitoring:

- *Full verification*: includes an annual site visit where the regulatory agency (or designee) personally inspects the credit-generating project. May require substantial written documentation to be provided as well, particularly in relation to ongoing practices such as nutrient management BMPs.
- *Interim verification*: this type of monitoring does not involve a site visit for the administrator. Instead, the administrator makes use of information provided by the project implementer, third party verifiers, and / or remote sensing technology to conduct a 'desktop review' of the credit-generating project. In cases where the administrator relies on information from another party, this may mean that monitoring outcomes have a lower degree of certainty compared to 'full' verification; however, when using remote sensing for amenable projects (e.g. tree planting), arguably the regulatory authority can achieve a similar level of certainty as an actual site visit would provide.

The precise nature of each of these monitoring types, and therefore the transaction costs involved, vary with each program. Table 12 reports estimated hours and monitoring regimes employed for the Virginia and Ohio Basin WQT programs and the Oregon temperature trading program. Conceptually, the frequency (as well as level) of verification may also be variable (although most programs evaluated in this report all use some annual level of verification).

Virginia DEQ currently employs remote sensing to monitor the land conversion projects which have so far generated the permanent credits (*pers. comm.* Allan Brockenbrough, VADEQ). This is a relatively low-cost regime because it does not involve site visits. Willamette Partnership has a moderately costly regime of 'full' site visits every 5 years, with 'interim' verifications each year in between (project lifespan is 20 years) (*pers. comm.* Carrie Sannemann, Willamette Partnership, 2014). At the opposite end of the scale is EPRI, which not only conducts a full on site verification every year, but also contractually obligates SWCD agents to report any suspected breaches to EPRI during the usual course of their activities with farmers in the project areas (*pers. comm.* Jessica Fox, EPRI, 2014; see appendix A5 for a diagram representing the EPRI trading program).

Table 12: Monitoring costs (hours per verification type): Willamette Partnership, Virginia DEQ, MD Department of Agriculture

	Willamette Partnership (Oregon)		Virginia DEQ	EPRI (Ohio Basin)
	Program administrator	3rd party verifier		
Monitoring - interim verification (hours per verification)	4	2	0.25	NA
Monitoring - full verification (hours per verification)	10	20	NA	NA
Monitoring regime	Full verification every 5 years; Interim annually for intervening years		Annual interim verification	Annual full verification + notification from SWCD staff

Sources: Willamette Partnership; Alan Brockenbrough, Virginia DEQ; Jessica Fox, EPRI.

Given that monitoring is a periodic activity occurring throughout the 'life' of a project, its contribution to total program transaction costs can be relatively large. Apart from the type of monitoring employed (e.g. interim vs. full verification), the interaction between frequency and intensity is important in determining the overall cost of a monitoring regime.

To demonstrate the effect of this interaction, we estimated the total net present value (NPV) of various monitoring regimes. We analyze costs over a 30 year period, assuming that the number of projects operating increases each year starts from a low number in initial years and increases to a plateau of 150 projects in operation by year 20 (see grey bars in Figure 3). This distribution of projects reflects the 'ramping up' of demand for credits from the trading program to match the phasing in of stormwater permits over the next 15 to 20 years. We assume that each project operates for 20 years; this means that towards the end of the 30 year period under analysis new projects come online to replace completed projects and keep the total number of projects operating constant.

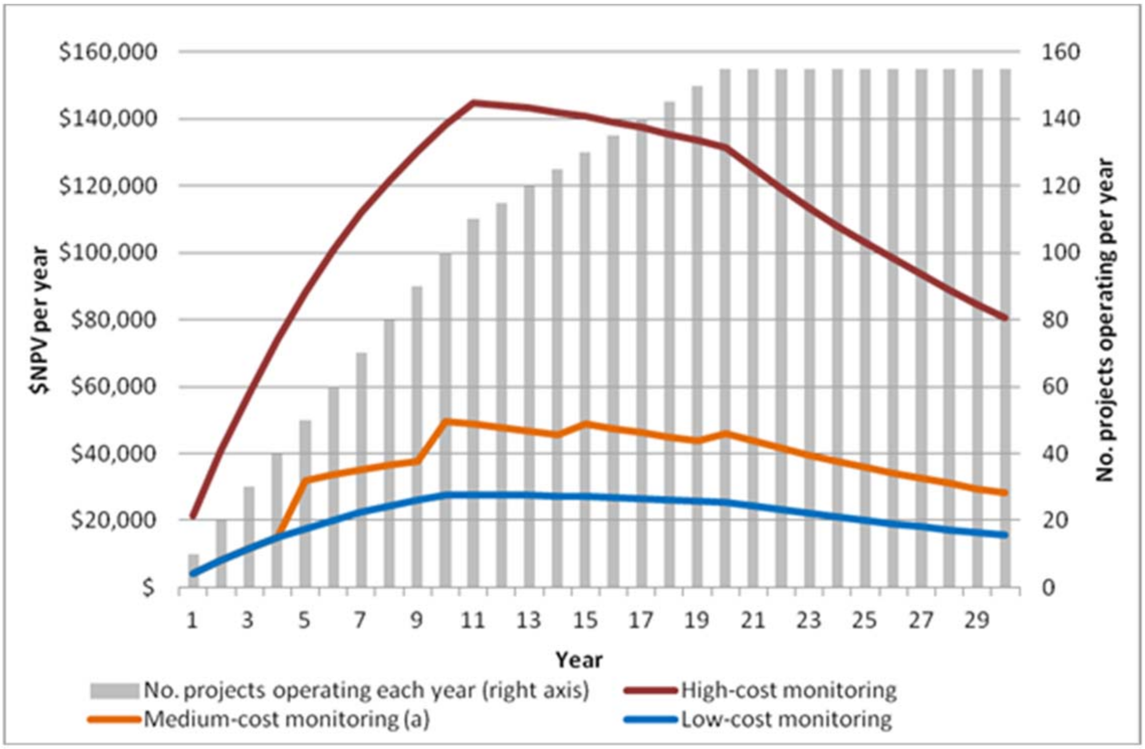
Assuming that credits are being generated with a view to their being used for compliance, this example assumes some kind of annual monitoring will be required. Therefore, we varied which type of monitoring is used while requiring some type of verification each year. Using the Willamette Partnership estimated hours for both the program administrator and third part verifier, we specified three cost regimes:

- (1) *low-cost* (annual interim verification)
- (2) *medium-cost* (full verification every 5 years and annual interim verification in intervening years); and
- (3) *high-cost* (full verification every year).[33]

Figure 3 shows the resulting distribution of costs of each regime. For this analysis a discount rate of 5% and an hourly wage of $75 for both administrator and verifier are assumed for all cost scenarios.

[33] Although the specification of monitoring regimes was loosely based on the reported regimes used by the programs we examined, these estimates are demonstrative only and should not be taken as estimates of the actual costs incurred under existing programs.

Figure 3: Costs of selected monitoring regimes ($NPV)



(a) Medium-cost monitoring curve is the same as the low-cost monitoring curve for years 1-4. "Spikes" in the medium-cost monitoring curve occur because of the "lumpy" nature of verification costs.

It is clear that both the total cost of the monitoring regime and the distribution of costs vary greatly with the regime selected. The estimated total net present value of the 'high-cost' monitoring regime over the 30 year period that projects are operational is around $ 3.3 million. In comparison, costs for Low-cost scenario were about $640,000. In other words, given the assumptions of the model, varying the type of monitoring used annually from only using 'interim' monitoring to only using 'full' monitoring resulted in the net present value cost of the monitoring regime over the 30 year period increasing by more than 5 times.

The cost profile for the medium-cost scenario is 'lumpy' compared to the high- and low-cost scenarios because full verifications, which require significantly more resources than interim verifications, occur only at 5 year intervals. The NPV cost for this scenario was approximately $1.1 million, or almost 70% higher than the low-cost scenario.

Depending on the type of project being monitored, there may be very different levels of certainty associated with interim versus full verification; it is anticipated that a full verification is more likely to identify whether the project is still fully compliant with program requirements. This indicates that there is likely a trade-off between certainty and cost that differs with project type. Agricultural land conversion projects, for example, are likely to have less of a trade-off than ongoing management practices purely because they are amenable to interim verification via remote sensing.

Use of remote sensing technologies for monitoring

As noted above, VADEQ currently annually monitors land conversion projects using GoogleEarth.. Given monitoring is an ongoing cost that can continue for many years (e.g. some projects last 20 to 30 years), there may be considerable cost savings if administrators are able to incorporate remote sensing into their monitoring regimes, as administrators may be able, via remote sensing, to rely more on 'interim' verification without sacrificing certainty about project outcomes.

Use of GIS, remote sensing, and online information technologies for monitoring (where feasible) has been recommended by the OECD's (2007) global study on policy-related transaction costs. According to the OECD's report, use of these technologies can ameliorate transaction costs in three ways: (1) using GIS for field identification can reduce error rates, number of administrative staff required for monitoring activities, and assists with targeted monitoring. Digital storage of monitoring information can also be less costly than paper-based storage systems; (2) Monitoring using remote sensing is less costly because less site visits are required, and it is also less disruptive to farmers; (3) use of online systems (e.g. online access for program participants) can reduce distribution costs of maps and related documents. However, remote sensing has limitations is not without limitation or error (for example if the vegetative species is important to functional success).

4.5 Potential Relative Change in Transaction Costs Associated with Trading Program Expansion

The discussion above highlights that nonpoint source transaction costs will increase in Virginia with growth in the demand and provision of term credits from working agricultural lands. Upfront search, negotiation, and contracting costs associated with credit certification will increase and these increases in costs will be spread over much shorter credit contract lifespans. Furthermore, ex post credit verification costs will also likely increase. This section brings together information from DEQ's estimates of certification costs, estimates of costs to search and negotiate credit creation with landowners (Section 4.2) and monitoring and verification(Section 4.4) to estimate ranges for per project transaction costs between permanent and term credits. While this analysis may exclude some elements of transaction costs (registry costs, overhead/management costs, etc) and may not reflect costs as experienced by program participants, it does provide an illustrative relative comparison that provides insight into magnitude of change that might occur as the type of credits changes.

Transaction costs associated with credit creation, certification, and verification costs are estimated for 3 different types of credit projects: permanent land conversion projects, term project associated with agricultural structural BMPs, and term projects associated with agricultural management BMPs. We estimate total transaction costs and do not distinguish based on who bears the cost. To generate an estimate of per project transaction costs associated with permanent credits from a land conversion project, we assume general costs and attrition rates similar to what is incurred by a NRCS-type land conversion project. DEQ certification costs are drawn from Table 7. Finally, verification is assumed to be consistent with remote annual monitoring. The credit creation, certification, and verification costs are then discounted and summed over an assumed 30 year time period to generate a present value and annualized transaction cost estimate. This transaction cost estimate is then compared to a two term credit cost scenarios that would represent low and high end cost projects.

The low cost term project assumes a medium-complex 10 year contract (renewed 3 times to generate a 30 year stream of credits). This project would require boots on the ground verification every 5 years and annual interim verification. We assume the hours required to certify (and re-certify) are increased compared to the case of perpetual credits (see table 13).[34] The high cost project is designed to represent the management style BMP practices (cover crops, reduced fertilizer application, etc). The project would require recertification (complex level) every 3 years (10 times over 30 years) and full annual verification. Again, we assume that these more complex projects require proportionally more hours for (re-) certification. The present value and annualized project costs for the permanent, low cost term, and high cost term credit scenarios are presented in Table 13.

Table 13: Comparison of Project Transaction Costs from Permanent and Term Projects

Project type	'Permanent' credits	10-year fixed term credits	3-year fixed term credits
Project description	simple project, costs counted for 30 years of project life	moderate project complexity; project life is 10 years (renewed 2 times for 30 year period)	complex project complexity; project life is 3 years (renewed 10 times for 30 year period)
Ex-post regime description ($NPV)	no re-certification; annual interim (remote) verification over project life (30 years)	project is re-certified in years 10 and 20; full verification in years 5, 15 and 25; interim verification in remaining intervening years	project is re-certified every 3 years ; full verification in intervening years
Commodity creation costs ($NPV) (including "false starts")	$2,772	$4,771	$7,328
Initial certification costs ($NPV)	$530	$901	$1,378
Ex-post re-certification costs ($NPV)	NA	$892	$6,503
Certification costs (initial + re-certification if required) ($NPV)	$530	$1,793	$7,881
Ex-post monitoring costs ($NPV)	$191	$936	$5,248
Total certification & monitoring costs ($NPV)	$721	$2,729	$13,129
TOTAL ($NPV)	**$3,493**	**$7,500**	**$20,457**
Annualized cost ($ per year)	**$227**	**$488**	**$1,331**
Ratio of commodity creation costs compared to permanent credits	NA	1.7	2.6
Ratio of certification costs compared to permanent credits	NA	3.4	14.9
Ratio of monitoring costs compared to permanent credits	NA	4.9	27.5
Ratio of total costs compared to permanent credits	NA	2.1	5.9

Assumptions: certification : permanents credits: 10.6 hrs; 10 year credits: 18 hrs; 3 year credits: 28 hrs; interim verification (all project types): 0.25 hrs; full verification (all project types): 10 hrs. 5% discount rate.

The results of this analysis suggest that, given the assumptions, total transaction costs of credit creation, certification and monitoring are around 2 and 6 times higher for the 10-year term credits

[34] Due to the fact that data on certification costs for term credits (that will be used for PS compliance) is not available, we have assumed that certification costs increase proportionally with credit creation costs.

and 3-year term credits, respectively. Ex-post re-certification and monitoring costs are disproportionately responsible for these cost increases. The final rows of Table 13 provide a ratio of costs in each category for the two types of term credits as compared to the permanent credit costs. The largest difference in costs occurs in relation to monitoring: for 3-year term credits which are assumed to receive annual full (on-site) monitoring, costs in this category are 27 times higher compared to perpetual credits which exclusively use interim (remote) monitoring.

The disproportionate increase in costs also means that the share of each cost category in total costs differs between project types. For permanent credits, upfront costs relating to credit creation constitute the majority (79%) of transaction costs, with certification costs and monitoring costs contributing 15% and 5%, respectively. At the opposite end, the distribution of costs for 3-year term credits is 36% for credit creation, 39% certification (including re-certification every 3 years), and 26% for monitoring. This analysis demonstrates that both the magnitude and distribution of transaction costs is closely linked to the type of credit being produced and the certification and monitoring regimes chosen.

Another relative comparison with implications for credit supply is the costs borne by credits suppliers relative to the number of credits created. This analysis assumes credit suppliers face credit creation costs (search, negotiation with landowners, etc.) similar to what is incurred by NRCS. However, rather than facing credit certification and monitoring costs directly, credit suppliers face credit fees that will be charged under DEQs proposed credit certification regulations (9VAC 25-900), but do not directly pay ex-post verification costs. Credit supplier transaction costs are estimated for the same 3 project types as described above and represent minimum transaction costs to provide credits (i.e. excluding transformation costs). The costs in each scenario are compared over range of nutrient credit prices for representative size projects.

We make the following assumptions about the 3 project types:

- Permanent credits: 70 acre land conversation project, generating approximately 60 P credits.
- 10-year term credits: 140 acre structural BMPs (structural practice with equivalent removal effectiveness)
- 3-year term credits: 140 acre land management BMPs (e.g. cover crops and 15% N reduction)

For purposes of illustration, we arbitrarily assume each type of project generates the same number of P credits (60). Since working land BMPs will generate fewer credits per acre, we initially assume working land BMPs will cover larger projects (on a per acre basis) .

We apply the fee schedule specified in Table 2 of Virginia DEQ proposed regulations (9VAC25-900). Credit creation costs are unchanged from the previous analysis (Table 13). As before, we use a 5% discount rate to generate net present value and annualized cost estimates. Results are shown in Table 14.

Table 14: Comparison of Transaction Costs faced by Credit Providers from Permanent and Term Projects

	Land conversion	Structural practice	Agricultural management practice
Credit type	Permanent	Term: 10 years	Term: 3 years
Plot size	70	140	140
P Credits generated (per year)	60	60	60
Credit creation costs	$2,772	$4,771	$7,328
Initial base application fee	$3,000	$3,000	$3,000
Initial supplementary fees	$3,000	$600	$180
Ex-post fees ($NPV)	NA	$1,585	$5,466
Total fees ($NPV)	$6,000	$5,185	$8,646
Total transaction costs ($NPV)	**$8,772**	**$9,956**	**$15,974**
Annualized costs	**$571**	**$648**	**$1,039**
Cost per credit	*$9.50*	*$10.80*	*$17.30*
Ratio of commodity creation costs compared to permanent credits	*NA*	*1.7*	*2.6*
Ratio of fees compared to permanent credits	*NA*	*0.9*	*1.4*
Ratio of total costs compared to permanent credits	*NA*	*1.1*	*1.8*

This analysis assumes that credit creation costs for credit suppliers are similar to cost estimates for each project type supplied by NRCS. In reality, there is reason to expect that costs to suppliers for creating the commodity may be higher than for NRCS staff. For example, NRCS contracting with landowners is standardized, with standard legal appendices being attached to each contract rather than having terms individually negotiated. In contrast, a credit provider may need to make use of legal services for each contract with landowners (and also with buyers when marketing credits), increasing transaction costs in these cost categories relative to those based on NRCS information. Also, the analysis does not take into account transaction costs associated with meeting baseline requirements, which may be substantial.

Given the assumptions of the analysis, differences in costs faced by credit providers are substantially lower: for 10-year term credits, total transaction costs faced by providers are similar to those for permanent credits; for 3-year term credits, total costs are slightly less than 2 times higher. This follows because fees calculated are substantially lower than the estimated costs for certification and monitoring reported in Table 13.

Assuming 60 P credits are generated, annual transaction costs per credit faced by the credit supplier are $9.50, $10.80 and $17.30, respectively, for the permanent, 10-year, and 3-year credits. The significance of these costs depends on the buyer's regulatory program. In Virginia, members of the the point source Nutrient Credit Exchange Association exchange P credits typically for less than $5 per annual credit. In this circumstance, nonpoint transaction costs alone (not including the abatement costs themselves) exceed the current point source P credit prices. On the other hand, P credit prices for stormwater compliance is much higher. Limited price information indicates that permanent credit prices are between $10,000 and $20,000 per credit. Annualizing these values (5%) implies an annual credit P credit price between $500 to $1000. The marginal costs of removing P via stormwater BMPs is often higher (Stephenson and Beamer 2009). In this circumstance, the transaction costs associated with generating agricultural nonpoint source credits are quite low relative to the potential avoided costs of on-site stormwater controls.

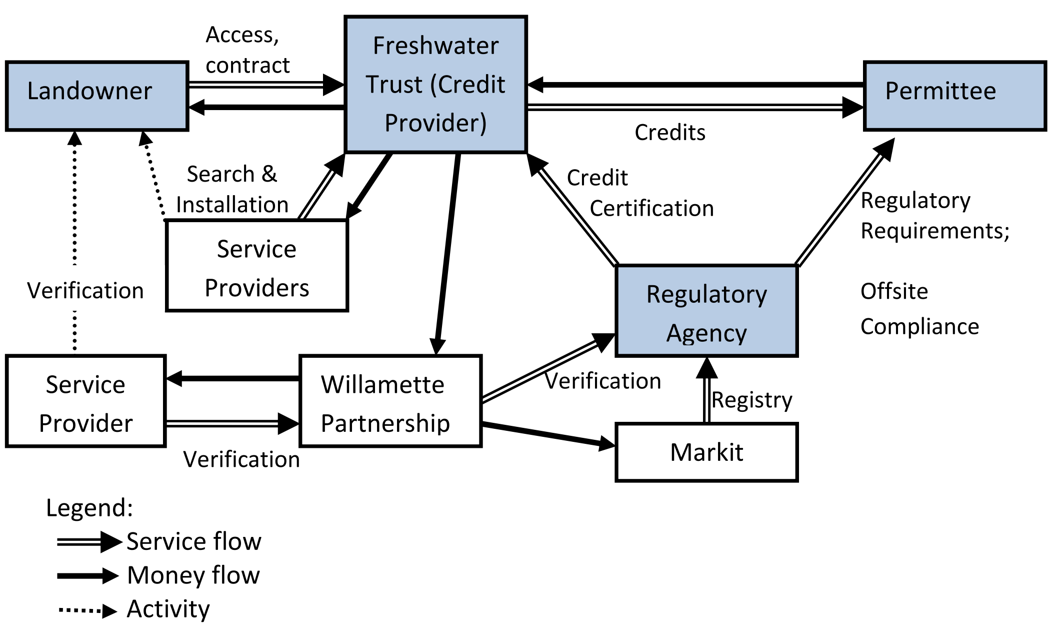
4.6 Use of Third Parties to Manage Costs

Considerable variation in program design was observed across programs, with the current Virginia program being the simplest of WQT programs studied. We have identified that one factor which contributes to the simplicity of the Virginia program vis-à-vis other programs studied is the absence of the use of third parties (refer to Figure 2). As the program expands in the future, Virginia DEQ and credit providers will need to consider whether it is cost effective to use third parties for various administrative activities (e.g. locating prospective credit-generating sites, registry services, monitoring, etc.). Also, as identified above, changes in the types and number of parties participating in credit markets may result in demand for third party market intermediaries.

Currently, the Virginia DEQ performs all verification, monitoring and enforcement, and registry activities for the program (see figure 2). In this, DEQ is unique among the programs studied; all other programs 'outsource' at least some of these functions. The credit providers likewise do not use third parties in 'creating the commodity'; the credit providers themselves provide the interface between the credit generator (farmer) and credit purchaser (permittee). They work with the landowners to ensure the land conversion project is implemented correctly, and holds the generated credits that are available for sale (Virginia currently retires 5% of credits generated) until such time as a trade occurs (*pers. comm.* Aaron Revere, Falling Springs LLC, 2014).

In contrast, the Rogue Basin temperature trading program (Oregon) makes extensive use of third parties. It is useful to compare the Rogue Basin program with the Virginia program since both are currently contracting for a similar service (land conversion to trees of riparian and working lands, respectively) even though they are producing different credits (temperature versus nutrient). Actors, service and financial flows for the Rogue Basin program are shown in figure 4.

Figure 4. Credit Generation and Transfer Process: Rogue Basin Temperature Trading (Oregon)



The regulatory agency in the Rogue Basin program is Oregon DEQ; however, management of the trading program is actually undertaken by Willamette Partnership, who is essentially a third party in this system that is providing key management services to Oregon DEQ. Willamette Partnership designed and oversees the program, and partners with Freshwater Trust to approach farmers and implement credit-generating projects. The projects are riparian plantings which have the effect of cooling the Rogue River; the credits generated are then sold to the City of Medford's wastewater facility. Also, Willamette Partnership trains and accredits third party verifiers who conduct on site monitoring and report back to the administrator. Further, Willamette Partnership has outsourced credit registry functions to Markit, a financial information services firm which provides registry functions for environmental programs worldwide (Markit: date NA). Comparison between figures 2 and 3 highlights the extensive use of third parties in the Rogue Basin program: the entities shown in blue (landowner, credit provider, regulatory agency and permittee) are also present in the Virginia program, and are the principal actors in the trading program. The other entities (shown in white) are third parties that participate in this program to provide a variety of services.

Use of third parties entails both costs and benefits:

Benefits

In general, third parties may be able to lower overall program transaction costs by providing specialized knowledge, scale economies, and scheduling flexibility. For instance, third parties may specialize in performing select functions which require unique or specialized skills. Third parties may also be able to achieve scale economies due the volume of services provided, thus lowering per unit costs. Finally, the use of third parties may allow the regulatory entity to quickly and easily alter the level of hired services depending on work demands. This flexibility is particularly important if agency staff resources tend to be fixed over significant period of time. Examples of possible use of third parties include:

- Use of market intermediaries (e.g. brokers, credit exchanges, government entity purchaser & reseller of credits) may lower trading partner search costs and/or mitigate market risks for trading parties.
- Use of third parties to provide registry functions may reduce registry costs and provide ancillary benefits (e.g. use of a common registry provider by several trading programs may facilitate cross-program / interstate trading)
- Use of specialized third party verifiers may be a cost-effective way to lower total program monitoring costs (e.g. if verifiers are locally sourced and therefore incur less travel costs than a program administrator would to conduct a site visit).
- Use of third parties may redistribute the burden of costs away from program administrators and/or principal program participants (e.g. permittees, landholders, credit providers). Note that this is a *distributional* 'benefit' and does not necessarily mean that total transaction costs are lowered.

Costs

The use of third parties also includes additional costs. These costs may arise of the following reasons:

- Each additional third party generally results in one or more new relationships (and possibly contracts) that require ongoing management.
- Some third parties (especially if they are already well-established prior to their involvement in a trading party) may have their own bureaucracies and / or standards. Management of such third party complications constitutes additional transaction costs.
- Third parties may have incentives that may not be in complete alignment with the trading program; if this occurs additional transaction costs may be incurred to manage incentives, monitor behavior, or to avoid conflicts of interest. Examples of incentive issues or conflicts of interest that may occur with the use of third parties are:
    - Third parties that have ongoing relationships external to the trading program may have a conflict of interest (real or perceived) if they are providing verification / monitoring services for the trading program;
    - Third parties providing market intermediary services (e.g. acting on behalf of a credit provider) may have a conflict of interest if they are also allowed to trade credits on their own behalf;
    - Third parties who are involved in conservation activities beyond the trading program may prefer to implement as much conservation as possible, without adequately considering costs (this may make it more difficult for a trading program to supply credits cost-effectively).

Given these benefits and costs, it is not immediately clear whether the use of a third party in a particular instance will result in net benefits to the program. Use of third parties should be carefully considered on a case-by-case basis.

Part V: Findings / recommendations

Based on best available evidence, the administrative costs of creating credits using management and structural BMPs will be significantly more costly on a per project basis than the activities involved in land conversions (the dominant credit generating practice in Virginia). It is estimated that it may be 2 to 3 time more costly to plan for working land BMPs than for land conversion an retirement. Furthermore, given dynamic and changing farm conditions and limited BMP lifespans, these costs are relatively frequent and recurring. However, while higher, costs need to be compared to the relative value created in terms of reduction. In some situations, these costs might be quite modest relative to overall possible nutrient credit prices.

The verification (compliance monitoring) protocols can be a significant costs for credits generated from working agricultural lands. Several programs require annual site visits to verify the existence and performance of credit generating practices. The cost of providing annual "boots on the ground" verification is estimated at around $500 - $750 per visit per year.. Significant reductions in transaction costs could be achieved through alternative verification processes. For instance, in our analysis monitoring costs were reduced 67% by allowing interim remote self-reporting of BMP status for 4 out of 5 years, and by 80% if all monitoring is undertaken remotely. Remote sensing technologies offer opportunities for dramatic reductions in verification costs. These results suggest an important cost/risk tradeoff between verification cost and compliance certainty for program designers to consider. Little is currently known about the efficacy of alternative verification regimes to deter noncompliance and to identify instances of noncompliance. Behavioral economic research may provide insight into how compliance can be maintained without requiring annual onsite verification.

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APPENDIXES

Table A1: Transaction costs categorizations used in empirical studies

Paper	Programs / services evaluated	TC categories used in study
Air pollution programs		
Antinori & Sathaye (2007)	41 greenhouse gas (GHG) projects worldwide[35]	Project search & feasibility studies; negotiation; monitoring & verification; regulatory approval & insurance. Did not include public agency staff administration time.
Ofei-Mensah & Bennett (2013)	3 alternative GHG policies in the Australian transport sector: Tradable Permit and Fee System (TPFS); the mandatory Fuel Label Program (FLP); the voluntary Fuel Efficiency Program (FEP)	Policy research & information; enactment; implementation; administration; contracting/trading; monitoring/detection; enforcement
Gangadharan (2000)	Regional Clean Air Incentives Market (RECLAIM), a nitrogen & sulfur emissions trading program for stationary sources in Los Angeles, USA.	Learning market rules, market entry decisions, trading partner search
Energy efficiency programs		
Mundaca (2007)	3 case studies: GHG energy efficiency project (GHG); "Free-of-Charge Energy Audit" (FCEA) program in Denmark; and the Energy Efficiency Commitment (EEC) in Great Britain	Costs of arranging a contract ex ante and monitoring and enforcing it ex post': - GHG: design, initiation, proposal, validation, monitoring, verification and certification. - FCEA program: search for information; contacts & contract negotiation; follow-up measures; search for contractors; accreditation. - EEC program: search for information; persuasion of customers; approvals; negotiations & contracting; random quality checks.
Water (quantity)		
Brown et al (1992)	Water rights markets in New Mexico	3 categories of trading applicant (seller) TCs: (1) broker commission; (2) total expenditures associated with the trade application excluding purchase price or sales commission: filing & publication fees; title search; attorneys; hydrologists or engineers; other; (3) amount of uncompensated time in days or hours expended by applicant and applicant's associated on the application.
Challen (2000)	Permanent water entitlement market in South Australia	Trading participant TCs: administrative fees & charges; commissions paid to agents; costs of imperfect (market) information
Colby (1990)	Water right transfers in selected US western states (Colorado, Utah, New Mexico & Nevada)	Searching for trading partners; ascertaining the characteristics of water commodities; negotiating price and other terms of transfer; obtaining legal approvals; attorneys' fees; engineering and hydrologic studies; court costs; and processing fees paid to state agencies. Authors note that "the costs of implementing a transfer once it has been approved [are excluded] because these costs are not specifically attributable to state policies."
Garrick & Aylward (2012)	Columbia Basin Water Transactions Program; acquisitions of water for environmental flows	Policy reform and implementation expenditures by governmental and non-profit actors to reallocate private water use rights into the public trust. Excludes private TCs faced by trading principals.
Hearne & Easter (1995)	Water allocation markets in Chile	Legal costs; Costs of engineering and modifying canal infrastructure (to allow transfer of water as a result of trade); Time invested; Information gathering (trading partner search)

[35] (26 with complete data): included different types of energy efficiency, forestry, renewable energy, fuel switching, and landfill gas projects.

Conservation programs		
Classen, Cattaneo & Johansson (2008)	Conservation Reserve Program (CRP)	The government's cost of formulating the program (e.g., establishing the EBI), the producer's cost of submitting an application and the government's cost of processing applications, selecting participants, entering into contracts, making payments, monitoring compliance, and taking enforcement actions when necessary. Also, an indirect component of transaction cost is the data collection and research on which indices like the EBI are based.
Falconer & Saunders (2002)	3 types of management agreements for conservation activities on sites of special scientific interest (SSSIs) in England[36]	Direct costs related to concluding and operating SSSI management agreements (excluding policing costs). Costs included time costs (wage rate * hours spent) + overheads (assumed 60% of salary costs) + legal fees.
Groth (2008)	2 conservation auctions	Monetary value of time spent to apply for the auction.
McCann & Easter (2000)	2 NRCS programs: technical assistance and cost-sharing for conservation programs	Overall definition: Research & information; enactment; design & implementation; support & administration; prosecution; monitoring. However: because NRCS programs are voluntary there essentially are no costs in the prosecution category. Also program enactment costs are not included since the programs studied "are not new".
Mann (2005)	Agricultural cross-compliance[37] programs in Switzerland	TCs were estimated "on the federal, the regional and the community level as well as on the farmers' side by the methodology as outlined by Mann (2000)".[38]
OECD (2005)	Conservation Reserve Program in the US	
Organic programs		
Sinabell (1998)[39]	Organic aid schemes in Austria	"Typical financial transactions only" - does not include estimates of time spent in applying, or administrator's costs other than to audit project.
Skuras (1998)[40]	Nitrate reduction schemes in Thessaly (Greece)	TCs relating to private participation in organic farm programs in Greece in 1996/97.
Water (quality) programs		
Fang, Easter & Brezonik (2005)	Rahr Malting Company water quality trading (WQT) project (trading N and P) in the Minnesota River Basin, United States	Time spent on permit negotiation; searching for trading partners; administrative expenditures; mandated communications between permittee & MPCA; MPCA staff time on credit verification, post-project site inspection, and project management. Analysis divided the projects into 2 phases: (1) permitting & (2) implementation. Engineering, material and consulting service costs during the implementation phase were not considered, although the salary-cost of the services of an intermediary were included in the Rahr project TCs.

[36] (1) Wildlife Enhancement Scheme (WES) - standardized agreements; (2) "Under hand" - individualized agreements, less formal, short-term agreements; (3) "Under seal" - individualized agreements, more formal, longer-term.
[37] Cross-compliance is "[t]he practice of granting public payments to farmers only if they comply with certain environmental standards" (Mann (2000), p471).
[38] Mann (2000) is unavailable, therefore the precise definition used in Mann (2005) is unable to be determined.
[39] Cited in Falconer (2000); original paper not available.
[40] Cited in Falconer (2000); original paper not available.

McCann & Easter (1999)	4 policies to reduce ag NPS pollution in the Minnesota River: (1) tax on phosphate fertilizers, (2) educational programs re: BMPs, (3) requirement for conservational tillage on all cropland, and (4) permanent conservation easement program ("RIM")	Research, enactment of legislation (incl. lobbying), policy design & implementation, ongoing program support & admin, monitoring / detection, prosecution / inducement. Administrative costs only (i.e. no TCs borne by farmers); ex ante (interviews rely on staff estimates of what costs will be)
Thompson (1999)	EPA technology-based non-tradeable effluent permit system vs. German effluent charge systems. Regulated entities were textile mills.	Enactment costs, Implementation Costs, Detection Costs, Prosecution Costs
Multiple agricultural-environmental programs		
Falconer & Whitby (2000)	37 AES schemes from EU member states participating in the STEWPOL survey. Types of schemes included are: Suasion & Advice; Regulation; Market mechanisms; Tradeable permit schemes; Voluntary management agreements; Public purchase of land	