Two analyses of costs of agricultural NPS pollution: ***Transactions costs of expanding nutrient trading to agricultural working lands: a Virginia case study*** **and** ***Impacts of transactions costs and differential BMP adoption rates on the cost of reducing agricultural NPS pollution in Virginia***

Gwendolen J. Rees

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Kurt Stephenson, Chair

Daniel B. Taylor

Zachary Easton

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ABSTRACT

For over 30 years, federal and state governments have been engaged in a collective effort to improve the water quality and living resources in the Chesapeake Bay (CB), focusing particularly on reducing delivered nitrogen and phosphorus loads. However, achievement of water quality objectives remains elusive. In Virginia, agriculture represents the single largest source of nutrient loads to the Chesapeake Bay. Despite aggressive regulatory efforts in other nutrient source sectors, state authorities rely on educational programs and voluntary financial assistance programs to induce landowners to adopt best management practices (BMPs) that reduce agricultural nutrient loads. This study explores two economic aspects of efforts to reduce agricultural nonpoint source (NPS) pollution in the Virginia portion of the CB watershed. Firstly, current and possible future transactions costs associated with specific aspects of agricultural NPS participation in water quality trading (WQT) programs are examined in Chapter 1. A case study approach is used to consider the possible cost consequences of expanding the use of NPS credits from agricultural 'working lands' BMPs in Virginia. Findings indicate that overall transactions costs for nutrient trades involving agricultural NPS in Virginia are currently relatively low, due to the type of activities being credited: simple land conversions. Based on best available evidence, the administrative transactions costs of creating credits on agricultural 'working lands' using management and structural BMPs will be 2 to 5 times more

costly on a per project basis than for credits generated from land conversions. Compliance monitoring protocols were found to be a significant driver of costs for credits generated from working agricultural lands. These results suggest an important cost/risk tradeoff between verification cost and compliance certainty for program designers to consider.

The second study (Chapter 2) considers the economic cost of meeting pollution reduction targets for the Virginia portion of the CB Watershed. Existing cost models are based on simplifying behavioral assumptions about public transactions costs, conservation adoption rates, and implementation costs of agricultural BMPs. This study builds on the existing literature and uses the estimates of transactions costs from Chapter 1 together with information on producer BMP adoption rates to examine the implications of including transactions costs and differential BMP costs and adoption rates when estimating the minimum costs of achieving specified nutrient reduction goals in Virginia. The paper uses a cost-minimizing mathematical programming approach and models a number of different cost scenarios. Results indicate that inclusion of transactions costs substantially affects estimates of total costs of meeting nutrient reduction goals; on average total costs increased by 44 percent, but ranged between 19 and 81 percent depending on the scenario analyzed. Analysis of the modelled scenarios shows that those BMPs that account for the most implementation costs do not necessarily account for the most transactions costs (and vice versa). This suggests that transactions costs should be acknowledged to vary with the type of practices being implemented, rather than being approximated as either a fixed amount or a fixed proportion of implementation costs. In addition, the analysis highlights the disproportionate costs associated with achieving nutrient reductions via high-cost adopters, and suggests there may be a role for education or extension to assist landholders to lower opportunity costs of participating in conservation.

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Dedication

For my mother, and Jackie, who inspire me to reach higher.

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Chapter 1. Transactions Costs of Expanding Nutrient Trading to Agricultural Working Lands: A Virginia Case Study.

I. Introduction

Involvement of nonpoint source (NPS) agriculture[1] in water quality trading (WQT) programs is currently encouraged by many trading program administrators, economists and policy makers (Jones et al, 2010; Ribaudo and Gottleib, 2011). In WQT programs, regulators grant regulated parties (point sources) off-site effluent control options for complying with legally enforceable effluent control requirements. Some researchers and regulators advocate expanding trading options to include agricultural sources on the grounds that these sources can achieve effluent reductions at lower cost than regulated point sources, thus potentially lowering the overall compliance costs (Van Houtven et al, 2012). Other purported benefits include increasing NPS participation in pollution mitigation efforts and expanding the use of conservation practices to more agricultural lands (USEPA, 2006).

However, crediting of nutrient reductions generated by agricultural NPS best management practices (BMPs) for use in regulatory compliance programs introduces additional administrative and coordination costs beyond effluent abatement costs. First, agricultural NPS crediting programs, if they are to operate on a sizeable scale, are likely to involve a relatively large number of small, decentralized actors (Abdallah et al, 2007). Co-ordination costs will be incurred to locate and contract landowners, and to aggregate credits for sale. Second, many

[1] According to the USEPA (2012), "[t]he term "nonpoint source" is defined to mean any source of water pollution that does not meet the legal definition of "point source" in section 502(14) of the Clean Water Act." Agricultural nonpoint sources include runoff from agricultural lands, sediment from crop and forest lands, and bacteria and nutrients from livestock.

agricultural or 'working lands'[2] BMPs involve complex activities being implemented in dynamic farm settings, making credit-generating projects costly to contract, certify and monitor. Third, assuming WQT is operating in a regulatory context, costs are incurred to demonstrate a high level of assurance that agricultural projects achieve (and continue to achieve) the required level of effluent abatement (which engenders costs beyond simply verifying the physical existence of a practice, such as modelling and/or monitoring water quality gains associated with particular practices). Finally, many agricultural BMPs generate effluent reduction services for a limited duration, which means that regulated parties may need to contract nonpoint source credits over multiple sources and terms to cover obligations for an entire regulatory period.

Empirical research on transactions costs[3] for WQT programs that include NPS agriculture is still an emerging field of inquiry. Despite widespread interest in point-nonpoint trading, large scale trading between regulated sources and agricultural operations remains rare. Nonpoint source credit trading has been largely confined to 'pilot programs' that operate on a small scale or limited timeframe, or used for non-regulatory purposes to demonstrate proof of concept. Understanding transactions costs in WQT programs is important because transactions costs may reduce the supply of nonpoint source credits, increase total compliance costs, and

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[2] 'Working lands' are lands used to produce agricultural, natural and forest resource goods and services.

[3] We adopt a broad definition of transactions costs to include both the cost of developing trading program rules and the costs involved in program and trade implementation. Thus transactions 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 (Marshall, 2013, McCann and Easter, 2000; Classen, Cattaneo & Johansson 2008; McCann et al 2005). We distinguish between transactions costs and 'abatement costs', also known as 'implementation costs', 'production costs' or 'transformation costs' (Marshall 2013, Ofei-Mensah & Bennet, 2013).

decrease the relative cost-effectiveness of agricultural reductions (Stavins, 1995). Also, improved knowledge of transactions costs assists agencies to better understand the upfront and continuing costs of WQT programs that include NPS agriculture and provides insight on how programs may be designed to be more cost-effective.

The objective of this study is to examine current and possible future transactions costs associated with specific aspects of agricultural NPS participation in WQT programs. We use a case study approach that examines the possible cost consequences of expanding the use of NPS credits from agricultural working lands BMPs in Virginia. Virginia has enacted several nutrient trading programs for regulated sources discharging into the Chesapeake Bay. To date, agricultural NPS involvement has been minimal, with credits being produced and sold for land being taken out of agricultural production. We construct plausible estimates of likely *administrative* transactions costs that could be incurred if the Virginia program expands to include agricultural NPS credits generated on working lands, drawing on experiences from other existing WQT programs and related conservation programs. In assessing possible future transactions costs, we focus particularly on two components: *ex ante* costs of contracting for credit-generating conservation projects, and *ex post* costs of monitoring regimes. We find that transactions costs in these components depend on the type of project(s) implemented, and on program decision variables such as type and frequency of monitoring actions.

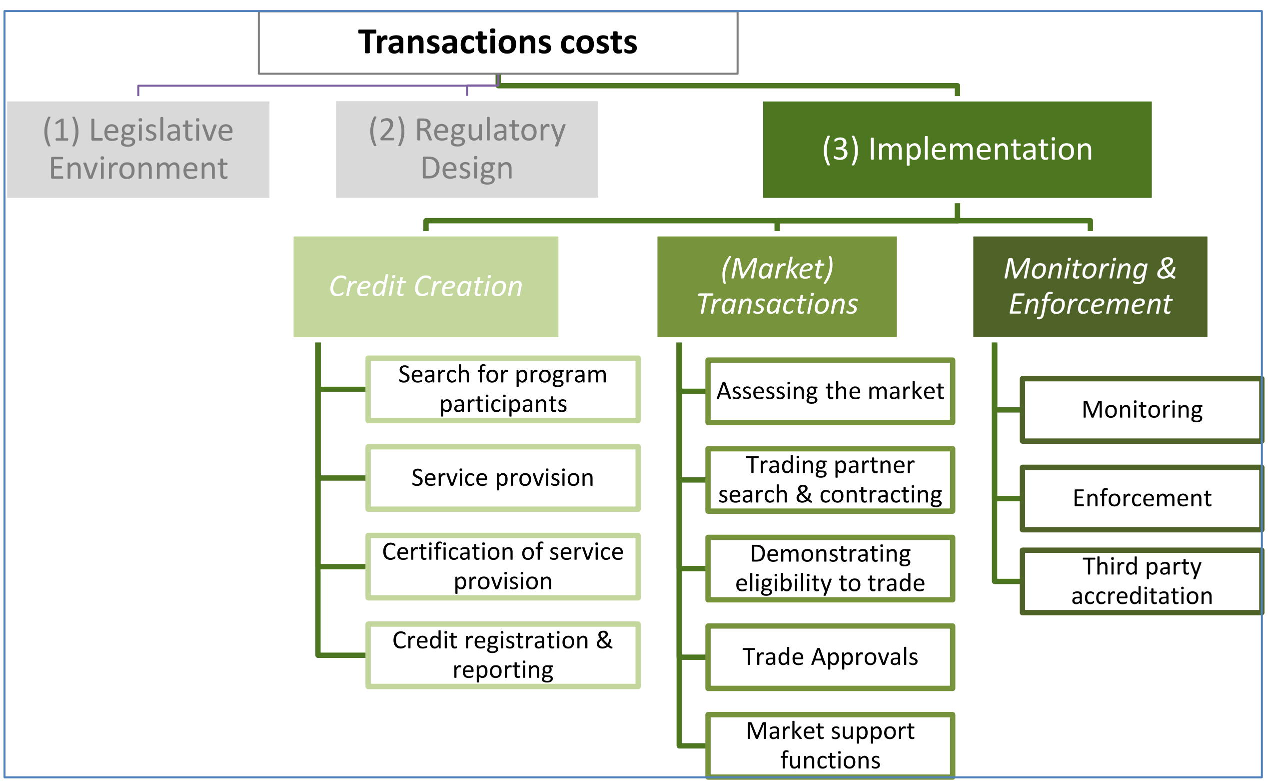
The analysis excludes some elements of administrative costs (e.g. fixed program costs) and may not reflect costs as experienced by program participants. Also, the analysis does not take into account transactions costs associated with meeting baseline requirements, which may be substantial. Nevertheless, we provide an illustrative relative comparison that offers insight into the magnitude of transactions costs changes that might occur if credits were generated from working lands BMPs rather than land conversion.

II. Transactions costs of Nutrient Trading Programs

A. Conceptual framework

Rees and Stephenson (2014) developed a comprehensive conceptual framework for assessing transactions costs in WQT programs (Figure 1.1). The framework classifies transactions costs into three stages: (1) the 'legislative environment' stage, in which necessary underlying rule structures, such as supporting or enabling legislation, are formulated; (2) the 'regulatory design' stage in which program rules are formulated; and (3) the 'implementation' stage, in which the program is operational. The current study restricts attention to *implementation* (stage 3).

Figure 1.1: Transactions costs conceptual framework



The implementation stage comprises what are typically considered "market transactions costs" (McCann et al, 2005), but is extended to allow for characteristics specific to water quality trading (and other similar environmental markets). Unlike markets for conventional goods and services, water quality markets involve the exchange of a 'regulatory commodity'[4] (Dudek and Wiener, 1996), the existence of which occurs entirely within the operation of the trading program. This leads to several types of transactions costs in the 'implementation stage' that may be additional to the notion of "market transactions costs" of trading other types of goods (e.g. agricultural commodities). We divide these into transactions costs that are incurred in the process of creating the marketable (regulatory) commodity (Figure 1.1, "Credit Creation") – and transactions costs incurred to verify the continued existence of the commodity (Figure 1.1, "Monitoring and Enforcement"). These two transactions costs categories are of principal interest in the current study.

Trading program rules provide "the necessary link between an uncertain natural process [the water quality improvement produced by the BMP] and the development of a tradable commodity [the nutrient credit]" (NRCS, 2011, p4-2). Implementation of the rules (stage 3) produces transactions cost-generating activities such as participant search costs (which may include costs related to targeting and / or verifying participation eligibility), contracting, provision of technical assistance and certification that practices have been installed as per rule

[4] There are various types of tradeable water quality credits, distinguished by pollutant type (nitrogen, phosphorus or temperature), and duration (e.g. permanent, fixed-term). Also, some programs distinguish between 'credits' (which refers to abatement in excess of current regulatory requirements or non-regulatory baseline), 'offsets' (abatement to 'offset' expansion in effluent discharge associated with new facilities and / or growth), and allowance (authorization to discharge a specified level of effluent load). We use the term 'credit' generically in this study.

requirements. Also, if programs make use of numeric or practice-based 'baselines'[5], transactions costs will be incurred to demonstrate baseline compliance.

After the commodity has been created (and creation is verified), it can be sold in the market. Market transactions costs incurred here are generally the same as those incurred for non-regulatory commodities (trading partner search, negotiation, trade approvals, registry costs, price reporting, etc). However, unlike conventional markets, WQT programs may include requirements to demonstrate trading eligibility. For example, point source buyers may need to demonstrate that they have exhausted onsite opportunities to reduce pollution and/or that there are no opportunities to purchase required credits from other point sources (Shabman et al, 2002).

In the 'monitoring and enforcement' element of implementation, transactions costs are incurred because of the program administrator's need to ascertain whether the 'link' between the tradeable credit and the underlying environmental service provision is being maintained, and to undertake enforcement actions if it finds that the link is broken[6]. In other words, costs are incurred after sale of the credit to verify the continued existence of the commodity. The timing and level of these *ex post* transactions costs will be driven by the types of activities that are eligible to generate credits (e.g. structural vs management BMPs or land conversion) and level of certainty that is required. Finally, if the administrator elects to outsource certain certification or

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[5] 'Baseline' refers to "the pollutant control requirements that apply to a buyer and seller in the absence of trading…A baseline for a nonpoint source can be derived from a load allocation (LA) established under a total maximum daily load (TMDL). Where an LA does not exist, EPA's Trading Policy states that state and local requirements and/or existing practices should determine a nonpoint source's baseline." (USEPA, 2007, p6)

[6] In a trading system where the credit purchaser retains regulatory liability for credits produced by voluntary program participants such as NPS agriculture, enforcement action by the program administrator may take place against the credit buyer (the permittee), who may in turn use contractual arrangements to 'enforce' against the credit supplier, for example, by requiring compensation.

monitoring functions to third parties, transactions costs may be incurred to train, accredit, and monitor these entities.

B. Existing evidence on transactions costs in water quality markets

Although there have been many studies on transactions costs of various conservation service provision programs (e.g. Classen et al (2008), Falconer and Saunders (2002), Groth (2008), Mann (2005), McCann and Easter (1999, 2000), OECD (2005a, b, c)), to date there are very few studies available that assess transactions costs of water quality trading programs specifically. Fang et al (2005) present transactions costs estimates for the Rahr Malting Company trading program in the Minnesota River Basin, which commenced in 1997 and allowed Rahr Malting Co. to offset projected loads of CBOD5 (five-day carbonaceous biochemical oxygen demand) from a new wastewater treatment plant by purchasing credits from agricultural NPS. Credits were generated from a combination of farmland reconversion to native floodplain and streambank erosion controls. The authors estimated program costs without and with transactions costs, and found a 35% increase over the five year project period when transactions costs were included. The majority of transactions costs were incurred in the initial permitting phase for the point-source buyer (which comprised elements of both *regulatory design* (stage 2) and *implementation* (stage 3) in our conceptual framework). In this case, the regulatory authorities had to simultaneously establish the underlying technical basis of the trade as well as implementing the trade for a single permittee.

Newburn and Woodward (2012) assessed the Great Miami Trading Program (GMTP) in Ohio, a pilot WQT program administered by the Miami Conservancy District (MCD). Five separate wastewater treatment plant (WWTP) point sources contributed to the program, sponsoring the generation of phosphorus (P) credits in advance of anticipated regulatory requirements.[7] Credit-generating projects are monitored by Soil and Water Conservation Districts (SWCD) agents who report to MCD. Estimated transactions costs include payments made from MCD to the SWCD for initial staff assistance to the farmer and SWCD monitoring costs (however Newburn and Woodward (2012) note that there was substantial under-recovery of SWCD costs from MCD[8]). MCD costs of administering an auction, recording of credits, program oversight/coordination, and remediation costs for noncompliant actors were not reported, nor were buyer or seller-related costs. Consequently, the transactions costs reported substantially underestimate the true costs of administering the trading program. These caveats notwithstanding, Newburn and Woodward (2012) report that total transactions costs of SWCD initial assistance plus monitoring are 5% of total program costs, with reported variation in this figure across counties from 0% to 12%.

It is worth noting that the costs cited by Newburn and Woodward (2012) relate to a *voluntary* program. One aspect of transactions costs of administering WQT programs that warrants further study is how costs vary as trading programs mature. Many studies on transactions costs for conservation programs in general assume costs will fall over time as learning occurs for both administrator and scheme participants, scale economies emerge (e.g. as the number of conservation contracts increases) and 'adaptive management' tends to streamline application and approval processes. Several studies show this result overall for a variety of

[7] 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. To date, the point sources have not used credits for regulatory compliance.
[8] SWCD staff could recover their costs from MCD by "explicitly include[ing] the costs of assistance and monitoring within the farmer bid application to the MCD" (Newburn & Woodward, 2012, p165). However, in several cases costs were not recovered as SWCD staff felt that "any increase in the overall bid amount would reduce the chance that the farmer application would be funded" (p165); it appears SWCD staff were more concerned with conservation implementation than recovering costs from MCD.

existing conservation programs (see for example Challen (2000), Falconer and Whitby (2000), Falconer, Dupraz and Whitby (2001), Garrick, Whitten and Coggan (2013), Groth (2008)). However, an evaluation by Antinori and Sathaye (2007) of 'nascent' versus 'mature' emissions trading markets suggests a more complex picture. While their results for overall transactions costs supports the notion that transactions costs fall over time, they find that costs for some components increase as the markets mature or as programs expand. In particular, insurance costs and regulatory costs increased substantially as compliance standards became stricter or more rigid when programs moved from a "pilot phase" to being used to generate credits for regulatory compliance. Further, expanding the scope of programs to allow more types of credit-generating projects may prevent standardization of processes which could serve to streamline transactions costs. These factors provide an important rationale for understanding changes in transactions costs as programs expand to cover different types of credits and strive to meet the levels of certainty required for regulatory requirements. Since the Virginia program that is the focus of our study already produces credits for regulatory compliance, we concentrate here on the latter of these factors: that is, on changes in transactions costs that could occur if the program expands, specifically into producing term credits.

III. Current transactions costs of nutrient trading in Virginia

Virginia has developed several related nutrient trading programs to serve the regulatory compliance needs of regulated source sectors, including regulated National Pollutant Discharge Elimination System (NPDES) municipal and industrial point sources and land developers. Virginia Department of Environmental Quality (VDEQ) is authorized to expand trading options to other sectors including the municipal stormwater permittees (MS4s). Virginia legislation broadly defines how certified nutrient reduction credits can be created (§10.1-603.15). Nutrient credits may be created by regulated point sources, agricultural BMPs, land retirement, manure conversion technologies, wetland and stream restoration, and enhancement of nutrient sink functions (e.g. algal and shellfish harvest). New and expanding point sources must offset all new loads but have yet to utilize agricultural NPS credits. Supported by a capital grants program, wastewater point sources have produced substantial over-compliance and excess point source credits (Stephenson et al, 2010).

NPS credit demand to date has come exclusively from the development community via construction activities under the Virginia Stormwater Management Program (VSMP). In Virginia, developers with land disturbance of a certain size must meet specific water quality criteria, defined as a per acre phosphorus load. 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 phosphorus credits.[9] Land conversion (e.g. conversion of agricultural working lands or degraded riparian areas to forest) is the key non-point source activity that generates permanent credits. To date, VDEQ has approved 15 agricultural NPS credit projects that produce a total of 1,637 permanent phosphorus credits[10] (VDEQ registry as of 8/22/2014). All projects except one are land conversion projects.

The transactions costs to administer permanent land conversion phosphorus credits in the Virginia program have been modest. Figure 1.2 shows the general process and entities involved in the Virginia credit trading option under the VSMP construction program. Attention is focused

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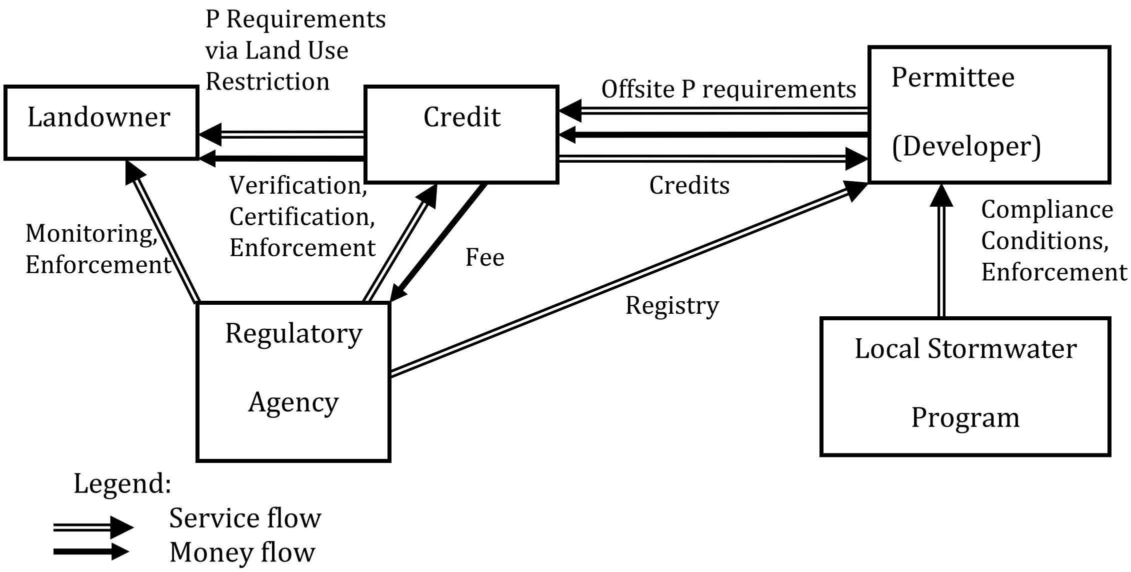
[9] Permanent credits are distinguished from fixed "term" credits by the duration over which they generate credits. Permanent credits are perpetual and are generated by permanent reductions in loads. Term credits are generated by an activity for a defined duration. In Virginia, development impacts are considered permanent; therefore, permanent credits are required to offset new development.

[10] 1 phosphorous credit = 1 lb (0.4536 kg) per year of total delivered phosphorous load. Nitrogen credits are defined analogously. (See Virginia regulation §9VAC25-820-10)

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.

Figure 1.2: Credit Generation and Transfer Process: Virginia (permanent) Phosphorus Credits



In the Virginia trading program credit providers typically contract with landowners to implement the land conversion project (see Figure 1.2 above). These credit providers incur the search and administrative costs necessary to certify credits through VDEQ rather than the landowner. The landowner can be thought of as an 'input supplier' who is contracted by the credit provider. 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 (i.e. conversion to forest); and (3) certification process to ensure that the project meets land conversion requirements (*pers. comm.* Aaron Revere, Falling Springs LLC, 2014). Under proposed credit certification regulations, credit providers pay fees to partially compensate VDEQ for the transactions costs incurred in the certification process (Virginia Regulation 9VAC25-900-210 and 220). Quantitative data on transactions costs incurred by credit providers was not available; however, the credit provider (broker) 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.

VDEQ verifies installation of the credit-generating practice(s) and certifies credit creation. VDEQ provided data for staff time spent in site visits for BMP verification and credit certification for five agricultural land conversion projects which have generated credits (see Appendix A). 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 VDEQ of staff wages and overhead costs, this equates to relatively modest costs ranging from $294 to $790 per project. Note that these estimates relate to site visits only and do not account for accompanying time spent reviewing project plans, processing paperwork relating to the site visit, unplanned trips, credit registry management, or compliance monitoring. Virginia proposes credit certification fees higher than these estimated costs under Virginia regulation 9 VAC 25-900. Regardless of the specific cost involved, VDEQ does not consider that these costs and activities are currently problematic or large.

Quantitative transactions 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 transactions costs typically constitute only a small proportion of total program costs (Rees and Stephenson, 2014).

VDEQ employs remote sensing to monitor the land conversion projects which have so far generated permanent credits (*pers. comm.* Allan Brockenbrough, VDEQ). VDEQ reported that it takes only around a quarter of an hour to remotely verify the status of a land conversion to forest project. This low cost arises because VDEQ's monitoring regime does not involve site visits, and because monitoring consists of simply ascertaining the number of stems evident per acre.

IV. Transactions costs of an expanded Virginia program: Credit Creation and Monitoring

Transactions costs of credit creation and *ex post* monitoring are likely to increase if nutrient trading is expanded to NPS credit generation from working agricultural lands. To estimate how costs might change, information and insight is drawn from conservation and WQT programs conducting activities similar to what would be required for an expanded Virginia program. We first present estimates of the costs of generating term credits using information from the National Resources Conservation Service (NRCS). Following this, we present evidence on transactions costs of different *ex post* monitoring regimes gathered from currently operating WQT programs.

A 'bottom-up' approach to assessing transactions costs is used: costs estimates are provided for specific activities undertaken, rather than parsing out transactions costs from organizational budgets. Program fixed costs (e.g. overhead for managing staff) are difficult to ascertain using this approach; accordingly estimates presented here do not constitute a measure of transactions costs in their entirety. Further, we restrict attention to 'administrative' transactions costs – those incurred by the program administrator and/or credit provider.[11]

A. Transactions costs of creating term credits

Estimates of the cost to create agricultural NPS term credits were based on estimates of staff time incurred by the NRCS to contract for the installation of conservation practices, called "best management practices" (BMPs). NRCS processes for conservation planning under federal financial assistance programs are similar to those activities needed to generate nutrient credits. Moreover, some WQT programs use state/federal conservation staff for this task within their programs (Newburn and Woodward, 2012). Also, NRCS conservation planning experience provides a common basis for estimating transactions costs of both permanent and fixed-term credits that is currently not available from existing WQT programs. We gathered staff time requirements via detailed consultation with NRCS field office Area II (in southwestern Virginia), and administrative staff located in Richmond. Estimates of staff hours and/or costs were corroborated by a private conservation consultant and by evidence from the Ohio River Basin Trading Project (ORBTP), a pilot program administered by the Electrical Power Research Institute (EPRI) (*pers. comm.* Jessica Fox, EPRI, 2014).

NRCS field staff described the various steps in their contracting process and provided estimates (measured in hours of agency staff time) on activities for 6 'stages' in the NRCS planning process: *inception* (initial meeting and site visit), *planning and application*, *approvals*,

[11] Note that some administrative activities may be undertaken by the credit supplier, program administrator, or a designated third party (e.g. a third party verifier if the administrator outsources this function). We do not distinguish based on who bears these administrative costs. However, we exclude purely private transactions costs incurred by landowners and credit buyers.

contracting, *implementation* (pre-construction meeting / site visit, engineering designs developed, technical assistance provision, follow-up and spot checking of contracted item(s)) and *check-out*[12] (verifying correct installation of practices). NRCS staff noted that time commitments vary substantially between contracts depending on the type and complexity of the practice(s) being installed. NRCS field staff provided time estimates (Table 1.1) required to complete each step of the planning and contracting process for 3 representative contract types:

1. *Simple contract*: *type (a)* single BMP that does not require engineering plans or complex management plans (e.g. cover crop or livestock exclusion fencing); *type (b)* land conversion to pasture or forest.
2. *Moderate contract*: Livestock exclusion fencing plus provision of alternative watering facilities. May include an invasive species control plan.
3. *Complex contract*: Animal waste management facilities on an intensive dairy farm: requires several engineering practices, such as heavy use area protection and animal waste storage structures. May include a rotational grazing plan.

Table 1.1: Estimate of NRCS Field Staff Hours Required to Complete Conservation Contracts [a]

	Simple contract			**Moderate contract**			**Complex contract**		
Task	Low	High	Avg [d]	Low	High	Avg [d]	Low	High	Avg [d]
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
Check-out [b]	0.3	1	0.65	0.5	0.5	0.5	2.0	3.0	2.5

12 We use the term 'check-out' here to distinguish NRCS certification of BMP installation from 'certification' in a WQT program, which requires both verifying correct BMP installation and certifying creation, registration, and release of credits.

TOTAL HOURS (excl. travel time) [c]	**17.1**	**24.45**	**20.9**	**34.0**	**47.4**	**40.7**	**55.8**	**76.3**	**66.0**

[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 site. [b] Check-out 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] Average = simple mean of *low* and *high* estimates.
Source: *pers. comm.* Hunter Musser, NRCS District Conservationist (Virginia, Area II)

For each contract type, the bulk of staff time is spent in three stages: planning and applications, contracting, and implementation. These stages are also where the greatest differences across contract types appear. For a simple contract, the total administrator time ranges from 17 to 24 hours (not including travel time). The most time-consuming task for a simple contract is planning and application. Implementation transactions 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, check-out is a simple task that generally takes around 20 minutes per item.

A significant increase in staff hours is required to administer a moderately complex contract compared to a simple contract; on average 41 hours are needed. 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’ (e.g. livestock exclusion fence, stream crossing and offstream watering facility). Also, more site visits occur during the planning stage for a moderate contact. Contracting costs increase because each item must be individually spelled out in the contract. 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, check-out also takes longer on average.

A further substantial increase in hours occurs for a complex contract. The largest driver of this increase is the need for substantial technical assistance when designing and constructing engineering practices. These contracts usually require the input not only of the NRCS District Conservationist, but also a NRCS soil scientist and / or NRCS engineer.

Thus far only individual cost components for a single completed contract were considered. In reality, the situation is more complex because not all projects commenced ultimately result in a completed contract and conservation 'on the ground'. According to NRCS district staff, around 75 to 80% of producers who have gone through at least part of the inception and planning stages submit an application. Of submitted applications, only around 40 to 45% of projects are actually approved, mostly due to funding constraints. Finally, a small number of projects fail at the implementation stage; in 2013 6% of contracts (weighted average of 2013 Farm Bill programs in Virginia, weighted by proportion of contracts in each program) were 'cancelled' (landowner cancels before receiving funding) or 'terminated' (full implementation has not occurred but some funding has been received) (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 are not successful. This result was corroborated confidentially by a private conservation provider in Virginia.

Estimates of the transactions costs of generating credits from working land BMPs were constructed based on the above time estimates and attrition rates, assuming a $75 per hour cost (wage rate that includes overheads) and accounting for time costs of the contracting process. We assume contracts are implemented over a 3 year period in which contracting takes place during years 1 and 2, and implementation (including 'check-out') takes place during years 2 and 3 (note that this does not include ex-post monitoring of the practice after installation is complete) (see

Appendix B). Table 1.2 shows the present value of costs to successfully complete the three representative types of conservation contracts.

Table 1.2: Transactions costs estimates for development of conservation contracts [c]

Stage of project	Inception	Planning & Application	Approval	Contracting	Implementation	Check-out	Cancellation & Termination [f]	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 ($NPV) [e]	145	541	158	469	98	22	188	75	**1,696**
Cost per stage per 1 completed project, accounting for attrition ($NPV)[d]	428	1,280	374	499	105	22	12	75	**2,794**
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 ($NPV) [e]	145	780	167	794	1,103	38	188	75	**3,288**
Cost per stage per 1 completed project, accounting for attrition ($NPV)[d]	428	1,845	394	845	1,173	38	12	75	**4,809**
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 ($NPV) [e]	145	1,234	202	1,204	2,008	188	188	75	**5,244**
Cost per stage per 1 completed project, accounting for attrition ($NPV)[d]	428	2,918	478	1,281	2,136	188	12	75	**7,516**

[c] travel costs not included. Assumed $75/hr unit cost (wages + overhead, *not* reflective of NRCS unit costs), 5% discount rate. [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. [f] Cancellation & termination costs only apply to projects that are not completed.

Estimated transactions costs vary significantly due to the complexity of the conservation activity. Simple contracts cost around $2,800 to complete after accounting for attrition. Complex contracts, however, are more than 2.7 times more costly to complete at around $7,600. Attrition rates account for a significant portion of these costs. Project attrition can increase costs by 40 % (complex contracts) to 64% (simple contract). The costs estimated developed here are broadly consistent with costs cited by another conservation organization operating in Virginia, whose estimates cannot be provided due to confidentiality. Hours estimates are also 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 (not accounting for attrition).

In terms of potential ability to generate credits, the NRCS simple contract type (b) – land conversion to forest – best corresponds to the generation of permanent credits. The moderate and complex contract types, and simple contract type (a) all relate to fixed term projects that, if used for credit generation, would produce fixed-term credits. For the permanent credits created to date in the Virginia program, only one ‘practice’ is being used per particular parcel of credits. This simplifies the process considerably compared to term credit generating projects where several practices are used in the generation of a parcel of credits. Apart from the lower transactions costs of a simple land conversion project, it is also worth noting that these costs are spread out ‘in perpetuity’ because the project generates permanent credits. In contrast, working lands contracts have limited duration and will require periodic renewal to generate an ongoing stream of term credits, increasing transactions costs on a ‘per credit’ basis (see following section).

The above analysis suggests that generation of term credits could involve considerably higher transactions costs than is currently the case for permanent credits in the Virginia WQT program. In addition, these higher costs are likely to underestimate the transactions costs that would be incurred in an expanded trading program.

It is worth noting that the transactions costs are also a function of program baseline requirements. Land conversion credits do not require implementation of baseline practices for the simple reason that load reduction calculations assume the full suite of relevant baseline practices have been implemented prior to the conversion. The setting of baseline levels of nutrient control performance is concerned with 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. ORBTP) have a time-based baseline, which seeks to ensure new BMPs are "additional" to what was currently on the landscape. In the Chesapeake Bay region (e.g. Maryland WQT, and Virginia for working lands credits), land must be in accordance with the relevant Chesapeake Bay TMDL Watershed Implementation Plan requirements before credits can be generated. Where baselines are used, transactions costs to generate credits must be incurred for both baseline and credit-generating practices. Baselines thus are an important contributor to the higher transactions costs of term credits, especially considering some programs allow funding from sources such as NRCS for baseline practices, essentially adding on an entire upfront process of NRCS applications, approvals and contracting.

In the Virginia programs, the *credit provider* (possibly with third party assistance) completes most of the steps involved in generating credits. Transactions costs of credit creation are likely to be higher than those experienced by NRCS staff, for several reasons. First, a credit provider may have less extensive networks of contacts to locate prospective applicants compared to NRCS field staff, driving up transactions costs in the "inception" stage. Second, the private credit provider must consider whether a particular project can profitably generate credits, producing additional transactions costs in the form of time spent to calculate credits and assess the market. Third, NRCS staff use fairly standard contracts with pre-constructed legal appendices that attach to all contracts. Also, it is likely that 'certification' costs for VDEQ will be higher than NRCS's 'check-out' costs, since credit certification involves additional activities beyond verifying correct BMP installation such as calculating the number of credits generated and registering them. As such, the NRCS contracting costs described above may be quite low compared to contracting costs in WQT programs which used individualized contracts, or contracts which require permanent annotations to land titles (e.g. an easement may be required).

B. Transactions costs of ex-post monitoring

Given that monitoring is a periodic activity occurring throughout the life of a credit project, its contribution to total program transactions costs can be relatively large. Features such as the *type* of monitoring employed, *frequency* (timing of monitoring actions) and *coverage* (proportion of relevant entities subject to a monitoring action) are important in determining the overall cost of a monitoring regime.

In order to explore the range of existing monitoring regimes employed in trading programs that involve NPS agriculture, we conducted detailed interviews with VDEQ and two other programs: the Willamette Partnership Rogue River Basin program in Oregon (temperature credits) and the Ohio River basin pilot trading project administered by the Electrical Power Research Institute (EPRI) (phosphorus and nitrogen (N) credits).

Program administrators interviewed distinguish between two levels or 'types' of monitoring:

- *On-site verification*: includes site visits where the regulatory agency (or designee) personally inspects the credit-generating project. Substantial written documentation may also be required, particularly in relation to ongoing practices such as nutrient management BMPs.
- *Remote verification*: the administrator makes use of information provided by the project implementer, third party verifiers, and / or remote sensing technology to verify service provision of the credit-generating project. Where the administrator relies on information from another party, monitoring outcomes may have a lower degree of certainty compared to 'on-site' verification; however, when using remote sensing for amenable projects (e.g. tree planting), arguably the administrator 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 transactions costs involved, vary across programs. Table 1.3 reports on the monitoring regimes employed for the Virginia and Ohio Basin nutrient programs and the Oregon temperature trading program.

Table 1.3: Ex Post Monitoring time estimates (hours per verification) for various programs

	Virginia DEQ	**Willamette Partnership (Oregon)** Program administrator	3rd party verifier	TOTAL	**EPRI (Ohio Basin)**
Monitoring – remote verification (hours per verification)	0.25	4	2	6	NA
Monitoring - on-site verification (hours per verification)	NA	10	20	30	NA
Monitoring regime	Annual remote verification	On-site verification every 5 years; Annual remote verification for interim years			Annual on-site verification + notification from SWCD staff

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

Differences in the type and frequency of monitoring activities caused substantial differences in the transactions costs of monitoring, measured in hours of agency (and third party) time. In comparison to the VDEQ monitoring regime, Willamette Partnership has a moderately costly regime of on-site visits every 5 years, with remote verifications each year in between (project lifespan is 20 years) (*pers. comm.* Carrie Sannemann, Willamette Partnership, 2014). By contrast, EPRI conducts an on-site verification every year, and also contractually obligates SWCD agents who assist with project implementation to report any suspected breaches to EPRI during the usual course of their activities with producers in the project areas (*pers. comm.* Jessica Fox, EPRI, 2014).

Depending on the type of project being monitored, verification regimes may provide different levels of certainty for assuring the provision of nutrient control services, implying a possible tradeoff between costs and certainty. On-site verification is more likely to identify whether the project is still fully compliant with program requirements, especially for ongoing management practices such as nutrient management and decision agriculture. However, to the extent that practices are amenable to verification via remote sensing, administrators may be able to rely more on remote verification without sacrificing certainty about project outcomes. Use of remote sensing together with geographic information systems (GIS) for monitoring (where feasible) has been recommended by the OECD's (2007) global study on policy-related transactions costs, as these technologies can help reduce error rates and the number of administrative staff required for monitoring activities, and also are less disruptive to producers.

Coverage refers to the proportion of projects that the monitoring actions are applied to. Within the programs analyzed, each project receives the same monitoring regime, so coverage is one hundred percent. However, administrators could choose to randomly monitor a certain percentage of projects every year, such that any individual faces a *probability* (as opposed to a certainty) of being subject to a particular monitoring action in any given year. Reducing coverage may be one tool to decrease monitoring costs while still maintaining an acceptable level of compliance. However, reducing coverage may also reduce incentives to maintain compliant practices, resulting in a tradeoff between costs and compliance levels.

V. Implications: Potential relative change in transactions costs associated with expansion into working lands credits

This section brings together information from previous sections to estimate indicative per project transactions costs for expanding NPS credits to term credits from working agricultural lands. Transactions costs associated with credit creation, certification, and *ex post* monitoring 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 (see Appendix C for further details).

Transactions costs associated with permanent credits from a land conversion project are used as reference. For this case, we assume general costs and attrition rates based on what is incurred by a NRCS land conversion project (i.e. a *simple contract – type (a)*). VDEQ certification costs are drawn from Table 1.4, and the monitoring regime is assumed to consist of remote annual monitoring. The credit creation (including certification) and verification costs are then discounted and summed over a 30 year time period to generate present value and annualized transaction cost estimates.

We then construct two scenarios that represent low- and high-cost term projects that could be used generate credits from agricultural lands. For purposes of illustration, we arbitrarily assume each type of project generates the same number of P credits (60 lbs/yr). The low cost term credit project assumes a medium-complex 10 year contract consisting of structural BMPs (renewed 3 times to generate a 30 year stream of credits). We assume that this project requires re-certification each time the contract is renewed (i.e. in years 10 and 20), plus onsite verification every 5 years and annual remote interim verification. We assume the hours required to certify (and re-certify) are increased compared to the case of perpetual credits (see notes accompanying Table 1.4).

The high cost term project is defined to represent management style BMP practices (cover crops, reduced fertilizer application, etc). This project type is assumed to require recertification every 3 years (10 times over 30 years) and full annual verification in interim years. Again, complex projects require proportionally more hours for (re-) certification.

Table 1.4: Comparison of Project Transactions 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)
P Credits generated (per year)	60	60	60
Ex-post regime description ($NPV)	no re-certification; annual remote verification over project life (30 years)	project is re-certified in years 10 & 20; on-site verification in years 5, 15 and 25; remote verification in interim years	project is re-certified every 3 years; on-site verification in interim years
Commodity creation costs ($NPV) (accounting for attrition)	$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**	**$20,457**
Annualized cost ($ /year)	**$227**	**$488**	**$1,331**
Annualized cost per credit ($ /lb/year)	**$4**	**$8**	**$22**
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 transactions costs compared to permanent credits	NA	2.1	5.9

Assumptions: certification: permanent credits: 10.6 hrs; 10 year credits: 18 hrs; 3 year credits: 28 hrs; remote verification (all project types): 0.25 hrs; on site verification (all project types): 10 hrs. 5% discount rate. $75/hr unit cost.

The estimated present value and annualized project costs for all scenarios are presented in Table 1.4. Given the assumptions of the analysis, total transactions costs of credit creation, certification and monitoring for the 10-year term credits and 3-year term credits are around 2 and 6 times higher, respectively, than for permanent credits. Ex-post re-certification and monitoring costs are disproportionately responsible for these cost increases. Monitoring costs for 3-year term credits – which are assumed to receive annual on-site verifications – are 27 times higher compared to perpetual credits, while certification costs are 15 times higher.

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 transactions 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. Both the magnitude and distribution of transactions costs is closely linked to the type of credit being produced and the certification and monitoring regimes chosen.

Assuming 60 P credits are generated, annualized transactions costs per credit are $4, $8 and $22, respectively, for the permanent, 10-year, and 3-year credits. While the absolute cost estimates are likely underestimated, this analysis suggests that transactions costs associated with working lands may be between 2 to 6 times more costly than for permanent credits. These transactions costs appear to be inversely related to the estimated cost of control. Several studies note that management practices have low nutrient abatement costs (Cools et al, 2011; Shortle et al 2014). The results generated here, however, suggest that transactions costs could significantly undercut the apparent cost-effectiveness of these nutrient control alternatives.

The significance of these costs depends on the buyer's regulatory program. In Virginia, NPS credit demand for working lands will likely come from municipal stormwater permittees (MS4s). In 2014 Virginia imposed special permit conditions that described how MS4s will quantify nitrogen, phosphorus, and sediment loads. The MS4s compliance options include implementation of onsite stormwater retrofits and the purchase of credits from point sources, nonpoint agricultural sources, or nutrient assimilation services.

Currently the Virginia wastewater point source program has generated hundreds of thousands of surplus P and N credits. The point source Virginia Nutrient Credit Exchange Association (2015) exchanges term P credits typically for less than $5 per annual credit. In this circumstance, nonpoint transactions costs alone (not including the abatement costs themselves) exceed the current point source P credit prices. Furthermore, in 2014 the point sources generated over 600,000 pounds of surplus phosphorus credits (VDEQ 2015), creating an immediate, low cost compliance option for the MS4s. On the other hand, permanent P credits currently sell for between $10,000 and $20,000 per credit (credit equals one pound). Annualizing these values (assuming a 5% discount rate) implies an annual phosphorus credit price between $500 and $1000 per pound. The marginal costs of removing P via stormwater BMPs are often considerable higher than this on a per pound basis (Stephenson and Beamer, 2008). In this circumstance, the transactions costs associated with generating agricultural NPS credits are quite low relative to the potential avoided costs of on-site stormwater controls.

VI. Conclusion

Currently, overall transactions costs for nutrient trades involving agricultural NPS in Virginia are relatively low. The levels of transactions costs experienced to date are modest largely due to the type of activities 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 projects typically do not involve the implementation and consideration of baseline practices. Verification and monitoring is straight-forward and can be done via remote monitoring of tree cover. In contrast, if credits were to be generated using management, vegetative, and/or structural practices, the procedures will become more complex to assess and monitor. Based on best available evidence, the administrative transactions costs of creating credits on working agricultural lands using management and structural BMPs will be significantly more costly on a per project basis than for credits generated from land conversions (the dominant agricultural NPS credit-generating practice in Virginia). It is estimated that it may be 2 to 5 time more costly to plan for working land BMPs than for land conversion and retirement. Furthermore, given dynamic and changing farm conditions and limited BMP lifespans, these costs are relatively frequent and recurring. Costs need to be compared to the relative value created in terms of nutrient reductions. For example, the estimated transactions costs of term credits may be several times larger than the price of nutrient credits currently being charged under the point source trading program.

Compliance monitoring protocols can be a significant driver of costs for credits generated from working agricultural lands. The evidence from the trading programs reviewed here suggests that choice of monitoring regime is complex, and that substantial cost differences can occur if monitoring regimes are varied. Key choice elements for monitoring regimes are the *type, frequency,* and *coverage* of monitoring actions. Several current 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 for a project is estimated between $500 - $750 per visit per year.

Significant reductions in transactions costs could be achieved through alternative verification processes, where possible. 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 for amenable practices (although some practices such as certain management practices will be difficult or impossible to verify remotely). 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. Nevertheless, administrators should explicitly recognize tradeoffs between transactions costs and certainty, and strike a balance that is appropriate to the program's needs while continuing to investigate other methods to mitigate the costs of uncertainty. Moreover, since this balance may shift as the program matures, monitoring regimes should be re-evaluated periodically.

Transactions costs of particular credit-generating projects should be accounted for alongside implementation costs, to ensure that comparisons between projects or BMPs are not biased towards those with low abatement costs but high transactions costs. The estimates provided in this study likely present a lower bound for the actual costs involved. Transactions costs of credit creation were drawn from NRCS – an organization that has long and comprehensive experience with contracting for conservation planning, but whose programs do not produce water quality credits for regulatory compliance. It is likely that credit creation costs experienced by WQT program administrators and credit providers will be higher, partly due to their relative inexperience but also because of the significant cost burden of monitoring credit-generating projects to a sufficient standard for a regulated program. Furthermore, our estimates omit certain categories of administrative transactions costs (e.g. program design costs, market transactions costs), and do not include any measure of transactions costs incurred directly by the buyer or landowner. More work is needed to measure these costs to provide a comprehensive picture of the true transactions costs of WQT programs.

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Chapter 2. The Impact of Transactions Costs and Differential BMP Adoption Rates on the Cost of Reducing Agricultural Nonpoint Source Pollution in Virginia

I. Introduction

For over 30 years, federal and state governments have been engaged in a collective effort to improve the water quality and living resources in the Chesapeake Bay. To achieve these goals, the Chesapeake Bay states, the District of Columbia, and the federal government have focused their policy attention on reducing nitrogen and phosphorus loads delivered to the Bay. Despite substantial effort and progress, achievement of water quality objectives remains elusive.

In Virginia, agriculture represents the single largest source of nutrient loads to the Chesapeake Bay, contributing 31% and 59%, respectively, of the total nitrogen and phosphorus loads discharged to the Bay from all nutrient sources in Virginia in 2013 (US EPA Chesapeake Bay Program 2014). Despite aggressive regulatory efforts in other nutrient source sectors, state authorities rely on educational programs and voluntary financial assistance programs to induce landowners to adopt practices that reduce agricultural nutrient loads. While progress has been made, the Environmental Protection Agency (EPA) estimates that nitrogen and phosphorus loads will need to be reduced approximately 30% from 2013 levels to reach the reduction goals established for the agricultural sector (US EPA Chesapeake Bay Program 2014).

Cost estimates to meet agriculture reduction goals for the Bay run into the billions (Kaufman et al 2014; Schwartz 2010). Most cost models, however, are based on simplifying behavioral assumptions about public transactions costs[13], adoption rates, and implementation costs of agricultural nutrient-reducing practices (called Best Management Practices or BMPs). Relatively little systematic research has been conducted on the transactions costs of implementing agricultural conservation programs (Rees and Stephenson 2014; Ribaudo and McCann 2012; McCann et al 2005). Consequently, many cost models do not include any transactions costs (e.g. Ribaudo, Savage and Aillery 2014) or assume a constant cost across all BMPs (Wainger et al 2013; Van Houtven et al 2012).

Similarly, watershed scale cost models typically assume constant and uniform costs for different BMPs. Yet, observed BMP adoption rates vary across producers and across BMP types, implying different opportunity costs of implementation. For instance, producers often adopt some types of BMPs without any external financial inducements, implying low farmer opportunity costs (Claassen et al 2014). Adoption of BMPs across farms is also uneven with some producers resistant to participating in any conservation programs (Fleming 2014; Benham et al 2007).

One relevant factor in examining the impacts of both transactions costs and differential adoption rates is whether nutrient loads from a given site are treated by one versus multiple BMPs. We refer to the latter as "stacked BMPs". Use of stacked BMPs involves a fundamental tradeoff: on the one hand, stacking practices together decreases removal effectiveness of the marginal practices; but stacking may also lower transactions costs by targeting willing

[13] In the context of conservation programs, transactions costs associated with program implementation include administration of environmental programs, communication and outreach, working with landowners to put conservation 'on the ground' (e.g. project planning, technical assistance, contracting, etc.), and monitoring conservation projects ex-post, enforcement activity, and program evaluation and reporting.

landowners and economizing on conservation planning. Also, stacking allows concentration of BMPs on high-load areas / landuses. Because of these tradeoffs, it is not clear *a priori* whether, and to what degree, stacked BMPs are cost-effective.

The objective of this paper is to examine the cost implications of including transactions costs and differential BMP costs and adoption rates associated with reducing nitrogen and phosphorus loads from agricultural sources in Virginia. The paper uses mathematical programming to estimate the minimum cost of achieving agricultural nutrient reductions under a number of different cost scenarios. Reflecting standard modelling practice, a baseline model estimates the minimum costs to achieve a given nitrogen and phosphorus load reduction delivered to the Chesapeake Bay assuming no transactions costs or differentiation across adopters. The baseline model varies unit implementation costs across three scenarios (low, medium and high costs). Next, transactions costs of implementing BMPs are introduced into the model. Transactions costs are based on estimated administration costs incurred in administering federal financial assistance programs and transactions costs vary by BMP type. Finally, we allow for three different types of adopters, distinguished by heterogeneous BMP implementation and transactions costs and maximum adoption rates for each type of adopter.

The total cost to achieve agricultural nutrient reduction goals under the transactions costs and adoption scenarios are compared to the baseline case to estimate the potential increase in costs associated with more plausible assumptions about transactions costs and differential adoption rates. Such information provides policy insight into the extent to which costs may be underestimated using conventional modelling assumptions and how the inclusion of transactions costs and heterogeneous adopters may affect cost-effective targeting of best management practices.

II. BMP Adoption Rates and Transactions costs

Economists have devoted considerable attention to estimating watershed scale costs to agriculture of meeting water quality objectives. In the Chesapeake Bay region, this literature includes estimating the total cost of implementing conventional voluntary programs with and without spatial targeting of financial incentives and estimating the cost-saving potential of trading nutrient control obligations with regulated sources (Schwartz 2010; Van Houtven et al. 2012; Wainger et al. 2013; Shortle et al 2014). These studies utilize cost estimation models that select among a suite of given agricultural BMPs. The cost coefficients for each BMP are typically assumed constant and based on the average per acre cost of installing or implementing (for management BMPs) the practice.

Studies on farmer behavior suggest considerable heterogeneity in BMP adoption rates and costs compared to what is typically reflected in cost models (e.g. Claassen, Cattaneo and Johansson 2008, Ducos and Dupraz 2006, Lichtenberg 2004). Adoption decisions can differ considerably across BMP types and can depend not only on economic factors but also on social factors such as family dynamics (Osmond et al 2012, Läpple and Kelley 2013, NRCS 2003). In general, producers voluntarily adopt management BMPs such as conservation tillage and cover crops at a much higher rate than structural BMPs such as riparian buffers or manure storage. Specific adoption rates for many structural BMPs typically fall below 10 percent without external financial assistance (Claassen et al 2014). For buffer practices, Claassen et al (2014) report 16 percent aggregate voluntary adoption without financial assistance (of which grassed waterways account for around 10 percent) and an additional 6 percent with financial assistance; while for soil conservation practices such as terraces and water and sediment basins, 9 percent of farms adopted voluntarily without assistance and additional 4 percent with financial assistance.

Producers also avoid implementing practices that require taking land out of production, such as riparian buffers (Osmond et al 2012).

By comparison, many types of crop management BMPs face lower up-front implementation costs and research suggests that many producers view these practices as low cost or net negative costs practices (Boyle 2006, McCann and Easter 2000). However, with the exception of conservation tillage, voluntary adoption of the most common management BMPs is not particularly high. Fleming (2014) reports results for adoption of agricultural management practices from a 2010 survey by the University of Maryland. Estimates of voluntary (unassisted) adoption on a per acre basis ranged from 20 percent for cover crops to 46 percent for conservation tillage. Boyle (2006) estimates that 60 percent of all farm cropland acreage in the United States was managed under some form of conservation tillage in 2004, while USDA's Natural Resource Conservation Service (2011) found that nearly 90 percent of cropland in the Bay region utilized some form of reduce tillage, most of which was likely implemented without external financial assistance.

Public financial incentive payment programs aim to increase adoption rates by paying for a share of estimated implementation costs. Additional financial inducements are likely to be needed to increase adoption for structural practices with higher upfront costs and for producers that have higher opportunity costs of adoption. While most research shows that the percentage of producers adopting BMPs with state or federal financial assistance is relatively low, participation is thought to be limited by both the availability of technical assistance and funding (Claassen et al. 2014; Osmond et al 2012). For certain types of management and structural practices the current level of financial assistance may also limit adoption (Osmond et al 2012). Benham et al.

(2007) report that while 81 percent of Virginia producers in the Chesapeake Bay adopted at least one BMP, only 31 percent have implemented conservation practices with cost-share assistance.

Cost studies also typically assume zero or constant administrative transactions costs of implementing BMPs. Transactions costs include public agency costs associated with promotion, implementation, and verification of conservation practices as well as information and contracting costs for the producer. The public and private transactions costs associated agricultural conservation, however, are generally poorly understood (McCann et al 2005). Consequently, researchers that look at the cost effectiveness of water quality programs may apply a zero or constant default value to every nonpoint source BMP applied. For example, Wainger et al (2013) apply transactions costs equal to 10 percent of implementation costs for agricultural BMPs while Van Houtven et al (2012) use a 38 percent "adjustment factor" when estimating costs of nutrient trading involving agricultural nonpoint sources. Recent work shows that public agency costs can represent a considerable share of total implementation costs (McCann et al 2005; Rees and Stephenson 2014). Public agency costs may differ across different types of conservation practices and be impacted significantly by program rules and procedures. Further, as additional levels of reductions are pursued, the incremental transactions costs of gaining the participation of reluctant or high cost producers would be expected to increase. Other research suggests that producer costs to gather and evaluate information on conservation practices might be relatively modest (McCann et al 2005, Groth 2008).

III. Cost Minimization Models and Scenarios

Three cost minimization models are developed to illustrate the cost implications of adoption rates and transactions costs on the minimum costs incurred to achieve a 20 percent load reduction for delivered total nitrogen and delivered total phosphorus from crop and pastureland.

The model does not account for the application of BMPs related to confined animal operations and use of manure as fertilizer.[14] The study area comprises approximately the Virginia portion of the Chesapeake Bay watershed and includes the James, Potomac, Rappahannock and York and Eastern Shore watersheds. The models were formulated as linear programming problems in GAMS.[15] Model specification follows Schwartz (2010), adapted as required.

A. Baseline model

The baseline model estimates the implementation costs of achieving specified nutrient reduction objectives in the study region without accounting for transactions costs or differential adoption rates. Three baseline scenarios were specified: *low*, *medium* and *high* implementation costs. Model specification is as follows:

Objective function:

$$\min_{x_{j,h,l}} \sum_{j} \sum_{h} \sum_{l \in F} x_{j,h,l} c_j \quad where\ l \in F\ if\ BMP\ system\ is\ feasible\ on\ landuse\ l \qquad (1)$$

s.t.

$$\sum_{j} \sum_{h} \sum_{l \in F} x_{j,h,l} r^{p}_{j,h,l} \quad \geq \alpha^{p} \sum_{h} \sum_{l} Baseline\ Load^{p}_{l,h} \quad \forall\, p \qquad (2)$$

$$\sum_{j \in J^L} x_{j,h,l} = AREA_{l,h} \quad \forall\, l \in F, h \qquad (3)$$

$$\sum_{j \in J^R} x_{j,h,l} \leq 0.05 AREA_{l,h} \quad \forall\, l \in F, h \qquad (4)$$

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14 That is, the models do not alter nutrient inputs except in the case of *enhanced nutrient management*. In particular, models do not alter the amount of manure entering the system.
15 General Algebraic Modelling Software. CONOPT solver used. See Appendix H for model documentation.

$$\sum_{j \in J^{LRC}} x_{j,h,l} \leq 0.25 CROPAREA_{l,h} \quad \forall\, l \in F, h \qquad (5)$$

$$\sum_{j \in J^{LRP}} x_{j,h,l} \leq 0.25 PASAREA_{l,h} \quad \forall\, l \in F, h \qquad (6)$$

$$x_{j,h,l} \geq 0 \qquad \forall\, j, h, l$$

Where:

$x_{j,h,l}$ acres of feasible BMP system *j* applied to landuse *l* in hydrogeomorphic region *h*

Indices:

J Set of systems of BMPs, applied to landuse *l* (56 BMP systems)

H Set of hydrogeomorphic regions (8 regions)

L Set of landuses (20 landuses; 14 eligible for BMP application)

F Set of landuses that are eligible to have BMPs applied to them (14 landuses)

J^R Subset of BMPs that include a riparian BMP (riparian BMPs are *riparian grass buffer (RGB)*, *riparian forest buffer (RFB)* and *livestock exclusion (LE)*)

J^L Subset of BMPs that is feasible to apply to landuse *l*

J^{LRC} *LRC - Land Retirement Constraint*: Subset of BMPs that apply the *land retirement (LR)*, *wetland restoration (WR)* or *RFB* BMPs to cropland landuses

Parameters:

c_j cost of implementing BMP system *j* (differs with scenario)

$r_{h,j}^{p}$ reduction factor for BMP system *j* implemented on landuse *l* in hydrogeomorphic region *h* for pollutant *p* (two pollutants: delivered Total Nitrogen and delivered Total Phosphorus) (see Appendix E for derivation of reduction factors)

α	target percentage reduction (the model specifies α = 0.2, i.e. 20% reduction target for both nitrogen and phosphorus)
$Baseline\ Load_{l,h}^{p}$	baseline load of pollutant *p* for landuse *l* in hydrogeomorphic region *h*
$AREA_{l,h}$	area of landuse *l* in hydrogeomorphic region *h*
$CROPAREA_{l,h}$	areas that are cropland
$PASAREA_{l,h}$	areas pastureland

The objective function (1) minimizes the cost of assigning BMP systems to all agricultural landuses in the study area. Equation (2) is the key constraint of the model, requiring reductions in delivered total nitrogen and total phosphorus to be at least 20 percent of baseline loads from agricultural landuses. Equation (3) requires the assignment of BMP systems to the entire study area, for the 14 landuses that are eligible to receive BMPs. Following Schwartz (2010), (3) holds with equality because untreated land is accounted for in the model as '*no treatment*' (*NT*). There are no costs or nutrient load reductions associated with *NT*, so this addition does not affect the model solution. The *NT* addition directly provides an estimate for the area that is *not* treated for each hydrogeomorphic-landuse combination. Equation (4) requires that BMP systems involving one or more riparian BMPs be applied to no more than 5 percent of applicable land. This assumption follows Palone and Todd (1998) and is used as a proxy for riparian area because data on the precise area of riparian land in each land-river segment and landuse is not available.

The *land retirement (LR)*, *wetland restoration (WR)* and tree planting *(TR)* BMPs each retire land from agricultural production.[16] Equations (5) and (6) restrict the total amount of land that is available to be retired under these BMPs to no more than 25 percent each of crop land and pasture land. Due to the effects on farm production possibilities that agricultural land retirement entails, it is considered unlikely that the bulk of working lands would be retired even if there were large nutrient load reductions. Further, large scale retirement of working agricultural lands would likely have general equilibrium effects (e.g. altering land prices) which would alter underlying input costs on which the model is based. Thus constraints (5) and (6) help ensure the model gives realistic results. Inclusion of such constraints is standard practice for such models in the literature, although exact parameters differ. For example, Shortle et al (2014) constrain land retirement BMPs, including riparian buffers, to 25 percent of applicable areas, and Wainger et al (2013) model various scenarios which include restriction of “land conversion” to 10 percent of farmland per land-river segment.

B. Data

The study region is divided into 8 hydrogeomorphic regions (HGMR) based on land physiography and rock type, following the Chesapeake Bay Watershed Model (CBWM), Phase 5.3.2 (USEPA, 2010). Hydrogeomorphic characteristics of the land to which a BMP is to be applied affect the nutrient load reduction effectiveness of the BMP (see Appendix D for maps of the study area by basin and hydrogeomorphic region).

[16] Riparian buffers also may take land out of production, but application of riparian BMPs is already restricted by equation (4).

Agricultural landuses as specified by the CBWM Phase 5.3.2 are available to be assigned a BMP system (forest and confined animal operations landuse areas are included in the model but are not available for BMP assignment). 'Landuses' are specified with reference to a particular 'land category' and nutrient management and tillage practices (for example, *cropland, high tillage, with manure*) reflecting the significantly different nutrient loading characteristics associated with tillage and nutrient management practices. Appendix D, table D.1 details the code and description and landuse type (cropland or grazing lands/pasture) for the landuses available for BMP assignment in the model.

All scenarios allow for the application of 13 agricultural BMPs: *cover crops*[17], *continuous no-till*, *enhanced nutrient management*, *decision agriculture*, *riparian grass buffers*, *riparian forest buffers*, *offstream watering*, *livestock exclusion fencing*, *land retirement*, *tree planting*, *wetland restoration*, *upland prescribed grazing* and *upland intensive rotational grazing*. Appendix D, table D.2 provides a short definition for each BMP type used in the model. The BMPs may all be applied singularly, and certain BMPs may be stacked together to treat the same area of land. In total, a set of 56 BMP systems are available to be applied; 13 single BMPs and 43 stacked systems. In specifying feasible stacked BMP systems we ensured BMPs were compatible with each other – that is, no systems employ mutually exclusive BMPs – and compatible in terms of the landuse they can be applied to, based on information from the CBWM.

Cross-indexing these BMP systems with the landuses they can feasibly be applied to yields a set of 345 unique BMP 'treatments' (i.e. BMP system *j* applied to landuse *l*). The unit of

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[17]Although in practice a multitude of cover crops are available, the model includes only one – *early drilled rye* without fall application of nutrients.

analysis in the model is this set of BMP treatments in each hydrogeomorphic region. This specification allows nutrient reduction potential of BMP systems to vary according to landuse and hydrogeomorphic region.

Implementation costs for each single BMP are provided in table 2.1. When two or more BMPs are stacked together in a system, implementation costs for each BMP are added. Reflecting the broad range of cost estimates available in the literature, for each BMP we specify low, medium and high unit implementation costs. Implementation cost estimates are annualized and include installation costs, annual maintenance costs over the BMP lifespan and annual land rental costs.

Table 2.1. Implementation costs (annualized $2010/acre)

BMPs	**Low**	**Medium**	**High**
Cover crops (early drilled rye)	27*	35	92*
Continuous no till	20	30	40
Decision Agriculture	13	21.5	30
Enhanced nutrient management	11.7*	19	37*
Land retirement	19	321.5	624
Livestock exclusion fencing	88	390.5	693
Offstream watering facilities	29.5*	32	32
Riparian forest buffer	98	500.5	903
Riparian grass buffer	44	338	632
Tree planting	56	448	840
Upland prescribed grazing	9	21	33
Upland intensive rotational grazing	53	73	93
Wetland restoration	318	602.5	887

*Implementation cost data from EPA BayFast and NRCS. All other implementation costs from Van Houtven et al (2012).

BMP performance data was taken from the Chesapeake Bay Commission (2012, Appendix B), with supplementary information from the Chesapeake Bay Phase 5.3 Community Watershed Model documentation (Date NA: Section 6) and Simpson and Weammert (2009). These sources specify, for each of the 13 BMPs, whether the BMP involves landuse change and/or an 'efficiency factor', the specific nature of landuse changes and the nutrient reduction efficiency factors, which may differ by HGMR (See Appendix E, table E.1). The methodology for calculating total load reduction factors is adapted from Chesapeake Bay Commission (2012, Appendix B) (See Appendix E).

C. Transactions Costs Model

The baseline model was expanded to include transactions costs as follows:

$$\min_{x_{j,h,l}} \sum_{j} \sum_{h} \sum_{l \in F} x_{j,h,l}(c_j + tc_j) \qquad (1a)$$

where tc_j is the unit transactions cost associated with BMP system *j*. All constraints remain the same as in the baseline scenarios. Because there are three levels of implementation costs (low, medium and high), and three levels of transactions costs (low, average, high), 9 scenarios were run to examine all possible combinations of implementation costs and transactions costs.

To account for the incremental transactions costs associated with additional BMP implementation, we derive agency costs of contracting for specific agricultural conservation projects through US Natural Resources Conservation Service (NRCS) financial assistance programs (Rees and Stephenson 2014). Extensive interviews with a NRCS District Conservationist provided estimates of hours spent on each stage of the NRCS conservation planning process, including inception (initial site visits), planning and application, plan approval, contracting, implementation, and certification. The time and effort spent by NRCS staff to implement BMPs varies by the type and complexity of the practice. NRCS staff grouped practices into three general types of contracts (simple, medium and complex) and estimated the level of technical expertise and planning required for each type. Low and high estimates of the typical hours required for each type of contract were provided.

The transactions costs estimates also account for failure of prospective projects during conservation planning process. Considerable staff time may be spent pursuing contracts that ultimately are not completed. For every successful contract resulting in 'conservation on the ground', approximately 2 inceptions occur that ultimately are not completed (Rees and Stephenson 2014). Using NRCS information about 'attrition rates' at specific points in the contracting timeline, we include the opportunity cost of agency staff time from uncompleted plans into BMP transactions cost estimates. Examples of each contract type are provided in table 2.2. We transformed the hour estimates into dollars per acre by assuming an average project size of 100 acres and a unit cost of $75 per hour (includes wages and overhead). Transactions costs estimates are only for program staff; in reality, transactions costs are also incurred by private actors – most importantly the landowner, but also in some cases third parties such as legal advisors and other technical experts. Also, estimates only include transactions costs of implementing BMPs and do not include any *ex post* monitoring or contract enforcement costs.

Table 2.2: Transactions costs by contract type ($2010/acre)*

Contract type	**Transactions costs**			**Examples**
	Low	***Average***	***High***	
Simple	$21	$25	$30	Land retirement, livestock exclusion fencing, riparian grass buffers, cover crops, continuous no-till
Moderate	$37	$44	$52	Decision agriculture, Offstream watering, riparian forest buffer, tree planting, upland prescribed grazing, *combinations of 2 simple BMPs*
Complex	$59	$70	$81	Upland intensive rotational grazing, wetland restoration, enhanced nutrient management, *combinations of 2 or more moderately complex BMPs*

* Data on staff time and attrition rates is available upon request from the authors.

Transactions costs were assigned for each of the 56 BMP systems. Annualized transactions costs were estimated using project lifespans and discounting used by Van Houtven et al (2012). Where a BMP system included two practices that had different time horizons, the longer time horizon was used. Annualized transactions costs for each BMP system included in the model are provided at Appendix F, table F.1.

D. Differential Adoption Rates Model

The differential adoption rates model ("adoption model") allows for cost heterogeneity by assuming three cost profiles or types, which are distinguished by having different implementation costs and transactions costs. To formulate this model we replaced the decision variable x_j with three separate variables; one for each cost type. We also assume further that there is a proportion of land on which no BMPs are placed, because there are some producers who do not adopt, and also producers who do adopt may not treat all available acres; this is incorporated into the model via upper limits on total adoption (see Table 2.3). Accordingly, the objective function (1) becomes:

$$\min_{lag_{j,h,l}, reg_{j,h,l}, good_{j,h,l}} \sum_{j} \sum_{h} \sum_{l \in F} \Big(a_{j,h,l}\big(c_j^{\,high} + tc_j^{\,high}\big) + b_{j,h,l}\big(c_j^{\,med} + tc_j^{\,avg}\big)$$

$$+ \, d_{j,h,l}\big(c_j^{\,low}\big)\Big) \qquad (1b)$$

where decision-making variables are:

$a_{j,h,l}$ is acres of BMP j assigned to landuse l for high cost type adopters in region h;

$b_{j,h,l}$ is acres of BMP j assigned to landuse l for medium cost type adopters in region h; and

$d_{j,h,l}$ is acres of BMP j assigned to landuse l for low cost type adopters in region .

Equations (2) through (4) are retained, *mutatis mutandis*. Equations (5) and (6) are replaced by the set of maximum adoption constraints, an example of which is given below. This further set of constraints restricts BMP application according to the type of adopter and BMP type. Equation (7) shows an example of this constraint for the *high cost* adoption type and BMP systems that contain the BMP continuous no-till (*j=CNT*).

$$\sum_{j \in J^{CNT}} a_{j,h,l} \leq \beta_{j,a} AREA^{CNT}{}_{l,h} \qquad \forall \; l \in F, h \qquad (7)$$

The parameter $AREA^{CNT}{}_{l,h}$ is calculated within the model as the sum of areas where it is feasible to apply *CNT*, either as a single BMP or stacked together with other permissible BMPs. The constraint requires that the sum of acreage containing the BMP *CNT* that is assigned to the high-cost type be at most $\beta_{j,a}$ percent of the applicable area. Table 2.3 provides the maximum adoption constraint percentages for each type, by BMP (for example, $\beta_{j,a}$ for *j=CNT* is 40%). The sum of adoption constraint percentages across cost types (low, medium, high) totals less than one hundred percent, reflecting the assumption that no BMP will be universally adopted (i.e. adopted on all applicable land) under any of the modelled scenarios.

Implementation costs and transactions costs were assigned for each cost type as follows:

- *low cost type*: this type reflects individuals who face relatively lower adoption costs and therefore adopt voluntarily, without financial assistance. This type is assigned *low* implementation costs and *zero* transactions costs.
- *medium cost type*: this type reflect individuals who face moderate adoption costs and are assumed to adopt with the aid of existing financial assistance. This type is assigned *medium* implementation costs and *average* transactions costs.
- *high cost type*: this type reflects individuals who are somewhat reluctant to adopt a specific BMP even with existing financial aid, because they perceive adoption costs to be high. This type is assigned *high* implementation costs and *high* transactions costs, and is assumed to adopt once sufficient public subsidies are provided.

Assumptions for the adoption rate constraints for each cost type, as well as the maximum adoption rate (determined by the rate of non-adoption) were drawn from the literature where available, and vary by BMP and by cost type (table 2.3). This reflects the reality that some BMPs are more readily adopted without cost share than others. For example, cover crops are often perceived to have additional benefits such as increasing soil organic matter (Fleming 2014), whereas enhanced nutrient management (which reduces fertilizer applications below agronomic recommendations) is generally perceived to increase yield risk and as such is more likely to be avoided by voluntary adopters (Baird, 2012).

Maximum adoption rates for the low cost type were based on estimates of the proportion of producers or acreage that adopt conservation practices without financial assistance. Data from Lichtenberger et al (2012) and Fleming (2014) informed the adoption rates for most BMPs for this type. Reflecting results from Benham (2007), which found that most famers had adopted at least one BMP, for most practices non-adoption is specified as 20 percent of the relevant available area. However, for certain practices such as enhanced nutrient management and those involving land retirement, a higher amount of non-adoption is specified, to better reflect a greater reluctance of producers to adopt practices which take land out of production or which are perceived to increase yield risk (Claassen, Cattaneo and Johansson 2008). Adoption rates for the medium and high cost types was calculated as equal residuals using [100% - %*non-adopt* - %*low cost type*]*0.5, for all BMPs except *livestock exclusion fencing* (LEX). For LEX, we used Chesapeake Bay data from Johnston (*pers. comm.*, 2015), which stated that by 2013, 86% of relevant degraded riparian land was fenced using financial assistance.

Table 2.3: Assumptions for adoption model: BMP implementation costs, transactions costs[†] (annualized \$2010/ac), and maximum adoption rates[‡] (%)

	Low cost type	**Medium cost type**	**High cost type**	**Non adopters**
Implementation cost (IC) & Transactions cost (TC)	*Low IC, No TC*	*Medium IC, Average TC*	*High IC, High TC*	*NA*
Cover Crops	\$27*, \$0 (12%)	\$35, \$27 (34%)	\$92*, \$32 (34%)	(20%)
Continuous No Till	\$20, \$0 (20%)	\$30, \$27 (30%)	\$40, \$32 (40%)	(20%)
Decision Agriculture	\$13, \$0 (10%)	\$21.5, \$48 (20%)	\$30, \$56 (20%)	(50%)
Enhanced Nutrient Management	\$11.70*, \$0 (0.1%)	\$19, \$75 (13%)	\$37*, \$87 (13%)	(75%)
Land Retirement	\$19, \$0 (1%)	\$321.5, \$4 (5%)	\$624, \$4 (5%)	(90%)
Livestock Exclusion Fencing	\$88, \$0 (4%)	\$390.5, \$4 (86%)	\$693, \$4 (0%)	(10%)
Off-stream Watering Facilities	\$29.5*, \$0 (20%)	\$32, \$6 (30%)	\$32, \$7 (30%)	(20%)
Riparian Forest Buffer	\$98, \$0 (7%)	\$500.5, \$5 (37%)	\$903, \$6 (37%)	(20%)
Riparian Grass Buffer	\$44, \$0 (14%)	\$338, \$3 (33%)	\$632, \$3 (33%)	(20%)
Tree Planting	\$56, \$0 (1%)	\$448, \$5 (4.5%)	\$840, \$6 (5%)	(90%)
Upland Prescribed Grazing	\$9, \$0 (10%)	\$21, \$48 (35%)	\$33, \$56 (35%)	(20%)
Upland Intensive Rotational Grazing	\$53, \$0 (0.1%)	\$73, \$75 (25%)	\$93, \$87 (25%)	(50%)
Wetland Restoration	\$318, \$0 (0.1%)	\$602.5, \$8 (1%)	\$887, \$9 (1%)	(98%)

*Implementation cost data from EPA BayFast and NRCS. All other implementation costs from Van Houtven et al (2012). †Transactions costs from Rees and Stephenson (2014), accounting for attrition, monetized using $75/hr wage and 100 acre average project size, annualized using a 7% discount rate and assumed practice life of: 1 year (CDR, CNT, DEC, EN, UGZ, UIGZ), 10 years (LR, OW, LE), and 15 years (RFB, RGB, WR, TR). ‡Adoption rate totals may not add to 100% due to rounding.

IV. Results

Table 2.4 compares the changes in both implementation costs and total costs for the 13 modelled scenarios.[18] Least cost achievement of the nutrient objectives in the baseline model (without transactions costs and unlimited adoption) was $170 million per year, with a low estimate of $34.7 million (scenario 1, low implementation costs (ICs)) to a high of $323 million annually (scenario 9, high ICs). Adding transactions costs increases in the cost of achieving the nutrient reduction objective by between 19 and 81 percent, depending on implementation cost assumptions. The wide range among these results demonstrates the uncertainty inherent in the identification of implementation costs, let alone trying to account for transactions costs and behavioral assumptions. Nevertheless, it is clear that addition of transactions costs substantially impacts total costs of achieving objectives.

[18] See Appendix J for detailed results.

Table 2.4: Aggregate annual costs and costs changes when transactions costs are included*

Implementation cost (IC) assumption	**Transactions Cost (TC) assumption**	**Scenario No.**	**IC ($m)**	**TC ($m)**	% increase in IC compared to No TC alternative	% increase in Total Cost compared to No TC alternative	TC as % of Total Costs
Low IC	No TC	1	35	-	-	-	-
	Low TC	2	42	15	21%	64%	26%
	Avg TC	3	42	18	21%	72%	30%
	High TC	4	42	21	21%	81%	33%
Medium IC	No TC	5	170	-	-	-	-
	Low TC	6	172	60	1%	37%	26%
	Avg TC	7	176	68	4%	44%	28%
	High TC	8	182	74	7%	50%	29%
High IC	No TC	9	323	-	-	-	-
	Low TC	10	324	62	0.3%	19%	16%
	Avg TC	11	324	75	0.3%	23%	19%
	High TC	12	326	85	0.9%	27%	21%
Adoption model	TC†	13	268	60	-	-	18%

* percentages are compared to the scenario with the same implementation costs assumptions, e.g. implementation costs for scenario 4 (Low IC, High TC) were 21% higher compared to scenario 1 (Low IC, No TC). †Low type: Low ICs, no TCs; Medium type: Med ICs, Avg TCs; High type: High ICs, High TCs.

Inclusion of transactions costs potentially affects total costs in two ways. First, total costs are directly increased because a new cost category is being added. The contribution of transactions costs to total costs, shown in the final column of table 2.4, ranges from 16 percent (scenario 10) to 33 percent (scenario 4). Unsurprisingly, transactions costs have the highest contribution when transactions costs are assumed to be high and implementation costs are low. The direct contribution of transactions costs was estimated to range from $60 to $85 million per year for the medium and high cost implementation cost scenarios (table 2.4). Transactions costs were only about a quarter of this amount for the low implementation cost scenarios because for these scenarios the majority of BMPs applied were low transaction cost practices (i.e. requiring "simple" contracts).

Secondly, total costs may be indirectly affected via higher implementation costs if including transactions costs alters the least cost allocation of BMPs, which could occur if transactions costs change the relative cost of nutrient removal across BMPs. It is apparent from the changes in implementation costs displayed in table 2.4 that this occurs particularly when *low* implementation costs are assumed. Implementation costs rise by around 20 percent when transactions costs are included in *low* implementation cost scenarios (2 to 4). For these scenarios, *upland prescribed grazing* (UGZ) (administered singly) was not selected in the least cost solution. With the addition of transactions costs the least-cost allocation has moved away from prescribed grazing (despite its very low implementation costs in these scenarios) and towards practices such as *tree planting*, *cover crops* and *decision agriculture*. Aggregate transactions costs are relatively low compared to other transactions costs scenarios in scenarios 2 – 4 since *tree planting*, which in these cases accounts for the highest acreage assigned to a BMP system, has very low transactions costs per acre. Scenarios 2 – 4 show that inclusion of transactions costs has the potential to significantly change the lease cost ordering of BMPs in cases where the magnitude of transactions costs is sufficiently high relative to implementation costs.

In contrast, when starting from a base of assumed medium (except scenario 8) or high implementation costs, transactions costs are generally not large enough to cause significant changes to BMP cost-effectiveness rankings. These results suggest that overall for scenarios assuming medium or high implementation costs, changes to total costs are largely the result of adding a new cost category, rather than indirectly via changes in implementation costs due to a different distribution of BMPs.

The inclusion of differential adoption rates also substantially impacted costs. The total costs for the adoption model (scenario 13) ($328 million) fall only a little below the high implementation cost scenarios estimated (Scenarios 9 through 12), and are considerably higher than the scenarios that assume medium implementation costs. These findings suggest that cost estimates based on plausible adoption rates across different types of producers can be substantially higher than mean estimates that are typically reported. Transactions costs constitute 18 percent of total costs in scenario 13 (adoption model); one of the lowest contributions across all scenarios. This result arises because the *low cost* type is assigned zero transactions costs (and relatively generous low-cost adoption rates are specified for some BMPs (e.g. *continuous no till*)), and therefore any BMP acreage assignment to this type consists solely of implementation costs. The distribution of costs across types in the adoption model is examined in further detail below.

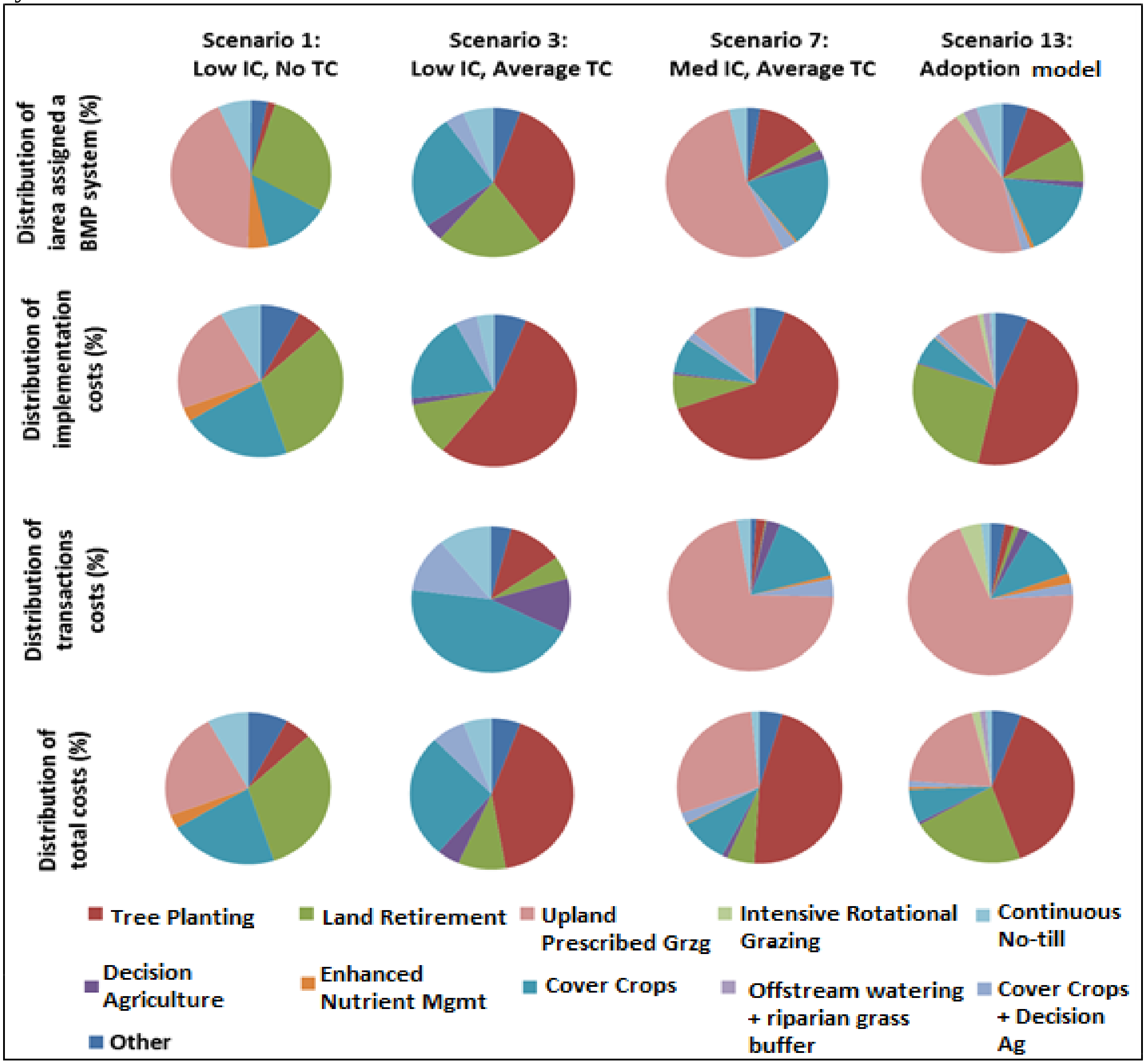
A. Area and cost assignment: results by individual BMP systems

Results by individual BMP system indicate that BMP systems that contribute most to transactions costs differ from those accounting for the majority of implementation costs (Appendix G, table G.1). Figure 2.1 shows the distribution of area assigned a BMP system and costs across BMP types, for selected scenarios. Although the ranking of BMP systems by area assigned is fairly stable across scenarios (with the exception of scenarios 2 to 4), the acreage and level of implementation and transactions costs of specific BMP systems varies across scenarios.

From an area perspective, *upland prescribed grazing* (UGZ) accounts for the largest amount of acreage assigned a BMP system in all scenarios except scenarios 2, 3, and 4. Further, as is evident in the third row of Figure 2.1, transactions costs associated with this BMP system are substantially higher than those of any other, for scenarios where UGZ is utilized. UGZ was identified by NRCS as being a "moderate" contract type, even though the time horizon for this BMP is only one year. This means that this BMP is among the most costly in terms of public transactions costs incurred. However, because this BMP has a low per acre implementation cost compared to other BMPs it does not account for the largest share of implementation costs.

BMPs that retire working lands – *tree planting* and *land retirement* – display an opposite pattern. These BMPs are relatively costly in terms of implementation costs but not in terms of transactions costs; hence, their share of implementation costs is much higher than either their share of assigned acreage or transactions costs. These results suggest that approximating transactions costs as a fixed proportion of implementation costs may not be appropriate. Currently implementation costs and technical assistance are often viewed as varying according to the specific practices being implemented; this analysis indicates that the transactions costs of administering financial incentive programs should be treated in the same manner.

Figure 2.1. Distribution of area, implementation costs, transactions costs and total costs, by BMP system for selected scenarios.



B. Single versus stacked BMPs

The role and importance of stacked BMP systems versus single BMPs depends on the scenario analyzed. It was hypothesized that inclusion of transactions costs could lead to an increased role for stacked BMPs if the gains in terms of streamlining transactions costs outweighed the decreased nutrient reduction capacity of the stacked practices. The scenario results indicate that this did occur for the *low implementation cost* scenarios (scenarios 2-4), where inclusion of transactions costs caused substantial changes in the least-cost assignment of BMPs. Area assigned to single BMPs fell by 46 percent when transactions costs were included, while area assigned to ‘stacked’ BMPs increased by approximately 70 percent (albeit from a low base), and these changes were stable regardless of whether transactions costs were assumed to be low, medium or high (table 2.5).

For transactions costs scenarios assuming medium and high implementation costs (scenarios 6-8, 10-12), as well as for the adoption scenario (scenario 13), inclusion of transactions costs did not significantly alter the mix of BMP systems between BMPs applied singularly versus those which stacked multiple BMPs together. The proportion of assigned acreage allocated to stacked BMP systems ranged between 5 and 7 percent of total area assigned in these scenarios.

Table 2.5: Change in area assignment when transactions costs are included in model

	Scenario No.	Area assigned a BMP system (acres)	*% Δ in total area**	Area – single BMPs ('000 acres)	*% Δ in single BMP area**	Area – multiple BMP systems ('000 acres)	*% Δ in multiple BMP area**
Low IC	1	2,058	-	2,001	-	56	-
	2	1,172	*-43%*	1,077	*-46%*	95	*70%*
	3	1,172	*-43%*	1,077	*-46%*	95	*70%*
	4	1,172	*-43%*	1,077	*-46%*	95	*69%*
Medium	5	2,042	-	1,940	-	102	-
IC	6	2,006	*-2%*	1,906	*-2%*	100	*-2%*
	7	1,908	*-7%*	1,807	*-7%*	100	*-2%*
	8	1,819	*-11%*	1,719	*-11%*	100	*-2%*
High IC	9	2,034	-	1,931	-	102	-
	10	2,034	*0%*	1,929	*0%*	105	*2%*
	11	2,035	*0%*	1,930	*0%*	105	*2%*
	12	2,006	*-1%*	1,902	*-2%*	105	*2%*
Adoption model	13	2,103	-	1,951	-	152	-

* percentages are compared to the scenario with the same implementation costs assumptions, e.g. area of single BMP implemented for scenario 4 (Low IC, High TC) was 46% lower compared to scenario 1 (Low IC, No TC).

C. Adoption scenarios: results by type

The adoption scenarios differ from the baseline and transactions costs scenarios in several ways: not only are implementation costs and transactions costs allowed to vary across types (meaning that the adoption scenarios mix elements of several earlier scenarios), but additional constraints on areas available for BMP placement vary both across type and BMP system.

One important dimension of the adoption model is how BMP systems – and therefore costs – are allocated across types. For each BMP, the low-cost type has an obvious cost advantage, but on the other hand has the most restricted available area (refer table 2.3 in previous section). BMPs assigned to the low-cost type accounted for 20% and 25%, respectively, of P and N reductions, but only 6% of implementation costs and 0% of transactions costs (due to the assumption of zero transactions costs for this type).

In contrast, the high-cost type disproportionately contributes to both implementation and transactions costs. As shown in Figure 2.2, despite accounting for a considerably lower proportion of nutrient reductions than the medium-cost type, implementation and transactions costs are roughly equal for the two types, reflecting higher marginal implementation and transactions costs for the high-cost type.

Figure 2.2: Adoption model: nutrient reductions and costs by adopter type

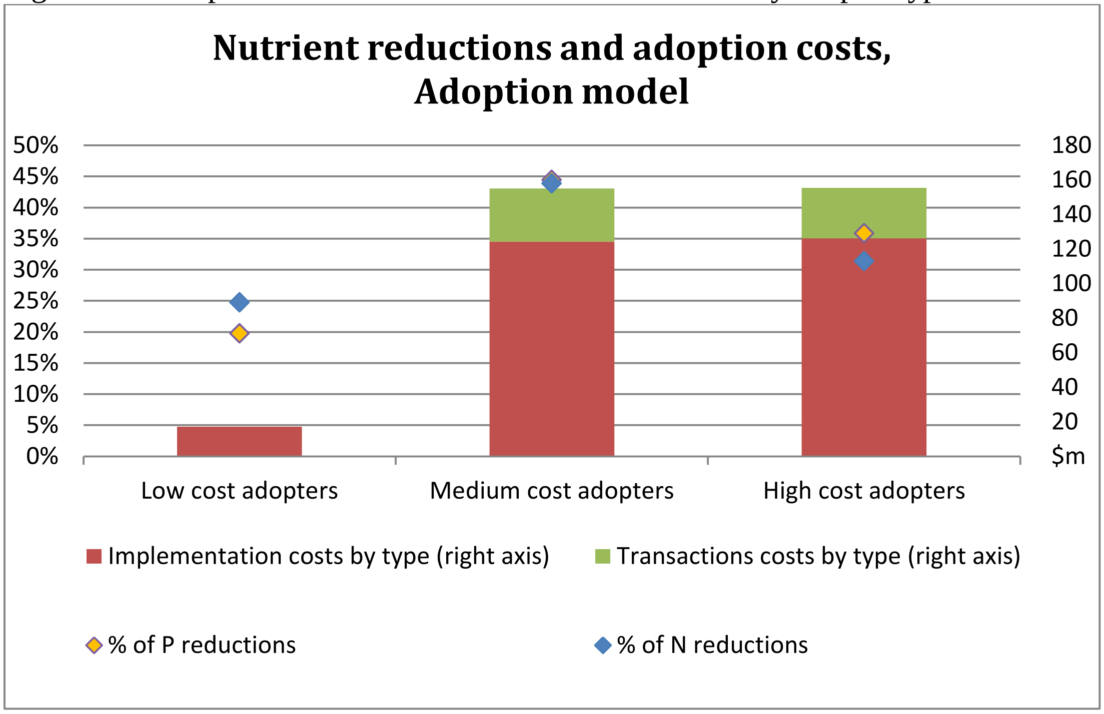


Table 2.6 shows the total area assigned a BMP system for each type for the adoption scenario, and a breakdown of this total area into systems containing a single BMP versus those containing multiple stacked BMPs (see Appendix G, table G.2 for area allocated to specific BMPs by adoption type). Several points are noteworthy here. First is that the aggregate area that is assigned any BMP system is, at 2.1 million acres, around 5 percent higher than the highest area assigned in previous scenarios. Accounting for adoption constraints results in BMPs being applied to a greater amount of land because the adoption constraints effectively limit the amount of land available to the most cost-effective BMPs.

Secondly, as expected, a preference is evident for assigning BMPs to the low-cost adopter type: although constraints for the low-cost type allow at most 20 percent of the relevant available area to be assigned to that type (and usually less than this for most BMPs), area assigned to the low-cost type accounts for 23 percent of assigned acreage.

Thirdly, assignment of BMP systems involving two or more “stacked” BMPs, while only accounting for around 8 percent of the overall acres assigned, is concentrated on the low-cost type: 60 percent of the stacked BMP systems occurring in the solution are assigned to the low-cost type, with stacked BMPs accounting for around 20 percent of low-cost type acreage. Conversely, high-cost types are almost exclusively assigned single BMP systems. The two most common stacked BMP systems are *offstream watering* paired with *riparian grass buffers* (applied to grazing lands), and *cover crops* paired with *decision agriculture* (applied to croplands). Area assigned to stacked BMPs in the adoption rate model was around 50 percent higher than in the baseline and transactions costs models.

Table 2.6: Area results for adoption model scenario, by type

	Low cost type	**Medium cost type**	**High cost type**	**Total**
Total area assigned a BMP system (‘000 acres)	488	931	684	2,103
% of total assigned area by type	*23%*	*44%*	*33%*	*100%*
-Area single BMP system (‘000 acres)	396	892	662	1,951
-Area "stacked" BMP system (‘000 acres)	92	39	21	152
% of single BMP area by type	*20%*	*46%*	*34%*	*100%*
% of stacked BMP area by type	*60%*	*25%*	*14%*	*100%*

Analysis of which adoption constraints are binding in the adoption model sheds light on the role that these constraints have on the least cost allocation of BMPs. For *upland prescribed grazing*, constraints were binding in all cases, indicating that this practice is relatively cost-effective even for high-cost adopters with transactions costs, and that the assumed maximum adoption rates *do* alter the least cost solution. For working land retirement BMPs (*tree planting* and *land retirement*), constraints are binding for the low-cost type adopter in almost all cases, but less so for the medium-cost and high-cost types. Shadow prices of binding land retirement constraints indicate that retirement of working lands is in many cases still more "desirable" in terms of cost-effectiveness than other available BMPs (see Appendix 2G).

In contrast, adoption constraints for the crop management practices *decision agriculture* and *enhanced nutrient management* were generally not binding on any type, despite the fact that these constraints were relatively stricter (a greater proportion of non-adoption was assumed). This indicates that these practices are simply not cost-effective in these scenarios, rather than being constrained by adoption rate assumptions. Constraints for BMP systems involving *continuous no-till* were binding for the low- and medium-cost types in the upland hydrogeomorphic regions (across all relevant landuses) but not in the coastal plain.

An important caveat to the results from the adoption model is that adoption constraints are not necessarily static in reality: in formulating this model we acknowledge that additional education and extension could facilitate lowering perceived opportunity costs of BMP adoption, thereby changing the distribution of types. For example, if investments in education or extension required to change types from high-cost to medium-cost are less than the marginal cost of securing nutrient reductions via high-cost type adopters, such investment could serve to lower the total costs of achieving nutrient obligations.

V. Conclusion

Results from the modelled scenarios help shed light on the role of transactions costs and cost heterogeneity (modelled using differential adoption types) on the distribution and magnitude of costs to achieve the specified nutrient targets. The simplest and perhaps most important result is that inclusion of transactions costs *does* affect total cost estimates by a non-trivial amount; on average total costs increased by 44 percent, but could increase anywhere between 19 and 81 percent depending on the scenario analyzed. Given that the estimates of transactions costs included in the model covered only the *public* costs of implementing conservation contracts and omitted other important costs such as those accruing to private actors and the public costs of administering programs, as well as ex-post costs such as monitoring, evaluation and enforcement, the contribution of transactions costs as presented here should be viewed as a lower bound.

Additionally, we showed that the magnitude of transactions costs generally is not sufficiently high to cause substantial changes in the cost-effective combinations of BMPs relative to the no-transactions costs baseline, except in the cases where low implementation costs are assumed. This suggests that the contribution of transactions costs to total costs is primarily related to "adding on" of another cost, rather than indirectly via changing the mix of practices in the least cost solution.

The results suggest a modest, targeted role for stacked BMP systems on land where adoption costs – both implementation costs and transactions costs – are lowest, a finding which complements previous work by Shortle et al (2014) that shows that spatial targeting of BMPs to areas where BMPs have greater nutrient reduction impacts can result in substantial cost savings. Widespread adoption of stacked BMPs does not appear to be a cost-effective method of securing nutrient reductions relative to single BMP alternatives, given the assumptions of the models. Inclusion of transactions costs shifted the selection of BMPs somewhat toward increased stacking in the *low implementation costs* case. Additionally, the adoption rate scenario showed that stacked BMPs accounted for a significant proportion of acreage for the low cost type.

Analysis of the distribution of different costs across BMP systems shows that those BMPs that account for the most implementation costs do not necessarily account for the most transactions costs (and vice versa). In particular, it suggests that transactions costs should be acknowledged to vary with the type of practices being implemented, rather than being approximated as either a fixed amount or a fixed proportion of implementation costs.

Finally, allowing for different types of adopters allows for a more realistic assessment of potential costs. Acknowledging different opportunity costs of BMP adoption and the limits to adoption rates in voluntary programs can significantly drive up costs relative to conventional model estimates. In addition, this analysis highlights the disproportionate costs associated with achieving nutrient reductions via high-cost adopters, and suggests there may be a role for education or extension to assist landholders to lower opportunity costs of participating in conservation.

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Appendices – Chapter 1

Appendix A – Supporting documentation for VDEQ site visit hours and costs

Table A.1: VDEQ: Staff costs for site visits, permanent phosphorus credits from land conversion

Project (Nutrient Bank)	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 (Hrs)/ Credit [b]	$5.93	$39.52	$4.45	$40.51	$4.45	**$18.97**
Staff cost (hrs per project) [c]	$516	$790	$485	$689	$294	**$554.80**

Source: Diane Beyer, Virginia Dept. of Environmental Quality

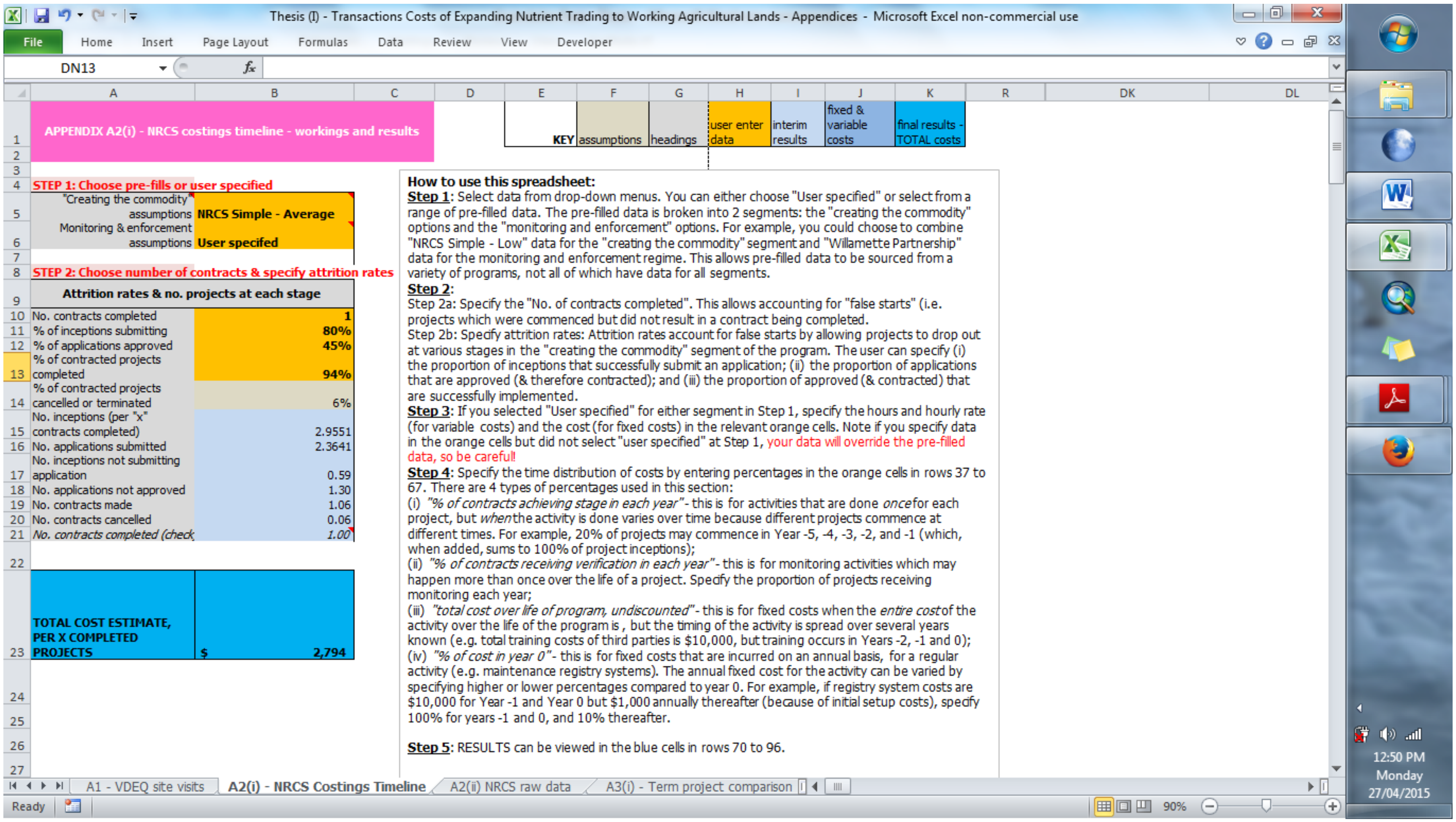
[a] (Total Hrs/#P credits)

[b] Based on $38 ES2 + 30% Admin ($49.40)

[c] generated by multiplying staff cost (hrs per credit)

Appendix B – Supporting documentation for NRCS timeline costings

Table B.1: NRCS costings timeline - workings and results
(screenshots of EXCEL worksheet)



Thesis (I) - Transactions Costs of Expanding Nutrient Trading to Working Agricultural Lands - Appendices - Microsoft Excel non-commercial use

APPENDIX A2(i) - NRCS costings timeline - workings and results

KEY: assumptions | headings | user enter data | interim results | fixed & variable costs | final results - TOTAL costs

STEP 1: Choose pre-fills or user specified

"Creating the commodity" assumptions	NRCS Simple - Average
Monitoring & enforcement assumptions	User specifed

STEP 2: Choose number of contracts & specify attrition rates

Attrition rates & no. projects at each stage	
No. contracts completed	1
% of inceptions submitting	80%
% of applications approved	45%
% of contracted projects completed	94%
% of contracted projects cancelled or terminated	6%
No. inceptions (per "x" contracts completed)	2.9551
No. applications submitted	2.3641
No. inceptions not submitting application	0.59
No. applications not approved	1.30
No. contracts made	1.06
No. contracts cancelled	0.06
No. contracts completed (check	*1.00*

TOTAL COST ESTIMATE, PER X COMPLETED PROJECTS	$ 2,794

How to use this spreadsheet:

Step 1: Select data from drop-down menus. You can either choose "User specified" or select from a range of pre-filled data. The pre-filled data is broken into 2 segments: the "creating the commodity" options and the "monitoring and enforcement" options. For example, you could choose to combine "NRCS Simple - Low" data for the "creating the commodity" segment and "Willamette Partnership" data for the monitoring and enforcement regime. This allows pre-filled data to be sourced from a variety of programs, not all of which have data for all segments.

Step 2:
Step 2a: Specify the "No. of contracts completed". This allows accounting for "false starts" (i.e. projects which were commenced but did not result in a contract being completed.
Step 2b: Specify attrition rates: Attrition rates account for false starts by allowing projects to drop out at various stages in the "creating the commodity" segment of the program. The user can specify (i) the proportion of inceptions that successfully submit an application; (ii) the proportion of applications that are approved (& therefore contracted); and (iii) the proportion of approved (& contracted) that are successfully implemented.

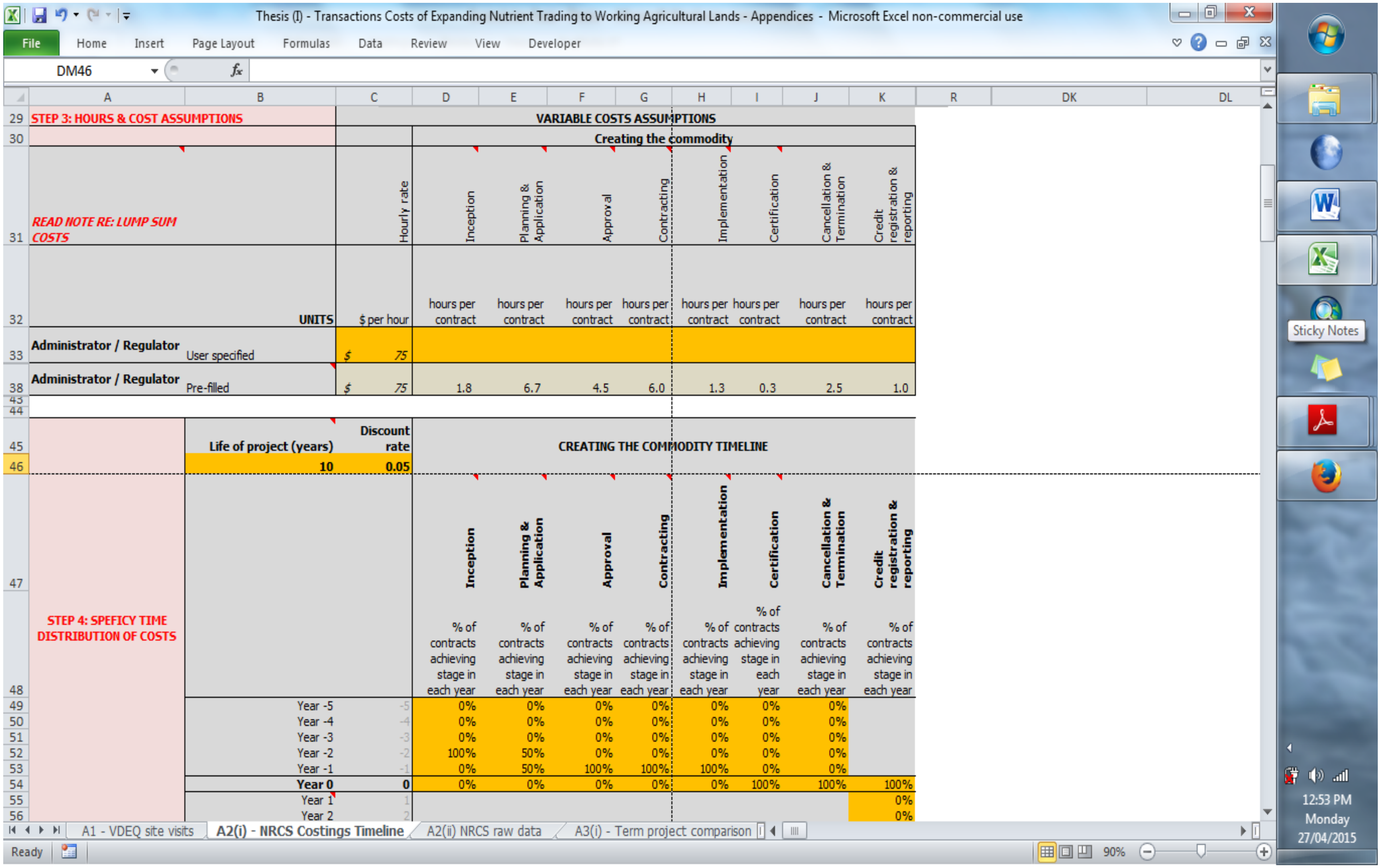
Step 3: If you selected "User specified" for either segment in Step 1, specify the hours and hourly rate (for variable costs) and the cost (for fixed costs) in the relevant orange cells. Note if you specify data in the orange cells but did not select "user specified" at Step 1, your data will override the pre-filled data, so be careful!

Step 4: Specify the time distribution of costs by entering percentages in the orange cells in rows 37 to 67. There are 4 types of percentages used in this section:
(i) *"% of contracts achieving stage in each year"* - this is for activities that are done *once* for each project, but *when* the activity is done varies over time because different projects commence at different times. For example, 20% of projects may commence in Year -5, -4, -3, -2, and -1 (which, when added, sums to 100% of project inceptions);
(ii) *"% of contracts receiving verification in each year"* - this is for monitoring activities which may happen more than once over the life of a project. Specify the proportion of projects receiving monitoring each year;
(iii) *"total cost over life of program, undiscounted"* - this is for fixed costs when the *entire cost* of the activity over the life of the program is , but the timing of the activity is spread over several years known (e.g. total training costs of third parties is $10,000, but training occurs in Years -2, -1 and 0);
(iv) *"% of cost in year 0"* - this is for fixed costs that are incurred on an annual basis, for a regular activity (e.g. maintenance registry systems). The annual fixed cost for the activity can be varied by specifying higher or lower percentages compared to year 0. For example, if registry system costs are $10,000 for Year -1 and Year 0 but $1,000 annually thereafter (because of initial setup costs), specify 100% for years -1 and 0, and 10% thereafter.

Step 5: RESULTS can be viewed in the blue cells in rows 70 to 96.

A1 - VDEQ site visits | A2(i) - NRCS Costings Timeline | A2(ii) NRCS raw data | A3(i) - Term project comparison

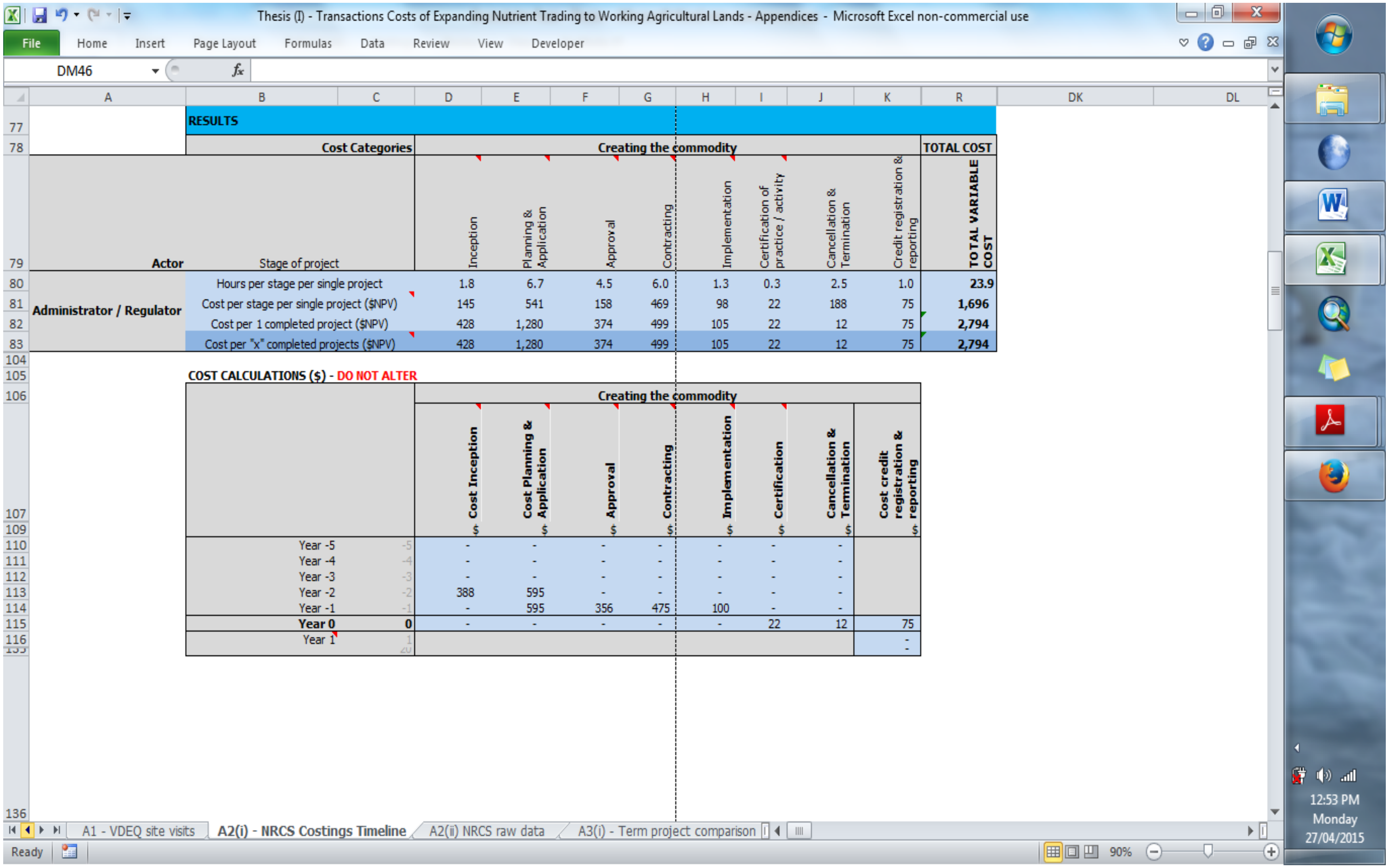
(1 of 4)



	A	B	C	D	E	F	G	H	I	J	K
29	STEP 3: HOURS & COST ASSUMPTIONS		VARIABLE COSTS ASSUMPTIONS								
30				Creating the commodity							
31	READ NOTE RE: LUMP SUM COSTS		Hourly rate	Inception	Planning & Application	Approval	Contracting	Implementation	Certification	Cancellation & Termination	Credit registration & reporting
32		UNITS	$ per hour	hours per contract	hours per contract	hours per contract	hours per contract	hours per contract	hours per contract	hours per contract	hours per contract
33	Administrator / Regulator	User specified	$ 75								
38	Administrator / Regulator	Pre-filled	$ 75	1.8	6.7	4.5	6.0	1.3	0.3	2.5	1.0

	A	B	C	D	E	F	G	H	I	J	K
45		Life of project (years)	Discount rate	CREATING THE COMMODITY TIMELINE							
46		10	0.05								
47				Inception	Planning & Application	Approval	Contracting	Implementation	Certification	Cancellation & Termination	Credit registration & reporting
48	STEP 4: SPEFICY TIME DISTRIBUTION OF COSTS			% of contracts achieving stage in each year	% of contracts achieving stage in each year	% of contracts achieving stage in each year	% of contracts achieving stage in each year	% of contracts achieving stage in each year	% of contracts achieving stage in each year	% of contracts achieving stage in each year	% of contracts achieving stage in each year
49		Year -5	-5	0%	0%	0%	0%	0%	0%	0%	
50		Year -4	-4	0%	0%	0%	0%	0%	0%	0%	
51		Year -3	-3	0%	0%	0%	0%	0%	0%	0%	
52		Year -2	-2	100%	50%	0%	0%	0%	0%	0%	
53		Year -1	-1	0%	50%	100%	100%	100%	0%	0%	
54		Year 0	0	0%	0%	0%	0%	0%	100%	100%	100%
55		Year 1	1								0%
56		Year 2	2								0%

(2 of 4)



RESULTS

Actor	Cost Categories / Stage of project	Inception	Planning & Application	Approval	Contracting	Implementation	Certification of practice / activity	Cancellation & Termination	Credit registration & reporting	TOTAL COST: TOTAL VARIABLE COST
		Creating the commodity								
Administrator / Regulator	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 ($NPV)	145	541	158	469	98	22	188	75	**1,696**
	Cost per 1 completed project ($NPV)	428	1,280	374	499	105	22	12	75	**2,794**
	Cost per "x" completed projects ($NPV)	428	1,280	374	499	105	22	12	75	**2,794**

COST CALCULATIONS ($) - DO NOT ALTER

		Cost Inception $	Cost Planning & Application $	Approval $	Contracting $	Implementation $	Certification $	Cancellation & Termination $	Cost credit registration & reporting $
		Creating the commodity							
Year -5	-5	-	-	-	-	-	-	-	
Year -4	-4	-	-	-	-	-	-	-	
Year -3	-3	-	-	-	-	-	-	-	
Year -2	-2	388	595	-	-	-	-	-	
Year -1	-1	-	595	356	475	100	-	-	
Year 0	**0**	-	-	-	-	-	22	12	75
Year 1	1								-

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DISCOUNTED COST CALCULATION ($NPV YEAR 0) - DO NOT ALTER

Row			Discounted cost Inception ($NPV)	Discounted cost Planning & Application ($NPV)	Discounted cost Approval ($NPV)	Discounted cost Contracting ($NPV)	Discounted cost Implementation ($NPV)	Discounted cost Certification ($NPV)	Discounted cost Cancellation & Termination ($NPV)	Discounted cost credit registration & reporting ($NPV)
138			Creating the commodity							
142	**TOTAL NPV (Year 0) per stage**		**428**	**1,280**	**374**	**499**	**105**	**22**	**12**	**75**
143	Year -5	-5	-	-	-	-	-	-	-	
144	Year -4	-4	-	-	-	-	-	-	-	
145	Year -3	-3	-	-	-	-	-	-	-	
146	Year -2	-2	428	656	-	-	-	-	-	
147	Year -1	-1	-	624	374	499	105	-	-	
148	**Year 0**	**0**	-	-	-	-	-	**22**	**12**	**75**
149	Year 1	1								-
150	Year 2	2								-
168		20								-

HOURS & COST ASSUMPTIONS

NOTE RE: LUMP SUM COSTS

Row		UNITS		Hourly rate ($ per hour)	Inception (hours per contract)	Planning & Application (hours per contract)	Approval (hours per contract)	Contracting (hours per contract)	Implementation (hours per contract)	Certification (hours per contract)	Cancellation & Termination (hours per contract)	Credit registration & reporting (hours per contract)
175				COSTS ASSUMPTIONS - hours and unit wage								
178		*User specified*	$	*75*	-	-	-	-	-	-	-	-
179		NRCS Simple - Low	$	*75*	1.50	5.50	3.67	5.17	1.00	0.25	*2.50*	*1.00*
180		NRCS Simple - High	$	*75*	2.00	7.92	5.25	6.75	1.50	0.33	*2.50*	*1.00*
181	**Administrator / Regulator**	NRCS Simple - Average	$	*75*	1.75	6.71	4.46	5.96	1.25	0.29	*2.50*	*1.00*
182		NRCS Moderate - Low	$	*75*	1.50	7.83	3.92	8.25	12.00	0.50	*2.50*	*1.00*
183		NRCS Moderate - High	$	*75*	2.00	11.50	5.50	11.92	16.00	0.50	*2.50*	*1.00*
184		NRCS Moderate - Average	$	*75*	1.75	9.67	4.71	10.08	14.00	0.50	*2.50*	*1.00*
185		NRCS Complex - Low	$	*75*	1.50	12.83	4.42	13.00	22.00	2.00	*2.50*	*1.00*
186		NRCS Complex - High	$	*75*	2.00	17.75	7.00	17.58	29.00	3.00	*2.50*	*1.00*
187		NRCS Complex - Average	$	*75*	1.75	15.29	5.71	15.29	25.50	2.50	*2.50*	*1.00*

A1 - VDEQ site visits | **A2(i) - NRCS Costings Timeline** | A2(ii) NRCS raw data | A3(i) - Term project comparison

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Table B.2: NRCS raw data

	Contract type - estimate type (low, high, average)	Hours: Simple - Low	Simple - High	Simple - Average	Moderate - Low	Moderate - High	Moderate - Average	Complex - Low	Complex - High	Complex - Average
NRCS Checklist Phase 1 - Accepting applications	*Initial site visit*	1.5	2	1.8	1.5	2	1.8	1.5	2	1.8
	Applicant has fully and properly completed a program application (NRCS-CPA-1200)	0.3	0.5	0.4	0.3	0.5	0.4	0.3	0.5	0.4
	Application has been entered into ProTracts	0.3	0.5	0.4	0.3	0.5	0.4	0.3	0.5	0.4
	NRCS representative has reviewed the Appendix with the applicant with special attention to sections 1, 3, 11 & 12	0.5	0.8	0.6	0.5	0.8	0.6	0.5	0.8	0.6
	Applicant has signed and been given a copy of the Appendix	0.3	0.5	0.4	0.3	0.5	0.4	0.3	0.5	0.4
	Applicant has been informed of their tax liability for NRCS payments	0.3	0.5	0.4	0.3	0.5	0.4	0.3	0.5	0.4
NRCS Checklist Phase 2 - Plan development	*Interim / Planning site visit*	2.0	3.0	2.5	2.0	3.0	2.5	2.0	3.0	2.5
	A natural resource concern has been identified and documented on the NRCS-CPA-52	0.5	1.0	0.8	1.5	2.0	1.8	3.0	4.0	3.5
	Conservation Plan has been developed for the resource concerns being addressed	1.0	1.0	1.0	2.0	3.0	2.5	5.0	6.0	5.5
	Cost estimate has been developed and entered into ProTracts	0.2	0.2	0.2	0.5	0.8	0.6	1.0	2.0	1.5
NRCS Checklist Phase 3 - Eligibility	Copy of the Producer Farm Data Report has been placed in file	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	Applicant is in compliance with the Food Security Act of 1985 as Amended	1.0	2.0	1.5	1.0	2.0	1.5	1.0	2.0	1.5
	For *legal entities*, CCC-901 or CCC-902 Members information has been completed and Proof of Signature Authority has been obtained	0.5	1.0	0.8	0.5	1.0	0.8	0.5	1.0	0.8
	If applicable, notarized Power of Attorney on file (FSA-211/FSA-211A)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
NRCS Checklist Phase 3 – Eligibility	For land not owned by the applicant, permission has been obtained from the landowner to install structural practices (practice lifespan >=2 yrs)	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3

(*cont'd*)	If applicable, a copy of the forest management plan has been obtained.	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	Applicant meets "other eligibility" requirements	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	If applicable, certified organic producers must provide a copy of their organic system plan. Producers transitioning to organic have provided the name of their certifying organic agent	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	Application's status has been changed to "Eligible" in ProTracts	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
NRCS Checklist Phase 4 - Ranking Eligible Applications	Application has been ranked	0.3	0.3	0.3	0.5	0.5	0.5	1.0	2.0	1.5
	Applicant has received a copy of the ranking results	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
NRCS Checklist Phase 5 - Final contract development	Applicant has been notified via a ProTracts generated letter that their application has been selected for funding.	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	$150,000+ contracts have been sent to the RAC for approval	NA	NA		2	3	2.5	4	5	4.5
	Applicant has provided electronic banking information on Form SF-1199A	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	Electronic banking information has been entered into ProTracts and a Vendor Cod has been requested.	0.25	0.25	0.3	0.25	0.25	0.3	0.25	0.25	0.3
	DUNS number has been entered into ProTracts, if applicable; and the applicant has been notified that and active CCR registration is required for all payments	1	2	1.5	1	2	1.5	1	2	1.5
	Finalize the CPC conservation plan schedule (Form NRCS-CPA-1155) via Toolkit and the Toolkit contracting wizard	0.3	0.3	0.3	0.5	0.8	0.6	1.0	2.0	1.5
NRCS Checklist Phase 5 - Final contract development (*cont'd*)	Upload the contract into ProTracts	0.2	0.3	0.2	0.3	0.3	0.3	0.5	0.8	0.6
	Change the status of the application for "Pre-Approved" to "Approved"	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	Pring form NRCS-CPA-1202 and the CPC Appendix. Obtain appropriate signatures on contract	0.8	1.0	0.9	0.8	1.0	0.9	0.8	1.0	0.9

	Enter the signature dates for the NRCS-CPA-1202 and CPC Appendix into ProTracts	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Commit funds by electronic signature of the NRCS Approving Official (Assistant State Conservatinoist or their designee) in ProTracts	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	NRCS has provided the participant of all relevant signed and dated documents following CPC approval	1.3	1.3	1.3	2.0	3.0	2.5	4.0	5.0	4.5
Implementation phase	*Pre-construction meeting*	0.5	1.0	0.8	2.0	3.0	2.5	3.0	4.0	3.5
	Engineering designs	0.0	0.0	0.0	8.0	10.0	9.0	15.0	20.0	17.5
	Follow-up / spot checking during construction / implementation of contracted items	0.5	0.5	0.5	2.0	3.0	2.5	4.0	5.0	4.5
	Checkout & certification	0.3	0.3	0.3	0.5	0.5	0.5	2.0	3.0	2.5

Raw data Source: Hunter Musser, NRCS District Conservationist, Area II

Aggregated categories	Simple - Low	Simple - High	Simple - Average	Moderate - Low	Moderate - High	Moderate - Average	Complex - Low	Complex - High	Complex - Average
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	5.17	6.75	5.96	8.25	11.92	10.08	13	17.58	15.29
Implementation	1.0	1.5	1.3	12.0	16.0	14.0	22.0	29.0	25.5
Certification ('checkout')	0.3	0.3	0.3	0.5	0.5	0.5	2.0	3.0	2.5
TOTAL hours	**17.1**	**23.8**	**20.4**	**34.0**	**47.4**	**40.7**	**55.8**	**76.3**	**66.0**

Appendix C – Supporting documentation for comparison of project transactions costs from permanent and term projects

Table C.1: Results: Supporting documentation for term project cost comparisons

		Creating the commodity (incl. initial certification)								Ex-post monitoring & re-certification				TOTAL COSTS
Description	Stage of project	Inception	Planning & Application	Approval	Contracting	Implementation	Cancellation & Termination	Credit registration & reporting	Certification of practice / activity	ex-post re-certification	Monitoring - interim	Monitoring - full	Monitoring costs - TOTAL	**TOTAL COSTS**
Permanent credits - NRCS SIMPLE AVERAGE COSTS, with 10.6 hrs for certification overwrite (from VA DEQ), ex-posts costs from "permanent credits" worksheet														
simple project, costs counted for 30 years of project life; no re-certification; annual remote verification over project life (30 years)	Hours per stage per single project	1.8	6.7	4.5	6.0	1.3	2.5	1.0	10.6	NA	0.3	NA	0.3	**34.5**
	Cost per stage per single project ($NPV)	145	541	158	469	98	188	75	530	NA	191	NA	191	**2,395**
	Cost per 1 completed project (accounting for attrition) ($NPV)	428	1,280	374	499	105	12	75	530	NA	191	NA	191	**3,493**
10 yr term credits - NRCS MODERATE AVERAGE COSTS, with 18 hrs for certification overwrite (=10.6*1.7 scaling factor for going from simple to moderate), ex-posts costs from "10 yr term credits" worksheet														
moderate project complexity; project life is 10 years (renewed 2 times for 30 year period); project is re-certified in years 10 & 20; on-site verification in years 5, 15 and 25; remote verification in interim years	Hours per stage per single project	1.8	9.7	4.7	10.1	14.0	2.5	1.0	18.0	18.0	0.3	10.0	NA	**79.7**
	Cost per stage per single project ($NPV)	145	780	167	794	1,103	188	75	901	892	NA	NA	936	**5,980**
	Cost per 1 completed project (accounting for attrition) ($NPV)	428	1,845	394	845	1,173	12	75	901	892	NA	NA	936	**7,500**
3 yr term credits - NRCS COMPLEX AVERAGE COSTS, with 28 hrs for certification overwrite (=10.6*2.6 scaling factor going from simple to complex), ex-posts costs from "3 yr term credits" worksheet														
complex project complexity; project life is 3 years (renewed 10 times for 30 year period); project is re-certified every 3 years; on-site verification in interim years	Hours per stage per single project	1.8	15.3	5.7	15.3	25.5	2.5	1.0	28.0	28.0	-	10.0	10.0	**133.0**
	Cost per stage per single project ($NPV)	145	1,234	202	1,204	2,008	188	75	1,378	6,503	-	5,248	5,248	**18,185**
	Cost per 1 completed project (accounting for attrition) ($NPV)	428	2,918	478	1,281	2,136	12	75	1,378	6,503	-	5,248	5,248	**20,457**

Table C.2: Ex-post costs of permanent credits – workings and results
(screenshots of EXCEL worksheet)

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	B	C	D	E	F	G	I	J
1	**Appendix Table A3(ii) – Ex-post costs of permanent credits (workings)**				$ 191	$NPV (30 yrs) MONITORING COST		
2	**DRIVER CELLS**				$ -	$NPV (30 yrs) EX-POST CERTIFICATION COST		
3	Verifier Rate	$ 75				Total No. Projects	1	**Year**
4	Administrator Rate	$ 50			No. projects commencing in each year:			0
5	Annual Inflation		5.00%	Discount rate			1	1
6	Annual Registry/Program Administration Cost		fixed cost		Yellow Cells Can Be Adjusted		0	2
7							0	3
8	Budget Per Project per activity	Hours	Cost				0	4
9	**Validation**						0	5
10	1) Administrator	4	$ 200				0	6
11	2) Verifiers	0	$ -				0	7
12	**Total Validation:**		**$ 200**				0	8
13	**Full Verification**						0	9
14	1) Administrator	10	$ 500				0	10
15	2) Verifier	0	$ -				0	11
16	Verifier Travel	NA	$ 250				0	12
17	**Total Per Full Verification:**		**$ 750**				0	13
18	**Interim Verification**						0	14
19	1) Administrator	0.25	$ 13				0	15
20	2) Verifiers	0	$ -				0	16
21	**Total Per Interim Verification:**		**$ 13**				0	17
22	**Certification**						0	18
23	1) Administrator	10.6	$ 530				0	19
24	2) Verifiers	0	$ -				0	20
25	**Total Per Certification:**		**$ 530**				0	21
26	**Registration**						0	22
27	1) Administrator	1	$ 50				0	23
28	2) Verifiers	0	$ -				0	24
29	**Total Per Registration:**		**$ 50**				0	25
30							0	26
31							0	27
32							0	28
33							0	29
34							0	30

A2(ii) NRCS raw data / A3(i) - Term project comparison / **A3(ii) Perm. credits workings** / A3(iii) 3yr term cred

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Row	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
35																	
36		No. projects commencing in each year:		1	0	0	0	0	0	0	0	0	0	0	0	0	0
37		Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
38		Validation	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
39		Initial full	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-
40	HOURS (administrator only)	Certification	10.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-
41		Registration	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
42		Interim Verification		0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
43		Subsequent full		-	-	-	-	-	-	-	-	-	-	-	-	-	-
44		Re-certification		-	-	-	-	-	-	-	-	-	-	-	-	-	-
45		**Total administrator hours each**	**25.6**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**
46		**TOTAL ADMINISTRATOR COST IN EACH YEAR ($NPV)**	$ 1,280	12	11	11	10	10	9	9	8	8	8	7	7	7	6
47		TOTAL ADMINISTRATOR EX-POST RE-CERTIFICATION HOURS IN EACH	$ -	-	-	-	-	-	-	-	-	-	-	-	-	-	-
48		TOTAL ADMINISTRATOR EX-POST RE-CERTIFICATION COST IN EACH	$ -	-	-	-	-	-	-	-	-	-	-	-	-	-	-
49		MONITORING HOURS IN EACH YEAR	-	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
50		TOTAL ADMINISTRATOR EX-POST MONITORING COST IN EACH YEAR	$ -	12	11	11	10	10	9	9	8	8	8	7	7	7	6
66		**TOTAL COST ($NPV)**	**$ 1,280**	**12**	**11**	**11**	**10**	**10**	**9**	**9**	**8**	**8**	**8**	**7**	**7**	**7**	**6**
67		**Future value using 1.5% inflation rate**	**$ 1,280**	**13**	**13**	**13**	**13**	**13**	**14**	**14**	**14**	**14**	**15**	**15**	**15**	**15**	**15**
68		**Sum TOTAL $NPV (without Fixed costs, including initial**	**$ 1,471**														
69		**TOTAL EX-POST RE-CERTIFICATION**		-	-	-	-	-	-	-	-	-	-	-	-	-	-
70		**Sum**	**$ -**														
71		**TOTAL EX-POST MONITORING & RE-CERTIFICATION COSTS ($**		**12**	**11**	**11**	**10**	**10**	**9**	**9**	**8**	**8**	**8**	**7**	**7**	**7**	**6**
72		**Total Ex-post monitoring & re-**	**$ 191**														

Row	B	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG
36	No. projects commencing in each year:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37	Year	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
38	Validation	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
39	Initial full	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
40	Certification	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
41	Registration	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
42	Interim Verification	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
43	Subsequent full	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
44	Re-certification	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
45	**Total administrator hours each**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**
46	**TOTAL ADMINISTRATOR COST IN EACH YEAR ($NPV)**	6	6	5	5	5	5	4	4	4	4	4	4	3	3	3	3
47	TOTAL ADMINISTRATOR EX-POST RE-CERTIFICATION HOURS IN EACH	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
48	TOTAL ADMINISTRATOR EX-POST RE-CERTIFICATION COST IN EACH	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
49	MONITORING HOURS IN EACH YEAR	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
50	TOTAL ADMINISTRATOR EX-POST MONITORING COST IN EACH YEAR	6	6	5	5	5	5	4	4	4	4	4	4	3	3	3	3
66	**TOTAL COST ($NPV)**	**6**	**6**	**5**	**5**	**5**	**5**	**4**	**4**	**4**	**4**	**4**	**4**	**3**	**3**	**3**	**3**
67	**Future value using 1.5% inflation rate**	**16**	**16**	**16**	**16**	**17**	**17**	**17**	**17**	**18**	**18**	**18**	**18**	**19**	**19**	**19**	**20**
68	**Sum TOTAL $NPV (without Fixed costs, including initial**																
69	**TOTAL EX-POST RE-CERTIFICATION**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
70	**Sum**																
71	**TOTAL EX-POST MONITORING & RE-CERTIFICATION COSTS ($**	**6**	**6**	**5**	**5**	**5**	**5**	**4**	**4**	**4**	**4**	**4**	**4**	**3**	**3**	**3**	**3**
72	**Total Ex-post monitoring & re-**																

A2(ii) NRCS raw data | A3(i) - Term project comparison | **A3(ii) Perm. credits workings** | A3(iii) 3yr term cred

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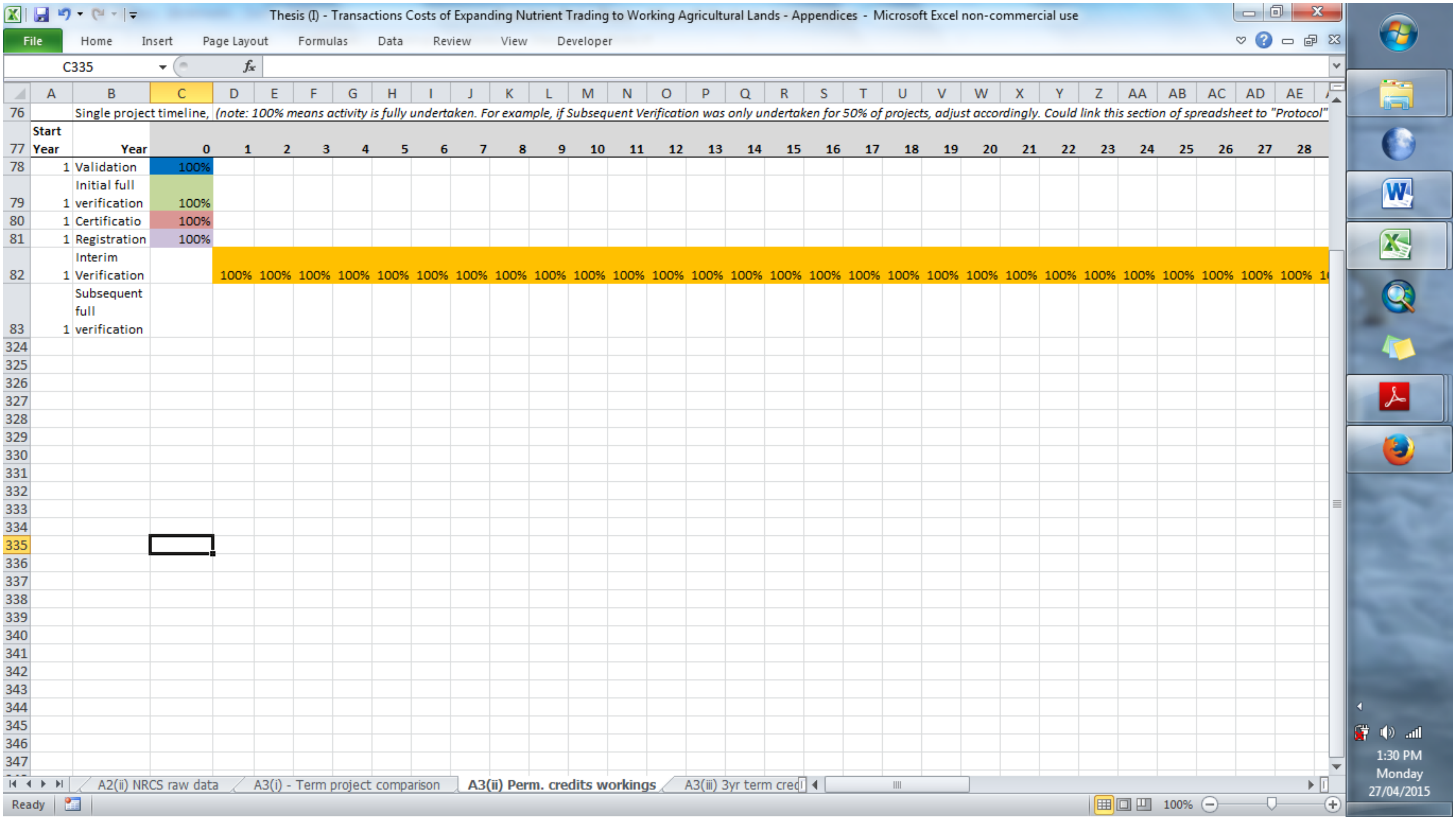

76 Single project timeline, *(note: 100% means activity is fully undertaken. For example, if Subsequent Verification was only undertaken for 50% of projects, adjust accordingly. Could link this section of spreadsheet to "Protocol"*

Row	Start Year	Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
78	1	Validation	100%																												
79	1	Initial full verification	100%																												
80	1	Certificatio	100%																												
81	1	Registration	100%																												
82	1	Interim Verification		100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
83	1	Subsequent full verification																													

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Table C.3 Ex-post costs of 3-year term credits (workings)

Appendix Table A3(iii) – Ex-post costs of 3-year term credits (workings)

$ 5,248 $NPV (30 yrs) MONITORING COST

$ 6,503 $NPV (30 yrs) EX-POST CERTIFICATION COST

Yellow Cells Can Be Adjusted

DRIVER CELLS			
Verifier Rate	$ 75		
Administrator Rate	$ 50		
Annual Inflation		5.00%	Discount rate
Annual Registry/Program Administration Cost		fixed cost	

Budget Per Project per activity	Hours	Cost
Validation		
1) Administrator	4	$ 200
2) Verifiers	0	$ -
Total Validation:		**$ 200**
Full Verification		
1) Administrator	10	$ 500
2) Verifier	0	$ -
Verifier Travel	NA	$ 250
Total Per Full Verification:		**$ 750**
Interim Verification		
1) Administrator	0.25	$ 13
2) Verifiers	0	$ -
Total Per Interim Verification:		**$ 13**
Certification		
1) Administrator	28	$ 1,400.00
2) Verifiers	0	$ -
Total Per Certification:		**$ 1,400**
Registration		
1) Administrator	1	$ 50.00
2) Verifiers	0	$ -
Total Per Registration:		**$ 50**

Total No. Projects	1	**Year**
No. projects commencing in each year:		**0**
	1	**1**
	0	**2**
	0	**3**
	0	**4**
	0	**5**
	0	**6**
	0	**7**
	0	**8**
	0	**9**
	0	**10**
	0	**11**
	0	**12**
	0	**13**
	0	**14**
	0	**15**
	0	**16**
	0	**17**
	0	**18**
	0	**19**
	0	**20**
	0	**21**
	0	**22**
	0	**23**
	0	**24**
	0	**25**
	0	**26**
	0	**27**
	0	**28**
	0	**29**
	0	**30**

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Thesis (I) - Transactions Costs of Expanding Nutrient Trading to Working Agricultural Lands - Appendices - Microsoft Excel non-commercial use

Row	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
36		No. projects commencing in each year:		1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37		**Year**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
38	HOURS (administrator only)	Validation	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
39		Initial full verification	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40		Certification	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
41		Registration	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
42		Interim Verification		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
43		Subsequent full verification		10	10	0	10	10	0	10	10	0	10	10	0	10	10	0
44		Re-certification		0	0	28	0	0	28	0	0	28	0	0	28	0	0	28
45		**Total administrator hours each year**	**43**	**10**	**10**	**28**	**10**	**10**	**28**	**10**	**10**	**28**	**10**	**10**	**28**	**10**	**10**	**28**
46	**TOTAL ADMINISTRATOR COST IN EACH YEAR**		$ 2,150	$ 476	$ 454	$1,209	$ 411	$ 392	$1,045	$ 355	$ 338	$ 902	$ 307	$ 292	$ 780	$ 265	$ 253	$ 673
47	TOTAL ADMINISTRATOR EX-POST RE-CERTIFICATION		$ -	$ -	$ -	$ 28	$ -	$ -	$ 28	$ -	$ -	$ 28	$ -	$ -	$ 28	$ -	$ -	$ 28
48	TOTAL ADMINISTRATOR EX-POST RE-CERTIFICATION		$ -	$ -	$ -	$1,209	$ -	$ -	$1,045	$ -	$ -	$ 902	$ -	$ -	$ 780	$ -	$ -	$ 673
49		TOTAL ADMINISTRATOR EX-POST MONITORING HOURS IN EACH YEAR	-	10	10	-	10	10	-	10	10	-	10	10	-	10	10	-
50		TOTAL ADMINISTRATOR EX-POST MONITORING COST IN EACH YEAR ($NPV)	$ -	$ 476	$ 454	$ -	$ 411	$ 392	$ -	$ 355	$ 338	$ -	$ 307	$ 292	$ -	$ 265	$ 253	$ -
51																		
65		**TOTAL HOURS (ADMINISTRATOR)**	**43**	**10**	**10**	**28**	**10**	**10**	**28**	**10**	**10**	**28**	**10**	**10**	**28**	**10**	**10**	**28**
66		**TOTAL COST (ADMINISTRATOR) ($NPV/YR)**	**$ 2,150**	**$ 476**	**$ 454**	**$1,209**	**$ 411**	**$ 392**	**$1,045**	**$ 355**	**$ 338**	**$ 902**	**$ 307**	**$ 292**	**$ 780**	**$ 265**	**$ 253**	**$ 673**
67		**Future value using 1.5% inflation rate**	$ 2,150	**$ 508**	**$ 515**	**$1,464**	**$ 531**	**$ 539**	**$1,531**	**$ 555**	**$ 563**	**$1,601**	**$ 580**	**$ 589**	**$1,674**	**$ 607**	**$ 616**	**$1,750**
68		**Sum TOTAL $NPV (without Fixed costs)**	$ 13,901															
69	**TOTAL EX-POST RE-CERTIFICATION COSTS ($ NPV)**			-	-	1,209	-	-	1,045	-	-	902	-	-	780	-	-	673
70		**Sum**	$ 6,503															
71	**TOTAL EX-POST MONITORING & RE-CERTIFICATION**			**$ 476**	**$ 454**	**$ -**	**$ 411**	**$ 392**	**$ -**	**$ 355**	**$ 338**	**$ -**	**$ 307**	**$ 292**	**$ -**	**$ 265**	**$ 253**	**$ -**
72		**Sum**	$ 5,248															
76		Single project timeline, depending on year comme *(note: 100% means activity is fully undertaken. For example, if Subsequent Verification was only undertaken for 50% of projects, adjust accordingly. Could link this sectionn of spreadsheet to "Protocol" cells above but this has not been done so far)*																
77	**Start Year**	**Year**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
78	1	Validation	100%															
79	1	Initial full verification	100%															
80	1	Certification	100%															
81	1	Registration	100%															
82	1	Interim Verification																
83	1	Subsequent full verification		100%	100%		100%	100%		100%	100%		100%	100%		100%	100%	
84	1	Re-certification				100%			100%			100%			100%			100%

Row	A	B	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG
36		No. projects commencing in each year:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37		**Year**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
38	HOURS (administrator only)	Validation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
39		Initial full verification	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40		Certification	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
41		Registration	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
42		Interim Verification	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
43		Subsequent full verification	10	10	0	10	10	0	10	10	0	10	10	0	10	10	0
44		Re-certification	0	0	28	0	0	28	0	0	28	0	0	28	0	0	0
45		**Total administrator hours each year**	**10**	**10**	**28**	**10**	**10**	**28**	**10**	**10**	**28**	**10**	**10**	**28**	**10**	**10**	**0**
46	**TOTAL ADMINISTRATOR COST IN EACH YEAR**		$ 229	$ 218	$$ 582	$ 198	$ 188	$ 503	$ 171	$ 163	$ 434	$ 148	$ 141	$ 375	$ 128	$ 121	$ -
47	TOTAL ADMINISTRATOR EX-POST RE-CERTIFICATION		$ -	$ -	$$ 28	$ -	$ -	$ 28	$ -	$ -	$ 28	$ -	$ -	$ 28	$ -	$ -	$ -
48	TOTAL ADMINISTRATOR EX-POST RE-CERTIFICATION		$ -	$ -	$$ 582	$ -	$ -	$ 503	$ -	$ -	$ 434	$ -	$ -	$ 375	$ -	$ -	$ -
49		TOTAL ADMINISTRATOR EX-POST MONITORING HOURS IN EACH YEAR	10	10	-	10	10	-	10	10	-	10	10	-	10	10	-
50		TOTAL ADMINISTRATOR EX-POST MONITORING COST IN EACH YEAR ($NPV)	$ 229	$ 218	$$ -	$ 198	$ 188	$ -	$ 171	$ 163	$ -	$ 148	$ 141	$ -	$ 128	$ 121	$ -
51																	
65		**TOTAL HOURS (ADMINISTRATOR)**	**10**	**10**	**28**	**10**	**10**	**28**	**10**	**10**	**28**	**10**	**10**	**28**	**10**	**10**	**0**
66		**TOTAL COST (ADMINISTRATOR) ($NPV/YR)**	**$ 229**	**$ 218**	**$$ 582**	**$ 198**	**$ 188**	**$ 503**	**$ 171**	**$ 163**	**$ 434**	**$ 148**	**$ 141**	**$ 375**	**$ 128**	**$ 121**	**$ -**
67		**Future value using 1.5% inflation rate**	**$ 634**	**$ 644**	**$$1,830**	**$ 663**	**$ 673**	**$1,914**	**$ 694**	**$ 704**	**$2,001**	**$ 725**	**$ 736**	**$2,093**	**$ 759**	**$ 770**	**$ -**
68		**Sum TOTAL $NPV (without Fixed costs)**															
69	**TOTAL EX-POST RE-CERTIFICATION COSTS ($ NPV)**		-	-	582	-	-	503	-	-	434	-	-	375	-	-	-
70		**Sum**															
71	**TOTAL EX-POST MONITORING & RE-CERTIFICATION**		**$ 229**	**$ 218**	**$$ -**	**$ 198**	**$ 188**	**$ -**	**$ 171**	**$ 163**	**$ -**	**$ 148**	**$ 141**	**$ -**	**$ 128**	**$ 121**	**$ -**
72		**Sum**															
77	**Start Year**	**Year**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
78	1	Validation															
79	1	Initial full verification															
80	1	Certification															
81	1	Registration															
82	1	Interim Verification															
83	1	Subsequent full verification	100%	100%		100%	100%		100%	100%		100%	100%		100%	100%	
84	1	Re-certification			100%			100%			100%			100%			

A3(ii) Perm. credits workings | **A3(iii) 3yr term credit working** | A3(iv) 10yr term credit working

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Table C.4: Ex-post costs of 10-year term credits (workings)

Row	A / B	C	D	E	F	H	I	J
1	**Appendix Table A3(iiv) – Ex-post costs of 10-year term credits (workings)**			$ 936	$NPV (30 yrs) MONITORING COST			
2	**DRIVER CELLS**			$ 892	$NPV (30 yrs) EX-POST CERTIFICATION COST			
3	Verifier Rate	$ 75				Total No. Projects	1	**Year**
4	Administrator Rate	$ 50				No. projects commencing in each year:		**0**
5	Annual Inflation		5.00%	Discount rate			1	**1**
6	Annual Registry/Program Administration Cost		fixed cost		Yellow Cells Can Be Adjusted		0	**2**
7							0	**3**
8	Budget Per Project per activity	Hours	Cost				0	**4**
9	**Validation**						0	**5**
10	1) Administrator	4	$ 200				0	**6**
11	2) Verifiers	0	$ -				0	**7**
12	**Total Validation:**		**$ 200**				0	**8**
13	**Full Verification**						0	**9**
14	1) Administrator	10	$ 500				0	**10**
15	2) Verifier	0	$ -				0	**11**
16	Verifier Travel	NA	$ 250				0	**12**
17	**Total Per Full Verification:**		**$ 750**				0	**13**
18	**Interim Verification**						0	**14**
19	1) Administrator	0.25	$ 13				0	**15**
20	2) Verifiers	0	$ -				0	**16**
21	**Total Per Interim Verification:**		**$ 13**				0	**17**
22	**Certification**						0	**18**
23	1) Administrator	18	$ 900.00				0	**19**
24	2) Verifiers	0	$ -				0	**20**
25	**Total Per Certification:**		**$ 900**				0	**21**
26	**Registration**						0	**22**
27	1) Administrator	1	$ 50.00				0	**23**
28	2) Verifiers	0	$ -				0	**24**
29	**Total Per Registration:**		**$ 50**				0	**25**
30							0	**26**
31							0	**27**
32							0	**28**
33							0	**29**
34							0	**30**

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Row	A	B	C	D	E	F	G	H	I	J	K	L	M
36		No. projects commencing in each year:		1	0	0	0	0	0	0	0	0	0
37		**Year**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
38		Validation	4	0	0	0	0	0	0	0	0	0	0
39		Initial full verification	10	0	0	0	0	0	0	0	0	0	0
40	HOURS	Certification	18	0	0	0	0	0	0	0	0	0	0
41	(administrator only)	Registration	1	0	0	0	0	0	0	0	0	0	0
42		Interim Verification		0.25	0.25	0.25	0.25	0	0.25	0.25	0.25	0.25	0
43		Subsequent full verification		0	0	0	0	10	0	0	0	0	0
44		Re-certification		0	0	0	0	0	0	0	0	0	18
45		**Total administrator hours each year**	**33**	**0.25**	**0.25**	**0.25**	**0.25**	**10**	**0.25**	**0.25**	**0.25**	**0.25**	**18**
46		**TOTAL ADMINISTRATOR COST IN EACH YEAR**	$ 1,650	$ 12	$ 11	$ 11	$ 10	$392	$ 9	$ 9	$ 8	$ 8	$ 553
47		TOTAL ADMINISTRATOR EX-POST RE-CERTIFICATION	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 18
48		TOTAL ADMINISTRATOR EX-POST RE-CERTIFICATION	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 553
49		TOTAL ADMINISTRATOR EX-POST MONITORING HOURS IN EACH YEAR	-	0	0	0	0	10	0	0	0	0	-
50		TOTAL ADMINISTRATOR EX-POST MONITORING COST IN EACH YEAR ($NPV)	$ -	$ 12	$ 11	$ 11	$ 10	$392	$ 9	$ 9	$ 8	$ 8	$ -
65		**TOTAL HOURS (ADMINISTRATOR + VERIFIER)**	33	0.25	0.25	0.25	0.25	10	0.25	0.25	0.25	0.25	18
66		**TOTAL COST (ADMINISTRATOR + VERIFIER) ($NPV)**	$ 1,650	$ 12	$ 11	$ 11	$ 10	$392	$ 9	$ 9	$ 8	$ 8	$ 553
67		**Future value using 1.5% inflation rate**	$ 1,650	$ 13	$ 13	$ 13	$ 13	$539	$ 14	$ 14	$ 14	$ 14	$ 1,044
68		**Sum TOTAL $NPV (without Fixed costs)**	$ 3,478										
69		**TOTAL EX-POST RE-CERTIFICATION COSTS ($ NPV)**		-	-	-	-	-	-	-	-	-	553
70		**Sum**	$ 892										
71		**TOTAL EX-POST MONITORING & RE-CERTIFICATION**		$ 12	$ 11	$ 11	$ 10	$392	$ 9	$ 9	$ 8	$ 8	$ -
72		**Sum**	$ 936										
76		Single project timeline, depending on year commenced:		*(note: 100% means activity is fully undertaken. For example, if Subsequent Verification was only undertaken for 50% of projects, adjust accordingly. Could link this section of spreadsheet to "Protocol" cells above but this has not been done so far)*									
77	**Start Year**	**Year**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
78	1	Validation	100%										
79	1	Initial full verification	100%										
80	1	Certification	100%										
81	1	Registration	100%										
82	1	Interim Verification		100%	100%	100%	100%		100%	100%	100%	100%	
83	1	Subsequent full verification						100%					
84	2	Re-certification											100%

Row	B	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG
36	No. projects commencing in each year:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37	**Year**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
38	Validation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
39	Initial full verification	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40	Certification	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
41	Registration	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
42	Interim Verification	0.25	0.25	0.25	0.25	0	0.25	0.25	0.25	0.25	0	0.25	0.25	0.25	0.25	0	0.25	0.25	0.25	0.25	0
43	Subsequent full verification	0	0	0	0	10	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0
44	Re-certification	0	0	0	0	0	0	0	0	0	18	0	0	0	0	0	0	0	0	0	0
45	**Total administrator hours each year**	**0.25**	**0.25**	**0.25**	**0.25**	**10**	**0.25**	**0.25**	**0.25**	**0.25**	**18**	**0.25**	**0.25**	**0.25**	**0.25**	**10**	**0.25**	**0.25**	**0.25**	**0.25**	**0**
46	**TOTAL ADMINISTRATOR COST IN EACH YEAR**	$ 7	$ 7	$ 7	$ 6	$241	$ 6	$ 5	$ 5	$ 5	$ 339	$ 4	$ 4	$ 4	$ 4	$ 148	$ 4	$ 3	$ 3	$ 3	$-
47	TOTAL ADMINISTRATOR EX-POST RE-CERTIFICATION	$ -	$ -	$ -	$ -	$ -	$ -	$-	$-	$-	$ 18	$-	$-	$-	$-	$ -	$-	$-	$-	$-	$-
48	TOTAL ADMINISTRATOR EX-POST RE-CERTIFICATION	$ -	$ -	$ -	$ -	$ -	$ -	$-	$-	$-	$ 339	$-	$-	$-	$-	$ -	$-	$-	$-	$-	$-
49	TOTAL ADMINISTRATOR EX-POST MONITORING HOURS IN EACH YEAR	0	0	0	0	10	0	0	0	0	-	0	0	0	0	10	0	0	0	0	-
50	TOTAL ADMINISTRATOR EX-POST MONITORING COST IN EACH YEAR ($NPV)	$ 7	$ 7	$ 7	$ 6	$241	$ 6	$ 5	$ 5	$ 5	$ -	$ 4	$ 4	$ 4	$ 4	$ 148	$ 4	$ 3	$ 3	$ 3	$-
65	**TOTAL HOURS (ADMINISTRATOR + VERIFIER)**	0.25	0.25	0.25	0.25	10	0.25	0.25	0.25	0.25	18	0.25	0.25	0.25	0.25	10	0.25	0.25	0.25	0.25	0
66	**TOTAL COST (ADMINISTRATOR + VERIFIER) ($NPV)**	$ 7	$ 7	$ 7	$ 6	$241	$ 6	$ 5	$ 5	$ 5	$ 339	$ 4	$ 4	$ 4	$ 4	$ 148	$ 4	$ 3	$ 3	$ 3	$-
67	**Future value using 1.5% inflation rate**	$ 15	$ 15	$ 15	$ 15	$625	$ 16	$ 16	$ 16	$ 17	$ 1,212	$ 17	$ 17	$ 18	$ 18	$ 725	$ 18	$ 19	$ 19	$ 19	$-
68	**Sum TOTAL $NPV (without Fixed costs)**																				
69	**TOTAL EX-POST RE-CERTIFICATION COSTS ($ NPV)**	-	-	-	-	-	-	-	-	-	339	-	-	-	-	-	-	-	-	-	-
70	**Sum**																				
71	**TOTAL EX-POST MONITORING & RE-CERTIFICATION**	$ 7	$ 7	$ 7	$ 6	$241	$ 6	$ 5	$ 5	$ 5	$ -	$ 4	$ 4	$ 4	$ 4	$ 148	$ 4	$ 3	$ 3	$ 3	$-
72	**Sum**																				
77	**Year**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
78	Validation																				
79	Initial full verification																				
80	Certification																				
81	Registration																				
82	Interim Verification	100%	100%	100%	100%		100%	100%	100%	100%		100%	100%	100%	100%		100%	100%	100%	100%	
83	Subsequent full verification					100%										100%					
84	Re-certification										100%										

A3(i) Perm. credits workings / A3(ii) 3yr term credit working / **A3(iv) 10yr term credit working**

(2 of 2)

Appendices – Chapter 2

APPENDIX D: Study Area, Hydrogeomorphic Regions, Landuses and Best Management Practice descriptions

Figure D.1: Watersheds of the Chesapeake Bay

Source: US Dept. of Interior & USGS (2000)

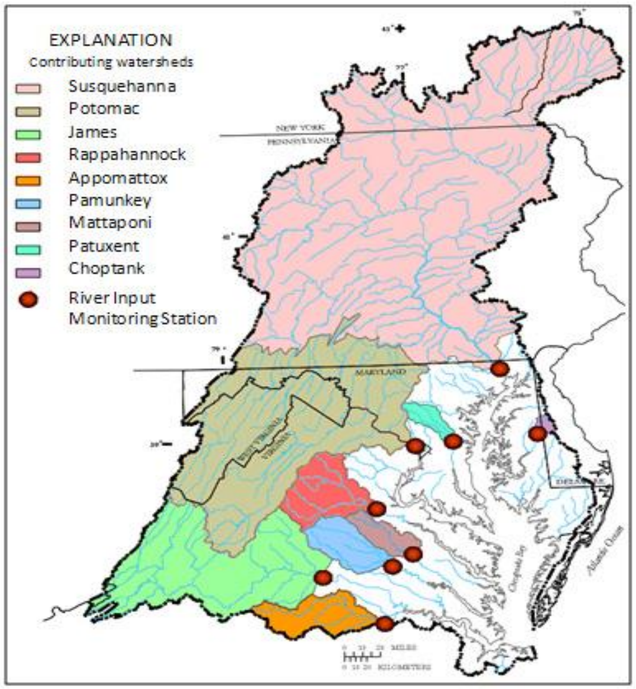

Figure D.2: Hydrogeomorphic regions

Source: Chesapeake Bay Program (2008)

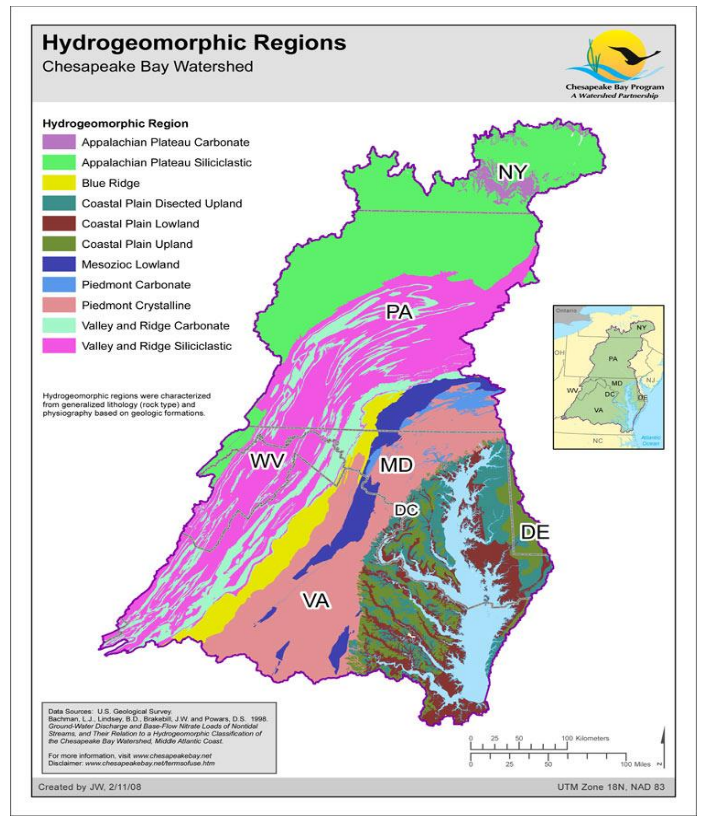

Table D.1: Landuses

Code	**Description**	**Landuse Type**
hwm	High Tillage w/ Manure	*Cropland*
hom	High Tillage w/o Manure	
lwm	Low Tillage w/ Manure	
nhi	Nutrient Management High Tillage w/ Manure	
nlo	Nutrient Management Low Tillage	
nho	Nutrient Management High Tillage w/o Manure	
hyw	Hay w/ Nutrients	*Grazing lands / pasture*
nhy	Nutrient Management Hay	
hyo	Hay w/o Nutrients	
alf	Alfalfa	
nal	Nutrient Management Alfalfa	
pas	Pasture	
npa	Nutrient Management Pasture	
trp	Degraded Riparian Pasture	

Table D.2: Agricultural BMPs used in the model

Name & code	**Definition**
Riparian Forest Buffer (*RFB*)	Linear wooded areas along rivers, stream and shorelines. Forest buffers help filter nutrients, sediments and other pollutants from runoff as well as remove nutrients from groundwater.
Riparian Grass Buffer (*RGB*)	Agricultural riparian grass buffers are linear strips of grass or other non-woody vegetation maintained between the edge of fields and streams, rivers or tidal waters that help filter nutrients, sediment, and other pollutants from runoff.
Wetland restoration (*WR*)	Agricultural wetland restoration activities re-establish the natural hydraulic condition in a field that existed before the installation of subsurface or surface drainage. Projects can include restoration, creation and enhancement acreage. Restored wetlands can be any wetland classification including forested, scrub-shrub or emergent marsh.
Tree planting (*TR*)	*See land retirement*
Land Retirement (*LR*)	Agricultural land retirement takes marginal and highly erosive cropland out of production by planting permanent vegetative cover such as shrubs, grasses, and/or trees. Agricultural agencies have a program to assist farmers in land retirement procedures. Land retired and planted to trees is reported under *Tree Planting*.

Enhanced Nutrient Management (*EN*)	Based on research, the nutrient management rates of nitrogen application are set approximately 35% higher than what a crop needs to ensure nitrogen availability under optimal growing conditions. In a yield reserve program using enhanced nutrient management, the farmer would reduce the nitrogen application rate by 15%. An incentive or crop insurance is used to cover the risk of yield loss. This BMP effectiveness estimate is based on a reduction in nitrogen loss resulting from nutrient application to cropland 15% lower than the nutrient management recommendation.
Decision Agriculture (*DEC*)	A management system that is information and technology based, is site specific and uses one or more of the following sources of data: soils, crops, nutrients, pests, moisture, or yield for optimum profitability, sustainability, and protection of the environment.
Cover Crop (Early Drilled Rye) *CDR*	*The model uses one type of cover crop: Early-Drilled Rye* Cereal cover crops reduce erosion and the leaching of nutrients to groundwater by maintaining a vegetative cover on cropland and holding nutrients within the root zone. This practice involves the planting and growing of cereal crops (non-harvested) with minimal disturbance of the surface soil. The crop is seeded directly into vegetative cover or crop residue with little disturbance of the surface soil. These crops capture or "trap" nitrogen in their tissues as they grow. By timing the cover crop burn or plow-down in spring, the trapped nitrogen can be released and used by the following crop. Different species are accepted as well as, different times of planting (early, late and standard), and fertilizer application restrictions. There is a sliding scale of efficiencies based on crop type and time of planting. Commodity cover crops differ from cereal cover crops in that they can be harvested for grain, hay, or silage and they might receive nutrient applications, but only after March 1 of the spring following their establishment. The intent of the practice is to modify normal small grain production practices by eliminating fall and winter fertilization so that crops function similarly to cover crops by scavenging available soil nitrogen for part of their production cycle.
Continuous No-Till Agriculture (*CNT*)	The Continuous No-Till (*CNT*) BMP is a crop planting and management practice in which soil disturbance by plows, disk or other tillage equipment is eliminated. *CNT* involves no-till methods on all crops in a multi-crop, multi-year rotation. When an acre is reported under *CNT*, it will not be eligible for additional reductions from the implementation of other practices such as cover crops or nutrient management planning.
Livestock Exclusion (*LE*)	Livestock Exclusion involves excluding a strip of land with fencing along the stream corridor to provide protection from livestock. The fenced areas may be planted with trees or grass, or left to natural plant succession, and can be of various widths. To provide the modelled benefits of a functional riparian buffer, the width must be a minimum of 35 feet from top-of-bank to fence line. The implementation of stream fencing provides stream access control for livestock but does not necessarily exclude animals from entering the stream by incorporating limited and stabilized in-stream crossing or watering facilities.
Offstream Watering (*OW*)	Offstream watering typically involves the use of permanent or portable livestock water troughs placed away from the stream corridor. The source of water supplied to the facilities can be from any source including pipelines, spring developments, water wells, and ponds. In-stream watering facilities such as stream crossings or access points are not considered in this definition.
Upland Prescribed Grazing (*UGZ*)	This practice utilizes a range of pasture management and grazing to improve the quality and quantity of the forages grown on pastures and reduce the impact of animal travel lanes, animal concentration areas or other degraded areas. Prescribed grazing can be applied to pastures intersected by streams or upland pastures outside of the degraded stream corridor (35 feet width from top of bank). Pastures under the proscribed grazing systems are defined as having a vegetative cover of 60% or greater.
Upland Precision Intensive Rotational	This practice utilizes more intensive forms pasture management and grazing techniques to improve the quality and quantity of the forages grown on pastures and reduce the impact of animal travel lanes, animal concentration areas or other degraded areas of the upland pastures. This practice requires intensive management of livestock rotation, also known as Managed Intensive Grazing systems (MIG), that have

Grazing (*UIGZ*)	very short rotation schedules. Pastures are defined as having a vegetative cover of 60% or greater.

Source: Adapted from Chesapeake Bay Commission (Date NA), Appendix 6 – BMP.

APPENDIX E: BMP efficiency calculations

Table E.1: removal efficiency factors (%) for individual BMPs and hydrogeomorphic region

	Nitrogen								Phosphorus							
Hydrogeomorphic region	BLUERIDGENT	CPDUPNT	CPLOWNT	CPUPNT	MESOLOWNT	PIEDCRYSNT	VRCARBNT	VRSILINT	BLUERIDGENT	CPDUPNT	CPLOWNT	CPUPNT	MESOLOWNT	PIEDCRYSNT	VRCARBNT	VRSILINT
RFB	34	65	56	31	34	56	34	46	30	42	39	45	30	42	30	39
RGB	24	46	39	21	24	39	24	32	30	42	39	45	30	42	30	39
WR	14	25	25	25	14	14	14	14	26	50	50	50	26	26	26	26
TR	*change from landuse to forest*								*change from landuse to forest*							
LR	*change from landuse to hay w/o nutrients*								*change from landuse to hay w/o nutrients*							
LE	25	25	25	25	25	25	25	25	30	30	30	30	30	30	30	30
CDR	34	45	45	45	34	45	45	34	15	15	15	15	15	15	15	15
CNT	15	10	10	10	15	15	15	15	40	20	20	20	40	40	40	40
EN	7	7	7	7	7	7	7	7	0	0	0	0	0	0	0	0
DEC	4	4	4	4	4	4	4	4	0	0	0	0	0	0	0	0
OW	5	5	5	5	5	5	5	5	8	8	8	8	8	8	8	8
UGZ	10	10	10	10	10	10	10	10	20	20	20	20	20	20	20	20
UIGZ	11	9	9	9	11	11	9	11	24	24	24	24	24	24	24	24

Sources: Chesapeake Bay Commission (2012, Appendix B), with supplemental information taken from the Chesapeake Bay Phase 5.3 Community Watershed Model documentation (Date NA: Section 6) and Simpson and Weammert (2009).

Feasible stacked BMP systems were specified given the following considerations, based on information from the CBWM:

- Some BMPs are mutually exclusive (e.g. forest and grass riparian buffers); stacked BMP systems can only include compatible BMPs.
- Stacked BMPs must be compatible in terms of the landuse they can be applied to.
- Continuous no-till (CNT) is mutually exclusive to all other BMPs except riparian buffers.

The methodology for calculating total load reduction factors is adapted from Chesapeake Bay Commission (2012, Appendix B). In generalized form, the total load reduction factor is calculated as the sum of efficiencies generated and reductions associated with landuse change, as follows:

$$Total\ reduction\ factor \equiv r_{j,h,l}^{p} \tag{A1}$$

$$= \%land\ converted \times \Delta land\ load + \%land\ treated \times efficiency\ factor \times load\ of\ land\ treated$$

Where:

- *%land converted* is the ratio of land converted to a new landuse relative to the total area treated and/or converted;
- Δ*land load* is the change in load that occurs when landuse is converted;
- *%land treated* is the ratio of land treated by the BMP relative to the total area treated and/or converted;
- *efficiency factor* is the improvement (lowering) in delivered nutrient loads associated with a BMP that involves load reduction, application reduction or efficiency change (all BMPs other than those that directly change landuse); and
- *load of land treated* is the baseline load of the landuse that the efficiency is being applied to, sourced from the CBWM (baseline loads as of 2009). Note that in cases where the area that the efficiency is applied to also has a change in landuse, the *load of treated land* is the baseline load of the new landuse.

The above formula needs to be adapted to account for stacked BMPs. For a BMP system that involves changing the riparian area to a different landuse than for the rest of the area, the first term in the above formula is broken into two terms: one for the riparian area and another for the rest of the area. Riparian BMPs are assumed to treat 4 times their area (Chesapeake Bay Commission: 2012, pB-11).[19]

For a BMP system that involves multiple efficiency factors being applied to the same land, the second term in equation (A1) is adapted to account for the efficiencies in a *multiplicative* manner; following Simpson & Weammert (2009), the BMP with the highest efficiency is accounted for first. For example, the system *cover crop, early drilled rye* + *decision agriculture* (*CDR+DEC*) involves the landuse for the entire area being changed to the nutrient management alternative (e.g. if applied to landuse *high tillage with manure* (*hwm*), landuse changes to *nutrient management high tillage with manure* (*nhi*)) and the application of two efficiency factors. In this case, for total nitrogen, the efficiency associated with *CDR* is higher than that of *DEC*. Equation (A1) is in this case adapted to:

$$r^{N}_{CDR+DEC,h,hwm} = 100\% \times \left(load_h{}^{hwm} - load_h{}^{nhi}\right) + 100\% \times (efficiency_h{}^{CDR} + efficiency_h{}^{CDR} \times efficiency_h{}^{DEC})\ load_h{}^{nhi} \quad \text{(A2)}$$

Equations (A1) and (A2) were used as required to estimate total reduction factors for each of the 56 specific BMP systems, applied to a particular landuse l in hydrogeomorphic region h, for use in the cost minimization model.

[19] A valuable possible extension would be to incorporate specific data on riparian area within each land-river segment.

APPENDIX F: Transactions costs data

Table F.1: Transactions costs by BMP system (annualized $2010/acre)

BMP system	**BMP time horizon (years)**	**Low**	**Average**	**High**	**BMP system**	**BMP time horizon (years)**	**Low**	**Average**	**High**
RFB	15	$4.06	$4.88	$5.71	**LR-UGZ**	10	$17.08	$20.54	$24.00
RGB	15	$2.33	$2.79	$3.25	**LR-UIGZ**	10	$27.31	$32.37	$37.42
WR	15	$6.49	$7.70	$8.90	**LE-RFB**	15	$4.90	$5.89	$6.88
TR	15	$4.06	$4.88	$5.71	**LE-RGB**	15	$4.90	$5.89	$6.88
LR	10	$3.02	$3.62	$4.22	**LE-UGZ**	10	$9.80	$11.74	$13.67
LE	10	$3.02	$3.62	$4.22	**LE-UIGZ**	10	$27.31	$32.37	$37.42
CDR	1	$22.72	$27.20	$31.68	**OW-RFB**	15	$5.73	$6.89	$8.05
CNT	1	$22.72	$27.20	$31.68	**OW-RGB**	15	$5.73	$6.89	$8.05
EN	1	$63.29	$74.99	$86.70	**RFB-WR**	15	$6.49	$7.70	$8.90
DEC	1	$39.58	$47.60	$55.62	**RGB-TR**	15	$2.33	$2.79	$3.25
OW	10	$5.27	$6.33	$7.40	**RGB-WR**	15	$6.49	$7.70	$8.90
UGZ	1	$39.58	$47.60	$55.62	**CDR-DEC-EN**	1	$63.29	$74.99	$86.70
UIGZ	1	$63.29	$74.99	$86.70	**CDR-DEC-RFB**	15	$13.17	$15.84	$18.51
CDR-DEC	1	$39.58	$47.60	$55.62	**CDR-DEC-RGB**	15	$13.17	$15.84	$18.51
CDR-EN	1	$63.29	$74.99	$86.70	**CDR-EN-RFB**	15	$21.06	$24.96	$28.86
CDR-RFB	15	$9.18	$16.05	$18.71	**CDR-EN-RGB**	15	$21.06	$24.96	$28.86
CDR-RGB	15	$9.18	$11.01	$12.84	**DEC-EN-RFB**	15	$21.06	$24.96	$28.86

CNT-RFB	15	$9.18	$11.01	$12.84	**DEC-EN-RGB**	15	$21.06	$24.96	$28.86
CNT-RGB	15	$9.18	$11.01	$12.84	**LR-LE-RFB**	15	$5.73	$6.89	$8.05
DEC-EN	1	$63.29	$74.99	$86.70	**LR-LE-RGB**	15	$5.73	$6.89	$8.05
DEC-RFB	15	$13.17	$15.84	$18.51	**LR-OW-RFB**	15	$5.73	$6.89	$8.05
DEC-RGB	15	$13.17	$15.84	$18.51	**LR-OW-RGB**	15	$5.73	$6.89	$8.05
EN-RFB	15	$21.06	$24.96	$28.86	**LR-RFB-UGZ**	15	$12.56	$14.96	$17.37
EN-RGB	15	$21.06	$24.96	$28.86	**LR-RFB-UIGZ**	15	$22.17	$26.29	$30.40
LR-LE	10	$5.27	$6.33	$7.40	**LE-RFB-UGZ**	15	$12.56	$14.96	$17.37
LR-OW	10	$5.27	$6.33	$7.40	**LE-RFB-UIGZ**	15	$22.17	$26.29	$30.40
LR-RFB	15	$4.90	$5.89	$6.88	**LE-RGB-UGZ**	15	$12.56	$14.96	$17.37
LR-RGB	10	$3.29	$3.93	$4.58	**LE-RGB-UIGZ**	15	$22.17	$26.29	$30.40

NB: 7% discount rate assumed.

APPENDIX G: Selected results

Table G.1: Percentage of area assigned a BMP system, by BMP system, all scenarios

		Low IC				Med IC				High IC			Adoption models	
Scenario No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Area assigned a BMP system (million acres)	2.06	1.17	1.17	1.17	2.04	2.01	1.91	1.82	2.03	2.03	2.04	2.01	2.11	2.10
						% of area assigned a BMP system								
UGZ		43%	-	-	-	57%	56%	54%	51%	57%	57%	57%	56%	40%
TR		2%	35%	35%	35%	9%	10%	13%	16%	10%	10%	10%	10%	11%
LR		28%	21%	21%	21%	5%	4%	2%	1%	4%	3%	4%	4%	8%
DEC		-	4%	4%	4%	-	2%	2%	3%	-	1%	2%	2%	1%
CDR		13%	25%	25%	25%	18%	18%	20%	20%	18%	18%	18%	18%	17%
CNT		7%	6%	6%	6%	3%	4%	4%	4%	3%	3%	3%	4%	5%
EN		4%	-	-	-	2%	-	-	-	2%	1%	1%	-	1%
DEC-EN		-	-	-	-	-	-	-	-	-	-	-	-	-
CDR-DEC		-	4%	4%	4%	-	3%	3%	3%	-	3%	3%	3%	2%
CDR-RGB		1%	2%	2%	2%	1%	1%	1%	1%	1%	1%	1%	1%	-
CDR-RFB		-	-	-	-	1%	1%	1%	1%	1%	1%	1%	1%	-
EN-RGB		1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
CDR-EN		1%	-	-	-	3%	-	-	-	3%	-	-	-	1%
WR		-	-	-	-	-	-	-	-	-	-	-	-	-
UIGZ		-	-	-	-	-	-	-	-	-	-	-	-	7%
RGB-WR		-	-	-	-	-	-	-	-	-	-	-	-	-
RGB-TR		-	-	-	-	-	-	-	-	-	-	-	-	-
RGB		1%	1%	1%	1%	-	-	-	-	-	-	-	-	-
RFB-WR		-	-	-	-	-	-	-	-	-	-	-	-	-
RFB		-	-	-	-	-	-	-	-	-	-	-	-	2%
OW-RGB		-	-	-	-	-	-	-	-	-	-	-	-	3%
OW-RFB		-	-	-	-	-	-	-	-	-	-	-	-	-
OW		-	-	-	-	-	-	-	-	-	-	-	-	-
LR-UIGZ		-	-	-	-	-	-	-	-	-	-	-	-	-
LR-UGZ		-	-	-	-	-	-	-	-	-	-	-	-	-
LR-RGB		-	-	-	-	-	-	-	-	-	-	-	-	-
LR-RFB-UIGZ		-	-	-	-	-	-	-	-	-	-	-	-	-
LR-RFB-UGZ		-	-	-	-	-	-	-	-	-	-	-	-	-
LR-RFB		-	-	-	-	-	-	-	-	-	-	-	-	-

		Low IC				Med IC				High IC			Adoption models	
Scenario No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
LR-OW-RGB		-	-	-	-	-	-	-	-	-	-	-	-	-
LR-OW-RFB		-	-	-	-	-	-	-	-	-	-	-	-	-
LR-OW		-	-	-	-	-	-	-	-	-	-	-	-	-
LR-LEX-RGB		-	-	-	-	-	-	-	-	-	-	-	-	-
LR-LEX-RFB		-	-	-	-	-	-	-	-	-	-	-	-	-
LR-LEX		-	-	-	-	-	-	-	-	-	-	-	-	-
LEX-UIGZ		-	-	-	-	-	-	-	-	-	-	-	-	-
LEX-UGZ		-	-	-	-	-	-	-	-	-	-	-	-	-
LEX-RGB-UIGZ		-	-	-	-	-	-	-	-	-	-	-	-	-
LEX-RGB-UGZ		-	-	-	-	-	-	-	-	-	-	-	-	-
LEX-RGB		-	-	-	-	-	-	-	-	-	-	-	-	-
LEX-RFB-UIGZ		-	-	-	-	-	-	-	-	-	-	-	-	-
LEX-RFB-UGZ		-	-	-	-	-	-	-	-	-	-	-	-	-
LEX-RFB		-	-	-	-	-	-	-	-	-	-	-	-	-
LEX		-	-	-	-	-	-	-	-	-	-	-	-	-
EN-RFB		-	-	-	-	-	-	-	-	-	-	-	-	-
DEC-RGB		-	-	-	-	-	-	-	-	-	-	-	-	-
DEC-RFB		-	-	-	-	-	-	-	-	-	-	-	-	-
DEC-EN-RGB		-	-	-	-	-	-	-	-	-	-	-	-	-
DEC-EN-RFB		-	-	-	-	-	-	-	-	-	-	-	-	-
CNT-RGB		-	-	-	-	-	-	-	-	-	-	-	-	-
CNT-RFB		-	1%	1%	1%	-	-	-	-	-	-	-	-	1%
CDR-EN-RGB		-	-	-	-	-	-	-	-	-	-	-	-	-
CDR-EN-RFB		-	-	-	-	-	-	-	-	-	-	-	-	-
CDR-DEC-RGB		-	-	-	-	-	-	-	-	-	-	-	-	-
CDR-DEC-RFB		-	-	-	-	-	-	-	-	-	-	-	-	-
CDR-DEC-EN		-	-	-	-	-	-	-	-	-	-	-	-	-

Table G.2: Area by type, adoption model (acres)

	Low Cost Type	Medium Cost Type	High Cost Type	TOTAL
Area assigned a BMP system	*487,947*	*929,886*	*683,862*	2,101,695
UGZ	116,224	406,793	406,793	929,810
CDR	103,289	159,395	84,168	346,852
TR	27,937	134,139	75,807	237,883
LR	26,228	110,553	57,711	194,492
CNT	72,953	20,105	16,534	109,592
OW-RGB	58,112	-	-	58,112
RFB	40,380	-	-	40,380
CDR-DEC	7,841	15,342	13,880	37,063
UIGZ	1,162	33,985	-	35,147
DEC	3,934	12,021	12,202	28,157
EN	64	8,411	7,701	16,176
CDR-EN	78	8,181	7,285	15,544
EN-RGB	71	13,870	-	13,941
CNT-RFB	13,293	-	-	13,293
WR	981	6,750	1,463	9,194
CDR-RGB	6,990	-	-	6,990
CDR-DEC-RGB	3,965	-	-	3,965
OW	2,829	-	-	2,829
CDR-RFB	1,372	-	-	1,372
DEC-EN	-	340	317	657
EN-RFB	212	-	-	212
CDR-EN-RFB	31	-	-	31
CDR-DEC-EN	-	-	-	-
CDR-DEC-RFB	-	-	-	-
CDR-EN-RGB	-	-	-	-
CNT-RGB	-	-	-	-
DEC-EN-RFB	-	-	-	-
DEC-EN-RGB	-	-	-	-
DEC-RFB	-	-	-	-
DEC-RGB	-	-	-	-
LEX	-	-	-	-
LEX-RFB	-	-	-	-
LEX-RFB-UGZ	-	-	-	-
LEX-RFB-UIGZ	-	-	-	-
LEX-RGB	-	-	-	-
LEX-RGB-UGZ	-	-	-	-
LEX-RGB-UIGZ	-	-	-	-
LEX-UGZ	-	-	-	-
LEX-UIGZ	-	-	-	-
LR-LEX	-	-	-	-
LR-LEX-RFB	-	-	-	-
LR-LEX-RGB	-	-	-	-
LR-OW	-	-	-	-
LR-OW-RFB	-	-	-	-
LR-OW-RGB	-	-	-	-
LR-RFB	-	-	-	-
LR-RFB-UGZ	-	-	-	-

LR-RFB-UIGZ	-	-	-	-
LR-RGB	-	-	-	-
LR-UGZ	-	-	-	-
LR-UIGZ	-	-	-	-
OW-RFB	-	-	-	-
RFB-WR	-	-	-	-
RGB	-	-	-	-
RGB-TR	-	-	-	-
RGB-WR	-	-	-	-
No Treatment	-	*1,780*	*688,832*	*690,612*

APPENDIX H: GAMS model documentation

Appendix H(i) Baseline models and transactions costs models

See *'BMP Model Paper - Appendix H(i) - Baseline & TC model documentation.txt'*. This file provides documentation for Scenario 12 – High implementation costs & High transactions costs. Model documentation for Scenarios 1 – 11 is the same as for scenario 12, with the only changes being to specify the appropriate implementation costs and transactions costs in the model objective function. For baseline scenarios (without transactions costs), transactions costs are set to zero in the objective function.

This digital appendix is located within the '*Rees_GJ_T_2015_f2.zip'* zipped file.

Appendix H(ii) Adoption model

See *'BMP Model Paper - Appendix H(ii) - Adoption model documentation.txt'.* This file provides documentation for Scenario 13 – Adoption model.

This digital appendix is located within the '*Rees_GJ_T_2015_f2.zip'* zipped file.

APPENDIX I: Model inputs workings

See *'BMP Model Paper - Appendix I - TMDL Model Inputs.xls*'

This digital appendix is located within the '*Rees_GJ_T_2015_f2.zip'* zipped file.

APPENDIX J: Model results & analysis workings

See *'BMP Model Paper - Appendix J(i) – TMDL Model Outputs.xls'* and *'BMP Model Paper – Appendix J(ii) – Constraints analysis – adoption model.xls'.*

These digital appendices are located within the '*Rees_GJ_T_2015_f2.zip'* zipped file.