LESSONS FROM WATER QUALITY TRADING CASE STUDIES

A LITERATURE REVIEW

REPORT FOR LONG ISLAND SOUND OBSTACLES AND OPPORTUNITIES STUDY

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1. Introduction

The Long Island Sound Study's 2015-2019 Comprehensive Conservation and Management Plan called for an exploration of the expansion of point source and nonpoint source (NPS) nutrient trading programs for the Long Island Sound Watershed. This exploration sought to build on the success of the existing Connecticut Nitrogen Credit Exchange Program, which dramatically reduced the costs for wastewater treatment facilities to reduce nitrogen loads to Long Island Sound (LIS).

NEIWPCC, a regional commission that helps the states of the Northeast preserve and advance water quality, was tasked with evaluating the obstacles and opportunities for a potential expansion of trading in the LIS watershed. This report is one part of that evaluation, which also included an economic analysis and an analysis of the potential for innovative approaches to incorporate ecosystem-based management into a trading program.

This report synthesizes a wide array of research and information about water quality trading programs in the United States and around the world. Papers reviewed in this study include economic analyses, policy documents and memos, project case studies, and more. Due to this diversity in subject matter and focus, not all papers share a common definition of a "successful" water quality trading program: a "successful" water quality trading program could entail attainment of improved water quality, but success could also refer to how well the water quality trading program itself functioned – for example a trading program with multiple trades occurred between sources. Some papers do not address the notion of a "successful program" at all.

This review provides information on four main components of a water quality trading program:

1. *Evaluating whether a water quality trading program is feasible to meet watershed goals.*
2. *Customizing the program structure to meet watershed conditions.*
3. *Determining the relationships and partnerships needed to support the trading program.*
4. *Instituting adaptive management after implementation to support long-term success.*

Within these main steps, specific elements of program design are discussed along with successful traits and less successful traits of past and current trading programs as relayed through case studies.

Throughout this document, key terms are identified by a double blue underline – these terms are defined in the key terms section.

2. Is Water Quality Trading the Right Tool?

Water quality trading programs vary throughout the world with most water quality trading occurring in the United States. Governmental agencies (including the EPA), economists, regulators, and other policymakers have promoted water quality trading programs as economically efficient tools for achieving nutrient load reductions and other water quality targets. This report and project focus primarily on nitrogen trading.

The project team is aware of and has closely reviewed the market-based water quality trading approach identified in the 2019 EPA Memo and 2020 paper "Water Quality Trading on a Watershed Scale"(EPA, 2019, 2020). However, there are several factors that limit a market-based approach to water quality trading in the LIS watershed which are detailed in this document and the accompanying reports by rbouvier consulting and Footprints in the Water.

Pollution Sources & Program Goals

Before establishing a water quality trading program, would-be program managers and leaders must determine whether a trading program is likely to be successful in meeting watershed goals. These goals will also determine the appropriate participants in a trading program. For some watersheds, trading between point sources may reduce the cost of compliance with water quality regulations; in others, trading may be structured to incentivize water quality improvements beyond those required by law. Any entity seeking to establish a trading program must be clear on the goal they are trying to meet through a trading program.

A 2005 study found that point source-nonpoint source trading was the most common type of trading program in the U.S. at that time, as these types of trades yielded the most cost savings (Morgan & Wolverton, 2005, p. 7; Puzyreva et al., 2019, p. 25). These trading programs also create incentives for unregulated or minimally-regulated agricultural non-point source dischargers to voluntarily reduce pollution (Jarvie & Solomon, 1998, p. 153; Mahjoobi et al., 2016, p. 2163). Though trading can also occur between point sources (as in the Connecticut Nitrogen Credit Exchange) and between non-point sources, these types of trades are less common (Selman et al., 2009).

A review by the Willamette Partnership found that trading between point and nonpoint sources is most likely to be a good fit for watersheds in which “there are clear sources of demand; state water quality agencies support trading; there is science to quantify water quality improvements from nonpoint sources; groups are ready to supply credits; and locally trusted leaders are ready and willing to champion trading.” (Willamette Partnership, 2012a, p. 6). These keys to success are applicable beyond point-nonpoint trading as well.

Market Size

The viability of a trading program depends largely on the supply of credits to be sold and the demand for those credits. Larger, more populated watersheds have more potential sources of supply and demand of credits for a trading market (Morgan & Wolverton, 2005, p. 12). In addition to the geographical area covered by the trading program, the number of potential trading participants and the supply and demand of credits are critical in assessing likely market size.

In smaller markets, the limited number of buyers and sellers can reduce potential flexibility in trading options and inhibit water quality trading. (Gasper et al., 2012; Willamette Partnership, 2012b). Trading markets can also be expanded by including more potential trading partners, including point sources and a variety of nonpoint source types. In the U.S., most trades occur between point and nonpoint dischargers and in large watersheds, which provide larger markets (Morgan & Wolverton, 2005, p. 47). However, larger markets can dilute environmental benefits and must implement policies to avoid the potential for localized pollution hotspots (EPA, 2008, p. 35). For more information on the projected market size for a trading program in the Long Island Sound watershed, refer to “Feasibility of Point-Nonpoint Nutrient Trading in the Long Island Sound Watershed” by rbouvier consulting (Bouvier et al., 2021). For more information on hot spots and the associated environmental justice concerns, section 11 of “Water Quality Trading in The Long Island Sound Study Area: A Preliminary Look At Some Economic Issues” by rbouvier consulting (Bouvier, 2020).

Program Drivers

Market size is determined by the drivers which foster participation in a trading program. Regulatory and economic drivers are fundamental to creating demand for trading credits. The economic drivers are generally produced by a strong regulatory program “with clear requirements, timelines and compliance enforcement" (Morgan & Wolverton, 2005, p. 7). In fact, research on water quality trading programs has shown that a lack of regulatory drivers like permit limits, watershed caps, or TMDLs generally resulted in a lack of trading in a water quality market (Gasper et al., 2012, p. 759).

There are several categories of drivers for water quality trading: regulatory, economic, voluntary, and community (Puzyreva et al., 2019, pp. 14, 22).

- **Regulatory drivers** include permit limits, watershed caps, or TMDLs. An agency, such as a federal or state agency, enforces these regulatory drivers.
- **Economic drivers** stem from varying costs to reduce discharges to meet a requirement, which are generally set by regulations.
- **Voluntary drivers** arise when business and organizations obtain stewardship credits, offset credits not utilized for compliance purposes, which promote sustainability efforts and objectives within the businesses and organizations. Voluntary drivers are often set by an organization or businesses' sustainability goals and/or community pressure.
- **Community drivers** come from a shared desire for demonstrated water quality improvements for social, economic, or personal reasons within a community.

Among case studies of water quality trading programs in the U.S., trading caps are a regulatory driver which has led to successful trading programs with active trading and improved water quality.

Capping discharges from regulated point sources can create a market in which nonpoint sources, especially agriculture, supply credits to allow point sources to meet their cap. This can reduce the cost of pollution reductions and provide an economic incentive for the nonpoint sources to contribute to water quality goals. (Ribaudo et al., 2014, p. 561).

The Connecticut Nitrogen Credit Exchange Program set a diminishing cap on nitrogen discharges through regulation; the variable costs of compliance with this cap served as the economic driver of their program (Powers, 2006, p. 2).

The Lake Taupo water quality trading program in New Zealand used the first NPS-NPS cap-and-trade policy in the world (Puzyreva et al., 2019, p. 13). In this program, load-based caps and careful monitoring of total pollutant loads that supported the cap-and-trade approach (Puzyreva et al., 2019, p. 24).

The Connecticut and the Lake Taupo trading programs both met their nitrogen reduction goals, suggesting that trading caps can play an important role in successful water quality trading programs (Powers, 2006, p. 5; Puzyreva et al., 2019, p. 14).

Costs of Compliance

Trading is facilitated by variable costs of compliance, which occur when costs to implement pollutant reductions and meet water quality requirements vary throughout a watershed. This variability provides an opportunity for trading between sellers with a low cost of abatement and buyers with relatively higher abatement costs. Larger markets with many potential buyers and sellers and many different discharge types are more likely to have a wide range of implementation costs of best management practices (BMPs) and other pollution abatement practices. (Charles River Watershed Association, 2014, p. 7). Therefore, a key first step in assessing the feasibility of water quality trading programs is to assess whether the watershed has enough potential participants with variable costs of compliance to support a trading market.

Point and nonpoint sources face variable costs of compliance with water quality regulations. While this variation allows for significant potential cost-savings from trading, this potential remains largely dependent on water quality and pollution reduction regulations and accountability to ensure that the nonpoint source is successful in achieving reductions (Jarvie & Solomon, 1998, p. 139).

Economic Modeling

Building an economic model prior to instituting a water quality trading program is vital in the development and establishment of a successful trading program (Motallebi et al., 2017). An economic model provides water quality managers and planners with insights into whether a water quality trading program is feasible within the context of a specific watershed. Economic modeling should determine the sources of supply and demand within a watershed, including whether there are adequate drivers to generate demand for credits.

The economic models must incorporate elements of trading program design as discussed in this report, including the effects of baselines, transaction and trading costs, and trade ratios. (Motallebi et al., 2017, p. 483). A clear and thorough assessment of these elements through economic modeling is important to support a successful water quality trading program.

Example: In economic analysis of the Jordan Lake watershed in North Carolina, researchers found that the supply of credits was only able to meet the demand for the first two years of the program's existence; after the two-year window, demand would outstrip supply. They therefore concluded that a trading program was not an appropriate tool for Jordan Lake watershed. (Motallebi et al., 2017, p. 489)

Additional modeling may also be helpful in determining credit prices and examining cost saving options. In the Gharesoo watershed in Iran, researchers completed a hydrological model, a water quality model, and an economic model to determine the feasibility of including nonpoint discharges within the watershed's water quality trading market. This combination of models allowed planners to survey potential buyers and sellers, ascertain credit prices, and discern cost-saving scenarios (Mahjoobi et al., 2016, pp. 2162–2163).

3. Program Design

After determining that there is potential for water quality trading within a watershed, program managers must design a trading program which fits the unique context and characteristics of their watershed. As no two watersheds are the same, no two trading programs will be the same (Puzyreva et al., 2019, p. 5). Customizing a trading process allows for both flexibility and exploration throughout the planning process: "successful" traits in some trading programs might not work in others, and traits which are unsuccessful in some contexts work in others. Customization offers the opportunity to "construct a water quality trading program which utilizes specific trends and characteristics to meet each watershed's unique needs" (Willamette Partnership, 2012b, p. 11). These unique needs may stem from watershed boundaries, land-use patterns, physical landscape characteristics, policy contexts, and socioeconomic factors (Puzyreva et al., 2019, p. 5). Programs which use innovative, lesser-used elements of water quality trading programs, such as credit-stacking or co-benefits, may require more customization, adaptive management, and risk-mitigation than those relying solely on more commonly used elements. (Liu & Swallow, 2016, pp. 3404–3405). Consequently, including lesser used elements of water quality trading programs requires more customization and trial and error than more commonly used elements of water quality trading.

A. Water Quality Trading Structures

Water quality trading structures vary to support different trading goals, frequencies, and program participants. Structures meant for singular, one-off trades differ from those designed for continuous, repetitive trades (Morgan & Wolverton, 2005, pp. 4–6). The most common trading structures include bilateral negotiations, clearinghouses, exchanges, and third party systems (Charles River Watershed Association, 2014, pp. 20–21).

In **Bilateral negotiations**, trades occur directly between buyers and sellers, who negotiate trading terms and develop their own agreements. A "public authority" approves trades and sets the trade ratio. (Charles River Watershed Association, 2014, pp. 20–21; EPA, 2008, pp. 2–6). Bilateral negotiations tend to have high transaction costs, and are frequently used for trading programs where many sellers provide heterogeneous credits for purchase (Morgan & Wolverton, 2005, p. 14).

Examples (Breetz et al., 2004; Selman et al., 2009)

- *Lake Dillon, Colorado*
- *Lower Boise River Effluent Trading Demonstration Project, Idaho*
- *Passaic Valley Sewerage Commissioners Pretreatment Trading Project, New Jersey*

A **Clearinghouse** structure relies on an intermediary to connect buyers and sellers and authorize trades. This oversight agency, sometimes a state, pays for nutrient reduction or other pollution abatement and sells the credits at a fixed price (Charles River Watershed Association, 2014, pp. 20–21; Morgan & Wolverton, 2005, p. 14). A clearinghouse is an optimal option in a watershed with similar pollution discharges allowing "for the transfer of rights between buyers and sellers". Transaction costs within a clearinghouse water quality structure may be quite low compared to other water quality trading structures (Morgan & Wolverton, 2005).

In many clearinghouse structures, the oversight agency establishes the market that acts as the clearinghouse. This can "ameliorate negative public perceptions if poorer communities had to buy credits from wealthier communities" (Powers, 2006, pp. 2, 6).

Examples (Breetz et al., 2004; Selman et al., 2009)

- *Chatfield Reservoir Trading Program, Colorado*
- *Cherry Creek Basin, Colorado*
- *Connecticut Nitrogen Credit Exchange Program*
- *Tar-Pamlico Nutrient Reduction Trading Program, North Carolina*
- *South Nation River Watershed Trading Program, Ontario, Canada*

An **exchange** operates with an open, transparent structure allowing "fluid transactions" between multiple buyers and sellers. Unlike in a bilateral negotiation, credit prices are fully transparent and visible between all buyers and sellers in a market. Exchanges are only a viable option when the trade ratio between buyers and sellers is 1:1; in other words, exchanges can only occur when a unit of pollutant reduction from sellers is equivalent to one unit for buyers (Charles River Watershed Association, 2014, pp. 21–22).

Examples (Breetz et al., 2004; Selman et al., 2009)

- *Hunter River Salinity Trading Scheme, New South Wales, Australia*

- *Pennsylvania Water Quality Trading Program*
- *West Virginia Potomac Water Quality Bank and Trade Pilot, West Virginia*

In **SOLE SOURCE OFFSETS**, no true trading occurs. Instead, an individual source takes action to offset its own discharges, either through on-site or off-site interventions to reduce pollution (Charles River Watershed Association, 2014, p. 20; Morgan & Wolverton, 2005, p. 29)

Examples (Breetz et al., 2004; Selman et al., 2009)

- *Clear Creek Colorado, U.S.*
- *Boulder Creek Trading Program Colorado, U.S.*
- *Lake Champlain New York/Vermont, U.S.*
- *Falmouth, MA* (Morgan & Wolverton, 2005, p. 29)

In a **THIRD PARTY** water quality structure, a regulatory agency, NGO, or some other independent body acts as a broker, identifying and managing trades between buyers and sellers. However, "...a third party does not eliminate contractual or regulatory links between sellers and buyers" (Charles River Watershed Association, 2014, p. 9; Morgan & Wolverton, 2005, p. 14).

Examples (Breetz et al., 2004; Selman et al., 2009)

- *Piasa Creek Watershed Project, Illinois*
- *Great Miami River Watershed Water Quality Credit Trading Pilot Program, Ohio*
- *Red Cedar River Nutrient Trading Pilot Program, Wisconsin*

The common structures described above serve as a basis from which to guide other decisions in the water quality trading program design process. The report, "Water Quality Trading and Offset Initiatives in the U.S.: A Comprehensive Survey" which covers water quality trading programs in the U.S. up to 2005, reveals that trading structures often diverge from these familiar structures or can have a mix of structures within their design.

Examples:

- *The Chatfield Reservoir Trading program in Colorado "includes a clearinghouse but also accepts bilateral agreements"* (Selman et al., 2009, p. 40)
- *The Southern Minnesota Beet Sugar Cooperative Permit in Minnesota has the structure of a "sole-source offset with bilateral negotiation"* (Selman et al., 2009, p. 186)

For more in depth economic information on exchanges, bilateral negotiations, clearinghouses, and sole-source offsets, refer to section 6 of *"Water Quality Trading in The Long Island Sound Study Area: A Preliminary Look At Some Economic Issues" by rbouvier consulting* (Bouvier, 2020).

As demonstrated in the following sections, all trading structures benefit from establishing a strong institutional framework and having a clearly outlined set of rules and structures (Puzyreva et al., 2019, p. 14).

B. Key Qualities for Successful Trading Programs

Simplicity

Research and analyses on water quality trading find that keeping programs as simple as possible can facilitate program success. In some cases, simplicity can refer to consistent and transparent rules for trading. In others, it can refer to the nature of relationships between a regulating authority and trading program participants. Critically, keeping programs simple can help reduce the barriers to participation in a water quality program. Although all trading structures will require some paperwork, program managers should explore ways to minimize the extent of paperwork needed to conduct trades (Electric Power Research Institute, n.d.).

Example: *The Southern Nation water trading program in Canada benefited from keeping monitoring and reporting procedures simple for landowners* (Puzyreva et al., 2019, p. 12)*.*

Flexibility

Trading programs also benefit from incorporating flexibility into their structure. There are many ways to integrate flexibility into a trading program, including offering leeway in the implementation of BMPs or in setting annual reduction targets as benchmarks instead of as requirements (Puzyreva et al., 2019, p. 24). Flexible program structures also allow space for further customization of the water quality trading program to meet local political, economic, and ecological conditions. Trading programs may allow flexibility for point sources to meet their permit limits or other regulatory requirements in more cost-effective ways. Though Zhao, Poe, and Boisvert (2015, p. 5) found that allowing for flexibility by relaxing constraints on trading across watershed zones can produce significant cost-savings, this must be done carefully to avoid pollution hotpots.

Accountability & Visibility

ACCOUNTABILITY and **VISIBILITY** often go hand and hand when designing and building support for a trading program.

Accountable trading programs have detailed, well publicized guidance about participant roles and water quality trading program operations. This can include the use of accessible, easily navigable databases and online registries which share the activities and results of the trading program. In their 2007 “Water Quality Trading Toolkit for Permit Writers”, the EPA identified several keys to past success directly related to the theme of accountability and transparency. These “keys” include “transparency, real [and visible] pollutant reductions, accountable tracking, clear lines of responsibility, and safeguarding property rights and privacy” (EPA, 2007, p. ix).

Nonpoint source pollution reductions can be especially challenging to account for. Trading programs must be able to demonstrate and estimate these improvements using robust, scientifically defensible water quality models to establish accountability of trading involving nonpoint sources (Puzyreva et al., 2019, p. 43).[1] These controls and forms of accountability may include loading limits with associated noncompliance fines, requiring retroactive trading based on loads after BMPs are installed, or by setting protective trade ratios (Mahjoobi et al., 2016, p. 2163; Morgan & Wolverton, 2005, p. 17).

To maintain accountability, avoid uncertainty about trading rules. Trading is impeded by lack of clear rules about how to determine credits for non-point sources, especially for ongoing offset programs (Morgan & Wolverton, 2005, p. 24). A “Statement of Roles and Responsibilities” for trading programs can help provide clarity, establish accountability and to avoid misunderstandings (Puzyreva et al., 2019, p. 33).

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[1]For detailed methods about accounting for nonpoint discharges, see “Management of unregulated agricultural nonpoint sources through water quality trading market” (Mahjoobi et al., 2016) and “Encouraging Reductions in Nonpoint Source Pollution through Point-nonpoint Trading: The Roles of Baseline Choice and Practice Subsidies” (Ribaudo et al., 2014).

Example: *The Ohio River Trading Project utilizes an online credit registry run by the Electric Power Research Institute. The online credit registry tracks trades and provides a public platform for accountability.* (Electric Power Research Institute, n.d.)

Example: *In the Tualatin River Offset program (Oregon), seeing visible and apparent changes within the landscape prompted stakeholder confidence and satisfaction in the program* (Puzyreva et al., 2019, p. 17)*.*

Risk Mitigation

Risk preferences of stakeholders significantly influence stakeholder participation in water quality trading programs. (Woodward, 2000, p. 264). There are many sources of risk, and different stakeholders may be sensitive to different risks of the program, which could include financial uncertainty, political consequences, or lack of environmental improvement. Program planners must identify these sources of risk, understand the risk tolerances of potential participants within a trading program, and explore opportunities to mitigate risks (Willamette Partnership, 2012b, p. 19).

By recognizing and addressing risk, water quality trading programs can increase the likelihood that credit buyers will participate in the trading program (Woodward, 2000, p. 263).

Reducing Financial risk:

- Create mechanisms to minimize swings in the value/cost of credits (Electric Power Research Institute, n.d.)
- Ensure revenue certainty for BMP installation regardless if credits are generated, and establish ways to address non-performance issues [2] (Electric Power Research Institute, n.d.; Puzyreva et al., 2019, p. 37).
- Explore opportunities to generate credits across several markets (cobenefits) (Liu & Swallow, 2016)

Reducing Regulatory, Legal, or Political Risk:

- Consider ways to reduce risk for regulatory agencies (Woodward, 2000, p. 262)
- Trades should pose no additional risk or responsibility for a point source to reduce effluent at a nonpoint source that is not under the point source's control (Jarvie & Solomon, 1998, p. 137)
- Limit legal liabilities for farmers involved as credit producers (ex. Do not hold farmers liable for not meeting point source reductions) (Puzyreva et al., 2019, p. 37)

Reducing Risk of Uncertain Environmental Improvement:

- *Offer easy access to technical assistance, including information about impacts of BMPs on crop yields (Electric Power Research Institute, n.d.)*
- Set efficient trade ratios well supported by scientific research and technological innovations (Woodward, 2000, p. 262)
- Set appropriate, conservative baselines. (Ribaudo et al., 2014)

Example: *In the Southern Nation Water quality trading program in southern Ontario, farmers participating in the program were not liable for a possible shortage of credits. This absence of*

[2] Any program that uses this method to reduce risk must also build in mechanisms to track and ensure that pollution reductions do occur.

liability was enforced through a contract between the Ministry of Environment, the Federation of Agriculture, and the South Nation Conservation (Puzyreva et al., 2019, p. 12).

Example: *Connecticut's Long Island Sound Nitrogen Credit Exchange Program serves as a prime example for institutional frameworks to minimize risk in a water quality trading program. Within the LIS Credit Exchange, a clearinghouse sets a fixed annual price for nitrogen credits and the state of Connecticut promises to cover credit surpluses. This means that the State of Connecticut purchases any credits supplied in excess of demand. This ensures that participating wastewater treatment plants enact measures to reduce discharges with less uncertainty about financial returns on those measures* (Powers, 2006, p. 4; Zhao et al., 2015, p. 30)

For more on risk and uncertainty, refer to section 3 of "Water Quality Trading in The Long Island Sound Study Area: A Preliminary Look At Some Economic Issues" by rbouvier consulting (Bouvier, 2020).

C. Program Elements

There are several elements of a trading program which have a significant role in determining how effective the program can be at meeting program goals. Each of these acts as a lever that must be calibrated carefully to balance water quality improvements, economic benefits, and other goals.

I. Transaction Costs

Transaction costs, the costs associated with administering and managing a trading program, are an important consideration when designing water quality trading programs. These costs vary greatly based on the trading program structure, regulatory environment, and watershed condition. To establish a successful water quality trading program, managers must minimize transaction costs to the extent possible. (Puzyreva et al., 2019, p. 39; Woodward, 2000, p. 263). An economic analysis of the Jordan Lake watershed in North Carolina found that high transaction costs significantly decreased demand for credits (Motallebi et al., 2017, p. 488).

Keys to Success:
Keep Transaction Costs Low

- *Choose an efficient **program structure***
- *Reduce administrative costs*
- *Explore options for low-cost, ongoing **monitoring***
- *Streamline **application process** and paperwork.*

Program Structure & Administration Costs

Trading program structure can play a significant role in the transaction costs associated with the program. For example, transaction costs within a clearinghouse structure may be comparatively low, as the central clearinghouse bears the transaction costs of trades (Morgan & Wolverton, 2005, p. 14; Woodward, 2000, p. 263).

In many water quality trading programs, the entity that pursues the trade bears the costs of transaction (Puzyreva et al., 2019, p. 40). In trades occurring between point sources and nonpoint sources, point sources often bear high transaction costs including the administrative costs of initiating trading and bargaining, the costs of collecting data, monitoring costs, and, in some cases, development and implementation of BMPs to reduce nonpoint sources. (Jarvie & Solomon, 1998, p. 138).

High administrative costs may deter trading. Administrative costs may be minimized by streamlining oversight and trade review processes and using extant monitoring systems already in use for other purposes. (Morgan & Wolverton, 2005, p. 20). "Efficient institutional arrangements" can also reduce administrative costs by establishing cost-sharing mechanisms or outright government assumption of costs. Arranging trades during large, multi-lateral meetings can help maintain low transaction costs.(Morgan & Wolverton, 2005, p. 18; Woodward, 2000, p. 263)

Programs with highly detailed application processes, lengthy approval processes, and complex bargaining systems often have higher transaction costs. (Morgan & Wolverton, 2005, p. 18)

Monitoring Costs

High costs of monitoring, along with costs of oversight and inspection for NPS BMPs, can lead to significant transaction costs. (Morgan & Wolverton, 2005, p. 20). Where possible, trading programs should rely on existing water quality and BMP monitoring programs. Where there are no existing water quality monitoring programs which can be applied to a trading program, program designers should opt for ongoing NPS BMP monitoring strategies which require less effort, are less time intensive, and do not need significant or ongoing maintenance. BMP selection can also play a significant role in the cost of monitoring; BMPs that rely on native vegetation may require less upkeep and monitoring once established. (Puzyreva et al., 2019, p. 45).

For more on Transaction Costs, see section 9 of "Water Quality Trading in The Long Island Sound Study Area: A Preliminary Look At Some Economic Issues" by rbouvier consulting (Bouvier, 2020).

II. Trade Ratios

Water quality trading programs must be designed to manage and address uncertainties stemming from the differences in how pollution reduction activities impact water quality in the target water body. This can include the variable impacts of different types of reductions and spatial variability.

Setting appropriate trade ratios is important to address variability and potential uncertainty within trades across different types of point and nonpoint discharge reductions. While reduction in pollution from point sources is easily measurable, reductions for non-point charges can be harder to measure. Consequently, trade ratios for programs which include both nonpoint and point sources must "adjust" the market so point and nonpoint discharges can trade "apples for apples" (Woodward, 2000, p. 262).

Often, programs control for uncertainty in non-point source controls by making the trade ratio greater than 1:1 – that is, requiring non-point sources to generate more reductions than a point source would have to earn (or offset) a single credit (Morgan & Wolverton, 2005, pp. 15, 47).

Discharges generally have a greater impact on water quality when they are closer to the target water body because pollution can be attenuated as discharges flow through the watershed or through upstream

> **KEYS TO SUCCESS:**
> **Balance Trade Ratios**
>
> Trade ratios must be set to ensure environmental improvements *and* maintain a feasible trading program.
>
> - *High trade ratios support greater environmental improvements.*
> - *Lower trade ratios support greater demand for credits and increased participation in trading.*

tributaries. Trade ratios also play an important role in accounting for this spatial variability between buyers and sellers.

In establishing trade ratios, trading program managers must strike a balance between economic goals, policy goals, farmer interests, and actual environmental improvements (Woodward, 2000, p. 262). If trade ratios are too generous (closer to 1:1 across the watershed), more credits will be generated at the potential cost of actual environmental improvements. While more stringent trade ratios (further from 1:1) ensure that each transaction results in water quality improvements, they may inhibit trading program participation overall and prevent markets from succeeding (Mahjoobi et al., 2016, p. 2163; Woodward, 2000, p. 262).

Example: *An economic analysis on Jordan Lake in North Carolina reveals that high trade ratios significantly decreased demand* (Motallebi et al., 2017, p. 488).

For more on Trade Ratios, see section 2 of "Water Quality Trading in The Long Island Sound Study Area: A Preliminary Look At Some Economic Issues" by rbouvier consulting (Bouvier, 2020).

III. Baselines

The ***baseline*** serves as the starting point for trading within a water quality market and determines when credits may be generated for trading.

To ensure additionality[3], baselines should be set at the amount of pollutant that would have been discharged in the absence of the trading program (Ribaudo et al., 2014, p. 563). In watersheds with established TMDLs, the TMDL load allocations can be used as the baseline for NPS trades. For point sources, baselines are largely set by permit limits.

Baselines should reflect the level of abatement required regardless of whether trading were to occur. EPA suggests that trading programs "set a nonpoint source eligibility baseline that extracts some "extra" abatement from nonpoint sources" to address uncertainty in nonpoint source reductions (Ribaudo et al., 2014, p. 560).

The stringency of the baseline can impact the demand for trading, the water quality improvements generated from trading, and the ability to build consensus among stakeholders (Woodward, 2000, p. 262). Baselines should be evaluated on a project-by-project basis to determine the appropriate level of stringency (Ribaudo et al., 2014, p. 573). Within the context of a point-nonpoint trade, baselines must balance the objectives of increasing nonpoint discharge abatement and reducing the cost for point source to meet discharge limits (Ribaudo et al., 2014, p. 572).

KEYS TO SUCCESS:
Balance Baselines

- *Set baselines to ensure that water quality will improve.*
- *In general, more stringent baselines are more protective of the environment, while less stringent baselines incentivize trading, generate more credits.*
- *Subsidies can reduce the cost of meeting baselines.*

[3] For a comprehensive discussion of additionality, refer to section 6 of *"Water Quality Trading in The Long Island Sound Study Area: A Preliminary Look At Some Economic Issues" by rbouvier consulting* (Bouvier, 2020).

Programs should be designed with baselines in place that ensure that policy objectives (water quality improvements) are achieved even if trading does not occur (Woodward, 2000, p. 263).

A less stringent baseline serves as an incentive for participation in a water quality trading program by allowing for the generation of more credits for point sources (Ribaudo et al., 2014, p. 572).

In a point-nonpoint trading scenario, a stringent baseline also limited the amount of pollution reduction from nonpoint sources due to lack of incentives for participation in the trading program (Motallebi et al., 2017, p. 488).

In a study focused on the Chesapeake Bay Watershed, more stringent baselines led to less trading in point-nonpoint trading programs and decreased overall abatement from agricultural nonpoint sources. (Ribaudo et al., 2014, p. 572). Subsidies established to help farmers and other nonpoint sources meet a baseline requirement increased overall nonpoint source pollution reduction, but reduced the number of credits available and therefore the opportunities for trading (Ribaudo et al., 2014, p. 560).

Gathering the cost and efficiency information needed to determine appropriate NPS baselines remains a challenge for project planners and leaders due to confidentiality around agricultural BMPs and limited monitoring. (Ribaudo et al., 2014, p. 572).

For more on baseline determination, see section 4 of "Water Quality Trading in The Long Island Sound Study Area: A Preliminary Look At Some Economic Issues" by rbouvier consulting (Bouvier, 2020)*.*

IV. Co-Benefits & Credit Stacking

Credit stacking and co-benefits are intertwined concepts with great potential for ensuring efficient market design. Within the context of a water quality trading program, co-benefits refer to the non-water quality benefits generated from measures taken to reduce pollutant discharges (Gasper et al., 2012, p. 758). Examples of co-benefits include carbon sequestration, ecosystem services, habitat enhancement, and reduction of excessive run-off (Jarvie & Solomon, 1998, p. 3388).

Credit stacking occurs when trading programs allow these co-benefits to be traded across multiple markets. For example, certain nonpoint pollution reduction BMPs also sequester carbon, and may therefore generate credits within carbon or climate-emissions trading markets in addition to water quality trading markets.

Integrating recognition of co-benefits into the structure of the water quality trading program could provide expanded opportunities for benefit to both conservation buyers and the public (Liu & Swallow, 2016, p. 3404). Economic models can assess the potential to integrate co-benefits and credit stacking into a water quality trading program (Gasper et al., 2012). These models should estimate the monetary value of various types of co-benefits (Liu & Swallow, 2016, p. 3404).

Co-benefits and credit stacking may incentivize participation in a program, including installation of more expensive, more effective BMPs (Gasper et al., 2012, p. 764). Including co-benefits in water quality trading can lead to more efficient market outcomes by providing multiple incentives to improve environmental quality (Liu & Swallow, 2016, p. 3404).

Co-benefits and credit stacking may also help build public support for a water quality market, though this is not always the case. (Gasper et al., 2012, p. 759). When incorporating credit stacking into a trading program, market managers must be careful to "preserve the market's environmental integrity" by ensuring that all trades result in a net reduction of pollution across all relevant markets (Gasper et al., 2012, p. 761).

***Example:** An analysis of EPRI's Ohio River Basin Trading found that incorporating co-benefits in a water quality trading program increased efficiency within the market.* (Liu & Swallow, 2016, p. 3404).

***Example:** Analysis of the Chesapeake Bay's water quality trading program found that half of the greenhouse gas emissions produced by the state's agriculture sector could be offset through water quality improvements; this means that agricultural sources could participate in both carbon and water quality markets, offering even more incentives for polluters to reduce their emissions and discharges* (Gasper et al., 2012, p. 758).

For more on credit stacking, see section 8 of "Water Quality Trading in The Long Island Sound Study Area: A Preliminary Look At Some Economic Issues" by rbouvier consulting (Bouvier, 2020).

4. Roles, Responsibilities, and Relationships

Leadership

Numerous studies highlight the value of strong, committed leadership as critical to the long-term success of a program (Puzyreva et al., 2019, p. 47).

Trading program leaders must have a clear, structured, and sustainable vision for the program that takes a long-term approach. Water quality trading programs require sustained focus and effort to guide the program through years-long development and implementation efforts (Puzyreva et al., 2019, p. 5). The ideal trading program administrator will also build community support through credibility, transparency, and accountability (Puzyreva et al., 2019, p. 37).

***Example:** Strong leadership in the Tualatin River (Oregon) offset program allowed the program to pioneer different trading policies and regulatory approaches* (Puzyreva et al., 2019, p. 17)

***Example:** Patient, committed leadership of the Lake Taupo, NZ trading program was necessary throughout the eleven-year process to establish a successful trading program* (Puzyreva et al., 2019, p. 14)

Working with Existing Programs

Working with existing institutions or with existing trading programs within a watershed increases the likelihood that a water quality trading program will actually generate trades (Puzyreva et al., 2019, pp. 6, 40). Integrating and building upon extant programs can also provide cost-savings, as new trading programs can build on research and modeling completed by the existing programs (Puzyreva et al., 2019, p. 40). As water quality trading programs are highly context-dependent, extant institutions and trading programs in a watershed can offer specific guidance and information attuned to the watershed's needs. Collaboration with existing institutions also offers an opportunity to build support and a network to foster acceptance of and respect for the trading program.

Facilitating Participation

Strong incentives for participation in a trading program can be a key factor in determining in program success (Jarvie & Solomon, 1998, p. 137). This is particularly true for trades involving nonpoint sources, which face less government regulation and therefore fewer drivers for trading. Program managers must be careful to balance actions that promote more trades with actions that promote environmental benefits. Though there are opportunities which increase both number of trades and environmental benefit, these two objectives can sometimes be at odds.

To facilitate trading:

- Strengthen regulatory drivers by establishing and enforcing more stringent baselines or trading caps; lower baselines provide stronger drivers to participation (Gasper et al., 2012; Jarvie & Solomon, 1998; Puzyreva et al., 2019; Ribaudo et al., 2014)
- Keep transaction costs low (Motallebi et al., 2017, p. 488)
- Institute lower trade ratios (Woodward, 2000, p. 262)
- Simplify documentation requirements and paperwork for partners and stakeholders (Electric Power Research Institute, n.d.)
- Allow credit stacking, which can also incentivize the pursuit of more expensive and more effective BMPs (Gasper et al., 2012, p. 764)
- Illustrate benefits of trading for local communities (Jarvie & Solomon, 1998, p. 137)
- Minimize risk, as "the risk preferences of participants in such a market will play a major role in determining whether they participate or not" (Woodward, 2000, p. 264)

Example: In the Lake Taupo, New Zealand water quality trading program, stakeholders were incentivized to participate through economic benefits and water quality benefits; participants in the program recognized the benefits of water quality improvements for the forestry industry and the tourism sector (Puzyreva et al., 2019, p. 14).

Agricultural Partnerships

Though stakeholders and the discharge types vary between watersheds, most water quality trading programs work with the agricultural sector[4] in some capacity. As such, managing institutions must establish positive relationships with farmers for successful trading. A well-designed water quality trading program could provide many benefits (including economic, ecological, and social) to farmers (Mahjoobi et al., 2016, p. 2175). In addition to the general guidelines described above for facilitating trading, there are several strategies which are specific to agricultural partners.

To work well with farmers:

- Engage and consult with farmers early in the program design process (Puzyreva et al., 2019, p. 35). Recognize and respect farmer's experience and environmental knowledge, which may include putting farmers in charge of decision-making processes and funding decisions that involve agricultural projects (Puzyreva et al., 2019, p. 12).
- Explore opportunities for peer-to-peer monitoring, in which farmers are hired as field representatives to conduct monitoring and reporting for the program. (Puzyreva et al., 2019, p. 36).
- Use a trusted intermediary to manage the program, especially where the government is leading efforts to establish a water quality trading program. Due to cultural differences, perceptions of working with "businesses" are often more positive than perceptions of working with the government (Puzyreva et al., 2019, p. 37).
- Provide information to farmers about how instituting best management practices (BMPs) affect crop yields (Electric Power Research Institute, n.d.)

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[4] For Long Island Sound, this should include aquacultural producers, who may generate nutrient reduction credits through BMPs (i.e. feeding and waste management practices on fish farms) or through expansion of aquaculture facilities focused on bioextraction.

- Accommodate each partner's unique needs regarding their lands (Puzyreva et al., 2019, p. 17).

Community Involvement

Public support is key to a water quality trading program's success. The communities affected by a proposed water quality program are a critical stakeholder and should be included in water quality trading program design. Community involvement can also encourage other stakeholders to participate in the water quality program and conduct trades; buyers and sellers are more likely to be interested in trading programs that their friends and neighbors support and benefit from. Increasing community involvement in an open and public manner also increases the likelihood of successful trading, while limited or minimal community involvement may lead to community opposition to the trading program (Jarvie & Solomon, 1998, pp. 137, 153, 155).

To engage the community:

- Inform the public early on in trading program design (Jarvie & Solomon, 1998, p. 155). For government-led trading programs, this may include the public input and comment requirements within regulatory processes.
- Program leaders and regulators should maintain an open-door policy when meeting with industry members to increase perceived and actual accessibility to program management (Jarvie & Solomon, 1998, p. 155).
- Highlight co-benefits of establishing a water quality trading program, which may include the possibility of added resources to a community, for example, construction jobs (Powers, 2006, p. 6).

Example: *The Lake Taupo water trading program in NZ demonstrates the importance of strong community interest in environmental protection and water quality towards success with a water quality trading program's objectives. The community viewed the Lake Taupo as a "national treasure," which built more support for and involvement in the program itself. Additionally, the program incentivized stakeholder participation through economic benefits as well as water quality benefits; program participants acknowledged the value of water quality improvements for the forestry industry and tourism sector* (Puzyreva et al., 2019, p. 14).

Example: *Tualatin River (Oregon) offset program found success by focusing on collaborative partnerships* (Puzyreva et al., 2019, p. 17).

For more on trust, norms, and communication within a water quality trading program, see section 10 of "Water Quality Trading in The Long Island Sound Study Area: A Preliminary Look At Some Economic Issues" by rbouvier consulting (Bouvier, 2020).

5. ADAPTIVE MANAGEMENT

Adaptive management is an iterative learning process structured to improve management outcomes. It can promote "flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood." (Williams et al., 2009, p. v) As trading programs must be customized to each individual watershed and inherently include significant uncertainty, adaptive management is an important tool to support successful trading programs.

Trading program management should be designed to track successes and failures and modify the program based on these lessons and on the program's actual impact on water quality. (Puzyreva et al., 2019, p. 5) This adaptive management approach allows program managers to continuously improve the water quality trading program to better meet program goals

(Willamette Partnership, 2012b, p. 5). Adaptive management also enables a program to grow over time in response to changes within the watershed and beyond.

6. CONTEXTUAL CONSIDERATIONS FOR THE LONG ISLAND SOUND

No two watersheds are the same, and therefore no two water quality trading program designs will be the same. A water quality trading program for the Long Island Sound watershed must be customized for the watershed. The following is a preliminary assessment of the obstacles and opportunities for water quality trading in the watershed; other reports will provide deeper context on the economic and environmental conditions in the watershed.

Opportunities for Trading in the LIS Watershed

Large Watershed means larger Market Size: In general, larger markets increase the likelihood of success (as defined by number of trades) in water quality trading programs. As a large watershed, there *may* be the potential for a large water quality trading market in Long Island Sound. The companion report by rbouvier consulting, Feasibility of Point-Nonpoint Nutrient Trading in the Long Island Sound Watershed, includes an analysis of the potential market.

Strong Network of Existing Programs: The LIS watershed has a successful existing trading program, the Connecticut Nitrogen Credit Exchange (NCE). Additionally, the Long Island Sound Study is an established, well-respected organization is a broad network of partners through which to build a successful program. Working with these programs could also offer more cost-saving options if a trading program was established for the entirety of the Sound. NEIWPCC and others are also positioned well to support these partnerships.

Obstacles to Trading in the LIS Watershed

Limited, Unclear Program Drivers: All successful trading programs need a strong "driver" to incentivize participation in a trading program. Though the LIS TMDL has incentivized participation in the existing NCE, the TMDL load reduction requirements have largely been met, and no longer provide an incentive to participate in trading. (Long Island Sound Study, 2019). The companion report by rbouvier consulting, Feasibility of Point-Nonpoint Nutrient Trading in the Long Island Sound Watershed, includes an analysis of potential program drivers.

Large, Complex Watershed Requires Complex Program: The Long Island Sound watershed is large and heterogeneous, with a wide variety of land uses and potential drivers for participation. While simpler trading programs are more likely to be successful, the level of heterogeneity in the watershed necessitates increased complexity (and paperwork) within the program design. (See Simplicity & Flexibility.) An approach developed by Footprints in the Water and described in a companion report for this project, could smooth this complexity and simplify the program.

Interstate Trading Introduces Risk: Very few existing water quality trading programs involve multiple states. The lack of precedent for interstate trading introduces an additional layer of risk for any program seeking to include this element in a trading system. This is especially true because many of the elements that minimize risk, including ensuring revenue for credits generated, rely on state government involvement and oversight. (See Minimize Risk.)

Though the plan for the Ohio River Trading Program includes interstate trading, a trial program for this project ended in 2019 and data is not yet available on the program's outcomes. During the trial period, the program had few to no trades, and most credits received were stewardship credits (Electric Power Research Institute, n.d.). Though NEIWPCC could support the interstate collaboration necessary to overcome this challenge, a strong regulatory driver is necessary.

7. Water Quality Trading: Key Terms

Adaptive Management

Adaptive management is an iterative learning process structured to improve management outcomes. It can promote "flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood." (Williams et al., 2009, p. v) As trading programs must be customized to each individual watershed and inherently include significant uncertainty, adaptive management is an important tool to support successful trading programs.

Source: Williams, B. K., Szaro, R. C., & Shapiro, C. D. (2009). *Adaptive Management: The U.S. Department of the Interior Technical Guide*. Adaptive Management Working Group, U.S. Department of the Interior. https://www.doi.gov/sites/doi.gov/files/migrated/ppa/upload/TechGuide.pdf

Additionality

Duke et al. (2014) define additionality as the idea that an introduced management practice provides an ecosystem service (i.e., nutrient load reduction or carbon sequestration) that is currently is not provided or would not have been provided in the absence of the management action. Further, they define Nonadditionality as "an ecosystem service provided prior to the policy, but that is claimed to be an environmental improvement outcome of the policy." Environmental quality can decrease if policymakers allow these nonadditional "reductions" to be traded as offsets and then emitted by another source.

Source: Duke, J. M., McGrath, J., Fiorellino, N. M., Monteith, T., & Rosso, E. (2014). *Additionality in Water Quality Trading: Evidence from Maryland's Nutrient Offset Program* (APEC RR14-06). Applied Economics and Statistics, Department of Delaware.

Co-Benefits

Within the context of a water quality trading program, co-benefits refer to the non-water quality benefits generated from measures taken to reduce pollutant discharges (Gasper et al., 2012, p. 758).

Source: Gasper, R. R., Selman, M., & Ruth, M. (2012). Climate co-benefits of water quality trading in the Chesapeake Bay watershed. *Water Policy*, *14*(5), 758–765. https://doi.org/10.2166/wp.2012.166

Credit Stacking

Credit stacking occurs when trading programs allow co-benefits to be traded across multiple markets. For example, certain nonpoint pollution reduction BMPs also sequester carbon, and may therefore generate credits within carbon or climate-emissions trading markets in addition to water quality trading markets.

Benefits of stacking include the additional financial incentives for nonpoint sources to participate in nutrient trading markets.

Sources:

Bouvier, R. (2020). *Water Quality Trading in the Long Island Sound Study Area: A Preliminary Look at some Economic Issues* (p. 32). rbouvier Consulting; NEIWPCC; LISS. https://neiwpcc.org/economic-issues-lit-review_rbouvier/

Gasper, R. R., Selman, M., & Ruth, M. (2012). Climate co-benefits of water quality trading in the Chesapeake Bay watershed. *Water Policy*, *14*(5), 758–765. https://doi.org/10.2166/wp.2012.166

Hotspots

Hotspots are areas where discharges from a credit buyer inadvertently cause a localized pollution problem (EPA, 2008, p. 35/ 3-9). Hot spots are often linked to concerns over environmental justice, as point sources after often sited in minority and/or low-income communities. If these point sources offset on-site discharges with off-site credits, nearby communities would face disproportionate impacts of pollution. (Bouvier, 2020, p. 23; Steinzor et al., 2012)

Sources:

EPA. (2008). *EPA Water Quality Trading Evaluation: Final Report*. 90. https://www.epa.gov/sites/default/files/2016-04/documents/wqt.pdf

Bouvier, R. (2020). *Water Quality Trading in the Long Island Sound Study Area: A Preliminary Look at some Economic Issues* (p. 32). rbouvier Consulting; NEIWPCC; LISS. https://neiwpcc.org/economic-issues-lit-review_rbouvier/

Steinzor, R. I., Verchick, R. R. M., Vidargas, N. W., & Huang, Y. (2012). Fairness in the Bay: Environmental Justice and Nutrient Trading. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.2139116

Trading Caps

A trading cap is a limit on the total amount of a pollutant (i.e. nitrogen) which can be discharged over a specific time period, often a year. These caps can be set by a TMDL, a discharge permit, or other regulatory action and are widely considered to be a main regulatory and economic driver of a successful water quality trading program (Puzyreva et al., 2019).

In some cases, like the CT Nitrogen Credit Exchange, the cap declines each year to gradually achieve a pollution reduction goal. (Powers, 2006)

In a review of six water quality trading programs, Puzyreva et al found that load-based caps are key for successful programs, as “in the case of concentration caps, the wastewater treatment facilities or lagoons may discharge their effluent at times of peak flow (e.g., in the spring) so that it dilutes to meet the regulated concentration limits on nutrients. This practice may not reduce overall nutrient loading or resulting eutrophication.”

Sources:

Puzyreva, M., Roy, D., & Stanley, M. (2019). *Case Study Research on Offsets for Water Quality Management* (Case Study Research on Offsets for Water Quality Management). International Institute for Sustainable Development (IISD); JSTOR. https://doi.org/10.2307/resrep21977.2

Powers, A. (2005). *Connecticut Nitrogen Credit Exchange Program*. 8.

Variable Costs of Compliance

Once a regulation is in place to control discharges of a specific pollutant, dischargers often face widely disparate costs to meet their regulatory requirements. This cost variability provides the main incentive for dischargers to participate in a trading program as it establishes favorable trading opportunities (Jarvie & Solomon, 1998). Without variable costs of compliance, there is no feasible market for trading.

Sources:

Jarvie, M., & Solomon, B. (1998). Point-nonpoint effluent trading in watersheds: A review and critique. *Environmental Impact Assessment Review*, *18*(2), 135–157.

Baselines

Baselines serve as the starting point for trading within a water quality market and determine when credits may be generated for trading. Often, this is set based on a TMDL waste load allocation or permitted discharge limit. EPA guidance suggests that “baselines for generating pollution reduction credits should be derived from and consistent with water quality standards.” (US-GAO, 2017)

Sources:

Ribaudo, M., & Savage, J. (2014). Controlling non-additional credits from nutrient management in water quality trading programs through eligibility baseline stringency. *Ecological Economics*, *105*, 233–239. https://doi.org/10.1016/j.ecolecon.2014.06.017

US-GAO. (2017). *Some States Have Trading Programs to Help Address Nutrient Pollution, but Use Has Been Limited*. U.S. Government Accountability Office.

Woodward, R. T. (2000). Market-Based Solutions to Environmental Problems: Discussion. *Journal of Agricultural and Applied Economics*, *32*(2), 259–266. https://doi.org/10.1017/S1074070800020344

EPA. (2019). *Water Quality Trading Under the National Pollutant Discharge Elimination System Program (FR Notice)* [Federal Register].

Transaction Costs

Transaction costs are those costs associated with administering and managing a trading program. They can include costs of entry into a program (i.e. application fees and requirements), costs of establishing individual trades, program administration and oversight costs, and monitoring and inspection costs to ensure that trading is having the intended environmental results.

Higher transaction costs tend to discourage trading.

Sources:

Bouvier, R. (2020). *Water Quality Trading in the Long Island Sound Study Area: A Preliminary Look at some Economic Issues* (p. 32). rbouvier Consulting; NEIWPCC; LISS. https://neiwpcc.org/economic-issues-lit-review_rbouvier/

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Puzyreva, M., Roy, D., & Stanley, M. (2019). *Case Study Research on Offsets for Water Quality Management* (Case Study Research on Offsets for Water Quality Management). International Institute for Sustainable Development (IISD); JSTOR. https://doi.org/10.2307/resrep21977.2

Woodward, R. T. (2000). Market-Based Solutions to Environmental Problems: Discussion. *Journal of Agricultural and Applied Economics*, *32*(2), 259–266. https://doi.org/10.1017/S1074070800020344

Trade Ratios

Not all sources of pollution are created equal within a watershed. A discharged pound of nitrogen may impact the receiving water differently based on a multitude of factors, including distance from the water body, geologic and hydrologic conditions in the watershed, discharge types, and others. This attenuation is often measured as a delivery factor, here higher delivery factors refer to lower rates of attenuation. To account for these differences, most trading programs establish trading ratios where not all units of pollution reduction are credited equally.

While reduction in pollution from point sources is easily measurable, reductions for non-point charges can be harder to measure. Consequently, trade ratios for programs which include both nonpoint and point sources must “adjust” the market so point and nonpoint discharges can trade “apples for apples” (Woodward, 2000, p. 262).

Appropriate trade ratios are a critical factor in establishing a successful program and can help address sources of risk within a program. The **bolded** sources below have in-depth discussions on potential factors for consideration in setting trade ratios.

Sources:

Bouvier, R. (2020). *Water Quality Trading in the Long Island Sound Study Area: A Preliminary Look at some Economic Issues* (p. 32). rbouvier Consulting; NEIWPCC; LISS. Section 2: Trading Ratios. https://neiwpcc.org/economic-issues-lit-review_rbouvier/

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Bouvier, R., Grandbois, J., Varney, A., & James, C. (2021). *Feasibility Of Point-Nonpoint Nutrient Trading In The Long Island Sound Watershed* (p. 76). NEIWPCC, rbouvier consulting. https://neiwpcc.org/feasibility-of-p-nps-trading-in-the-lis-watershed_rbouvier/

Breetz, H., Fisher-Vanden, K., Garzon, L., Jacobs, H., Kroetz, K., & Terry, R. (2004). *Water Quality Trading and Offset Initiatives in the US: A Comprehensive Survey*. 337.

Charles River Watershed Association. (2014). *Online Phosphorus Trading System: Final Report*. https://archives.lib.state.ma.us/bitstream/handle/2452/214471/ocn893441904.pdf?sequence=1&isAllowed=y

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