EVALUATING WATER QUALITY TRADING FOR PHOSPHORUS IN THE LOWER CATAWBA RIVER BASIN

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\textbf{Abstract.} This study explores the concept of water quality trading and its potential application for phosphorus pollution in the Lower Catawba River Basin of North and South Carolina. In order to evaluate the attractiveness of such a program, marginal phosphorus treatment costs were estimated and compared among fourteen major point sources of phosphorus within the watershed. Recognizing that many existing trading programs do not necessarily account for the relative impacts of discharges from different locations, this study also presents a simple tool for calculating equivalence ratios, which can be used to ensure that a trade does not result in degraded ambient water quality.

The results of this study indicate that water quality trading may be able to decrease the costs of reducing phosphorus loadings within the Lower Catawba. Equivalence ratios can be an important instrument for helping water quality trading gain broader acceptance. The tool for calculating equivalence ratios in this study can serve as a model that can be exported to other watersheds that wish to explore water quality trading.

\section*{INTRODUCTION}

\textit{Water quality trading} is promoted as an innovative approach to water quality management that can lower the costs of reducing pollutant loadings by allowing sources with high treatment costs to purchase reductions from other sources in order to meet permit requirements. This study presents a framework for ensuring that water quality trades between point sources of effluent does not result in degradation of ambient water quality. A preliminary application of this framework to the Lower Catawba River Basin (Figure 1) indicates that water quality trading has the potential to lower the costs of reducing phosphorus loadings from fourteen major municipal and industrial waste water treatment plants (WWTPs). The framework presented here can serve as a tool for potential trading partners, regulators, and other stakeholders in determining whether a proposed trade will satisfy water quality requirements.

\begin{figure}
\centering
\includegraphics[width=\textwidth]{lower_catawba_map.png}
\caption{Map of the Lower Catawba River Basin showing the locations of the fourteen major point sources of phosphorus.}
\end{figure}

\section*{BACKGROUND}

\textbf{Water Quality Trading}

The concept of water quality trading and subsequent interest in trading programs stems from economic theories of pollution, property rights, and transferable discharge permits (Dales, 1968; Montgomery, 1972). In a water quality trading program, regulators allow discharge permit holders to transfer reduction requirements in order to reduce private costs of maintaining compliance. Montgomery (1972) provides the first formal treatment of trading in a market for permits and shows that, under
certain conditions assumed by economic models, trading can minimize the total costs of pollution control and prevention while achieving environmental outcomes equivalent to those under traditional regulatory approaches.

Interest in water quality trading has been building for decades, and the United States Environmental Protection Agency (EPA) has expressed support for trading programs since the release of its Draft Framework for Watershed-Based Trading in 1996 (USEPA, 1996). More recently, the EPA has issued its Final Water Quality Trading Policy, which establishes guidelines for trading programs to follow (USEPA, 2003).

Trading between two point sources is the most straightforward type of water quality trading. A basic example is a case in which a WWTP is facing required loading reductions, and another WWTP can make equivalent reductions at a lower cost. If trading is allowed, the WWTP facing the reductions can meet its regulatory requirements by purchasing equivalent reductions from the plant with lower costs.

In order for trading to result in equivalent or better water quality, regulators must be able to know or estimate the relationship between loadings in different locations within a watershed (Letson, 1992). That is, trades must take into account the water quality equivalence between loadings from each source. One method for doing so is the use of an equivalence ratio or trading ratio, which defines the amount of reductions that a buyer must purchase in order to produce equivalent loading reductions. An equivalence ratio is based on the comparative water quality effects of trading partners, thus accounting for the behavior of a pollutant in a river system as well as specific characteristics of the watershed. Generally, the further upstream a source is from impaired waters, the less effect it has on downstream water quality; however, hydrologic features and bio-chemical processes that may impact water quality should also be considered. The EPA states that most trading systems in the United States use some sort of mechanism to account for the water quality equivalence between trading partners (USEPA, 2004); however, a recent survey of water quality trading reveals that only a handful of programs explicitly address water quality equivalence, and most point sources trade at a 1:1 ratio (Breetz et al., 2004).

**Phosphorus Pollution in the Lower Catawba**

The chain of reservoirs from Fishing Creek Reservoir to Lake Wateree are all listed on South Carolina’s 303(d) list as impaired waters that do not support their aquatic life uses due to excess amounts of total phosphorus (SC DHEC, 2008). The South Carolina Department of Health and Environmental Control (SC DHEC) is currently working to establish total maximum daily loads (TMDLs) for phosphorus in the reservoirs of the Lower Catawba River Basin. Upon establishment of TMDLs, mass loadings of total phosphorus will be allocated among point and non-point sources located within the watershed. The waste load allocations for point sources may have the weight of regulatory action behind them, provided that National Pollutant Discharge Elimination System (NPDES) permits are synchronized with the TMDL allocations.

There is precedent for water quality trading in the Lower Catawba River Basin. In the North Carolina portion, the Department of Environment and Natural Resources (NC DENR) has approved phosphorus trading among three WWTPs operated by Charlotte-Mecklenburg Utilities (CMU) (USEPA, 2007). The plants share a combined permit limit for phosphorus discharges, and CMU may allocate that load among the three plants at its discretion. In South Carolina, SC DHEC regulators have shown a willingness to consider water quality trading by writing the option into the permit for Celanese Acetate LLC, which has had trouble meeting its phosphorus discharge requirements (SCDHEC, 2004).

**RESEARCH DESIGN**

Experiences in the Lower Catawba River Basin indicate that dischargers and regulators are willing to explore water quality trading as a tool for water quality management. This study seeks to evaluate the potential for a basin-wide trading program among fourteen major point sources of phosphorus within the watershed. For such a program to gain acceptance, it must offer significant potential economic gains for the participants and assurances to regulators and stakeholders that trading will achieve the desired water quality outcomes.

Water quality trading can create economic gains for trading partners that have different marginal cost schedules for the treatment of phosphorus in effluent. However, proving that a trade would not result in degraded ambient water quality can place lofty data requirements on prospective trading partners. Such a burden increases the transaction costs associated with trading, thereby reducing the potential economic gains. As such, the development of a simple tool that could determine the relative impacts of loadings from different sources – with minimal data requirements for trading partners – would help to reduce the transaction costs that may discourage trading. Such a tool could be used to calculate the proper equivalence ratio of a trade.

Preliminary evaluation for a potential water quality trading program for the Lower Catawba River Basin relies on two factors: variation in marginal phosphorus treatment costs among point sources and the ability to ensure that no trades will result in degraded ambient water quality.
METHODS

The first step in evaluating the potential for a water quality trading program in the Lower Catawba was to estimate marginal costs of phosphorus treatment for each of the fourteen major point sources. Marginal cost schedules for phosphorus treatment were developed for each source using the unit costs of several phosphorus treatment methods for various plant capacities and effluent concentrations published in Jiang et al. (2005). Assuming that all the WWTPs were operating at maximum permitted capacity with an effluent phosphorus concentration of 2.0 mg/l, the unit treatment costs were plotted against the plant capacities of the fourteen WWTPs and regression analyses were conducted to produce a marginal cost schedule for mass reductions of phosphorus at each point source.

To develop a tool for calculating proper equivalence ratios, the Watershed Analysis Risk Management Framework (WARMF) model was employed to simulate pollutant loadings (from both point and non-point sources) and water quality for the Lower Catawba. The WARMF model has been previously calibrated and verified as a good predictor of phosphorus loadings and resulting water quality effects in the Lower Catawba (Tufford et al., 2003), and a version of it is being used by SC DHEC to develop TMDLs for phosphorus in the river basin.

The tool for calculating proper equivalence ratios was developed using the following procedures: (1) In WARMF, one of the fourteen point sources was chosen and its phosphorus loadings were reduced to zero. (2) Next, WARMF was used to simulate water quality for a five year period. (3) Once the simulation completed, the results were compared to a base scenario in order to determine phosphorus attenuation between the discharge point and the inflow of Lake Wateree. (4) The proportion of the load that remained was then plotted against the downstream distance between the WWTP and the inflow of Lake Wateree. (5) These steps were repeated for each of the fourteen point sources included in this study, and (6) then a regression analysis was conducted to develop the tool for calculating the proper equivalence ratio of a trade.

CONCLUSIONS

The estimated marginal cost schedules, shown in Figure 2, indicate a significant amount of variation among phosphorus treatment costs for the fourteen point sources. Therefore, it is reasonable to conclude that a basin-wide water quality trading program in the Lower Catawba River Basin could reduce the costs of phosphorus loading reductions among point sources.

Figure 2. Estimated marginal cost curves of phosphorus treatment. Variation indicates gains from trade are possible.

The downstream phosphorus load attenuation analysis (Figure 3) resulted in the following regression equation (standard errors in parentheses):

\[ y = -0.3379x + 99.125 \]

(0.046) (2.92)

Where \( x \) is equal to the distance of a point source discharge upstream of a chosen downstream location, and \( y \) is equal to the percentage of the load remaining at the downstream point.

This regression offers a simple tool that can be used to calculate the equivalence ratio of a trade between two point sources. This tool only requires trading partners to know their distance upstream from a water quality point of interest, reducing transaction costs and increasing the likelihood of trades.

DISCUSSION

The results of this study have significance for water quality management within the Lower Catawba River Basin as well as for the practice of water quality trading around the country. The analysis of marginal treatment costs among the fourteen major point sources of phosphorus in the Lower Catawba indicates that trading might be an attractive option that can decrease the costs of reducing phosphorus discharges. The tool that was developed for calculating the equivalence ratio of a trade, however, has significance beyond the Lower Catawba River Basin.
Once established, a TMDL will serve as a cap on phosphorus loadings within the Lower Catawba and waste load allocations under the TMDL could serve as the initial permit distributions for a water quality trading program. From that point on, participants would be free to negotiate trades so long as a trade achieves compliance with the TMDL. The tool for calculating equivalence ratios would serve to ensure compliance with the TMDL.

Although there are numerous water quality trading programs in existence around the country, the use of equivalence ratios for trades between point sources does not appear to be a common practice. While the tool for determining equivalence ratios presented in this study was developed specifically for the Lower Catawba, the concept can be exported to any watershed in which the relative impacts of point sources on downstream ambient water quality can be determined. Models like WARMF, which are often used to calculate TMDLs, can be used to develop equivalence ratio tools for specific watersheds. A tool like the one presented in this study is simple enough for broad acceptance and can be an important instrument for ensuring that water quality trading does not result in degraded ambient water quality.

Future research should explore practical solutions for incorporating non-point sources of pollution, such as urban and agricultural stormwater, into trading programs. Such programs could increase permit compliance among regulated sources and significantly reduce the costs of maintaining and improving water quality. Other research might also explore the possibility of trading programs for multiple pollutants. Such programs might increase the number of participants and help establish thriving water quality trading markets.

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LITERATURE CITED


Figure 3. Plot of phosphorus attenuation against upstream distance, used to develop regression for calculating equivalence ratios.

y = -0.3379x + 99.125
R² = 0.8158
F = 53.13
p = 0.0001