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Introduction

Water pollution trading, which is being promoted by the United States Environmental Protection Agency (EPA), has been adopted by several states and some multi-state regional water quality authorities. Further, water pollution trading is being actively considered by many others as means for achieving water quality goals, especially within the context of EPA's Total Maximum Daily Load (TMDL) program. The EPA issued a water quality trading policy in January 2003, and has funded demonstration projects in watersheds across the nation.[1] Water quality trading programs are also active in Canada and Australia.[2]

The development of water quality trading is part of a broader trend towards the use of market-based strategies to address environmental and natural resource problems. Markets provide an economically efficient method for rationing all varieties of private goods and services, and the same can often be said for public goods provided that the right institutional mechanisms can be put into place.[3] Trading has become, for example, a major tool for air quality protection and for rationing access to fisheries and water resources, and is of great interest as a mechanism for managing greenhouse gas emissions as well as water quality and other environmental resources.[4] The broad interest in trading has a

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1. U.S. Environmental Protection Agency, Final Water Quality Trading Policy, http://www.epa.gov/owow/watershed/trading/tradingpolicy.html (last visited Mar. 1, 2006).
2. Environmental Trading Network, Trading Programs, http://www.envtn.org/wqt/programs/programs1.htm (last visited Mar. 1, 2006).
3. Thomas H. Tietenberg, *Tradable Permits in Principle and Practice*, 14 PENN ST. ENVTL. L. REV. --- (2006).
4. ORG. FOR ECON. COOPERATION & DEV., IMPLEMENTING DOMESTIC TRADABLE PERMITS: RECENT DEVELOPMENTS AND CHALLENGES (2002).

variety of origins, but economic arguments, which are supported by increasing empirical evidence about the potential cost-savings from trading by comparison to traditional command-and-control approaches, have been particularly compelling.[5]

Thomas Crocker and J.H. Dales were the first to propose trading as an alternative to the "command-and-control" approach to pollution control.[6] Their work led to extensive exploration in academic literature concerning the merits of pollution trading relative to conventional design and performance standards, and the optimal design of pollution markets.[7] The major theme emerging from this literature is that well-designed trading programs could achieve environmental objectives at lower social costs than traditional design or performance standards, subject to some caveats about the characteristics of pollutants and the structure of markets.[8]

Prompted by this literature, a number of trading programs related to air quality protection were initiated in the U.S. in the mid-1970s and have been expanded greatly since, most notably as a result of the 1990 Clean Air Act (CAA) Amendments. The Early U.S. emissions policy initiatives expanded the vocabulary of pollution control to include concepts of "bubbles," "offsets," "banking," and "netting," with subsequent initiatives leading to the "cap and trade" or "allowance trading" approach. *Ex post* evaluations of air quality trading indicate that well-designed programs can meet, and in some cases even exceed, environmental targets while significantly reducing costs by comparison to traditional regulatory approaches.[9] The "crown jewel" of U.S. trading programs is the SO_2 allowance trading program authorized by the 1990 CAA amendments. Target emissions reductions under the program have

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5. ORG. FOR ECON. COOPERATION & DEV., IMPLEMENTING DOMESTIC TRADABLE PERMITS: RECENT DEVELOPMENTS AND CHALLENGES (2002); Tietenberg, *supra* note 3; NAT'L CTR. FOR ENVTL. ECON., U.S. ENVTL. PROT. AGENCY, THE UNITED STATES EXPERIENCE WITH ECONOMIC INCENTIVES IN ENVIRONMENTAL POLLUTION CONTROL POLICY (2001).

6. THOMAS D. CROCKER, THE STRUCTURING OF ATMOSPHERIC POLLUTION CONTROL SYSTEMS: THE ECONOMICS OF AIR POLLUTION 61-86 (1966); J.H. Dales, *Land, Water and Ownership*, 1 CANADIAN J. ECON. 791, 791-804 (1968).

7. An extensive bibliography compiled by Tom Tietenberg is available at http://www.colby.edu/~thtieten/trade.html.

8. *See, e.g.*, A. Denny Ellerman, *A Note on Tradable Permits*, 31 ENV'T & RESOURCE ECON. 123, 123-31 (2005); THOMAS STERNER, POLICY INSTRUMENTS FOR ENVIRONMENTAL AND NATURAL RESOURCE MANAGEMENT (2002).

9. ORG. FOR ECON. COOPERATION & DEV., IMPLEMENTING DOMESTIC TRADABLE PERMITS: RECENT DEVELOPMENTS AND CHALLENGES (2002); Tietenberg, *supra* note 3; NAT'L CTR. FOR ENVTL. ECON., U.S. ENVTL. PROT. AGENCY, THE UNITED STATES EXPERIENCE WITH ECONOMIC INCENTIVES IN ENVIRONMENTAL POLLUTION CONTROL POLICY (2001).

been achieved and exceeded, with an estimated cost savings of up to $1 billion per year annually by comparison to command-and-control regulatory alternatives.[10] Lessons about the gains from trading are not limited to U.S. air quality programs. Water quantity and fisheries programs are also areas with notable success stories.[11]

But while theory and experience show success in some cases and indicate promise in others, students of trading recognize that there can be significant political, institutional, and technical challenges to the development of effective trading programs.[12] Water quality trading, particularly when it involves nonpoint sources of pollution, is a case where these sorts of challenges arise and, if not adequately addressed in the program design, can significantly limit the potential economic and environmental gains that trading can offer. This paper examines the current interest in water quality trading, briefly reviews the status of water quality trading, and discusses some of the major challenges in designing successful programs. We see much potential for trading to improve the effectiveness and efficiency of water quality protection in the U.S. for significant classes of pollutants, most notably nutrients and sediments. The challenge is to design trading programs that can realize this potential.

Water Quality Trading: Basic Concepts and Objectives

Trading, whether in water quantity, water quality, air emissions, or fish harvests, is fundamentally a mechanism for rationing use of the commons. In the case of consumptive uses of natural resources (e.g., fisheries or water supplies), trading is used to allocate consumption among competing demanders (e.g., harvests or water withdrawals). In the case of pollution into environmental media (e.g., air or water), trading is a mechanism to allocate the waste disposal services of the media. This is generally achieved by allocating air emissions or discharges to waters among demanders for waste disposal services.

In the current context, water quality trading is a mechanism for allocating pollution loads among alternative sources in order to achieve

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10. Robert N. Stavins, *Lessons Learned from SO2 Allowance Trading*, CHOICES, http://www.choicesmagazine.org/2005-1/environment/2005-1-11.htm (last visited Mar. 1, 2006).

11. ORG. FOR ECON. COOPERATION & DEV., IMPLEMENTING DOMESTIC TRADABLE PERMITS: RECENT DEVELOPMENTS AND CHALLENGES (2002); Tietenberg, *supra* note 3.

12. *See* Ellerman, *supra* note 8; ORG. FOR ECON. COOPERATION & DEV., IMPLEMENTING DOMESTIC TRADABLE PERMITS: RECENT DEVELOPMENTS AND CHALLENGES (2002); Tietenberg, *supra* note 3; Richard T. Woodward, *Markets for the Environment*, CHOICES, http://www.choicesmagazine.org/2005-1/environment/2005-1-10.htm (last visited Mar. 1, 2006); Stavins, *supra* note 10.

an overall pollution load target (e.g., TMDL, mean annual loads, etc.) set by water quality authorities. The economic appeal of the mechanism is that trading can ensure the water quality goals are achieved cost-effectively because individual polluters will respond to the market in a way that allocates load reductions at minimum costs. Cost minimization essentially requires allocating greater pollution abatement to sources with lower costs than to sources with higher costs. Trading achieves this outcome in theory by creating incentives for high cost sources to pay low cost sources to reduce their discharge (subject to restrictions that water quality is equal or better as a result of the trade). To the extent high cost (HC) sources can pay low cost (LC) sources an amount less than the amount it would cost HC sources to make the reduction (but greater than the amount actually incurred by LC sources), trading is to their mutual benefit. But this market system can only work to provide economic and environmental benefits if the markets are properly designed and implemented. As we describe below, existing water quality trading programs have perhaps suffered because of poor market design.

Water Quality Trading: Slow and Rocky Start, But Can Lessons Be Learned?

In contrast to air pollution, trading for water quality protection has been limited both in application and success. The first water quality trading initiative in the U.S. was developed on the Fox River in Wisconsin in 1981. The Fox River program allowed effluent trading between point sources, initially along a thirty-five mile stretch of the river, but later along 500 miles of the river, to control biological oxygen demand (BOD). The program produced only one trade between a municipal waste water plant and a paper mill more than 10 years after it was initiated.[13] A handful of other localized initiatives were also developed before the mid-1990s (e.g., Cherry Creek, CO; Tar-Pamlico Basin Project, NC), with trades between point and nonpoint sources being a primary objective.[14] Assessments of these early initiatives are largely critical, due mainly to the paucity of trades with nonpoint sources.[15]

13. Richard T. Woodward & Ronald A. Kaiser, *Market Structures for US Water Quality Trading*, 24 REV. AGRIC. ECON. 366, 366-83 (2002).

14. MARC O. RIBAUDO ET AL., U.S. DEP'T OF AGRIC. ECON. RES. SERV., ECONOMICS OF WATER QUALITY PROTECTION FROM NONPOINT SOURCES: THEORY AND PRACTICE (1999).

15. *See* Dana L. Hoag & Jennie S. Hughes-Popp, *The Theory and Practice of Pollution Credit Trading in Water Quality Management*, 19 REV. AGRIC. ECON. 252, 252-62 (1997); Dennis M. King & Peter J. Kuch, *Will Nutrient Credit Trading Ever Work? An Assessment of Supply and Demand Problems and Institutional Obstacles*, 33 ENVTL. L.

The disappointing results of these early initiatives have not seemed to greatly dampen enthusiasm about the potential of water quality trading. One reason is that limited trades in these and other programs are often attributed to design flaws.[16] Reasons reported for few or no trades in the Breetz et al.[17] data base as reported in Morgan and Wolverton[18] include lack of trading partners, lack of adequate regulatory drivers (i.e., limits on effluents are not sufficiently stringent to create a demand for trades, or delays in EPA TMDL approval), uncertainty about trading rules, legal and regulatory obstacles to trading, high transactions costs, cheaper alternatives for point sources to meet regulatory requirements than trading with nonpoint sources, or simply, the programs being too new to permit trades.[19] These factors generally raise more questions about the design of trading programs and the specific contexts in which they are applied than they do questions about the fundamental merits of trading. Recognizing that program design matters to outcomes, the EPA has developed nuts-and-bolts guidance for organizations developing trading programs that go beyond the guidelines issued in the 2003 policy.[20]

Additionally, research using simulation models routinely indicates that the approach offers significant potential efficiency gains in achieving water quality goals by capitalizing on control cost differentials among sources.[21] For example, EPA's Draft Report on The National

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REP. 10352 (2003); RIBAUDO ET AL., *supra* note 14; Leonard Shabman et al., *Trading programs for environmental management: Reflections on the air and water experience*, 4 ENVTL. PRAC. 153, 153-62 (2002); Kurt Stephenson & Leonard Shabman, *The Trouble With Implementing TMDLs*, 24(1) REG. (2001); NAT'L CTR. FOR ENVTL. ECON., U.S. ENVTL. PROT. AGENCY, THE UNITED STATES EXPERIENCE WITH ECONOMIC INCENTIVES IN ENVIRONMENTAL POLLUTION CONTROL POLICY (2001).

16. DENNIS M. KING, AM. AGRIC. ECON. ASS'N, CRUNCH TIME FOR WATER QUALITY TRADING 71 (2005), *available at* www.choicesmagazine.org/2005-1/environment/2005-1-14.pdf; RIBAUDO ET AL., *supra* note 14; Hoag & Hughes-Popp, *supra* note 15; Shabman et al., *supra* note 15; Stephenson & Shabman, *supra* note 15.

17. HANNA L. BREETZ ET AL., DARTMOUTH COLLEGE ROCKEFELLER CENTER, WATER QUALITY TRADING AND OFFSET INITIATIVES IN THE UNITED STATES: A COMPREHENSIVE SURVEY (2004), *available at* http://www.dartmouth.edu/~kfv/waterqualitytradingdatabase.pdf.

18. Cynthia Morgan & Ann Wolverton, *Water Quality Trading in the United States* (Nat'l Ctr. Envtl. Econ., U.S. Envtl. Prot. Agency, Working Paper #05-07, 2005).

19. Morgan & Wolverton, *supra* note 18.

20. U.S. ENVTL. PROT. AGENCY, WATER QUALITY TRADING ASSESSMENT HANDBOOK: CAN WATER QUALITY TRADING ADVANCE YOUR WATERSHED'S GOALS? (2004), *available at* http://www.epa.gov/owow/watershed/trading/handbook/.

21. Richard D. Horan & James S. Shortle, *Environmental Instruments for Agriculture*, *in* ENVIRONMENTAL POLICIES FOR AGRICULTURAL POLLUTION (James S. Shortle & David G. Abler eds., 2001); Richard D. Horan et al., *Nutrient Point-Nonpoint Trading in the Susquehanna River Basin*, 38(5) WATER RESOURCES RES. 8-1, 8-1 to 8-13 (2002); Richard D. Horan et al., *Probabilistic, Cost-Effective Point/Nonpoint*

Cost to Implement Total Maximum Daily Loads (TMDLs) estimates that flexible approaches to improving water quality, of which trading is the premier model, could save $900 million dollars annually compared to the least flexible approach.[22]

Recent Developments

Despite the limited success of early programs, interest in water quality trading has expanded greatly since the mid-1990s, with trading initiatives in a number of states, and since 2003, EPA policy guidelines to facilitate trading of nutrients and sediment. Morgan and Wolverton,[23] (hereinafter M&W) utilizing data from Breetz et al.,[24] report that there were eight trading initiatives before 1995, but more than seventy initiatives since. These initiatives include at least four one-time offset agreements (Table 1). Offset agreements make possible an increase in discharges by one source (typically nutrient discharges by a point source)[25] by reducing discharges from another source (typically a nonpoint source). The initiatives include at least nineteen trading programs encompassing multiple sources (generally both point and nonpoint) for specific water bodies (Table 2). There are also numerous case studies, pilot studies, or feasibility studies exploring the usefulness of trading in a range of contexts.[26]

The most interesting initiatives are, however, the development of trading policy frameworks at state and regional levels that guide the development of trading programs in multiple watersheds. Nine state (Colorado, Idaho, Maryland, Michigan, Oregon, Pennsylvania, Virginia, West Virginia, and Wisconsin) and one multi-state-watershed (Chesapeake Bay) policy frameworks are reported in M&W to be developing or to have approved trading policies. The EPA's trading website indicates an additional multi-state watershed framework being

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Management in the Susquehanna River Basin, 38 J. AM. WATER RESOURCE ASS'N 467, 467-77 (2002); Richard D. Horan et al., *Point-Nonpoint Trading Programs and Agri-Environmental Policies*, 33(1) AGRIC. & RESOURCE ECON. REV. 61-78 (2004); Richard D. Horan & James S. Shortle, *When Two Wrongs Make a Right: Second Best Point Nonpoint Trading*, 87(2) AM. J. AGRIC. ECON. 340, 340-52 (2005).

22. OFFICE OF WATER, U.S. ENVTL. PROT. AGENCY, THE NATIONAL COSTS OF THE TOTAL MAXIMUM DAILY LOAD PROGRAM (Draft Report, 2001).

23. Morgan & Wolverton, *supra* note 18.

24. HANNA L. BREETZ ET AL., DARTMOUTH COLLEGE ROCKEFELLER CENTER, WATER QUALITY TRADING AND OFFSET INITIATIVES IN THE UNITED STATES: A COMPREHENSIVE SURVEY (2004), *available at* http://www.dartmouth.edu/~kfv/waterqualitytradingdatabase.pdf.

25. Morgan & Wolverton, *supra* note 18.

26. Morgan & Wolverton, *supra* note 18.

developed for the Ohio River Basin.[27] The policy frameworks almost all encompass trading between point sources. Most allow trading between point and nonpoint sources, and a few allow trading between nonpoint sources. Pollutants covered vary from state to state. They commonly include nutrients, but others include sediment, salinity, toxics, temperature, and BOD.

The current interest in trading can be attributed primarily to the challenges posed to state water quality authorities by compliance with the EPA Total Maximum Daily Load (TMDL) program. The history of environmental markets indicates that trading programs typically have been adopted after traditional regulatory approaches have failed, forcing regulatory authorities to explore alternative, innovative options.[28] In this case, the failure is that of traditional water pollution regulations to control nonpoint sources of water pollution, and to achieve mandated water quality objectives. These failures led to the current TMDL program and it is in the context of meeting the challenges posed by this program that interest in water quality trading has soared.[29]

Since the enactment of the 1972 Clean Water Act (CWA), the principal approach to water quality protection in the U.S. has been effluent limits on industrial and municipal sources of water pollution. While these controls have done much to improve the quality of the nation's surface waters, water quality goals in many rivers, lakes and estuaries have not been met, often because significant nonpoint sources of water pollution, including agriculture, remain largely unregulated.[30] TMDLs represent the primary policy tool for addressing these remaining water quality problems.

Section 303(d) of the 1972 CWA requires states and certain other jurisdictions to identify waters that do not meet water quality standards even after point sources of pollution have installed the minimum required levels of pollution control technology. The law requires that these jurisdictions establish priority rankings for impaired waters and develop TMDLs for these waters. A TMDL specifies the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and allocates pollutant loadings among point and nonpoint

27. U.S. Environmental Protection Agency, Summary information on current trading efforts in the U.S., http://www.epa.gov/owow/watershed/trading/tradingactivities.html (last visited Mar. 1, 2006).

28. Tietenberg, *supra* note 3.

29. Or similar limits on discharges at watershed or other scales. Morgan & Wolverton, *supra* note 18.

30. MARC O. RIBAUDO, *Non-point Source Pollution Control Policy in the U.S.*, *in* ENVIRONMENTAL POLICIES FOR AGRICULTURAL POLLUTION CONTROL (James S. Shortle & David G. Abler eds., 2001).

pollutant sources. While TMDLs were required by the 1972 CWA, there was little progress in developing them until EPA's recently initiated TMDL program.

An important feature of the TMDL program is that it provides states with substantial freedom for selecting policy instruments to achieve the required load reductions. The EPA, as we have noted previously, has been promoting trading for nutrients and sediments. But even before the January 2003 EPA trading policy announcement, several states had been exploring and in some cases implementing pollution trading programs.

Water quality trading is an appealing tool for states to achieve TMDLs insofar as minimizing the social costs of achieving environmental targets is an important goal. With trading, final allocations of loads among pollution sources required by the TMDL program can be determined by polluters through mutually beneficial trades, thus eliminating the need for water quality authorities to specify the allocations. The flexibility and incentives offered to polluters in well-designed trading programs can, in theory, lead to the discovery and use of least-cost options, thus fulfilling the goal of cost-minimization while achieving environmental targets.[31] This outcome would be in sharp contrast to the highly inflexible and demonstrably inefficient technology-based effluent standards used traditionally to control point sources since the 1970s under the EPA's National Pollution Discharge Elimination System (NPDES).[32] The documented successes of air quality trading, along with research indicating great potential for water quality trading to improve the cost-effectiveness of water quality protection (provided that program design issues are addressed), provide a basis for expecting these gains despite the limited success of early initiatives.

Finally, water quality trading is also appealing as a means for achieving historically elusive reductions in water pollution from agricultural and other nonpoint sources. While federal programs, most notably the U.S. Department of Agriculture's incentive-based conservation and environmental programs, can help reduce pollution from agricultural and other nonpoint sources, authority for nonpoint regulation under the CWA falls to the states. Most states have relied on voluntary approaches to agricultural nonpoint pollution control that have had limited impact.[33] Achieving TMDLs in many watersheds will require new approaches that effectively reduce agricultural and other

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31. RIBAUDO ET AL., *supra* note 14.
32. J. CLARENCE DAVIES & JAN MAZUREK, POLLUTION CONTROL IN THE UNITED STATES: EVALUATING THE SYSTEM (1998).
33. MARC O. RIBAUDO, *supra* note 30.

sources of nonpoint pollution. Trading offers an alternative to traditional nonpoint policies instruments with the promise of greater effectiveness and efficiency. Virtually all ongoing trading programs and state trading policy frameworks allow trading with nonpoint sources.[34] Trades with nonpoint sources in existing trading programs have, however, been few in number.[35]

Achieving the Promise

The discussion to this point suggests the potential benefits of trading, but does not hint at the complexities of realizing the promise. Below we examine some of the challenges that must be addressed in the design of water quality trading programs that can fulfill the economic and environmental goals of trading. We focus our discussion of these challenges around the two primary policy tools that are applied in water quality trading programs. The first tool is a pollution permit, which creates scarcity in the market for pollution rights and causes polluters to seek out trades. The second tool is a trading ratio. In water quality markets the trading ratio is usually only applied to trades involving point and nonpoint sources, and it is defined as the required reduction in emissions from a nonpoint source that are needed for a point source to increase emissions by one unit. The trading ratio is used to affect the relative prices of permits from these two different types of sources because, as we describe below, the emissions from these sources are imperfect substitutes for each other. A larger ratio makes it more expensive for point sources to purchase nonpoint permits and less expensive for nonpoint sources to purchase point source permits, and vice versa. Our discussion focuses only on the trading ratio between point and nonpoint sources, although in principle a trading ratio can be applied between any two point sources or any two nonpoint sources when the emissions from those sources have different environmental impacts (e.g., due to occasional differences between the sources).

Pollution Permits: Measurability and What to Trade

Pollution permits provide the impetus to trade: if polluters did not have to reduce emissions in some way, either on their own or through trade, then they would have no incentive to reduce their own emissions or to pay for someone else to reduce theirs. The ability to trade these permits is the mechanism by which emissions can be allocated more cost-effectively among alternative sources. It is often taken for granted

34. Morgan & Wolverton, *supra* note 15.
35. Morgan & Wolverton, *supra* note 15.

that permits are traditionally based on emissions. But this is an important policy choice that further improves cost-effectiveness, as basing permits on emissions gives firms the flexibility to choose least cost methods to achieve emissions reductions within their own facilities, in contrast to traditional technology-based command and control methods. But the use of emissions-based permits means there is a need to monitor and measure emissions by source. Trading will not occur, nor targets achieved, if there is no way to determine compliance with permitted emissions.

This monitoring and enforcement requirement leads to one of the fundamental challenges in water quality trading: what nonpoint sources are to trade. One of the expectations of water quality trading enthusiasts is that the approach can effectively address nitrogen, phosphorous, sediment, and possibly other pollutants from historically unregulated or under-regulated nonpoint sources. Yet, the essential feature of nonpoint pollution is that it cannot be metered accurately and routinely by individual agents at a reasonable cost given current technology. In consequence, trading with nonpoint sources generally cannot be based on measured emissions.

The inability to accurately and routinely monitor nonpoint emissions has been a major challenge but not an insurmountable obstacle to the development of trading programs including nonpoint sources. Most one-time offsets, ongoing trading programs, and state or regional trading initiatives encompass trading with nonpoint sources.[36] These initiatives use modeled or estimated reductions in nonpoint emissions, as opposed to measured reductions, to measure compliance by nonpoint sources. This means that farmers or other nonpoint sources must make observable and measurable management changes, either in production (i.e., nutrient management) or on the landscape (i.e., plant buffer strips), the water quality impacts of which are then estimated by a simulation model to gauge compliance.

For a trading program to reliably satisfy water quality goals, it is essential that the maximum load consistent with the goals be explicit and that the trading program is effectively designed to cap total emissions at some maximum allowable level. The simple creation of trading as an option for reducing effluents is not enough to lead to trading or to trading that achieves water quality goals. As emphasized recently by King,[37] markets are not an alternative to water quality regulations. Markets are fundamentally and most appropriately viewed as a mechanism for allocating emissions among sources within the context of a regulatory

36. Morgan & Wolverton, *supra* note 15.
37. KING, *supra* note 16.

restriction on total loads. They should not be the determinant of the total load. In the current context where point sources generally face strong regulatory restrictions while nonpoint sources often do not, an essential key to success in trading is having meaningful restrictions on nonpoint sources. Implementing tight restrictions on point sources simply cannot produce the trades needed to achieve water quality goals where nonpoint sources are the major cause of water quality problems.

Within the context of an overall restriction, a key issue is the type of trading to implement to achieve the target. The most straight forward design for achieving water quality goals is the *cap-and-trade* model. A cap-and-trade program begins with an explicit determination of total allowable discharges. Permits for the total allowable discharges are then allocated among polluters. Methods for the initial allocation include auctions, lotteries, and "grandfathering."[38] The initial allocations can then be traded to determine equilibrium allocations among sources. The NO_x and SO_2 trading programs are the most important examples of cap-and-trade.

The main alternative to cap-and-trade is *credit trading*. In a credit trading program, polluters generate credits by reducing discharges below a baseline, typically defined as a legal limit on emissions.[39] Credits generated by one source may be sold to another to offset emissions in excess of the legal limit. The earliest air pollution trading programs in the U.S. were of this type.[40]

Credit trading and cap-and-trade programs can be equally effective in achieving a target load if the aggregation of the baseline levels in credit trading equals the cap in the cap-and-trade. However, achieving and maintaining this equivalence is no easy task. For example, in the case of water pollution, point sources have defined limits based on NPDES permits that provide a basis for defining credits. However, comparable regulatory restrictions do not exist for nonpoint sources. Accordingly, at the outset of a the creation of a credit trading system, planners face the task of selecting the proper basis for defining over-compliance by nonpoint sources, and if the program is to achieve target loads, assuring that the aggregation of point and nonpoint source

38. Tietenberg, *supra* note 3.

39. This form of credit trading is referred to as "averaging." The key elements of averaging are that credits are generated automatically through over-compliance, and that those who have earned credits can sell them to others without "certification" by regulators. Ellerman, *supra* note 8. Certification in credit trading refers to a determination by regulators whether over-compliance is "credit-worthy" and whether the credits can be transferred. The high transactions cost of certification, and the restrictions on firm-level abatement decisions, have limited the gains and trading level in credit-trading with certification. Shabman et al., *supra* note 15; Ellerman, *supra* note 8.

40. Tietenberg, *supra* note 3; Ellerman, *supra* note 8.

baselines equal the target. Further, if the target is to be maintained, rules for adjusting baselines with changes in the number of sources would be required. For example, the entry of new firms will not increase the total pollution load in a cap-and-trade system but could in a credit trading system depending on how the baseline for new entrants is determined.

Cap-and-trade systems allow planners to dispense with the knotty issues involved in defining individual baselines for credit generation, and focus instead on total allowable level of pollution. This feature, plus emerging literature indicating that cap-and-trade programs promise both better environmental and economic performance than credit-trading,[41] make for a compelling argument for the cap-and-trade policy in general. Nevertheless, the EPA's water quality trading policy calls for the credit trading approach. This choice most directly aligns the trading policy with the existing NPDES regulatory structure. The EPA's policy calls for baselines "... be derived from and consistent with water quality standards..." For example, where a TMDL has been approved or established by the EPA, the applicable point source waste load allocation or nonpoint source load allocation would establish the baselines for generating credits."[42] Essentially, this guidance requires states to do what a cap-and-trade trading system could do for them within a TMDL context—determine load allocations between sources while dispensing with the complications of baselines for credit trading.

Trading Ratios: The Impact of Heterogeneity and Nonpoint Risk

The second policy tool is the trading ratio, which defines the rate at which nonpoint source permits trade for point source permits. Specifically, a larger rate increases the number of nonpoint permits required for a one unit reduction in point source emissions, increasing the cost of trading with nonpoint sources relative to point sources. The justification for using a trading ratio is that nonpoint source emissions and point source emissions are generally imperfect substitutes for each other. Nonpoint emissions leaving a farm are not generally deposited directly into rivers or streams, in contrast to point source emissions, meaning that only a fraction of the emissions leaving a site will make it to a water resource. Moreover, once point or nonpoint emissions enter a river or stream, only a fraction of the pollutants may be transported to its final location (e.g., only a fraction of nutrients deposited into the

41. Shabman et al., *supra* note 15; Donald N. Dewees, *Emissions Trading: ERCs or Allowances?*, 77(4) LAND ECON. 513, 513-26 (2001).

42. U.S. Environmental Protection Agency, Final Water Quality Trading Policy, http://www.epa.gov/owow/watershed/trading/tradingpolicy.html (last visited Mar. 1, 2006).

Susquehanna River will wind up in the Chesapeake Bay, and this fraction will differ depending on where in the Susquehanna the initial deposit is made). The trading ratio accounts for these differences in environmental impacts. If a smaller percentage of the nonpoint source's emissions are transported to a particular water resource relative to the point source's emissions, then the trading ratio would exceed unity to require greater nonpoint reductions for a trade to occur. Some recent trading programs (such as in Michigan) specify the trading ratio to vary spatially in accordance with the spatial transport of emissions, but this has not been the norm. Rather, a single ratio typically has been applied. In this case, the ratio should exceed unity in watersheds in which, on average, a higher percentage of point source emissions are transported relative to nonpoint sources. The trading ratio would be less than unity in the opposite situation. For simplicity, in what follows we focus on the most common case of a non-spatial trading ratio, but we note that most of the general insights would also apply to the spatial case.

Well-designed trading ratios are also influenced by the inherent risk of nonpoint emissions, as there is inherent variability or stochasticity of nonpoint loads, often due to weather-related events. Accordingly, nonpoint pollution cannot be controlled deterministically. This nonpoint risk has important implications for the design of the trading ratio; however, there are two opposing perspectives on this issue.

The most common perspective in practice is that *diverting controls from point sources to nonpoint sources is risky*. This perspective comes from the view that the appropriate policy objective is to maintain a particular level of control of emissions. Point source controls are viewed as relatively certain, since point source emissions are not highly stochastic and they are fairly easily measured. In contrast, nonpoint controls are highly uncertain due to the stochastic and unobservable nature of nonpoint emissions. Trades that involve point sources purchasing nonpoint permits are therefore seen as reducing the certainty of controls, creating risk. The best policy response in this case is to increase the trading ratio.[43] On the one hand, a larger ratio provides a margin of safety as point sources must purchase more nonpoint permits in order to increase their emissions. On the other hand, a larger ratio increases the cost of purchasing nonpoint permits, thereby discouraging trades between point and nonpoint sources. Typical ratios used in practice are greater than unity, and range between 2:1 and 3:1 to address this margin of safety issue.[44]

43. Horan et al., *Nutrient Point-Nonpoint Trading in the Susquehanna River Basin*, *supra* note 21.

44. Richard D. Horan, *Differences in Social and Public Risk Perceptions and*

The second perspective on nonpoint risk comes from the economic theory on point-nonpoint trading.[45] Here, the appropriate policy objective, consistent with TMDLs and other water quality goals, is to reduce the probability of water quality damages from point source and nonpoint source emissions. Given this objective, it turns out that *failure to control nonpoint emissions is risky*. The reason is that highly variable nonpoint emissions result in highly variable damages, and it is this variability in damage costs that are risky. Since risk is socially costly, the appropriate policy response is to reduce the trading ratio in order to encourage more nonpoint controls and thereby reduce this important source of risk. Economic welfare theory indicates that this perspective is the correct one, in which case the large ratios used in practice are counter-productive in two important ways: (i) they increase rather than decrease water quality risk, thereby increasing the economic damages from water quality impairments, and (ii) they discourage trades involving nonpoint sources, which can only increase aggregate control costs. Economic simulations find optimal trading ratios to be much lower than those found in most trading programs, in large part because of these risk effects.[46]

The discussion so far has focused on a single, fixed trading ratio within a watershed. As mentioned above, the use of spatially-explicit trading ratios would generally improve cost-effectiveness by accounting for spatial factors influencing the fate and transport of pollutants. There are additional ways to improve cost-effectiveness. For instance, Shortle and Horan[47] have recently argued that fixed trading ratios are a suboptimal approach to adjusting for nonpoint risk and offer an alternative based on grading nonpoint trades based on the risk that nonpoint emissions entail.

Putting It All Together: Implementing Permit Choices and Trading Ratios

Although we have discussed the choice of permits and trading ratio

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Conflicting Impacts on Point/Nonpoint Trade Ratios, 83 AM. J. AGRIC. ECON. 934, 934-41 (2001).

45. James S. Shortle, *The Allocative Efficiency Implications of Abatement Cost Comparisons*, 26 WATER RESOURCES RES. 793, 793-97 (1990); Arun S. Malik et al., *Point/Nonpoint Source Trading of Pollution Abatement: Choosing the Right Trading Ratio*, 75 AM. J. AGRIC. ECON. 959, 959-67 (1993).

46. Horan et al., *Nutrient Point-Nonpoint Trading in the Susquehanna River Basin*, *supra* note 21; Horan et al., *Point-Nonpoint Trading Programs and Agri-Environmental Policies*, *supra* note 21.

47. James S. Shortle & Richard D. Horan, *Alternatives to Trade Ratios for Managing Nonpoint Risk* (The Pa. State Univ., Dep't of Agric. Econ. & Rural Sociology, working paper, 2006).

separately, they are in fact a joint decision. For instance, Horan and Shortle[48] have shown that if the trading authority only has power to choose the trading ratio (and not permit levels), then the economically optimal trading ratio may be much different than the ratio the agency should choose if it has control over both choices. If these decisions are made correctly, research suggests that water quality trading can be successful.

Simulation studies based largely on synthetic data indicate that the use of modeled reductions with trading ratios to adjust for heterogeneity and uncertainty is reasonable, provided that acceptable models and data to implement them are available and applied appropriately, and that the trading rules intended to address nonpoint uncertainty are appropriately designed.[49] Water quality modeling is an essential component of scientifically sound water quality management, providing planners with methods to predict how, for example, changes in land use practices will affect pollution loads, and how changes in loads will affect water quality conditions. Models are needed not only to predict changes in nonpoint loads, but also to determine the transport and fate of point and nonpoint pollutants in water resources. Suites of models of varying complexity have been developed for these purposes.[50] Depending on data availability, pollutant types, and other factors, such models can provide a basis for predicting outcomes for nonpoint trades. However, there is inadequate experience in trading to assess models or their application. This is an area in which careful experimentation and assessment within the context of emerging trading programs is essential to the development of reliable trading programs.

Importantly, predictions from water quality models should not be treated as "certainty equivalents." Such models can vary greatly in their sophistication, but even the most sophisticated are subject to significant errors due to imperfect knowledge of the relationships between determinants and actual outcomes, and imperfect data.[51] Accordingly,

48. Shortle & Horan, *supra* note 47.

49. *See* Horan et al., *Nutrient Point-Nonpoint Trading in the Susquehanna River Basin*, *supra* note 21; Horan et al., *Probabilistic, Cost-Effective Point/Nonpoint Management in the Susquehanna River Basin*, *supra* note 21; Horan et al., *Point-Nonpoint Trading Programs and Agri-Environmental Policies*, *supra* note 21; Richard D. Horan & James S. Shortle, *When Two Wrongs Make a Right: Second Best Point Nonpoint Trading*, 87(2) AM. J. AGRIC. ECON. 340, 340-52 (2005).

50. NAT'L RESEARCH COUNCIL, ASSESSING THE TMDL APPROACH TO WATER QUALITY MANAGEMENT (2001); Marc O. Ribaudo & James S. Shortle, *Estimating Benefits and Costs of Pollution Control Policies*, *in* ENVIRONMENTAL POLICIES FOR AGRICULTURAL POLLUTION CONTROL (James S. Shortle & David G. Abler eds., 2001).

51. NAT'L RESEARCH COUNCIL, ASSESSING THE TMDL APPROACH TO WATER QUALITY MANAGEMENT (2001).

water quality model predictions are not a perfect substitute for measured loads. The uncertainty about the relationship between modeled and actual nonpoint load reductions can also be addressed in the design of trading programs

Policy Coordination

The success of water quality trading programs depends not only on the design of the programs, but on other policies that affect the demand for and supply of trades to the detriment of trading. An example is the "flush tax" levied in Maryland in 2004 that provides subsidies for the installation of advanced treatment technologies in wastewater treatment plants. The effect of the subsidies is to diminish the demand for trades from these facilities, and thus the potential for trading in the region.[52] Similarly, subsidies that diminish the gains to potential suppliers of trades will diminish the market. An example is subsidies for agricultural nonpoint pollution control that lead to reductions that cannot be counted as credits by agricultural producers.[53] Regulations that affect the opportunities and rewards for participating in markets can have similar impacts.

While the outcomes of trading policies can be diminished by policies that reduce the demand or supply of trades, complementarities are also possible. Horan et al.,[54] for example, demonstrate that a mixed strategy of trading with subsidies for agricultural best management practices can achieve better outcomes than trading or subsidies alone. An interesting finding of their study is that "double dipping," which refers to granting credits to farmers of other sources that can be offered in trading markets that result from subsidized adoption of BMPs, can, though need not, improve the economic and ecological outcomes of trading.

Moving Forward

Despite the notable complexities, and the mixed results of programs implemented to date, a compelling case can be made for water quality trading as an important tool for states to manage nutrients, sediments, and possibly other water pollutants to meet the challenges of complying with the EPA's TMDL program, especially in watersheds in which nonpoint sources are major causes of impairments. But whether trading

52. KING, *supra* note 16.
53. KING, *supra* note 16; Horan et al., *Point-Nonpoint Trading Programs and Agri-Environmental Policies*, *supra* note 21.
54. Horan et al., *Point-Nonpoint Trading Programs and Agri-Environmental Policies*, *supra* note 21.

will become a major tool remains an open question. There has been a burst of interest, experimentation, and policy development since the mid-1990s. Evaluations of these initiatives suggest two main challenges. One is the implementation of rules governing trades, and institutions to facilitate trades, that can lead to successful outcomes. There is now much useful advice in the academic literature on trading, as well as from environmental agencies and some nongovernmental organizations. But much remains to be learned from actual practice. A second challenge is implementing caps that will lead to trades. As argued by King[55] among others, the binding limits on effluents load needed to drive trading are often missing. Addressing this challenge will often require contending with the long-standing problem of capping unregulated or "lightly" regulated nonpoint sources. An additional challenge, not often mentioned in the trading literature, but recognized in the TMDL literature, is gaps in the science of watershed management that slow the implementation of TMDLs viewed as essential to trading.[56]

55. KING, *supra* note 16.

56. NAT'L RESEARCH COUNCIL, ASSESSING THE TMDL APPROACH TO WATER QUALITY MANAGEMENT (2001).

Table 1: One-Time Offset Agreements

Program Name	Pollutant	Year of Trade
Boulder Creek, CO	Nitrogen	1991
Piasa Creek Watershed, IL	Sediment	1995
Edgartown WWTP, MA	Nitrogen	
Falmouth WWTP, MA	Nitrogen	
Specialty Minerals, MA	Temperature	
Wayland Business Center, MA	Phosphorus	1998
Rahr Malting Co., MN	Phosphorus, nitrogen, BOD	1997
Southern Minnesota Beet Sugar Cooperative, MN	Phosphorus	1999

Table 1 Source: Cynthia Morgan & Ann Wolverton, *Water Quality Trading in the United States* (Nat'l Ctr. Envtl. Econ., U.S. Envtl. Prot. Agency, Working Paper #05-07, 2005), based on data from HANNA L. BREETZ ET AL., DARTMOUTH COLLEGE ROCKEFELLER CENTER, WATER QUALITY TRADING AND OFFSET INITIATIVES IN THE UNITED STATES: A COMPREHENSIVE SURVEY (2004), *available at* http://www.dartmouth.edu/~kfv/waterqualitytradingdatabase.pdf.

Table 2: Ongoing Offset Trading Programs

Program Name	Type of Trade	Pollutant	Yr. Program Introduced	Active?	TMDL?	Number of Trades
Grassland Area Farmers Tradable Loads Program, CA	NPS-NPS	Selenium	1998	Yes	Yes	39
Bear Creek, CO	PS-PS	Phosphorus	1992	Yes		1
Chatfield Reservoir, CO	PS-PS, PS-NPS	Phosphorus	1993	Yes	Yes	1
Cherry Creek, CO	PS-PS, PS-NPS	Phosphorus	1997	Yes	Yes	3
Clear Creek, CO	PS-NPS	Heavy metals	1998	No	No	1
Lake Dillon, CO	PS-NPS, NPS-NPS	Phosphorus	1984	Yes	Yes	3
Long Island Sound, CT	PS-PS	Nitrogen	2002	Yes	Yes	63
Lower Boise River, ID	PS-NPS	Phosphorus	1998	No	In Development	0
Charles River, MA	PS-NPS	Water flow		No	In Development	0
Kalamazoo River, MI	PS-NPS	Phosphorus	1996	Yes	Yes	0
Truckee River Quality Settlement Agreement, NV	PS-PS, PS-NPS	Phosphorus, nitrogen, total dissolved solids	1996	Yes	Yes	33
Passaic Valley Sewerage Commission Pretreatment Trading, NJ	PS-PS	Heavy metals	1996	Yes		2
New York City Watershed Offsets Pilot Program, NY	PS-PS, PS-NPS	Phosphorus	1997	Yes	Yes	1
Neuse River Basin, NC	PS-NPS	Nitrogen	2002	Yes	Yes	0
Tar-Pamlico Basin, NC	PS-NPS	Phosphorus, Nitrogen	1990	Yes	Yes	0
Great Miami River Watershed Trading Pilot Program,	PS-NPS	Phosphorus, Nitrogen	2004	No	In Development	0
Fox-Wolf Basin, WI	PS-PS, PS-NPS	Phosphorus	1997	No	No	0
Red Cedar River, WI	PS-NPS	Phosphorus	2000	Yes	No	66
Rock River, WI	PS-PS, PS-NPS	Phosphorus	2000	Yes	No	0

Table 2 Source: Cynthia Morgan & Ann Wolverton, *Water Quality Trading in the United States* (Nat'l Ctr. Envtl. Econ., U.S. Envtl. Prot. Agency, Working Paper #05-07, 2005), based on data from HANNA L. BREETZ ET AL., DARTMOUTH COLLEGE ROCKEFELLER CENTER, WATER QUALITY TRADING AND OFFSET INITIATIVES IN THE UNITED STATES: A COMPREHENSIVE SURVEY (2004), *available at* http://www.dartmouth.edu/~kfv/waterqualitytradingdatabase.pdf.