The primary means for achieving water quality goals in the United States is the requirement under the Clean Water Act that point sources of pollution—mostly industrial facilities and municipal wastewater treatment plants—obtain permits delineating maximum discharge quantities. Several studies suggest that this law produced significant net benefits between 1972 and the late 1980s, while important local water pollution problems from point sources were remedied, but that around 1990, marginal costs began to exceed marginal benefits (Carson and Mitchell 1993; Lyon and Farrow 1995; Freeman 2000). More than ten years ago, the US Environmental Protection Agency (2001) estimated that expanded use of water quality trading could significantly reduce Clean Water Act compliance costs.

While nearly three dozen water pollution trading programs have been established in the United States, many have seen no trading at all, and few are operating on a scale that could be considered economically significant (Breetz, Fisher-Vanden, Garzon, Jacobs, Kroetz, and Terry 2004; Morgan and Wolverton 2005). The global experience with water quality trading is not much more extensive, though there are active programs in Australia and Canada (Selman, Greenhalgh, Branosky, Jones, and Guiling 2009). While water quality trading holds substantial promise, many challenges remain to be worked out by economists and by environmental managers. These challenges involve both physical aspects of water pollution problems that require modifications to the typical structure of pollution trading as practiced for...

Karen Fisher-Vanden is Associate Professor of Agricultural Economics and Rural Sociology, Pennsylvania State University, University Park, Pennsylvania. Sheila Olmstead is a Fellow at Resources for the Future, Washington, DC. Their email addresses are fishervanden@psu.edu and olmstead@rff.org.
air quality, as well as constraints imposed by current regulatory approaches to water pollution control that limit market function, including the implied assignment of rights to pollute.

This paper seeks to assess the current status of water quality trading and to identify possible problems and solutions. We begin with some background on US water pollution regulation, and then present an informal assessment of the current status of water quality trading. We describe six criteria for successful pollution trading programs and consider how these apply to standard water quality problems, as compared to air quality. We then highlight some important issues to be resolved if current water quality trading programs are to function as the “leading edge” of a new frontier in cost-effective pollution permit trading in the United States.

Background on US Water Quality Regulation and the Role of Trading

Water quality concerns were a major impetus for the establishment of the Environmental Protection Agency in 1970; for example, the infamous fire on the Cuyahoga River near Cleveland, Ohio, occurred in 1969—though in truth it was the tenth such fire that had occurred since the mid-1800s, and not the worst. The Federal Water Pollution Control Act, commonly known as the Clean Water Act, became law in 1972. The stated goals of the Clean Water Act were: 1) the attainment of fishable and swimmable waters by July 1, 1983; and 2) the elimination of all discharges of pollutants into navigable waters by 1985 (Freeman 2000). Obviously, those deadlines have been postponed through amendments, and distinctions have since been made between different types of pollutants. However, one should not underestimate the degree to which these original goals have influenced regulation under the law.

The Clean Water Act’s main tool is a set of effluent standards, implemented through point-source permitting. The National Pollutant Discharge Elimination System (NPDES) specifies quantitative effluent limits by pollutant, for each point source, based on available control technologies. For the most part, industrial point source compliance with these permits has been high (Freeman 2000). Municipal sewage treatment has also expanded dramatically, resulting in impressive improvements in urban water quality—for examples, see Boston Harbor and the Hudson River near New York City. But the gains from point source controls are reaching their limits. Even if all point sources were to achieve zero discharge, only 10 percent of US river and stream miles would rise one step or more on EPA’s water quality ladder (Bingham et al. 2000).

Nonpoint source pollution such as agricultural and urban runoff, atmospheric deposition, and runoff from forests and mines has become the major concern of

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1 Statistical analyses attempting to link water quality improvements with the Clean Water Act itself suggest that the Act’s impact on water quality has been somewhat small, though this remains an empirically ambiguous question (Bingham et al. 2000; Gianessi, Peskin, and Young 1981).
water pollution abatement efforts. In fact, nonpoint source pollution from agricultural activities is now the primary source of impairment in US rivers and streams (US Environmental Protection Agency 2009). Nonpoint source pollution involving nutrients like nitrogen and phosphorus causes excessive aquatic vegetation and algae growth and eventual decomposition, which deprives deeper waters of oxygen, creating hypoxic or “dead” zones, fish kills, and other damages. This problem is geographically widespread; seasonal dead zones in US coastal waters affect Puget Sound, the Gulf of Mexico, the Chesapeake Bay, and Long Island Sound.

However, agricultural nonpoint source pollution is essentially unregulated by the Clean Water Act, creating a de facto property rights distortion that strongly affects the ability to attain water quality goals. Although the Act does not address this issue directly, an important provision is Section 303(d), which requires states to establish a Total Maximum Daily Load (TMDL)—basically a “pollution budget”—for each water body that does not meet ambient water quality standards for its designated use, despite point source controls. Designated uses include recreational use, public water supply, and industrial water supply, and each designated use has an applicable water quality standard. State courts began ordering the development of TMDLs in the 1980s and 1990s in response to lawsuits by environmental groups.

Since 1996, the states in cooperation with the Environmental Protection Agency have completed thousands of TMDLs. Establishing a TMDL is a “holistic accounting exercise” in which all permitted sources and land uses within a watershed drainage area, including agriculture and urban runoff, are inventoried and allocated responsibility for portions of the pollution budget (Boyd 2000).

While regulators cannot implement enforceable caps on agricultural pollution through this process, they have recognized the importance of incorporating agricultural abatement into clean-up processes, and water quality trading is one tool they have employed for this purpose. Not surprisingly, marginal abatement costs for point sources which have faced stringent regulation over the past 40 years tend to be high relative to those for nonpoint sources, which have been unregulated. Thus, allowing point sources of water pollution to offset their effluent, or to trade credits for abatement by farms and other entities responsible for nonpoint source pollution, could be cost-effective (Stephenson and Shabman 2011). In almost all water quality trading programs established in the United States, the regulatory driver has been the establishment (or anticipated establishment) of a Total Maximum Daily Load. The US Environmental Protection Agency (2001) estimated that expanded use of water quality trading between point and nonpoint sources could reduce compliance costs associated with TMDL regulations by $1 billion or more annually between 2000 and 2015.

The Environmental Protection Agency established a “draft framework for watershed-based trading” in 1996, and many water quality trading programs were 2 The Environmental Protection Agency offers a survey of TDM L lawsuits and outstanding obligations under these lawsuits at http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/lawsuit.cfm and http://ofmpub.epa.gov/tmdl_waters10/attains_nation_cy.control?p_report_type=TAPRTMDLS.
established during the 1990s. EPA formalized its overarching policy toward water quality trading in January 2003 (US Environmental Protection Agency 2003). At that time, the agency also funded 11 pilot trading projects across the United States. A few important specifics in the 2003 policy continue to shape US water quality trading programs. First, once a Total Maximum Daily Load has been established, all trading must take place “within a watershed or a defined area for which a TMDL has been approved.” Second, the policy supports trading of nutrients (nitrogen and phosphorus) and sediment, but notes that trading of other pollutants will trigger increased scrutiny and can only be implemented with prior approval. Third, point sources cannot typically use trading to fulfill their National Pollutant Discharge Elimination System permit requirements; instead trading or offsets can only be applied to a source’s effort to comply with the additional TMDL-related restrictions. This rule has been relaxed in some cases, allowing some industrial and municipal point sources—on a case-by-case basis—to purchase water quality abatement from other sources (usually farms), to reduce their cost of compliance with permits issued under the National Pollutant Discharge Elimination System.

**Current Status of Water Quality Trading**

Water pollution permit trading programs tend to be small, diffuse, and low-profile, and have rarely been comprehensively described and analyzed in the peer-reviewed literature. Including active programs and completed or otherwise inactive programs, we identify approximately three dozen initiatives. We assessed the status of current programs using existing sources (Breetz et al. 2004; Industrial Economics 2008; Selman, Greenhalgh, Branosky, Jones, and Guiling 2009), as well as extensive use of phone calls and Internet searches for program websites.

Table 1 describes several characteristics of the 21 current active and pilot programs. We divide these active programs into two categories: those that involve actual trades, and pure offset programs. As we define them, trading programs must involve multiple recipients and multiple sources. The offset programs, by contrast, with one exception, all involve a single recipient of water quality credits from one source or multiple sources. Typically, the offset credit recipient invests directly in credit-generating projects rather than purchasing credits outright. Within each category, programs in Table 1 are ordered by their year of establishment.

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3 The list of active programs in Table 1 differs considerably from others in the literature. In some cases, programs described as active by earlier researchers are clearly inactive as of 2012; in others, we were not able to gather enough information on program characteristics to justify their inclusion. We were fairly conservative in our definition of what counts as an active water quality trading or offset program; a more liberal definition would have resulted in closer to 60 such programs (Selman et al. 2009). A more comprehensive list of programs including maps showing all trading programs at the state and watershed levels can be found at: http://www.envtn.org/State_Programs___Rules.html.
Nine of the 13 active trading programs in Table 1 have been established since 2000, with the remainder established during the 1990s. With the exception of Australia’s Hunter River Basin salinity trading program, the pollutants traded in all active programs in Table 1 are nutrients, or a combination of nutrients and sediment.

We distinguish between three market structures in Table 1 (adapted from Woodward, Kaiser, and Wicks 2002; Selman, Greenhalgh, Branosky, Jones, and Guiling 2009): bilateral, clearinghouse, and exchange markets. In bilateral programs, participants engage in individual negotiations to arrange trades or offsets. The required one-to-one negotiations lead to higher transaction costs than
other structures, though these cost differences vary across trading programs. In the Pennsylvania Nutrient Credit Trading program, per-pound transaction costs for bilateral nitrogen trades are estimated at about two times those for auction trades (Ribaudo and McCann 2012).

In clearinghouse programs, a single broker or intermediary may generate credits; for example, in the Neuse River program in North Carolina, point-source participants may engage in bilateral trades with other point sources, or they may pay into a state wetland restoration fund, which funds nonpoint source abatement projects. The intermediary in a clearinghouse program may also convert the abatement activities of diffuse nonpoint sources into a uniform “credit currency” that can be purchased by point sources. For example, in the Great Miami River program in Ohio, farmers submit applications for “best management practices” projects to generate credits, and a public clearinghouse holds a reverse auction to fund the most cost-effective projects from these applications. Credits are then allocated to participating point sources in proportion to their investments in the aggregate credit bank. Nguyen, Shortle, Reed, and Nguyen (forthcoming) find that a clearinghouse market structure is more efficient at facilitating trades between point and nonpoint sources than bilateral trading. Finally, two active programs, the Hunter River Salinity Trading program in Australia and the Pennsylvania Nutrient Credit Trading program, have established true exchange markets, where buyers and sellers trade uniform credits at transparent prices. (A third program, Maryland Water Quality Trading, is set up as an exchange market, but there hasn’t been activity on this market.)

Table 2 offers further detail on market participants. In all but one of the active trading programs, point source participants include municipal wastewater treatment plants. Several programs also involve industrial point sources: Tar-Pamlico, South Nation, Minnesota River Basin, Pennsylvania Nutrient Credit Trading, and Chesapeake Bay Watershed Nutrient Credit Exchange. With one exception, the Neuse River Basin Total Nitrogen Trading program, nonpoint source participants in the active trading programs are agricultural sources.

Trading activity is very limited in most of these programs, however. In this section, we describe six of the most active markets (two of them, in Pennsylvania and Virginia, developed under a single Total Maximum Daily Load for the Chesapeake Bay Watershed).

1) Hunter River Salinity Trading. Since 2004, the Australian state of New South Wales, in Southeast Australia, has operated a trading program to control salinity in the Hunter River Basin. Sources of salinity include agricultural irrigation, disposal of brine from coal mining, and water diversions for cooling in electricity generation which concentrates salts in the water remaining instream. The river is divided into numbered blocks, measured by units of water that will flow past Singleton, New South Wales (the downstream endpoint of the trading scheme) on a particular day. Daily caps are established through continuous monitoring of ambient salinity concentrations and flow levels, with the goal of meeting a maximum allowable salinity concentration at Singleton. The Hunter River Salinity Trading
Scheme restricts saline discharges by coal mines and power plants to periods when river flows are high, and to amounts less than or equal to a facility's salinity credit allocation. If discharges exceed credits, participants may purchase credits from other facilities.

2) **Long Island Sound Nitrogen Credit Exchange.** In response to a 2001 Total Maximum Daily Load for dissolved oxygen for Long Island Sound, the state of Connecticut established the Long Island Sound Nitrogen Credit Exchange in

### Table 2

**Participants and Trading Ratios in Active Trading and Offset Programs**

<table>
<thead>
<tr>
<th>Program name</th>
<th>Participants</th>
<th>NPS:PS trading ratio, if any</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Trading programs</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tar-Pamlico Nutrient Trading</td>
<td>POTWs, ind. PS, ag. NPS</td>
<td>2:1</td>
</tr>
<tr>
<td>South Creek Bubble Licensing</td>
<td>POTWs</td>
<td>N/A</td>
</tr>
<tr>
<td>Cherry Creek Reservoir Watershed</td>
<td>POTWs, ag. NPS</td>
<td>≥2:1</td>
</tr>
<tr>
<td>Phosphorus Trading</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chatfield Reservoir Trading</td>
<td>POTWs, ag. NPS</td>
<td>2:1</td>
</tr>
<tr>
<td>South Nation River Watershed Trading</td>
<td>POTWs, ind. PS, ag. NPS</td>
<td>4:1</td>
</tr>
<tr>
<td>Long Island Sound Nitrogen Credit Exchange</td>
<td>POTWs</td>
<td>N/A</td>
</tr>
<tr>
<td>Credit Exchange</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neuse River Basin Total Nitrogen Trading</td>
<td>POTWs, wetland restoration fund (NPS)</td>
<td>None</td>
</tr>
<tr>
<td>Hunter River Salinity Trading</td>
<td>Ind. PS</td>
<td>N/A</td>
</tr>
<tr>
<td>Great Miami River Watershed Trading Pilot</td>
<td>POTWs, ag. NPS</td>
<td>1:1–3:1</td>
</tr>
<tr>
<td>Maryland Water Quality Trading</td>
<td>POTWs, ind. PS, ag. NPS</td>
<td>TBD</td>
</tr>
<tr>
<td>Minnesota River Basin Trading</td>
<td>POTWs, ind. PS, ag. NPS</td>
<td>1.1:1–1.2:1c</td>
</tr>
<tr>
<td>Pennsylvania Nutrient Credit Trading</td>
<td>POTWs, counties, ind. PS, ag. NPS</td>
<td>1.1:c</td>
</tr>
<tr>
<td>Chesapeake Bay Watershed Nutrient Credit Exchange</td>
<td>POTWs, ind. PS, ag. NPS</td>
<td>2:1</td>
</tr>
<tr>
<td><strong>Offset programs</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rahr Malting</td>
<td>Single ind. PS, multiple ag. NPS</td>
<td>2:1</td>
</tr>
<tr>
<td>Pinnacle Foods</td>
<td>Single ind. PS, multiple ag. NPS</td>
<td>2.3:1 for N, 7.9:1 for Pd</td>
</tr>
<tr>
<td>Southern Minnesota Beet Sugar Cooperative</td>
<td>Single ind. PS, multiple ag. NPS</td>
<td>2:6:1</td>
</tr>
<tr>
<td>Bear Creek</td>
<td>Two POTWs</td>
<td>N/A</td>
</tr>
<tr>
<td>Piasa Creek Watershed Project</td>
<td>Single drinking water system, ag. NPS</td>
<td>2:1</td>
</tr>
<tr>
<td>Clean Water Services/Tualatin River</td>
<td>Single POTW with two facilities, ag. NPS</td>
<td>2:1f</td>
</tr>
<tr>
<td>Red Cedar River Nutrient Trading Pilot</td>
<td>Single POTW, ag. NPS</td>
<td>2:1f</td>
</tr>
<tr>
<td>Alpine Cheese Company/Sugar Creek</td>
<td>Single ind. PS, ag. NPS</td>
<td>3:1f</td>
</tr>
</tbody>
</table>

**Notes:**

- Abbreviations in column 2 indicate publically owned treatment works (POTWs), industrial (ind.), agricultural (ag.), point sources (PS), and nonpoint sources (NPS). In column 3, N/A indicates that the program does not involve PS-NPS trades or offsets.
- PS-PS trading ratios are based on distance of each facility to hypoxic zones in Long Island Sound.
- Clearinghouse sets NPS nitrogen abatement price/lb. greater than average marginal cost of PS abatement, but no formal trading ratio.
- PS-PS trading ratios are unique to trading pairs, using a formal trading ratio system.
- No formal ratios; reported ratios are averages for transacted offsets.
- Refers to ratio for NPS:PS temperature offsets; ratios for other contaminants unknown.
2002, with 79 municipal sewage treatment plants participating. The Long Island Sound program is structured as a clearinghouse, where the annual price is set by regulators based on the estimated average cost of nitrogen removal among participating plants. Because source location affects the environmental impact of a unit of nitrogen discharged, the program uses a system of trading ratios based on geographic trading zones. Abatement cost differentials are generally driven by plant size, as there are significant economies of scale in municipal sewage treatment. The Connecticut Department of Environmental Protection (2010) estimates cost savings from trading through 2009 of $300–$400 million. Though no study has definitively linked the trading program with improved water quality in the Sound (given the significant annual variation in water conditions), the general trend of summer hypoxia incidents is decreasing, despite several years of record-setting warmth since the program began (Connecticut Department of Environmental Protection 2011).

3) South Nation River Watershed Trading. A local watershed organization in Ontario, Canada, South Nation Conservation, developed a phosphorus trading program for the South Nation River watershed in 2000. Participants include 16 municipal and industrial dairy wastewater lagoon operators, who are allowed to expand their effluent discharge to waterways only if they invest in offsetting reductions in nonpoint source agricultural runoff. The watershed organization acts as a clearinghouse in this program, collecting payments from dischargers, investing the proceeds in abatement projects that it identifies on specific farms, and distributing phosphorus credits in exchange. South Nation Conservation estimates that the trading program reduces abatement costs per kilogram of phosphorus for participating dischargers by about 40 percent, compared with the traditional wastewater treatment methods that would otherwise be required (O’Grady 2010).

4) Minnesota River Basin Trading. To address low dissolved oxygen levels caused by algae blooms related to high phosphorus concentrations, the Minnesota Pollution Control Agency issued in 2005 a single National Pollutant Discharge Elimination System permit (updated in 2009) for phosphorus discharges to the Minnesota River, applicable to 47 permitted sources—mostly municipal sewage treatment plants and some industrial point sources (Minnesota Pollution Control Agency 2009). While the general permit does not relieve individual facilities of obligations under individual permits before the Total Maximum Daily Load was implemented, it allows facilities to trade phosphorus abatement allocations required by the new limit. A system of facility-specific trading ratios is used. In 2011, 17 facilities participated in seasonal trades. Unlike a market or clearinghouse approach, trades in the Minnesota River program are made through bilateral negotiations between point sources.

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4 Although the Total Maximum Daily Load requires both Connecticut and New York to reduce nitrogen loads to Long Island Sound by 58.5 percent between 2001 and 2014, New York opted to not create a trading program. The Connecticut program does allow participating municipal sewage treatment plants to sell excess credits to facilities in New York or industrial point sources in Connecticut if total nitrogen loading falls below the aggregate cap, but this option has not yet been exercised.

5 Current numbers of sources and facilities trading from Lisa McCormick, Minnesota Pollution Control Agency, personal communication, August 23, 2012.
5) **State-level trading under the Chesapeake Bay Total Maximum Daily Load.** Table 1 includes three active water quality trading programs related to the 2010 Chesapeake Bay Total Maximum Daily Load, which limits allowable discharges of nitrogen, phosphorus, and sediment to rivers and streams in the watershed by six states (Delaware, Maryland, New York, Pennsylvania, Virginia, West Virginia) and the District of Columbia. Pennsylvania, Virginia, and Maryland have chosen to implement water quality trading programs to reduce compliance costs for the required effluent abatement, with an additional program under development in West Virginia. A small amount of nutrient trading had been taking place in some of these states, but the establishment of these new markets could be a gateway to large-scale trading to lower compliance costs throughout the region.

A prospective study estimated the potential cost savings from water quality trading to achieve compliance with the Chesapeake Bay Total Maximum Daily Load at $78 million per year if point sources are allowed to trade only with other point sources within a river basin and within a state—a 20 percent decrease in costs relative to no trading (Van Houtven, Loomis, Baker, Beach, and Casey 2012). However, if trading was allowed watershed-wide across state and basin boundaries and between all sources, compliance costs could be reduced by almost half relative to no trading. The major gains come from allowing trades between point sources and agricultural nonpoint sources.

Both the Pennsylvania and the Virginia programs allow trading of nitrogen and phosphorus. Pennsylvania’s program, which started in 2010, thus far includes municipal sewage treatment plants, counties, industrial point sources, and several brokers or credit aggregators of nonpoint source abatement. Trades are facilitated through online auctions or through bilateral negotiation between point and nonpoint sources (Ribaudo and McCann 2012). In Virginia’s program, which started in 2011, participating point sources meet their allocations through their own abatement, purchase of credits from other point sources, or payments made to a state water quality improvement fund used for agricultural abatement projects. Trades can either be negotiated bilaterally between point sources, or can be made through a clearinghouse organization of municipal and industrial point sources.

West Virginia and Maryland are also setting up water quality trading programs to lower compliance costs. Maryland’s program, listed in Table 1, is quite well-developed, though to our knowledge, no trades have yet taken place. There is little information available on West Virginia’s program (and it is likely to be much smaller in scale, given that state’s relatively small portion of the Chesapeake Bay watershed), thus it is excluded from Table 1. Current plans suggest that both of these will be exchange markets, which would double the current number of water sources.

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6 The possibility of Maryland’s program developing significant trading activity may be hampered by the fact that its program is more restrictive than Pennsylvania’s and Virginia’s. For example, municipal sewage treatment plants will not be able to purchase credits to meet their allocations, but must implement specific nutrient removal technologies, instead (Van Houtven et al. 2012; Branosky, Jones, and Selman 2011).
quality trading exchange markets in existence and place three out of four in the Chesapeake Bay watershed.

Trading Programs with Minimal Activity

The remaining seven trading programs in Table 1 are much less active. Some of the programs are quite new, like the Maryland Water Quality Trading Program, briefly mentioned above, and the Great Miami River Watershed Trading Pilot in Ohio (Newburn and Woodward 2012), and activity may increase in the future. Others are small-scale because they target local pollution problems involving only a few sources (the South Creek Bubble Licensing program in New South Wales, Australia is an example).

In other cases, problems with program design limit participation. For example, Colorado’s Cherry Creek and Chatfield Reservoir phosphorus trading programs are among the oldest such programs in the United States. However, in their 13–15 years of operation, the Cherry Creek program has produced only four trades, and Chatfield Reservoir, only seven trades (Selman, Greenhalgh, Branosky, Jones, and Guiling 2009). Later in this paper, we consider program design issues that may limit trading.

Active Offset Programs

Most of the active US water quality offset programs in Table 1 were created through a modification to a single National Pollutant Discharge Elimination System permit, giving a regulated point source the flexibility to more cheaply reduce discharge and achieve compliance through direct investments in abatement projects outside its own facility. The active US offset programs were established between 1997 and 2008. Of the US programs, all but Bear Creek, a very small annual phosphorus trading arrangement between two Colorado municipal sewage treatment facilities, involve a single point source offsetting nutrient-related permit requirements through investments in off-site abatement. All but one are bilateral exchanges, where the regulated point source negotiates directly with farms regarding investment in projects sufficient to meet its permit requirements.

Since the programs are generally quite similar, a few examples suffice for description of program design. In the Alpine Cheese Company program, a cheese manufacturer was required, as part of its plan to expand production, to reduce phosphorus discharge from its wastewater treatment plant from 225 parts-per-million to 1 part-per-million. Through a treatment plant upgrade, the company reduced phosphorus discharge to 3 parts-per-million. The cost of reducing further to 1 part-per-million was sufficiently high that the firm sought to achieve these remaining reductions through investments in nonpoint source agricultural abatement (Wood 2011). Thus, the company paid 25 local dairy farmers to reduce phosphorus discharge. In a much larger program, the Southern Minnesota Beet Sugar Cooperative, a beet processor, pays its 256 grower-members to invest in phosphorus-reducing land management changes so that the processor can meet its permit requirements for expanded production (Werblow 2007; Fang, Easter, and Brezonik 2005). In this
case, the beet growers and the processing facility are treated under the processor’s permit as a single source to meet an overarching phosphorus effluent cap. The structure of Wisconsin’s Red Cedar River program is similar, except that the regulated point source investor is a municipal wastewater treatment plant, which pays local farmers to reduce discharge, thereby avoiding a costly treatment plant upgrade.

Inactive or Completed Trading and Offset Programs

Table 3 offers descriptive information on 12 additional trading and offset programs that are currently inactive. In some cases, a very small amount of trading or offset activity occurred before the programs became inactive (for example, Grassland Area Farmers Tradable Loads Program, Lake Dillon Trading Program). In other cases, early studies suggested that trading was unlikely to be successful, so programs were never formally implemented (for example, Vermillion River, Non-Tidal Passaic River Trading Program, Charles River Flow Trading Program). In the remaining cases inactivity has been due to a number of factors including delays in the development of the Total Maximum Daily Load due to litigation, unresolved scientific modeling issues, or lack of demand for pollution credits. In the next section of this paper, where we discuss criteria for successful trading systems, we consider the limitations of some of these programs in more detail.

Applying Criteria for Successful Pollution Permit Trading Systems to Water

The primary objective of any trading program is to meet or exceed the environmental goal at least cost. The environmental goal is best achieved if two conditions are met: a) the pollutant is uniformly mixed to avoid the potential for hot spots; and b) the pollutant can be easily measured and monitored, allowing enforcement to be effective at deterring noncompliance. The cost-effectiveness goal is best achieved if three additional conditions are met: c) sources have significant cost differentials so that the potential gains from trade are large; d) the number of polluting sources is large enough and the regulatory driver stringent enough to generate sufficient trading volume; and e) there is flexibility in when, where, and how reductions and trades are made. In this section, we discuss challenges related to these five criteria in the case of water quality trading, as well as possible solutions.

Uniformly Mixed Pollutants and Non-uniform Mixing

In the case of climate change, the location of greenhouse gas reductions is not important, since these gases are uniformly mixed—that is, the environmental impact of a ton emitted in one location is equal to the impact of a ton emitted elsewhere. In contrast, marginal damages from water pollution may vary dramatically.

\[^7\] For alternative lists of criteria for successful pollution trading, see Stavins (1998), Benkovic and Kruger (2001), and Schary and Fisher-Vanden (2004).
Table 3
Selected Inactive or Completed Water Quality Trading and Offset Programs and Pilot Programs

<table>
<thead>
<tr>
<th>Program name</th>
<th>Year est.</th>
<th>Location</th>
<th>Types of trades/offsets</th>
<th>Pollutants</th>
<th>Reason(s) for inactivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lake Dillon (Dillon Reservoir) Trading Program</td>
<td>1984</td>
<td>Colorado</td>
<td>PS-NPS</td>
<td>P</td>
<td>Low/no credit demand</td>
</tr>
<tr>
<td>Boulder Creek Trading Program</td>
<td>1990</td>
<td>Colorado</td>
<td>PS-NPS</td>
<td>NH4</td>
<td>NPS uncertainty</td>
</tr>
<tr>
<td>Kalamazoo: Gun Lake Tribe Trading Initiative</td>
<td>1996</td>
<td>Michigan</td>
<td>PS-NPS</td>
<td>P</td>
<td>No regulatory driver</td>
</tr>
<tr>
<td>Fox-Wolf Basin</td>
<td>1997</td>
<td>Wisconsin</td>
<td>PS-NPS</td>
<td>P</td>
<td>No regulatory driver; low credit demand/supply</td>
</tr>
<tr>
<td>Rock River</td>
<td>1997</td>
<td>Wisconsin</td>
<td>PS-NPS</td>
<td>P</td>
<td>Low credit demand</td>
</tr>
<tr>
<td>Grassland Area Farmers Tradable Loads Program</td>
<td>1998</td>
<td>California</td>
<td>NPS-NPS</td>
<td>Selenium</td>
<td>No regulatory driver</td>
</tr>
<tr>
<td>Lower Boise River Effluent Trading</td>
<td>1998</td>
<td>Idaho</td>
<td>PS-NPS</td>
<td>P</td>
<td>Low/no credit demand</td>
</tr>
<tr>
<td>Upper Middle Snake Rock Subbasin</td>
<td>2001</td>
<td>Idaho</td>
<td>PS-PS</td>
<td>P</td>
<td>Litigation</td>
</tr>
<tr>
<td>Charles River Flow Trading Program</td>
<td>2003</td>
<td>Massachusetts</td>
<td>PS-PS</td>
<td>P, flow</td>
<td>Unsuccessful pilot</td>
</tr>
<tr>
<td>Non-Tidal Passaic River Trading Program</td>
<td>2005</td>
<td>New Jersey</td>
<td>PS-PS</td>
<td>P</td>
<td>Trading not cost-effective</td>
</tr>
<tr>
<td>Vermillion River</td>
<td>2006</td>
<td>Minnesota</td>
<td>NPS-NPS</td>
<td>Temp.</td>
<td>Trading not cost-effective</td>
</tr>
</tbody>
</table>

Notes: Due to lack of available information, we exclude many programs that were studied but never established. Abbreviations in column 4 refer to point sources (PS) and nonpoint sources (NPS). In column 5, abbreviations refer to nitrogen (N), phosphorus (P), ammonia (NH4), and temperature (temp).

a New removal technology reduced the cost of point source abatement, driving credit demand to zero.
b Inconclusive evidence for agricultural best management practice effectiveness.
c Full set of Total Maximum Daily Loads (TMDLs) has not been developed for the basin, point-source controls are cheaper than expected, and agricultural sources have not participated.
d Point sources are able to cost-effectively reduce effluent below required levels without trading. May change if final TMDL results in more stringent limits.
e Nine trades took place in 1998–1999, then regional irrigation water re-use project, subsidized by federal and state governments, has kept selenium below cap, with no need for trading since then (Wallace 2007).
f TMDL development held up for many years.
g Difficulty obtaining cooperation from local municipalities; point sources felt that lack of regulations for nonpoint source pollution was unfair.
h For each of these programs, research determined that trading would not result in cost-effective pollution reductions, so program did not develop. For the Passaic River program, cost savings over uniform standard was 2–3%, excluding administrative costs, due to abatement cost homogeneity among participating sewage treatment plants (Obropta, Goldfarb, Strom, Uchrin, Kardos, Boisvert, Poe, and Potent, n.d., http://www.water.rutgers.edu/Projects/trading/FINAL_Water%20quality%20trading%20report_Mar-201003242010.pdf). For the Vermillion River program, research showed agricultural nonpoint source controls did not affect temperature, reducing pool of potential participants to developers and small private property owners, who had homogeneous abatement costs. Transaction costs among many small participants would also have been high (http://www.vermillionriverwatershed.org/index.php?option=com_content&view=article&id=52&Itemid=61).
with the location of discharge, depending on the characteristics of receiving waters and other factors that influence the effectiveness of reductions made in different locations in a watershed. In this case, establishing location-based trading ratios for each pair of polluters, in the manner of exchange rates, has been shown to be an efficient approach (Oates, Krupnick, and Van de Verg 1983; Tietenberg 1985; Rodríguez 2000; Hung and Shaw 2005; Farrow, Schultz, Celikkol, and Van Houtven 2005; Konishi, Coggins, and Wang forthcoming). In fact, Montgomery’s (1972) original article introducing the theory of markets for pollution control considered the case of non-uniform mixing and developed a trading-ratio-based system.

Several current water trading programs use systems of trading ratios to ensure that credits traded have equivalent impacts on the water quality problem of concern at a particular location or set of locations. Examples include the three largest active programs discussed in the previous section: nitrogen trading in Long Island Sound, salinity trading in Australia’s Hunter River Basin, and phosphorus trading in the Minnesota River.

The cost savings from trading, relative to a prescriptive uniform standard, are reduced when trading ratios are introduced (they are, after all, constraints on trade). However, getting trading ratios right can also increase the benefits of water quality regulation if high-damage sources also have high abatement costs and, without trading ratios, would engage in little abatement when the option to purchase (cheaper) permits is available. Thus, this is an important concern not just for cost-effectiveness, but for efficiency as well. In sum, while non-uniform mixing poses a system design problem that may be generally more significant for water pollution than for air pollution problems, the problem can be addressed in plausible ways.

**Measurement, Monitoring, and Enforcement**

Effluent from point sources of water pollution, like wastewater treatment plants, is easily measured and monitored. However, the large potential gains from trade in water quality will likely be realized in systems where point sources are net buyers of abatement by nonpoint sources, since these sources are the “low-hanging fruit” of water pollution abatement options. The measurement and monitoring of water pollution from nonpoint sources is challenging, however. In at least one case, the inactive Boulder Creek Trading Program, inconclusive evidence for the effectiveness of agricultural pollution controls was a direct reason for the program’s failure.

There are three main sources of uncertainty in measuring and monitoring nonpoint source pollution. First, nonpoint source pollution is inherently more stochastic than point source pollution, because it depends more heavily on weather-related factors such as rainfall and temperature (Shortle and Dunn 1986). Second, there may be scientific or technical uncertainty regarding the effectiveness of abatement projects affecting nonpoint sources, which can lead actual reductions to be less than expected (Harrington et al. 1985). Third, the technical estimation of expected abatement may be correct, but flaws in a project’s
implementation and/or operation (institutional uncertainty) may produce less abatement than expected.

Regulators have typically dealt with these uncertainties by requiring more than one unit of abatement in nonpoint source pollution in exchange for each credit toward abatement of point source pollution. These requirements are typically referred to as “trading ratios,” a term that economists use to describe the systems of exchange rates used to account for locational differences in damages from pollution. However, economic theory does not necessarily support the use of high trading ratios between point and nonpoint sources to address uncertainty. Indeed, the optimal trading ratio from point to nonpoint sources could be either greater than or less than 1:1 in the presence of stochastic pollutant loading (Shortle 1990; Malik, Letson, and Crutchfield 1993). If regulators are risk-averse, then investments to reduce nonpoint source pollution are doubly beneficial from the perspective of social welfare, because nonpoint source pollution imposes both direct damages from pollution and additional risk, given its inherently stochastic nature (Horan 2001). Thus, regulators seeking to address this aspect of uncertainty ought to skew trades in favor of reductions in nonpoint source pollution, rather than against them (Shortle 1990; Malik, Letson, and Crutchfield 1993). Alternatively, one might try to define water pollution abatement credits in terms of expected units of abatement, which consider both the mean and the variance of nonpoint source abatement (Horan and Shortle 2011).

Scientific or technical uncertainty, in contrast, may be more efficiently handled through improved liability rules. Segerson and Wu (2006) suggest a hybrid instrument that includes an ambient tax imposed if nonpoint source abatement projects do not result in real reductions. Regulatory agencies might also develop a preapproved list of “best management practices” for agricultural nonpoint source reductions, which gives point sources certainty over the amount of credit for a specific investment (Schary and Fisher-Vanden 2004). Regulatory agencies could also fund implementation of pilot projects and new scientific research to resolve some uncertainty.

The current approach, in contrast, stacks the deck against nonpoint source reductions. Consider the point/nonpoint source trading ratios (reported in Table 2) for the many programs that involve this component, ranging from 1:1 to 4:1 for active trading programs, and from 2:1 to almost 8:1 for active offset programs. In addition, it may discourage trades that could have reduced pollution and lowered compliance costs. For example, Ontario’s South Nation trading program uses a 4:1 trading ratio. As a result, while the cost per kilogram of phosphorus removal through nonpoint sources is 85 percent lower than traditional wastewater treatment

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8 Given that high trading ratios between point and nonpoint sources cannot be justified by theory, what explains their prevalence? Regulators may seek to maximize abatement, rather than minimize pollution damages (Horan 2001). It is also possible that high trading ratios could be optimal in a second-best setting, where trading ratios are set independent of allowable discharge; in an efficient setting, these would be jointly determined (Horan and Shortle 2005).
by point sources, with the 4:1 trading ratio, the cost saving per pound of phosphorus abatement is only about 40 percent (see Environment Canada, n.d.).

The difficulty of measuring nonpoint source pollution abatement clearly makes enforcement difficult, too. Imposing liability rules if promised abatement does not occur provides one potential mechanism for dealing with this problem. However, unlike the air case, where the performance and effectiveness risk of projects to generate emission credits is borne by credit sellers, in many water quality trading programs involving trades between point and nonpoint sources, liability for nonperformance or ineffectiveness lies with point-source credit buyers. Some attribute low trading volumes in current water quality trading programs to this problematic assignment of liability (Stephenson and Shabman 2011; Jarvie and Solomon 1998). However, the current liability structure of trading is a reflection of the fact that agricultural sources are unregulated, and the Environmental Protection Agency can only impose penalties on permitted point sources through the National Pollutant Discharge Elimination System.

Private bilateral contracts between point and nonpoint sources could include provisions that subject nonpoint sources to penalties for nonperformance, though the transaction costs associated with this approach would be high. As an alternative, in some “clearinghouse” water quality trading programs—like Ontario’s South Nation River program, and the Great Miami River program in Ohio—the same public or nonprofit third parties that facilitate trades may also assume liability in the case of nonperformance by nonpoint sources. Finally, in other programs, such as the Pennsylvania Nutrient Credit Trading program, private for-profit brokers or credit aggregators work directly with agricultural nonpoint sources on abatement, and then sell credits to point sources, assuming liability for nonperformance.

**Abatement Cost Differentials**

The larger the differences in marginal abatement costs, the greater the potential gains from trading pollution permits (Newell and Stavins 2003). Such cost differentials among point sources may stem from differences in industrial sector, process, technology, or other source characteristics. Abatement cost differentials can be large between point sources of water pollution: three of the most significant water quality trading programs discussed earlier (Hunter River, Long Island Sound, and Minnesota River) all involve exclusively trades between point sources. However, at least two of the inactive programs mentioned in Table 3, the Vermillion River and Non-Tidal Passaic River programs, failed to mature due to insufficient abatement cost heterogeneity among potential participants.

More significant gains from trade are likely to come from trades between point and nonpoint sources. Faeth (2000) summarizes the list of control options for both point and nonpoint sources of phosphorous, and generates a least-cost curve for reducing phosphorous in three watersheds. In each case, reductions of up to 50 percent can be achieved through low-cost changes in agricultural practices. After this point, the least-cost curve rises sharply, as low-cost agricultural options are exhausted and higher-cost point source controls (phosphorus removal and
filtration) are implemented. Faeth (2000) estimates that savings of 40–80 percent in the per-pound cost of phosphorus removal are achievable through trading between point and nonpoint sources. If US water quality trading programs are to expand significantly, particularly in smaller watersheds, they will need to increase possibilities for trading or offsets between point and nonpoint sources.

Sufficient Trading Volume

Adoption of permit trading for air pollutants has, in most cases, been prompted by a significant increase in regulatory stringency, creating demand for permits among regulated entities. For example, the Clean Air Act Amendments of 1990 used tradable pollution permits to achieve a required 50 percent reduction in sulfur dioxide emissions from coal-fired power plants, and the European Union Emissions Trading Scheme was born of a need to meet European nations’ carbon dioxide emissions reduction targets under the Kyoto Protocol. In contrast, during the era in which pollution trading has been widely accepted and practiced, the goals of the Clean Water Act have been relatively unchanged, with the important exception of the Total Maximum Daily Load provisions. These “pollution budgets” for impaired water bodies have been the most important regulatory impetus for water quality trading in the United States. In fact, the regulatory driver for all but two of the US trading programs in Table 1 was the development or anticipated development of a TMDL. The two exceptions are the Colorado programs—Cherry Creek and Chatfield Reservoir—both of which were prompted by the state environmental regulatory agency’s development of a total maximum annual load for nutrients, a very similar framework.

However, disputes over Total Maximum Daily Loads have affected the ability of this regulatory driver to prompt trading activity. Litigation over the scientific models that underlie the development of these pollution budgets is common. In the Upper Middle Snake Rock Subbasin program in Idaho, and the Willamette Partnership program (“Counting on the Environment”) in Oregon, litigation over TMDLs prevented the initiation of trading programs. In other cases, backlogs in TMDL development for impaired water bodies and delays that occur for other reasons can prevent trading programs from operating. For example, Idaho’s Lower Boise River Effluent Trading program began development in 1998. Trading was initially expected to commence by 2001, but a downstream TMDL (for the Snake River/Hell’s Canyon) was not approved until 2004. An “implementation plan” was subsequently prepared for the Lower Boise in lieu of a TMDL, but the Environmental Protection Agency discourages water quality trading without an official TMDL. Given that the Snake River TMDL calls for a 79 percent reduction in phosphorus loading from the Lower Boise, the inability to use water quality trading to bring down the costs of such a large pollution reduction will likely have significant economic

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9 Marti Bridges, Idaho Department of Environmental Quality, personal communication, June 16, 2012.
implications. But without a strong regulatory driver, the demand for permits simply does not materialize.

Even where regulation is sufficient to prompt market creation, existing water quality trading markets do not generally have a large number of buyers and sellers in comparison to their counterparts in air pollution regulation. While it operated, the sulfur dioxide allowance trading program comprised approximately 2,500 sources. In contrast, of the six significant programs described in detail earlier, the numbers of trading participants (thus far) are as follows: Hunter River, 23 point sources; Long Island Sound, 79 point sources; South Nation, 16 point sources, plus a single clearinghouse; Minnesota River, 45 point sources; Pennsylvania Nutrient Credit Trading, nine point sources and three brokers for nonpoint sources of effluent; and Virginia’s Chesapeake Bay Watershed Nutrient Credit Exchange, 34 point sources, plus the clearinghouse and a few nonpoint source participants.

Thin participation in these programs could be attributed to the restriction of trading within watershed boundaries or simply to the fact that some of the programs are quite new. Nonetheless, even after accounting for the small number of participants, trading volume has been strikingly low. A number of other explanations have been offered, some already discussed: some farmers do not trust the programs, even if participation may be to their financial benefit (Breetz, Fisher-Vanden, Jacobs, Schary 2005); liability rules may discourage participation of point sources (Stephenson and Shabman 2011; Jarvie and Solomon 1998); lack of regulatory stringency may limit demand (King and Kuch 2003); and the existence of agricultural subsidies for nutrient reductions, which may substitute for participation in trading programs, could hamper supply of credits (King and Kuch 2003). In the future, if comprehensive Total Maximum Daily Loads are developed for very large watersheds—the 2010 Chesapeake Bay TMDL is a good example—these markets may grow to encompass many more participants than has been the norm.

Trading Flexibility

An optimal approach to pollution trading is first to allocate allowances to sources and then to grant full discretion to these sources to decide how reductions will be made. Shabman and Stephenson (2007) distinguish between two types of flexibility: waste control flexibility, which allows the source to decide how reductions will be made; and exchange flexibility, which allows sources to trade across time and location. Although water quality trading, in most cases, allows for waste control flexibility, exchange flexibility is limited. Sources are not typically allowed to trade across watershed boundaries or time, and trades are subject to discounting through trading ratios. There are logical reasons for some of these restrictions, often involving non-uniform mixing over space and time. For example, hypoxia from nutrient pollution tends to be a warm-weather phenomenon, thus regulators may not want to allow ambient reductions in winter months to be banked to allow higher discharge in summer months. That said, exchange restrictions do reduce trading volumes and potential cost savings.
One particular issue of inflexibility is that in trades involving point and nonpoint sources, nonpoint sources may be required to prove that reductions have been made before credit is awarded to point sources. In most water quality offset programs, regulators must approve each credit purchase by point sources through modification of their existing permits, raising transaction costs significantly and stifling the cost-effectiveness potential of this approach (Schary and Fisher-Vanden 2004). The preapproval requirement adds to transaction costs and inhibits trading.

**Policy Recommendations and Future Research**

Since 1990, the Environmental Protection Agency, prodded by the courts, has pushed forward on the development and enforcement of ambient Total Maximum Daily Load “pollution budgets” for impaired water bodies. At the same time, the EPA has shown increasing support for experimentation with market-based approaches applied to water pollution control, including water quality trading and offset programs.

Some of these water quality trading programs face natural limits. For example, the offset programs summarized at the bottom of Table 1 are small-scale examples of what is achievable through more flexible regulatory approaches under the Clean Water Act, but they generally involve case-by-case negotiation between point sources and regulators, resulting in unique modifications to a single discharge permit, or a very small set of permits. The cost savings from this approach will always be disappointing in comparison to the potential savings from larger-scale trading programs envisioned by regulators in their promotion of water quality trading (US Environmental Protection Agency 2001, 2003). Given the very high transaction costs associated with such an approach, it is unlikely that these offset programs will expand to make a significant dent in the total cost of compliance with US water quality regulations.

There is greater cause for optimism when we consider the trading programs summarized at the top of Table 1, particularly those active programs described in detail earlier in the paper. However, the active programs developed thus far are significantly thinner than what might be optimal from an economic perspective. The reasons for this can be described along the two primary dimensions raised at the beginning of the paper: 1) challenges due to the physical characteristics of water pollution problems; and 2) challenges posed by the implied rights to pollute created by the current regulatory environment. We summarize these primary challenges below and note that some are easier to surmount than others.

**Challenges Inherent to Water Quality Problems**

Damages from water pollution can vary significantly with the location of the discharge, in contrast to the more straightforward cases described by economists in the original theory of environmental policy instrument choice, and in contrast to
many of the applications of cap-and-trade programs thus far (to greenhouse gases and, to some extent, sulfur dioxide and nitrogen oxides). This spatial heterogeneity inherent to water quality problems requires water quality trading programs to institute spatial trading ratios, zones, or other mechanisms to ensure that environmental goals are met. This is a surmountable problem and has been addressed both in theory and in practice.

A related problem has to do with the spatial scope of trading programs. Due in part to the problem of location-specific damages, water quality trading takes place within specific watersheds, limiting the potential number of participating sources, abatement cost heterogeneity, and other market dimensions (US Environmental Protection Agency 2003). An obvious way to increase trading volume is to combine multiple Total Maximum Daily Loads across watersheds (Faeth 2000) to the extent allowed by the particular water quality problem under concern. A recent example is the broad Chesapeake Bay TMDL, which encompasses the Potomac, Susquehanna, James, and Rappahannock river basins (and five smaller basins), to address hypoxia related to nutrient runoff in the Bay. This single TMDL has given rise to nascent trading programs in at least three states and may be a model for a broader vision of how trading can work for particular regional water quality problems. The challenge within such systems is to ensure that local upstream water quality standards are met (for example, in the Chesapeake Bay’s individual river basins) while reducing the cost of achieving regional water quality goals (in the Bay, itself) as much as possible through trading.

Another related issue is that nonpoint source pollution—the most significant remaining source of water pollution in the United States and many industrialized countries, and the source of the lowest-cost abatement opportunities for many contaminants—is characterized by significant uncertainty in measurement and monitoring. Unfortunately, to address this uncertainty, regulators often require two, three, four, or more times as much in abatement from nonpoint sources in exchange for a reduction of one unit in point source discharge. This is not the economically optimal way to address such uncertainty, and in recent interviews conducted as part of a water quality trading evaluation, respondents suggested that this approach was a major barrier to increased point–nonpoint source trading (Industrial Economics 2008). Several potential solutions have been offered: regulators can develop a preapproved list of “best management practices” for reducing agricultural nonpoint source pollution, with accepted performance metrics (Schary and Fisher-Vanden 2004); trading programs could denominate abatement units that incorporate both the mean and variance of expected abatement in nonpoint sources (Horan and Shortle 2011); and point–nonpoint source trading could be accompanied by a tax that kicks in if nonpoint source pollution is not reduced as projected (Segerson and Wu 2006). Only the first of these three solutions has been applied in practice, but even where regulators develop a preapproved list of best management practices, they still require more than one unit of abatement from these efforts in exchange for one unit of credit to the purchasing point source.
Challenges Due to Implicit Rights to Pollute and Other Regulatory Barriers

Perhaps the most significant barrier to expanding water quality trading in the United States (and, indeed, to improving water quality at all) is the effective exclusion of agricultural nonpoint sources from direct water quality regulation. As a result, these large collective contributors to water quality problems are not obligated to abate, and must instead be offered incentives to engage in abatement. This exclusion seems at present to be politically nonnegotiable. The water quality implications of agricultural runoff are dealt with primarily by the US Department of Agriculture through federal subsidies for best management practices designed to entice farmers to produce environmental quality along with their other outputs. The use of Total Maximum Daily Loads in combination with water quality trading offers a mechanism for improving water quality in a more cost-effective manner, by allowing regulated point sources with much higher abatement costs to purchase credits from nonpoint sources.

However, this approach has its limits. First, recall that little remains to be achieved through point source abatement in many US rivers and streams (Bingham et al. 2000). Thus, it is not just the low-hanging fruit that is in short supply among point sources of water pollution; the fruit, altogether, is becoming scarce. In many watersheds, the remaining point source pollution problem is not a significant fraction of overall pollution, the vast majority of which is contributed by nonpoint sources. Thus, even if point sources are required to purchase many units of nonpoint source reductions for every unit of credit they receive (as most programs are structured), the net result for water quality may not be a significant improvement.  

Second, though participation in water quality trading programs would appear to be in many farmers’ financial interest, it has often proven difficult to encourage them to participate. Many farmers have a historic mistrust of regulators, or they may worry that the monitoring required for participation in water quality trading is a step toward full incorporation in the regulatory structure; thus, it may be necessary to work through trusted third parties or existing relationships such as cooperatives or irrigation districts to deal with these issues (Breetz, Fisher-Vanden, Jacobs, and Schary 2005). In addition, the federal US Department of Agriculture subsidies for water quality measures on farms are often an appealing alternative to participation in water quality trading, limiting farmers’ interest in participation. Program objectives differ significantly from those of water pollution regulation under the Clean Water Act, so combining them would be difficult (Breetz and Fisher-Vanden 2007). For example, one concern is whether and how farmers should “double dip,” receiving Department of Agriculture subsidy payments as well as payments from credit buyers in a water quality trading program (Woodward 2011; Horan, Shortle, and Abler 2004). Economists have proposed reasonably low-information ways to deal with the problem of uncertain nonpoint source pollution flows in the context of a water pollution tax (Segerson 1988; Xepapadeas 1991, 1992; Herriges, Govindasamy, and

10 We owe this point to Leonard Shahman at Resources for the Future.
Shogren 1994; Horan, Shortle, and Abler 1998; Hansen 1998). Working out how a water pollution abatement subsidy (like those received by farmers from US Department of Agriculture programs) might be integrated with a trading system in which credit buyers face an enforced cap would be an important step forward.

Third, aside from the distortions introduced by the exclusion of major agricultural pollution sources from the “caps” represented by ambient water quality standards, there are other challenges to expanding water pollution trading related to the structure of regulations. Interviewees in a recent water quality trading program evaluation suggest that the National Pollutant Discharge Elimination System permitting process should be modified and made more flexible to better support trading (Industrial Economics 2008). Currently, when a point source wishes to use purchased credits to offset a portion of the discharge limit specified in its permit, all effluent covered in the entire permit must be reopened for discussion. However, there are now some examples in which a single permit has been issued for a particular contaminant, across many point sources. These “aggregate permits” are similar to “emissions bubble” approaches for air quality in that permitted sources are jointly responsible for meeting a standard and may engage in cost-reducing trades in order to do this. Aggregate permits are critical to the functioning of promising water quality trading programs in the Tar-Pamlico, Neuse, and Minnesota Rivers.

Beyond these specific suggestions for addressing structural challenges related to water quality problems themselves and to the institutions that manage them, some of the larger water quality trading programs could be analyzed empirically. Such measurement after the programs have taken place occurs only rarely in regulatory settings and was only incorporated into routine US regulatory functions in January 2011 (Executive Order No. 13563, 2011). Little is known, however, about how well any of these trading programs has actually worked in terms of both environmental impacts and abatement cost savings, though there is a good before-the-program analysis of the potential cost savings from trading under the Chesapeake Bay program as a whole (Van Houtven, Loomis, Baker, Beach, and Casey 2012). The Hunter River, Long Island Sound, and Minnesota River programs may be particularly good candidates for such analysis, since they are reasonably large and have been operating for several years. If more were known quantitatively about environmental outcomes and cost-effectiveness, regulators might demonstrate more flexibility in the future design and implementation of water quality trading programs.

Similarly, the development of efficient and effective trading programs could be helped by new field research targeted at developing a better understanding of factors such as: the effectiveness of nonpoint source controls; the impact of behavioral incentives for farmers to engage in trading with point sources of water pollution; or the potential for alternative approaches such as trading in the mean and variance of pollution or the use of nonperformance taxes as an alternative to high point–nonpoint source trading ratios that hamper trading. Field experimentation using randomization is particularly useful in sorting out policy complications like these that may be hard to understand or control (List 2011).
The scope for water quality trading will always be significantly smaller than for permit trading related to air quality for reasons inherent to water pollution problems, such as the need to limit some trading programs to within a watershed, significant non-uniform mixing of pollutants, and difficulties in measuring and monitoring nonpoint sources. However, the economic performance of market-based instruments in practice—regardless of the environmental objective—may always be disappointing relative to the theoretical ideal (Tietenberg 1990). Many current barriers to expanding trading regionally have more to do with program design than the physical characteristics of water pollution, and can potentially be overcome. Today’s trading programs may serve as important laboratories for researchers in economics, supporting analysis that leads to better future program design and eventual expansion in the use of these cost-effective policy instruments.

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