THE STRUCTURE AND PRACTICE OF WATER QUALITY TRADING MARKETS

Richard T. Woodward, Ronald A. Kaiser, and Aaron-Marie B. Wicks

ABSTRACT: The use of transferable discharge permits in water pollution, what we will call water quality trading (WQT), is rapidly growing in the U.S. This paper reviews the current status of WQT nationally and discusses the structures of the markets that have been formed. Four main structures are observed in such markets: exchanges, bilateral negotiations, clearinghouses, and sole source offsets. The goals of a WQT program are environmental quality and cost effectiveness. In designing a WQT market, policy makers are constrained by legal restrictions and the physical characteristics of the pollution problem. The choices that must be made include how trading will be authorized, monitored and enforced. How these questions are answered will help determine both the extent to which these goals are achieved, and the market structures that can arise. After discussing the characteristics of different market structures, we evaluate how this framework applies in the case of California’s Grassland Draining Area Tradable Loads Program.

(KEY TERMS: transferable discharge permits; nonpoint source pollution; water policy/regulation/decision making; water quality.)

INTRODUCTION

The use of market based approaches to environmental policy in the U.S. is clearly on the rise. Acid rain is being addressed using tradable permits for sulfur dioxide (SO$_2$) emissions, cities throughout the country allow trading in Nitrogen Oxide (NO$_x$), wetlands mitigation banks are being widely used, and trading in greenhouse gases is authorized by the Kyoto Protocol on Climate Change. Market based approaches are also being pursued for the control of water pollution. While only three such programs existed in 1990, a recent report to the U.S. Environmental Protection Agency (EPA) lists 16 programs that are in various stages of implementation and nine more programs under development (Environomics, A Summary of U.S. Effluent Trading and Offset Projects, November 1999; Report to Dr. Mahesh Podar, U.S. EPA, Bethesda, Maryland).

A market based approach to pollution control refers to a program in which individual polluters are able to trade among themselves to determine who will pollute less and who will pollute more. In the textbook model (e.g., Tietenberg, 2000), a total cap on pollution is established; rights and responsibilities are allocated to the various sources of pollution; then trading is allowed to reallocate these rights among the sources. If one source can decrease its pollution at low cost, it may sell pollution credits to other sources for which the cost of abatement is relatively high. While actual designs sometimes differ from the cap and trade framework (Haddad, 1997), all such programs have the common goal of achieving a pollution reduction goal while at the same time reducing abatement costs.

In our discussion we use the term “pollution trading program” to refer to any program that allows polluters to satisfy regulatory pollution reduction requirements by arranging to reduce pollution at some other point. A source that arranges to increase its allowed pollution will be referred to as the buyer of pollution credits while the source that has reduced pollution to generate the credits will be referred to as the seller.

There has been an enormous amount of research on pollution trading in general and water quality trading (WQT) in particular. However, little has been said about one of the most basic issues that must be faced
when establishing a WQT program, What are the possible structures for WQT markets? By market structure we refer to a market’s standards for obtaining information and exchanging rights. Specifically, structures are distinguished by two factors: the extent to which information regarding the good is publicly visible, and whether the transaction relationships in the market are discrete, terminating when the contract performance is complete, or relational, persisting over time (Williamson, 1985). For example, contracts for services are arranged through bilateral negotiations in which information is obtained through personal contact, terms of trade are negotiated, and the relationship persists beyond the terms of the original contract. In contrast, a commodity exchange is characterized by publicly visible prices and offers to buy and sell, and contracts that are discrete.

Based on a review of current and proposed pollution trading programs, pollution trading markets fall into four main structures: exchanges, bilateral negotiations, clearinghouses, and sole source offsets. A market's structures may evolve over time in response to changes in the information about the market, transaction costs, legal restrictions, evolving norms, and market size. Coase (1937) argued that firms evolve to reduce their transaction costs. Similarly, a WQT market's structure will change over time if more fluid means of sharing information or less costly means of consummating and executing trades can be found.

However, in addition to the goal of cost effectiveness, WQT programs also seek to achieve a high level of environmental efficacy (i.e., a high degree of certainty that environmental targets are reached). But rules that are put in place to ensure environmental efficacy frequently lead to less efficient markets by increasing transaction costs or decreasing flexibility. Hence, although there is an economic tendency for market participants to seek the most efficient structure, this is constrained by regulatory decisions that are made to ensure environmental efficacy. There is, therefore, an interdependence between market structure and the extent to which the goals of WQT are reached.

As we have indicated, market structure is intimately related to the problem of transaction costs. In pollution trading, transaction costs have received substantial attention in recent years (e.g., Stavins, 1995), and some authors have made recommendations as to steps that can be taken to reduce these costs (Hahn and Hester, 1989a; Tripp and Dudek, 1989; Haddad, 1997). Most writers refer to three main types of transaction costs: search and information, bargaining and decision, and monitoring and enforcement (Stavins, 1995), though Dahlman (1979) also included costs associated with transportation and set up. Transaction costs might be one time costs associated with initiating a market, or might be present in each trade. They might be borne by the buyer, the seller, or the government. For example, government costs might include those associated with monitoring to ensure that the program’s compliance goals are achieved (e.g., Malik 1992). When we use the term market efficiency, we refer to a market’s ability to complete transactions without imposing transaction costs on the participants.

WQT markets distinguish themselves from markets for most goods and services in that government determines not only the institutional setting of the market, but also the very nature of the good being transacted. A WQT credit consists of a set of rights and responsibilities that are defined by the legal decisions that are made in the design of the program. The characteristics of the credits will help determine the market structure that results, the market’s efficiency, the program’s environmental efficacy, and the overall success of the program.

This paper is organized as follows. In the next section we discuss the current state of water quality trading in the U.S. and evaluate the reasons that interest in this policy tool has grown so rapidly in recent years. In the following section we discuss how the legal and physical environments of a trading program must be overcome when defining its rules. How the program is authorized and how trades are monitored and enforced prove critical to determining the market structure that results. Next, we compare the alternative structures in terms of their impact on abatement costs, the associated transaction costs, and their environmental efficacy.

To highlight our main contribution, we discuss the case of California’s Grassland Drainage Area Tradable Loads Program. Because this program’s characteristics make it amenable to a wide range of market structures, it well illustrates how the issues of environmental efficacy, economic cost, and transactions costs influence and are influenced by the market structure that results. The lessons that we learn, both in general and in terms of the Grasslands program, are summarized in the conclusion.

THE STATE OF WATER QUALITY TRADING IN THE U.S.

Table 1 lists 15 WQT programs that are either in place or under development. Of the 12 existing programs, all but three did not exist prior to 1989 and six have been started since 1996. Furthermore, WQT programs are expanding not only in number, but also in scope. Michigan is in the process of finalizing rules that will allow WQT in any watershed in the state.
TABLE 1. U.S. Water Quality Trading Projects in Progress or Under Development.

<table>
<thead>
<tr>
<th>Project</th>
<th>Participants in the Trading Program</th>
<th>Pollutants Traded</th>
<th>Year Established</th>
<th>Market Structure*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Projects In Progress</strong></td>
<td></td>
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<tr>
<td>Fox River, Wisconsin</td>
<td>PS/PS</td>
<td>Phosphorus</td>
<td>1981</td>
<td>BN</td>
</tr>
<tr>
<td>Lake Dillon, Colorado</td>
<td>PS/NPS, PS/PS, NPS/NPS</td>
<td>Phosphorus</td>
<td>1984</td>
<td>BN</td>
</tr>
<tr>
<td>Cherry Creek, Colorado</td>
<td>PS/NPS</td>
<td>Phosphorus</td>
<td>1984</td>
<td>C</td>
</tr>
<tr>
<td>Tar Pamlico, North Carolina</td>
<td>PS/PS</td>
<td>Nitrogen and Phosphorus</td>
<td>1989</td>
<td>BN</td>
</tr>
<tr>
<td>Boulder Creek, Colorado</td>
<td>PS/NPS</td>
<td>Ammonia, Nutrients</td>
<td>1990</td>
<td>SS</td>
</tr>
<tr>
<td>New Jersey Chemical Industry, New Jersey</td>
<td>Pretreatment by PSs</td>
<td>Metals</td>
<td>1996</td>
<td>SS</td>
</tr>
<tr>
<td>Rahr Malting Co., Minnesota</td>
<td>PS/NPS</td>
<td>BOD, Phosphorus and Nitrogen</td>
<td>1997</td>
<td>C</td>
</tr>
<tr>
<td>Grassland Drainage Area, California</td>
<td>NPS/NPS</td>
<td>Selenium</td>
<td>1998</td>
<td>BN</td>
</tr>
<tr>
<td>Kalamazoo River, Michigan</td>
<td>PS/NPS</td>
<td>Phosphorus</td>
<td>1998</td>
<td>BN</td>
</tr>
<tr>
<td>Chatfield Basin, Colorado</td>
<td>PS/NPS, PS/PS</td>
<td>Phosphorus</td>
<td>1999</td>
<td>BN</td>
</tr>
<tr>
<td>Southern Minnesota Beet Sugar Cooperative, Minnesota</td>
<td>PS/NPS</td>
<td>Phosphorus</td>
<td>1999</td>
<td>BN</td>
</tr>
<tr>
<td><strong>Projects Under Development</strong></td>
<td></td>
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</tr>
<tr>
<td>Long Island Sound, Connecticut and New York</td>
<td>PS/NPS</td>
<td>Dissolved Oxygen</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Lower Boise River, Idaho</td>
<td>PS/NPS, PS/PS</td>
<td>Phosphorus</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Rock River, Wisconsin</td>
<td>PS/PS, PS/NPS</td>
<td>Phosphorus</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>State of Michigan (Statewide)</td>
<td>PS/NPS, PS/PS</td>
<td>Phosphorus and Nitrogen</td>
<td>BN</td>
<td></td>
</tr>
</tbody>
</table>

*BN = Bilateral Negotiations; C = Clearinghouse; SS = Sole Source Offsets.

Sources:
- Jarvis and Solomon, 1998
- State of Michigan, Department of Environmental Quality, Surface Water Quality Division, 1999.

The growing interest in WQT can be attributed to three main factors. First, to some extent, the idea is simply catching on. The highly visible pollution trading program in \( \text{SO}_2 \) and the numerous regional programs in other pollutants have demonstrated that such programs can "work roughly as the textbooks describe" (Schmalensee et al., 1998). With the overall success of these programs, political resistance to trading by the environmental community appears to be falling (e.g., National Wildlife Federation, 1999), although some distrust remains in the agricultural sector (McCann and Easter, 1999). Similarly, based on
simulation modeling efforts, there is the growing evidence that substantial opportunities for gains from trading programs. Perhaps most importantly, the experience with air pollution trading has created a cadre of agency staff with experience and confidence in the management and design of such programs.

The second reason for WQT’s popularity can be tied to EPA’s new emphasis on Total Maximum Daily Load (TMDL) programs to achieve water quality goals. Traditionally, water pollution control has focused on the question, “How much pollution should each source be allowed to emit?” In contrast, the implicit questions in a TMDL are, “What is the total pollution load that should be permitted, and how should that load be allocated among the various sources?” Market-based approaches are a more appropriate answer to these new policy questions.

The final reason we see for the increased interest in WQT is related to the changing face of the nation’s water pollution problems. The historical practice of water quality regulation has been to use “end of the pipe” restrictions on PSs that can easily be monitored. The resulting National Pollutant Discharge Elimination System (NPDES) has been quite successful in addressing the nation’s most egregious water quality problems, but has left nonpoint sources (NPSs) outside the regulatory umbrella. A majority of the nation’s remaining water quality problems are associated with excess nutrients, primarily coming from NPSs (Faeth, 2000). Accordingly, as seen in Table 1, the vast majority of the listed WQT programs address nutrients and pollution from NPSs.

NPS pollution is very difficult to regulate because it is hard to both monitor and control such pollution (Griffin and Bromley, 1982). Imposing a regulatory “stick” on such polluters is, therefore, problematic. However, many analysts believe that WQT can create positive incentives for NPS abatement. The marginal abatement costs of NPS polluters is believed to be lower than for PSs (Letson, 1992). This cost differential would create opportunities for NPSs to profit from pollution abatement while at the same time reducing total abatement costs. The EPA (1994) found that trading would reduce the costs of completing President Clinton’s Clean Water Initiative by between $0.65 and $7.5 billion, with a majority of the savings resulting from trades between point and nonpoint sources. The hope, therefore, is that WQT programs would create positive incentives for NPSs to reduce their pollution and could thereby succeed where traditional approaches have been largely ineffective.

It would be overly optimistic, however, to believe that WQT will easily reduce NPS pollution. WQT does not escape the central challenge of NPS regulation – pollution from these sources cannot be easily monitored. A variety of ways to circumvent this informational problem have been proposed (Segerson, 1988; Horan et al., 1998; Ribaudo and Horan, 1999). In practice, however, policies have consisted almost exclusively of regulations and incentives designed to encourage the use of pollution-reducing best management practices (BMPs) (Ribaudo et al., 1999). This pattern is also seen in WQT; of the programs presented in Table 1, NPS credits are uniformly based on pollution loads that are predicted based on changes in land use practices.

LEGAL FOUNDATIONS FOR MARKET STRUCTURES

“[M]arkets can only exist within a social and legal system that has consciously set out to create ordered domains of exchange” (Bromley, 1997:1387). Recognizing the institutional setting of a market is particularly important in the case of WQT markets since the very good that is transacted in such markets has no meaning outside of the legal context; it is a legal right that is being exchanged.

The laws that establish WQT rights must take into account both the legal and physical environments in which those rights are to be transacted. The Clean Water Act (CWA) and state regulations governing water quality are the most important elements of the legal environment. The physical environment is defined by the characteristics of the pollutant and the watershed in which trading is to take place. To respond to these environmental constraints, three principle legal issues must be addressed: authorization, monitoring, and enforcement. How these hurdles are overcome determines the institutional nature of the market that results, and has important consequences for the efficiency of the market, market concentration, and the environmental efficacy of the program.

Authorization

WQT is a significant departure from traditional water quality policies. There are, therefore, serious questions about whether or under what conditions, such a program is authorized. Any WQT program must be consistent with the substantive and procedural mandates of federal and state law. Although trading is not explicitly prohibited in the major laws governing water pollution, neither is it explicitly authorized. Legal authority can only be inferred from sections of the CWA (33 U.S.C. §§ 1312, 1313), recently approved revisions to TMDL regulations (40
CFR part 9), and the EPA’s “Draft Framework for Watershed-Based Trading” (EPA, Office of Wetlands, Oceans, and Watersheds, 1996).

The challenge for developers of WQT programs is to find ways to authorize trading without violating existing regulations. For example, if a trading program is tied to the system of NPDES permits, then each trade would amount to a NPDES permit revision, requiring substantial government and public review, including public hearings.

Monitoring and Reporting

Verification that the terms of trade have been met is an important part of all markets. In markets for most goods, this process is relatively straightforward; when the good has changed hands and a receipt has been issued the transaction is verified, usually without additional monitoring or reporting. In the case of WQT, however, a transaction is completed only when the legal requirements for transfer of rights and obligations have been satisfied. Due to the statutory restrictions of the CWA and the characteristics of the pollutants and polluters, designing appropriate reporting and monitoring requirements is an important step in any WQT policy (Malik, 1993).

The CWA imposes substantial monitoring and reporting requirements on point source dischargers (see 33 U.S.C. 1316(a)(4) (A)) and there are similar requirements in programs that allow point sources to generate credits for sale. These include water quality sampling, maintenance of monitoring equipment, record keeping and reporting. Hence, there are costs associated with the overall policy, but they are of similar magnitude to the costs faced under traditional regulatory regime.

When NPSs generate credits, additional monitoring and reporting challenges arise. As noted above, credits are typically based on practice changes rather than directly on loads. Monitoring practices is not trivial. Satellite imagery might help, but in most cases costly on site inspections would be required. Monitoring and reporting are essential to ensuring that pollution abatement goals are achieved, but they also impose transaction costs on the market that can diminish market efficiency.

Enforcement

A system for enforcing a transfer of rights is also critical to any market. While the purchaser of most goods can relatively easily verify that a product of satisfactory quality has been delivered, the same cannot be said for WQT markets. A transaction in a WQT market shifts responsibility for improving water quality and in general the buyer of the credit has no incentive to ensure that the necessary water quality improvement actually occurs. Adequate compliance is important not only to ensure that the achievement of the environmental goals, but also for the market’s efficiency (Malik, 1990). The questions of who is liable if pollution abatement does not occur and when a transfer of rights is complete must be explicitly addressed.

The shift from a permit system to a system of transferable credits changes the nature of enforcement. Enforcement under permits is usually unidirectional: from the agency to the permittee. Contract enforcement flows are often multidirectional, involving the buyer and the seller with the legal support of the courts. Liability must be assigned to either the buyer or the seller. In a system of seller liability the contract is discrete and does not create a future obligation to monitor compliance over time. A system of buyer liability, on the other hand, creates incentives for monitoring by the buyer, potentially reducing government administrative costs and/or increasing the probability that the necessary pollution reductions are achieved. In short, buyer liability tends to increase a program’s environmental efficacy, while seller liability reduces transaction costs in the market (Victor, 2001). Decisions regarding the allocation of liability have important implications for the magnitude and distribution of transaction costs and market structure.

MARKET STRUCTURES IN POLLUTION TRADING

A market is a forum for completing trades and exchanging information about those trades (Bromley, 1997). The structures of pollution trading “markets” can be categorized into four main types: exchanges, bilateral negotiations, clearinghouses, and sole-source offsets. A market’s structure will evolve over time if there is a feasible alternative to the existing norms of trade that allows the sharing of information and/or completion of transactions at lower cost. The choices made regarding authorization, monitoring and enforcement help determine a market’s structure for they establish what structures are feasible and influence the transaction costs that will be faced under those structures.
Exchange Markets

Exchanges like the New York Stock Exchange are in many ways the textbook ideal of a market. An exchange is characterized by its open information structure and fluid transactions between buyers and sellers. Information regarding prices being asked and offered are publicly available and products are uniform. At any one time there is a unique market clearing price so that any interested party could enter the market to make marginal purchases or sales at the market price. In an exchange the price is fully visible, information regarding buyers' and sellers' interests is easily transmitted, and transactions are easily consummated. These features cause transaction costs in such markets to be quite small relative to the price paid. Hence, exchanges come very close to achieving the fully efficient allocation where any trade that would make both the buyer and seller better off is fulfilled.

Needless to say, not all goods and services are bought and sold on exchanges. One critical characteristic for the sale of goods on an exchange is uniformity. That is, exchanges can develop only when a unit of the good from one seller is viewed as equivalent to one from any other source. Such goods can typically be described quite completely and concisely (e.g., a share of IBM common stock or one ton of Chicago #2 Hard Winter Wheat). Although exchanges can lead to very low transaction costs per trade, initial cost of establishing the infrastructure for communication and enforcing trades is more significant. Because of these high fixed costs, this structure tends to arise only when there are adequate economies of scale. However, as a result of advances in information technology, the cost of establishing exchanges is clearly falling rapidly and these costs will probably continue to decline over time.

In market based approaches for controlling air pollution, numerous markets have arisen that can roughly be categorized as exchanges. The market for SO\textsubscript{2} allowances established under Title IV of the Clean Air Act Amendments (CAA), is the clearest example (Schmalensee et al., 1998). SO\textsubscript{2} allowances under this program are actually transacted on the Chicago Board of Trade. This has resulted in a fluid and growing market that moves SO\textsubscript{2} rights from one source to another at very low cost. For example, at the Workshop on Market-Based Instruments for Environmental Protection in July 1999, Brian McLean of the U.S. Environmental Protection Agency reported that brokerage fees were as low as 20¢ per permit, which at that time were trading for about $200.

Because the SO\textsubscript{2} trading program was established in the amendments to the CAA, designers had a relatively high degree of flexibility. There were no other federal pollution control acts that restricted their ability to design a trading program. This allowed the establishment of a national cap on SO\textsubscript{2} emissions and the creation of a national market with uniform credits. Because accurate and timely monitoring is available through the Continuous Emissions Monitoring System, a system of seller liability is used.

By defining a national cap on SO\textsubscript{2} with few restrictions, the program's designers sought to make the market as efficient as possible. This market efficiency, however, was achieved at some expense to environmental efficacy. The marginal environmental impact of a unit of SO\textsubscript{2} pollution clearly varies depending on its point of origin; acid rain associated with SO\textsubscript{2} emissions is most important in the Northeast. But since the market ignores this diversity, in general it will not lead to the cost effective allocation of pollution responsibilities and trades might even cause a decline in environmental quality in regions where the problems are already most severe. We see, therefore, that in designing this program, tradeoffs were allowed between the goal of environmental efficacy and the goal of market efficiency.

Bilateral Negotiations

A market characterized by bilateral negotiations is one in which each transaction requires substantial interaction between the buyer and the seller to exchange information and negotiate the terms of trade. As an example, consider the market for used cars sold by private parties. Car buyers must choose between a wide range of vehicles, each unique in terms of its price and quality. Since it is not possible to succinctly present a vehicle's characteristics, for they include everything from the make and model to its complete maintenance history, the only way to obtain fairly complete information about the vehicle is through personal inspection. Further, since no exact substitutes exist for a vehicle and relatively few buyers have information about a vehicle's characteristics, the price is typically arrived at through a process of bargaining, not simply by observing an existing price on the market.

Compared to typical transactions made in an exchange, information, contracting, and enforcement costs are quite high under bilateral negotiations. This market structure's strength, however, lies in its ability to accommodate nonuniform goods that could not be traded through an exchange. Although homogeneity might be increased, for example by using insurance markets, the persistence of bilateral negotiations suggests that achieving the uniformity necessary for
an exchange to form is often more costly than the transaction costs that follow from this structure.

Bilateral negotiations is the most common structure for WQT markets. Of the cases listed in Table 1, six programs have clearly established bilateral trading programs: Wisconsin’s Fox River program, the PS/PS trading in the Tar Pamlico Basin in North Carolina, the plan developed for the Southern Minnesota Beet Sugar Cooperative, and both the statewide and Kalamazoo case study programs in Michigan. This structure is particularly common in programs that seek to include NPS polluters. Credits based on predicted emissions are specific to the associated NPS and the management practices used to abate pollution. Each source’s credits are also unique because they can only be confirmed by monitoring practices that are often multidimensional and time varying. To overcome monitoring problems, in some programs shared liability is written into the rules of the program. For example, for a PS to make use of a NPS credit in the Dillon program, they must specify how the load reductions will be monitored (State of Colorado Water Quality Control Commission, 1996). As in the market for used cars, therefore, a bilateral negotiations structure is well suited to WQT markets because it can accommodate the need to exchange detailed information about each credit and allows for negotiating the terms of monitoring over time that is required under buyer liability.

Policies such as shared liability, strict monitoring, or extensive reporting increase the certainty that trading will be consistent with the stated environmental goals, but they can also impose substantial transaction costs on both participants and regulators. In the Fox River program, for example, each trade was subject to a review process that could take up to six months before a permit modification was granted (Hahn and Hester, 1989). These rigid restrictions were placed on the program because the paper mill effluent being traded contained toxic organic compounds, giving regulators reason to fear that trading could lead to dangerous “hot spots” within the watershed. However, the result was a program that, despite substantial cost savings potential (O’Neill et al., 1983), had transaction costs so great that they have been blamed for its failure to generate any trades (Hahn and Hester, 1989).

Aware of the need to reduce transaction costs, newer programs are seeking to decrease agency oversight without losing track of the need to control pollution flows. For example, Michigan’s proposed rules contain an expedient two stage process for approval of trades in which a ruling by the agency must be provided within thirty days at each stage (State of Michigan Department of Environmental Quality, 1999, §323).

**Water Quality Clearinghouses**

A clearinghouse market structure is one in which the link between the buyer and the seller is completely broken by an intermediary. An example of a clearinghouse would be a retailer who purchases meat from a large number of producers and pays many different prices, but who sells all the packages of a particular grade of ground meat at a uniform price. In this case the clearinghouse converts a product with variable price and quality into a uniform product, substantially reducing search and information costs. While contracts with the producers are typically relational and require case-by-case negotiation, the transactions with the final clients are discrete and are completed when the client pays a cashier the asking price. In the case of WQT, a clearinghouse is an entity authorized by the oversight agency to pay for pollution reductions and then sell credits to sources needing to exceed their allowable loads. A WQ clearinghouse differs from a broker in a bilateral market in that it eliminates all contractual or regulatory links between sellers and buyers.

WQ clearinghouses are possible only if the laws that established the program admit this structure. These laws must authorize the state or some other entity to play the role of the clearinghouse; it must have the authority to pay for pollution reductions, denominate credits based on the reductions obtained, and resell those credits to interested buyers. Furthermore, since the benefit of clearinghouse is its ability to create a uniform good for final sale, this structure is not well suited to situations in which the law requires final buyer liability for pollution reduction.

The PS/NPS trading program in the Tar Pamlico Basin PSs is a good example of a WQ clearinghouse. Starting in 1989, point and nonpoint sources in the Tar Pamlico Basin began a two-phase program to reduce nitrogen loadings by thirty percent and hold phosphorous loadings constant (North Carolina Department of Environment and Natural Resources, 1999). Trading between PSs and agricultural NPSs takes place via a WQ clearinghouse. This clearinghouse, managed by the state’s Agricultural Cost Share program, pays farmers 75 percent of the cost of implementing BMPs that reduce runoff of nitrogen and phosphorus. Credits are then sold to PSs at a fixed price based on the average cost of achieving reductions (EPA, Office of Wetlands, Oceans, and Watersheds, 1997).

Compared to bilateral trading, WQ clearinghouses are able to reduce transaction costs in the market in three ways. First, a WQ clearinghouse reduces the search and information costs since both purchasers and sellers interact with only one party, the
clearinghouse. Second, credits are known to be acceptable to regulators, reducing uncertainty. Third, if the selling price is publicly visible and standardized practices for completing a trade are clear, bargaining and negotiation costs would also be reduced. Since the relative advantage of a clearinghouse is greatest when it can be used to create some degree of uniformity for buyers faced with diverse sellers of these credits, it is particularly appropriate in markets involving NPS to PS trading.

Of course there are both initial and ongoing costs associated with the operation of a clearinghouse, such as the establishment of norms and the review and completion of trades. These costs might be borne by the government or passed on to traders, but the structure is more efficient than bilateral trading only if operating costs are less than the transaction cost savings.

Sole Source Offsets

The final structure for WQT programs that has been promoted as market based actually does not involve trading at all. Sole source offsets are analogous to a firm's decision to vertically integrate production processes that could have been provided by outside suppliers. In water quality management, a sole source offset takes place when a source is allowed to meet a water quality standard at one point if pollution is reduced elsewhere, either on site or by carrying out pollution reduction activities off site.

The legal foundations for sole source offsets appear to be more easily satisfied than for any other market structure. Authorization can be obtained within the existing NPDES structure and monitoring and enforcement provisions can be defined there as well. Since only one party is involved, the responsibility for achieving the necessary offsets remains with the single source, eliminating the need to define the property right that is implicit in the other market structures.

The program developed for the City of Boulder's wastewater treatment plant is representative of this approach. In 1995, a TMDL analysis found that in order for Boulder Creek to achieve its designated use, substantial reductions in un-ionized ammonia were necessary, reductions even beyond those that could be achieved by closing the plant. The city addressed the problem through partial improvements in the plant's facilities, but also took measures to restore the riparian zone along Boulder Creek. After accounting for the cost of the stream improvements, the EPA estimates that the city may save over $1.5 million because of the program (EPA, Office of Water, 1998).

Relative to other structures, sole source offsets might have lower transaction costs because there are no formal transactions. Such costs are not, however, eliminated. In Boulder's case, negotiating to make improvements on land it did not own required substantial bargaining costs (personal communication, Chris Rudkin, Water Quality Coordinator, City of Boulder Public Works/Utilities, December 30, 1999).

From a regulator's perspective, sole source offsets internalize management and facilitate enforcement relative to other structures since this approach does not introduce any additional parties into the equation.

Even if trading is permitted, in some instances sole source offsets might be the choice of a polluter looking to reduce its net pollution load since firms may find it more attractive to abate within their own organization. However, if agencies limit the range of options by only allowing sole source offsets, the resulting program may not deliver the cost savings that could be achieved through WQT; not all polluters have options for offsets. Additionally, a program that only allows sole source offsets creates no incentives for pollution reduction by entities that are already in compliance with pollution standards.

A Comparison of Market Structures

Table 2 presents the market efficiency and environmental efficacy characteristics of typical transactions within each structure. For example, exchanges are typically characterized by low transaction costs per trade, but high initial set up costs. On the other hand, exchanges do not allow some policies that can improve a program's environmental efficacy and neither buyer liability nor nonuniform credits can easily be accommodated in an exchange.

As noted above, the legal and physical environment in which WQT are developed presents numerous challenges that distinguish it from the case of the CAA. First, although authorization for trading can be inferred from sections of the CWA, it is not specifically authorized. Any WQT program is, therefore, tightly constrained by legal standards in the CWA which restricts the extent to which pollution loads from different sources are substitutable; the spatial tradeoffs allowed in the SO₂ program would not be permitted in most WQT programs.

The monitoring and enforcement challenges associated with NPS pollution also make the creation of a uniform credit quite difficult. In NPS water pollution, credits are usually only estimates of the reduction in pollution achieved by a management practice. The actual pollution reduction will depend on the weather, a multitude of location specific characteristics, and how well the practice is implemented. Even within the same watershed, water pollution from two sources

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<thead>
<tr>
<th>Indicators of Market Efficiency</th>
<th>Exchange</th>
<th>Clearinghouse</th>
<th>Bilateral Negotiations</th>
<th>Sole Source Offsets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transaction Costs Per Trade</td>
<td>Lowest</td>
<td>Low</td>
<td>Highest</td>
<td>NA</td>
</tr>
<tr>
<td>Initial Set Up Costs</td>
<td>High</td>
<td>High</td>
<td>Low</td>
<td>Lowest</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Indicators of Ability to Ensure Environmental Efficiency</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Degree of Uniformity Required</td>
<td>Highest</td>
</tr>
<tr>
<td>Buyer Liability a Possibility</td>
<td>No</td>
</tr>
</tbody>
</table>

may have substantially different environmental impacts. By nature, therefore, WQT credits generated by NPSs are nonhomogeneous, making the development of an exchange very difficult. Additionally, because of the difficulty of monitoring, governments may turn to a system of buyer liability to facilitate enforcement. If buyer liability is used, however, the contract is by nature relational, eliminating the credits' uniformity. In light of the challenges created by the legal environment and physical nature of the water pollution problems, it is not surprising to find that no WQT program to date has taken the form of an exchange.

By set up costs we are referring to the costs required to establish the necessary legal and technical infrastructure for trading. For example, for bilateral negotiations all that is required is to define those aspects of their pollution rights that can be traded and to establish the necessary reporting and monitoring mechanisms. In contrast, for a clearinghouse, the necessary structure for the organization must be established, individuals to operate the clearinghouse must be identified, and institutional standards defined. Structures with high set up costs and lower transaction costs per trade have economies of scale and are most suited to programs with a large number of traders or active trading.

The Grassland Area Farmers (GAF) is an association of six irrigation districts that serve about 84,000 acres of agricultural land on the west side of California's San Joaquin Valley. The pollutant traded in the Grasslands program is selenium, a naturally occurring nonmetallic trace element that bioaccumulates in predators and can be toxic in high concentrations. High levels of selenium are found throughout the region's soils. Selenium dissolves in irrigation water, which drains from the fields through underground tiles. In the mid-1980s, selenium was identified in agricultural drainage water that flowed into the wetlands of the Grassland Water District. From that time until the mid 1990s the GAF sought to control the selenium levels, primarily by voluntarily adopting BMPs to reduce selenium in their drainage water.

In 1996, faced with the likelihood that water quality standards would be tightened, the GAF began diverting their drainage into the Bureau of Reclamation's (BR) San Luis Drain, a concrete lined canal that drains into the Kesterson Reservoir, a national wildlife refuge (Austin 2001). As part of the agreement authorizing the GAF to discharge into the Drain, both monthly and annual limits on the amount of selenium that can be discharged by the GAF were established, starting at over 6,600 pounds in 1997 and declining to about 3,000 2009 (U.S. Department of Interior, 2001). If, in aggregate, the districts in the GAF release more than either a monthly or annual

THE CALIFORNIA GRASSLANDS SELENIUM TRADING PROGRAM

In this section we apply our framework of market structures to the case of the California's Grassland Tradable Loads Program. This relatively new and successful trading program provides a useful test case for the structure that we have outlined above. We will evaluate the applicability of the alternative market structures and discuss whether the market structure that has arisen is most suited to the program. Our analysis is made possible by the detailed analysis of the Grasslands program in Austin (2001) and unless otherwise noted, factual details are taken from this source.

Legal and Physical Characteristics of the Market

The Grassland Area Farmers (GAF) is an association of six irrigation districts that serve about 84,000 acres of agricultural land on the west side of California's San Joaquin Valley. The pollutant traded in the Grasslands program is selenium, a naturally occurring nonmetallic trace element that bioaccumulates in predators and can be toxic in high concentrations. High levels of selenium are found throughout the region's soils. Selenium dissolves in irrigation water, which drains from the fields through underground tiles. In the mid-1980s, selenium was identified in agricultural drainage water that flowed into the wetlands of the Grassland Water District. From that time until the mid 1990s the GAF sought to control the selenium levels, primarily by voluntarily adopting BMPs to reduce selenium in their drainage water.

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limit, a fine is levied on the group and continuous exceedence would result in the rescission of the GAF's access to the Drain, forcing them to find an alternative (and probably much more costly) way to dispose of their drainage water. As long as the aggregate cap is not exceeded, there are no restrictions on individual districts.

The Grasslands program has been described as involving NPSs (Austin, 2001:338). However, Griffin and Bromley (1982:547) define a nonpoint externality as existing "contributions of individual agents can not be practically measured by direct monitoring." This does not apply in the Grasslands case since loads from each irrigation district are metered at the sumps throughout the districts where water collects before being pumped into the Drain. Hence, despite the fact that the selenium loads cannot be easily controlled by the districts, because of the high level of information about the loads the program is more akin to a PS program.

In addition to accurate monitoring of the districts' loads, the aggregate selenium loads, which are uniformly dispersed in the Drain, are monitored by the BR (U.S. Department of Interior, 2001). These data provide a firm foundation from which participants can trade Selenium Load Allocations (SLA) and a high degree of certainty to the BR that the aggregate cap has not been exceeded. Because district loads are monitored, each district is allocated monthly and annual SLAs and can purchase rights to avoid paying penalties if they exceed their cap. Like other PS trading programs, trades in the Grasslands program are made ex post, based on selenium loads that were actually discharged, rather than predicted loads as is true in most WQT programs.

The legal authority of the Grasslands association is derived from the districts' joint contract with the BR. The six districts that make up the association are governed by a steering committee and all actions taken by that committee must be approved unanimously by a quorum. The steering committee allocates selenium discharge rights and determines the structure of fines in the event of an exceedence. Trading is fostered by the collegial environment that exists because district managers meet regularly to address a range of issues.

An Analysis of the Market Structures for the Grasslands Trading Program

Using the framework from Table 2, we can now consider the applicability of the four market structures considered for the Grasslands program. Because of the monitoring of selenium loads and the high degree of flexibility provided by the aggregate cap, any of the four structures might be feasible. Unlike most WQT scenarios, uniformity was possible because of the accurate monitoring and uniform impacts of loads so that even an exchange might have formed. Although a clearinghouse is not written into the GAF's contract with the BR, neither is one precluded and this structure could have been adopted.

In this case, therefore, in choosing the market's design, policy makers are not required to consider sacrificing environmental efficacy to achieve a more efficient market. The question of which market structure is most appropriate comes down to the issue of market efficiency. Here, the small number of traders is an important factor. With only six districts represented in the trading association, it is unlikely that there would be a significant improvement in information transfer by creating institutional basis for an exchange or clearinghouse. To date, trading has been limited: as of February of 2000 only nine trades had been completed for a total of 605 monthly and 128 annual SLAs. Moreover, the open lines of communication between the six districts have allowed trades to take place at relatively low cost. The Regional Drainage Coordinator can assist in the negotiating process, further reducing transaction cost. When asked about costs required to complete a transaction, most traders reported negligible time or monetary expense with only one district reporting $500 and $1,000 fees paid to a lawyer to review the trading contract (Austin, 2001:339).

Under the current system, trading only takes place between the irrigation districts, which then need to provide incentives for farmers to control their selenium loads. However, since sumps throughout each district are monitored, it could be relatively easy to conduct trading at the level of each sump. The main benefit of moving to greater disaggregation would be to improve farm level incentives to find cost effective ways to reduce selenium discharges and to take advantage of variability in cost effectiveness within districts. However, there would be initial costs to establish such a system, and search and information costs per trade would likely rise as the number of traders increased. In a more disaggregated market, therefore, an exchange structure might have lower transaction costs and these benefits might more than offset the initial costs required to move to this structure.

As with an exchange, a clearinghouse structure seems inappropriate in the Grasslands case because of the costs to establish such a market. Moreover, because in the Grasslands market both buyers and sellers are irrigation districts, the clearinghouse's advantage of facilitating transactions between different types of firms is not realized.
The structure that has arisen in the Grasslands program is a system of bilateral negotiations. As noted above, transaction costs have been quite low and do not appear to have been prohibitive to trading. The search and information costs are low because the SLAs are uniform and verified through monitoring. All that is required to complete a trade is that it "be documented in a written Trading Agreement [and] certified by the Regional Drainage Coordinator" (Grassland Basin Drainage Steering Committee, 1999). Bargaining costs are also low because of the existing relationships between traders. Through bilateral negotiations, traders have been able to quickly and inexpensively identify trading partners and negotiate terms of the trade.

In general (Table 2), bilateral negotiations structure have the advantages of lower initial costs and are the ability to accommodate markets with highly variable goods, but the disadvantage of having relatively high transaction costs on each trade. In the Grasslands case, the disadvantage of this structure is minimized because transaction costs per trade are kept low by the small homogenous group of traders and the high level of information regarding discharges. Hence, in this case the advantage of moving to an alternative structure is small and does not appear to warrant the initial costs of making such a change.

Sole source offsets have been a major feature of the Grasslands program. A variety of ways of reducing the region's selenium load are in use or being developed: drainage water is recirculated and redirected, land is managed specifically to reduce selenium discharge, and water treatment options are being explored. Some of these options are less costly than purchasing credits from other districts. Although there are no data on the extent of such practices, Austin's discussion suggests that sole-source reductions play a larger role in overall selenium discharges reductions than the SLA market. However, because the districts also have the option to trade, sole source offsets are only pursued to the extent that they are less costly than purchasing credits (personal communication, David Cory, Grassland Tradable Loads Program Advisory Committee, January 9, 2001).

The Grasslands case provides a good example of how a market structure has arisen in response to the institutional and economic environment in which the program is set. The program enjoys a higher degree of flexibility than most other WQT programs, making all four market structures possible. However, because transaction costs are low in the current bilateral negotiations structure, this structure has persisted. Although sole source offsets have continued to play a role, they are used only when they cost less than trading. Hence, the market that has arisen in the Grasslands program appears to be creating the appropriate economic incentives for cost-effective pollution reductions.

CONCLUSIONS

The goals of a WQT program are to improve water quality while at the same time reducing costs. The extent to which these goals can be achieved is subject to numerous constraints: by laws that restrict the extent to which trading is allowed, by the physical characteristics of the pollution problem, and by the size of the WQT market. The structure of the WQT market that results will be determined to a significant degree by how policy makers respond to these constraints in their pursuit of the sometimes competing goals of market efficiency and cost effectiveness.

As we have seen, the structures of pollution trading markets can be broken into four main types. These are, however, not necessarily mutually exclusive. Sole source offsets can remain part of any trading program and a gradual evolution from bilateral negotiations to an exchange or clearinghouse might occur. As summarized in Table 2, these structures differ in terms of the market efficiency that they foster and the flexibility they offer to regulators seeking to ensure that water quality goals are achieved.

Following the logic of Coase (1937), a market will tend to use the structure or structures that minimize transaction costs. However, the structure that creates the most efficient market may not provide the highest certainty that environmental targets are being reached. Hence, in designing a pollution trading program regulators frequently confront tradeoffs between market efficiency and environmental efficacy.

In the case of the Grasslands program, monitoring of loads from each district and the uniform dispersion of the pollutant make possible a high level of confidence that environmental targets are being reached, regardless of the structure that results. In this case, therefore, policy makers were not forced to sacrifice environmental efficacy to facilitate a more efficient market. Hence, we would expect the market structure that has arisen to be the one that minimizes transaction costs, and this appears to hold. Although trading takes place via bilateral negotiations, which typically have higher transaction costs, these costs are quite low in the Grasslands program because of the frequent communication between districts and simplified contracts that are possible because of the accurate monitoring of loads.

There are a variety of reasons why it is helpful to recognize the various market structures that might arise. The first is to have a sense of realistic
expectations. In air pollution markets, a high level of uniformity has often been achieved and many of these markets fall into an exchange structure. However, this is not the only option for pollution trading, and agencies seeking to establish WQT should not necessarily seek to establish an exchange. Secondly, among the remaining three structures, each is appropriate in different settings. While bilateral negotiation is the most common structure used in WQT to date, agencies may want to give more consideration to other structures such as the clearinghouse structure, which has lower per-trade transaction costs, or simply relying on sole source offsets if regulatory restrictions do not allow sufficient flexibility for trading or if opportunities for cost savings within firms are substantial. Finally, in developing WQT markets, regulators should keep in mind that the rules that are written will have important impacts on the structure of the market that results. This in turn will affect transaction costs, market efficiency and, in the end, the success of the program. Market structure should, therefore, be considered from the very outset of the planning process.

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LITERATURE CITED


