WORLD
RESOURCES
INSTITUTE

ISSUE BRIEF

ADDRESSING RISK AND UNCERTAINTY IN WATER QUALITY TRADING MARKETS

SARA WALKER AND MINDY SELMAN

SUMMARY

Across the United States, water quality trading is being explored as a mechanism for reducing the costs of cleaning up impaired waterbodies. Trading between point sources, such as wastewater treatment plants, and nonpoint sources, such as agriculture, can cut costs for regulated entities needing to reduce pollutants, and generate revenue for agricultural producers who generate credits. However, water quality trading, particularly between point and nonpoint sources, can face inherent uncertainties around quantification of nonpoint source reductions, participant behavior, regulations, and market supply and demand. Effectively addressing uncertainties is crucial to ensuring the success of these markets and improving water quality. This paper establishes a framework from which to engage federal and state agencies, program developers, and stakeholders in a dialogue about these uncertainties and appropriate mechanisms for addressing them.

EXECUTIVE SUMMARY

With the emergence and growing maturity of water quality markets as a compliance tool for regulated sources of pollution, it is increasingly important to ensure that these programs are designed to protect water quality as well as to create efficient and credible markets for the participants. However, water quality markets, especially those that include nonpoint sources, have inherent uncertainties that actual environmental benefits will be achieved. In the case of reductions from nonpoint sources such as agriculture, uncertainties are common because pollution is diffuse and therefore difficult to quantify. In addition to uncertainty related to nonpoint source credit estimation, water quality trading markets may also face uncertainty related to participant behavior, regulations, and market supply and demand. Adequately addressing the risks of uncertainty can mean the difference between a vibrant water quality trading market that capitalizes on the most cost-effective pollutant mitigation measures and a stagnant, or nonexistent, market in which permitted entities must either invest in expensive technological upgrades or fail to meet permit limits and accommodate growing populations.

As water quality markets have developed, programs have put in place unique approaches to addressing uncertainties and risks associated with market uncertainties. The purpose of this paper is to establish a framework identifying the uncertainties and risks that are common in water quality trading programs, as well as some common mechanisms for addressing them. We hope it will serve as a foundation from which to engage federal and state agencies, program developers, and stakeholders in a national dialogue about guidelines for addressing uncertainty and risk in water quality markets. The types of uncertainty discussed in this report include:

- **BIOPHYSICAL AND SCIENTIFIC UNCERTAINTY.** Biophysical and scientific uncertainty refers to uncertainty regarding how land-based activities implemented to generate credits—especially agricultural best management practices (BMPs) such as forest buffers or cover crops—perform given the natural variations in weather and site-specific conditions, as well as uncertainty about our ability to predict and estimate the performance of these activities.
- **EXTREME EVENT UNCERTAINTY.** Extreme or stochastic events, such as fires, floods, droughts, disease, and earthquakes, can lead to failure of nonpoint source control measures that were implemented to generate credits. Whereas biophysical uncertainty includes natural variations in weather due to seasonal changes and historical weather patterns,

Adequately addressing the risks of uncertainty can mean the difference between a vibrant water quality trading market and a stagnant, or nonexistent, market in which permitted entities must either invest in expensive technological upgrades or fail to meet permit limits and accommodate growing populations.

extreme event uncertainty captures those variations that are largely unpredictable.

- **BEHAVIORAL UNCERTAINTY.** Behavioral uncertainty is associated with whether the credit seller will abide by the agreement and implement the BMP as planned. Uncertainties can arise because of the possibility of farmers breaching their contracts, either because they did not implement practices, adequately maintain practices, or otherwise unintentionally defaulted on the trade agreement. Because regulated point sources retain legal liability for meeting their permit, they may find it too risky to enter into an agreement in which there is uncertainty regarding the seller's actions and the credits actually generated.
- **REGULATORY UNCERTAINTY.** Regulatory uncertainty largely concerns wariness about participating in the trading market because of the potential for policies to change in the future that could affect credit generation and sales. The agricultural community may face uncertainty about the possible impact of changes in agricultural regulations or market policies, or they may face uncertainty about how precompliance actions will be treated if future regulations are imminent. Risks of litigation over concerns with water quality trading can create reluctance for both buyers and sellers. Likewise, litigation risks could prevent state agencies from certifying credits or approving trades.
- **MARKET UNCERTAINTY.** Market uncertainty arises from the ambiguity about supply and demand within water quality markets. Particularly in the early stages of a market, potential sellers may be reluctant to enter the marketplace if there is uncertainty about demand for their credits. When markets are thin and credit prices unknown, uncertainty about credit prices leads to uncertainty for producers about profitability entering the market. Likewise, buyers who need to purchase credits to meet permit limits or offset growth may find it risky to rely on future credits whose availability and price is unknown.

Mechanisms to Address Uncertainty in Water Quality Trading Markets

Many mechanisms are available for mitigating risks. Mechanisms to address these risks can be employed in tandem or individually, depending on the program's goals, needs, available resources, and other circumstances. Mechanisms include:

Biophysical and Scientific Uncertainty

- **IMPROVED SCIENCE.** Improved scientific understanding of the impacts that biophysical characteristics have on the performance of BMPs leads to better predictive certainty about how BMPs impact water quality.
- **DIRECT MEASUREMENT.** Direct measurement of the effects of BMPs through monitoring before and after water quality effects of the practice captures the interannual variability inherent in many nonpoint source BMPs.
- **BMP EFFECTIVENESS ESTIMATES.** Effectiveness estimates based on the best available science reflect conservative average values; they are particularly useful in markets with large volumes of trades.
- **ESTIMATION TOOLS AND MODELS.** Estimation tools and models, from spreadsheets to dynamic models, estimate nonpoint source credits by allowing for more variables in credit calculation estimates than effectiveness estimates alone, thus avoiding the need for directly measuring pollutant loads.
- **TRADING RATIOS.** Uncertainty ratios serve as a margin of safety to ensure water quality is not degraded despite the variability in nonpoint source BMP effectiveness. Likewise, retirement ratios are applied to credit transactions to ensure a net improvement to water quality.

Extreme Event Uncertainty

- **CENTRALIZED CREDIT RESERVE/ INSURANCE POOL.** Credit reserves and insurance pools hedge against BMP failure as a result of extreme weather events.

Behavioral Uncertainty

- **AGGREGATORS.** Aggregators pool together credits from multiple projects and act as intermediaries between buyers and sellers, absorbing the up-front capital risks and liability.
- **SELF-INSURANCE.** Self-insurance for aggregators absorbs liability and protects them from the risks of projects failing to generate sufficient credits.
- **VERIFICATION.** Common in water quality trading programs, verification confirms that a practice is installed and maintained to meet design specifications, creating a system of transparency, accountability, and consequences for noncompliance.
- **SHARED FINANCIAL LIABILITY.** With shared liability, the seller shares financial liability for regulatory noncompliance with the regulated buyer, thereby mitigating risks associated with behavioral uncertainty.

Regulatory Uncertainty

- **GRANDFATHERING.** Grandfathering guarantees to buyers and sellers that already certified or sold credits will remain valid for the life of the contract if regulations change.
- **AGRICULTURAL CERTAINTY PROGRAMS.** Certainty programs recognize precompliance credit-generating activities as sufficient for meeting future regulations.
- **STANDARDS FOR WATER QUALITY TRADING PROGRAM DESIGN AND IMPLEMENTATION.** Policies promote consistency and transparency among programs, which provides assurance to the public and market participants.

Market Uncertainty

- **PREIMPLEMENTATION CERTIFICATION.** Certifying credits before BMPs are implemented lowers the risk to sellers, who may hesitate to install practices without a guarantee that the generated credits will be sold.
- **CREDIT BANKS/CLEARINGHOUSES.** Banks serve as brokers or clearinghouses for credits, offering buyers and sellers an attractive option for transacting credits efficiently and with low risk.
- **GOVERNMENT GUARANTEE PROGRAM.** Government guarantee programs protect early actors by agreeing to purchase credits that go unsold.

The benefits and drawbacks of each risk mitigation option should be carefully considered along with region-specific factors such as available data, tools, and resources, as well as the presence of policies that may impact or guide the trading program. In the end, water quality trading programs should be designed in such a way that water quality goals can be achieved in a cost-effective manner and uncertainty is minimized.

In the end, water quality trading programs should be designed in such a way that water quality goals can be achieved in a cost-effective manner and uncertainty is minimized.

I. INTRODUCTION

In the United States, over half of assessed water bodies were impaired for their designated uses in 2010 (U.S. EPA 2010). Many of these impairments were from excessive nutrients. Agricultural runoff, wastewater, and urban runoff are common sources of nutrients in our waterways. Increasingly, the discharge of nutrients is being regulated through individual source permit limits and other local regulations, in which total maximum daily loads (TMDLs) often serve as the basis for allocating allowable loads (see Box 1). Water quality trading is one mechanism that states and local governments are exploring as a means of reducing the costs of controlling nutrients. Water quality trading allowing sources with high abatement costs to purchase credits, or units of reduced pollution, from sources with lower abatement costs. Water quality trading is also used in cases where new and expanding sources of nutrients in a watershed must offset their nutrient load through the purchase of offsets.

Water quality trading can take place between two or more point sources that discharge pollutants from single, identifiable sources such as pipes. Trading might also occur between a regulated point source and an unregulated nonpoint source. A nonpoint source is a source of pollution that is diffuse in nature, for example, agricultural runoff. In many cases, agricultural sources may be able to reduce nutrient pollution at lower cost than traditional point source emitters. Therefore, water quality trading programs between point and nonpoint sources can save money for permitted point sources needing to reduce their pollutant load, and generate additional revenue for nonpoint sources that generate credits, ensuring that water quality targets are met in a cost-effective manner. Most water quality trading programs currently active in the United States allow point to nonpoint source trading (see Figure 1) (Selman et al. 2009).

BOX 1

TOTAL MAXIMUM DAILY LOADS AND WATER QUALITY TRADING

"Under section 303(d) of the Clean Water Act, states, territories, and authorized tribes are required to develop lists of impaired waters. These are waters that are too polluted or otherwise degraded to meet the water quality standards set by states, territories, or authorized tribes. The law requires that these jurisdictions establish priority rankings for waters on the lists and develop Total Maximum Daily Loads (TMDLs) for these waters. A TMDL is a calculation of the maximum amount of a pollutant that a waterbody can receive and still safely meet water quality standards."*

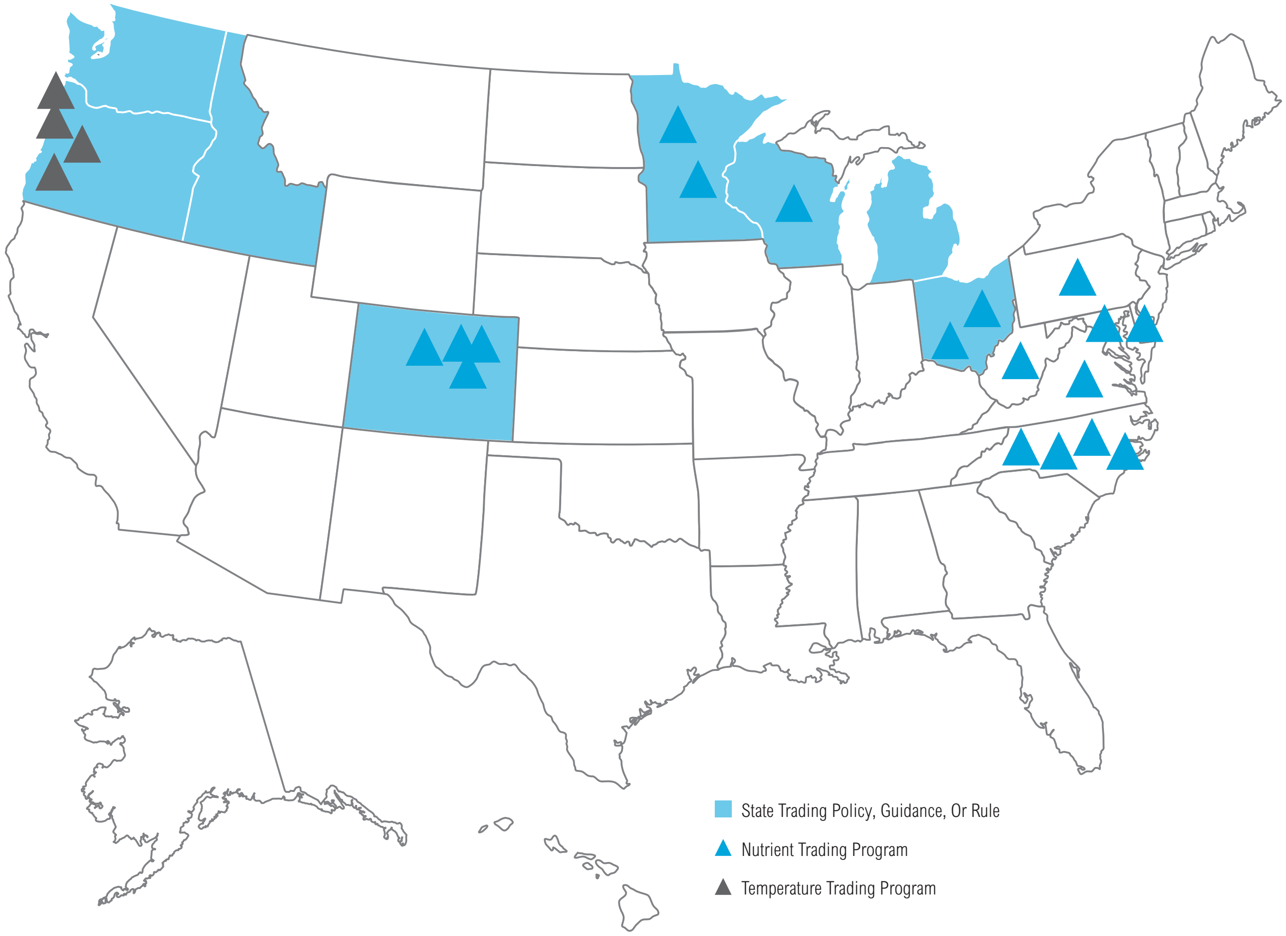
The TMDL's maximum pollutant load is allocated to point and nonpoint sources in the watershed. Point sources receive wasteload allocations, which are incorporated as water-quality-based effluent limitations in their National Pollution Discharge Elimination System permits. Permitted entities with an allocated pollutant load can use trading in lieu of investing in expensive onsite technological upgrades to more cost-effectively achieve their cap. The presence of TMDLs can also spur local regulations on pollutant loads from other sectors, such as private developers, who can also participate in trading.**

*U.S. Environmental Protection Agency. 2013. "Impaired Waters and Total Maximum Daily Loads." Available at: <http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/>.

**Selman, M., S. Greenhalgh, E. Branosky, C. Jones, and J. Guiling. 2009. "Water Quality Trading: An International Overview." Washington, DC: World Resources Institute. Available at: <http://www.wri.org/publication/water-quality-trading-programs-international-overview>.

FIGURE 1

MAP OF U.S. POINT TO NONPOINT WATER QUALITY TRADING PROGRAMS



Source: Willamette Partnership 2012

As water quality markets continue to emerge and mature as a compliance tool for regulated point sources, it becomes increasingly important to ensure that these programs are designed to protect water quality as well as to create efficient and credible markets for the participants. When developed well, water quality trading programs will ensure that market participants have confidence in the trading program and be willing to engage in transactions. As a result, the cost of achieving water quality standards may be less than it would be using only traditional command and control approaches (Faeth 2000; Selman et al. 2009). However, there are uncertainties inherent in any environmental market about whether credits represent real and equitable offsets to regulated loads, the behavior of the participants, and the strength of the market. These real or perceived risks that are generated as a result of these uncertainties can break public trust and jeopardize cost effectiveness.

One of the most persistent areas of uncertainty in water quality markets centers on nonpoint source reductions from agricultural practices. Unlike point sources (e.g., wastewater treatment plants), which often discharge from a pipe, nonpoint sources of pollution (e.g., farms) are difficult to measure or estimate because they are diffuse in nature. Whereas the treatment effects of point source pollution controls are perceived to be certain, nonpoint source control treatment is perceived to be uncertain due to the variable nature of nonpoint source pollution. There is a widespread perception of reduced certainty of control when nonpoint source pollution reductions are substituted for point source pollution reductions in a trading program, thus resulting in the potential to degrade water quality if nonpoint source reductions are insufficient (Shortle and Horan 2008). In addition to uncertainty about nonpoint source reductions, water quality trading markets also can face uncertainty regarding participant behavior, regulations, and supply and demand in the market.

The purpose of this paper is to establish a framework that identifies types of uncertainties and risks that are common in water quality trading programs, as well as some common mechanisms for addressing them. Adequately addressing uncertainty, especially the types of uncertainty arising from the participation of agricultural nonpoint sources, can mean the difference between a vibrant water quality trading market that capitalizes on the most cost-effective pollutant mitigation measures and a stagnant, or nonexistent, market in which permitted entities must either invest in expensive technological upgrades or fail to meet permit limits and accommodate growing populations. As water quality markets have developed and evolved over the years, each program has developed unique approaches to address uncertainties and risks associated with agricultural nonpoint source credits as well as other market uncertainties. We hope this paper will serve as a foundation to engage federal and state agencies, program developers, and stakeholders in a national dialogue about guidelines for addressing uncertainty and risk in water quality markets. Effectively addressing these uncertainties will be crucial to ensuring the success of these markets and to improving water quality.

We hope this paper will serve as a foundation to engage federal and state agencies, program developers, and stakeholders in a national dialogue about guidelines for addressing uncertainty and risk in water quality markets.

The forms of uncertainty[1] described in this paper include:

- **BIOPHYSICAL AND SCIENTIFIC UNCERTAINTY.** Uncertainty as to how activities on the land, especially agricultural best management practices (BMPs) such as forest buffers or cover crops, perform given natural variations in weather, as well as uncertainty regarding our ability to accurately predict and estimate the performance of these activities.
- **EXTREME EVENT UNCERTAINTY.** Uncertainty associated with extreme or stochastic events that can lead to failure of nonpoint source control measures.
- **BEHAVIORAL UNCERTAINTY.** Uncertainty associated with whether or not the credit seller will abide by the agreement and implement the BMP as planned.
- **REGULATORY UNCERTAINTY.** Uncertainty emanating from wariness about participating in the trading market because of the potential for policies to change in the future that could affect credit generation and sales.
- **MARKET UNCERTAINTY.** Uncertainty about the potential mismatch between supply and demand and how trading revenue will compare to foregone crop revenue.

To identify ways in which uncertainty is addressed, or could be addressed, in water quality trading programs, we reviewed literature on trading, water quality trading programs, and interviewed water quality trading practitioners throughout the United States.

II. TYPES OF UNCERTAINTY IN WATER QUALITY TRADING MARKETS

We have divided uncertainties within water quality markets into five main categories. These categories include uncertainty about the performance and estimation of nonpoint source reductions themselves, uncertainty due to extreme events, buyer uncertainty about nonpoint source implementation, and seller uncertainty about market and regulatory dynamics.

Biophysical & Scientific Uncertainty

Biophysical and scientific uncertainty refers to the uncertainty inherent in predicting and measuring the benefits of land-based mitigation activities given the unpredictability of the natural world. In water quality trading programs where nonpoint sources can participate in the market, these types of land-based activities might include implementation of agricultural or urban BMPs like riparian buffers or bioswales. Because nonpoint source pollution is diffuse and traverses over and under landscapes, it is challenging to predict with certainty the actual pollution reductions that are generated as a result of BMP implementation, even with the best available science. This form of uncertainty is especially relevant in regulatory markets where nonpoint source reductions are being applied toward a point source's permit obligations.

The effectiveness of BMPs can vary by location, soil type, topographical features, season, weather, and also by existing crop management system, in the case of agricultural BMPs. For example, cover crops planted to reduce nutrient losses in areas with highly erodible soils may be more effective than cover crops planted in areas with relatively stable soils. Therefore, effectiveness is subject to variation based on the specific landscape where BMPs are applied. Weather patterns and seasonal variations in temperature and climate also impact the effectiveness of BMPs, leading to annual and interannual variability. Drainage ditches, for example, could flood during periods of rainfall and no longer provide their service of slowly filtering nutrients. If not accounted for, this temporal uncertainty regarding the interannual variability of nonpoint source credits may affect a credit buyer's permit compliance. There may be a time lag between when a BMP is implemented and when it becomes fully effective, and/or between when reductions achieved at the mitigation site are actually realized in the waterbody of interest. For example, when planted, a riparian forest buffer composed of saplings will not be very effective in reducing nutrient runoff, but its effectiveness will increase as the trees grow and increase their filtration capacity. Likewise, the impact of a mature riparian buffer may be immediate at the project site, but the downstream benefits to the waterbody of interest may take months or even years to become evident due to lag times in the subsurface transport of nutrients and/or the presence of impoundments such as dams, which can impede surface water flows.

Extreme Event Uncertainty

Extreme events—such as fire, flood, drought, disease, and earthquakes—may not only compromise the effectiveness of land-based mitigation activities, but may also render them completely ineffective. In particular, stochastic weather events like floods and drought pose risks to agricultural production systems. A producer might reduce fertilizer use as a way of reducing nutrient runoff, but a severe storm or flooding event may cause greater nitrogen runoff than would have occurred on an average year. Similarly, a drought might kill a stand of trees planted as riparian shade, and hurricane winds may blow down a riparian fence meant to exclude cows from the stream.

Biophysical uncertainty includes natural variations in weather due to seasons and historical weather patterns. Extreme events are those that are largely unpredictable. With climate change we might expect more extreme events than in the past, which will increase the risk of failure of land-based mitigation activities.

With climate change we might expect more extreme events than in the past, which will increase the risk of failure of land-based mitigation activities.

Behavioral Uncertainty

In water quality trading markets, there may be uncertainty as to whether the credit seller will properly install and maintain a BMP throughout its life. This type of behavioral risk might be characterized as moral hazard. Moral hazard refers to "imperfect information about farmers' actual compliance" (Hart and Latacz-Lohmann 2005). Lack of certainty regarding seller behavior can result in potential buyers perceiving that there is an increased risk that agricultural sellers will not honor their trade agreements and maintain BMPs as promised. Because agricultural nonpoint source sellers are generally unregulated, there is asymmetrical risk borne between the buyer and the seller if a BMP that is generating offsets fails. Under the Clean Water Act (CWA), when a regulated point source purchases credits from an unregulated nonpoint source, the legal liability of meeting the permit remains with the buyer. Thus, for example, if an agricultural producer fails to implement BMPs in accordance with the trade agreement, it is the point source that could be found in violation of its permit, not the credit seller. Given this legal reality, permitted entities may find it too risky to enter into an agreement in which there is uncertainty regarding the seller's actions and the reductions achieved (Selman et al. 2009).

Imperfect information becomes problematic when also combined with inadequate enforcement of seller activities and/or from the difficulty of verifying certain behavioral practices that cannot be empirically observed (e.g., nutrient management). When prospective buyers perceive that that enforcement of seller activities is inadequate, their own perceived risk for exposure to legal liability may increase.

Regulatory Uncertainty

Regulatory uncertainty refers to wariness about how potential future changes in policies could affect credit generation and sales. An uncertain regulatory landscape could prevent buyers or sellers from participating in an environmental market that typically involves multiyear agreements. For example, the agricultural community may face uncertainty about the possible impact of changes in agricultural regulations or market policies, in particular, policies around trading eligibility. In water quality trading, nonpoint sources generally have a baseline requirement that must be met before being eligible to trade. If the baseline changes in future years, activities that generate credits today may not be eligible in the future. Producers may find it too risky to commit to and implement multiyear projects if they believe financial compensation for their efforts is in jeopardy. Therefore, unless the water quality market has a mechanism for addressing this type of regulatory uncertainty, credit supply may suffer.

Similarly, when new regulations are imminent, producers may face uncertainty about how their precompliance actions will be treated once the regulations are in place. For example, if a trading program

In designing a water quality trading program, it is important that policymakers identify specific causes of uncertainty and develop appropriate mechanisms for mitigating these uncertainties.

is under development, and it establishes a date of eligibility, (e.g., practices can only generate credits if implemented after 2013), a producer may find it too risky to invest in BMPs before the date of eligibility is established because the pollutant reductions generated by the BMPs implemented before that date could not be sold as credits.

Finally, regulatory uncertainty may arise when there is a risk of litigation. In the Chesapeake Bay, for example, a lawsuit was filed challenging the legality of water quality trading (Food and Water Watch et al. vs. U.S. EPA) (Wheeler 2012). Similar concerns with water quality trading have arisen in other emerging markets; for example, Northwest Environmental Advocates sent a letter to U.S. EPA Region 10 calling for better oversight of trading in Oregon in relation to the Clean Water Act (Northwest Environmental Advocates 2013). When the trading programs themselves are challenged, buyers as well as sellers are reluctant to enter the market. Furthermore state agencies may be reluctant to certify credits or approve trades if the trading program is threatened by legal action.

Market Uncertainty

Market uncertainty refers to uncertainties that affect willingness to participate in the market due to the unknown financial benefits or consequences of trading. Particularly in the early stages of a water quality trading market, potential sellers may be reluctant to enter the marketplace if there is uncertainty about demand for their credits. As in any market, there is no guarantee that when a good is produced, there will be a demand for that good. Producers may invest time, energy, and resources into certifying credits for sale in a water quality market, but these investments can be risky if demand is low or unknown. Furthermore, if practices are implemented before credits are certified and sold, the producer will face uncertainty about whether a buyer will be willing to pay enough money per credit to cover the cost of implementation.

Agricultural producers may also face uncertainty around credit prices and commodity prices. Because implementing practices to generate credits could restrict their ability to react to changes in the commodity market, produces may need some income assurances if they are to commit to multiyear projects.

Likewise, buyers may face uncertainty about whether there will be adequate supply of credits. Buyers who need to purchase credits to meet permit limits or offset growth may find it risky to rely on future credits whose availability is unknown and out of their control.

III. MECHANISMS TO ADDRESS UNCERTAINTY IN WATER QUALITY TRADING MARKETS

There are mechanisms available for addressing uncertainty in water quality trading markets. Uncertainty ratios are one common mechanism employed when trades occur between a regulated point source and a nonpoint source. Uncertainty ratios are applied when pollutant credits cannot be exchanged on a one-to-one basis to discount or normalize credits being exchanged (U.S. EPA 2009). However, uncertainty ratios only address certain forms of uncertainty, notably biophysical and scientific uncertainty associated with nonpoint source credits. In designing a water quality trading program, it is important that policymakers identify specific causes of uncertainty and develop appropriate mechanisms for mitigating these uncertainties. Each mechanism presented below addresses certain types of uncertainty and has unique benefits and drawbacks. This paper does not make recommendations about which mechanisms are the best; rather, it presents the variety of mechanisms that are appropriate for each type of uncertainty and the pros and cons of each of these mechanisms.

Mechanisms for Addressing Biophysical and Scientific Uncertainty

Biophysical and scientific uncertainties associated with the effectiveness of nonpoint source mitigation practices can be addressed in several ways. First, the science of biophysical fluctuations and processes might be improved to increase our knowledge of practice effectiveness, allowing us to better predict the impact of certain activities on nonpoint source runoff. Secondly, direct measurement or improved estimation methods can be used to more accurately quantify reductions from nonpoint source mitigation practices. Finally, biophysical and scientific uncertainty can be addressed through use of trading ratios applied to nonpoint source reduction estimates to account for uncertainties in science and measurement methods. Water quality trading programs typically use a combination of these mechanisms to reduce biophysical and scientific uncertainty associated with nonpoint source credits.

Improved Science

Quantifying the environmental impacts of agricultural systems and management practices is an ongoing field of research. Scientific observations and studies are important for examining and characterizing the impacts that biophysical characteristics (e.g., soil, weather) have on farm losses as well as the performance of nonpoint source BMPs in reducing these losses. Having sufficient scientific understanding and data helps to describe these relationships and leads to better predictive certainty about how agricultural systems and BMPs impact water quality. By improving scientific understanding, we can begin to reduce the uncertainties associated with estimating nonpoint source loads. Integrating improved science into a water quality trading program is generally done through adaptive management processes, where improved science is integrated into the program systematically as part of a process to iteratively improve management as new information becomes available.

Direct Measurement

Direct measurement is one possible way to determine the environmental impact of nonpoint source BMPs with greater certainty. Direct measurement of the effects of BMPs involves monitoring before and after water quality effects of the practice, either through in-field measurements, edge-of-field measurements, or in-stream sampling. When there is an ideal situation for monitoring BMPs (e.g., when there is a drainage pipe for the field or some other direct outlet for runoff), direct measurement may leave the least room for uncertainty regarding whether the BMP is performing properly.

The design of Idaho's Lower Boise River Effluent Trading Demonstration Project has two options for assessing the effectiveness of agricultural BMPs at treating phosphorus: directly measuring BMP reductions, where possible, or calculating estimates when direct monitoring is not feasible. The latter method uses uncertainty discounts for each BMP, reducing the number of credits that can be sold. If reductions can be, and are, directly measured per monitoring specifications, the Lower Boise River Effluent Trading Demonstration Project does not discount the reductions for uncertainty (Ross & Associates Environmental Consulting, Ltd. 2000).

However, monitoring requires sophisticated system design and implementation and is typically labor and cost intensive (Abdalla et al. 2007). As a result, it is not commonly used to quantify nonpoint source reductions in environmental markets. And although taking direct measurements has the potential to generate more accurate results than estimation methods, other sources and controls in the watershed and the potential for noise (i.e., monitoring errors) in the observation make it difficult to ensure changes in runoff or in-stream concentrations are accurate and solely attributable to the nonpoint source BMP that was implemented to generate credits (Willamette Partnership et al. 2012). Furthermore, depending on the monitoring program's design, it may take years or even decades to capture temporal lags in water quality improvement that result from the implementation of the BMP. For these reasons, monitoring may be best suited in areas where the infrastructure and expertise is already in place and where pollutant loads are primarily from surface water that can be closely monitored.

In California's San Joaquin valley, the Grassland Area Tradable Loads Program for salinity is one such example of a water quality trading program where direct monitoring was cost effective. Now inactive, the program directly monitored selenium loads but was considered to have low administrative costs because a monitoring system was already in place that the trading program could use without investing significantly in additional infrastructure or labor (Morgan and Wolverton 2005). The Grassland Tradable Load program operated in an area with irrigated agriculture with ditches and irrigation pipes, which were conducive to monitoring activities. For this program, direct measurement was decided to be the most appropriate method given the available resources and infrastructure already in place.

Because a direct monitoring approach can capture interannual variability inherent in many nonpoint source BMPs, it may reduce biophysical uncertainty but may actually introduce increased market uncertainty. As credits awarded on the basis of actual monitoring are likely to fluctuate annually, it is likely that a monitoring approach will introduce uncertainty about year-to-year credit supply in any project.

BMP Effectiveness Estimates

Compared to direct monitoring, nonpoint source BMP effectiveness estimates can offer a less expensive and resource-intensive mechanism for mitigating biophysical and scientific uncertainty. Effectiveness estimates are "based on the best available science that connects a specific BMP to the percent or mass reduction in a pollutant following installation of that BMP" (Willamette Partnership et al. 2012). This method often relies on scientific observations that have already been collected and published in the literature. In some cases, it may be necessary to cull the literature, or even conduct monitoring or modeling studies, to develop average

> Compared to direct monitoring, nonpoint source BMP effectiveness estimates can offer a less expensive and resource-intensive mechanism for mitigating biophysical and scientific uncertainty.

BOX 2

ADDRESSING TEMPORAL COMPLIANCE

Regulated point source compliance is tracked annually, or sometimes monthly or seasonally. Thus, if the efficiencies or models used to estimate credits do not adequately take into account annual and interannual variability of nonpoint source practices, there is a risk of temporal permit exceedances on the part of the regulated point source that satisfies its permit requirements using nonpoint source credits. For example, let's say a regulated point source purchases 100 nonpoint source nitrogen credits per year. The 100 nitrogen credits represent the average nitrogen reduction achieved by a riparian buffer annually. However, in any given year, the actual nonpoint source reductions may be higher or lower than 100 pounds of nitrogen. For years when the actual nitrogen reduction is lower than 100 pounds, it could ultimately lead to water quality degradation in that particular year. If nonpoint source credits are not estimated using appropriately conservative factors or with factors that do not account for temporal variability, then an explicit uncertainty ratio may be necessary so that a margin of safety is in place that ensures permit requirements are met. In cases where credit purchasers themselves have estimated credit needs based on annual averages, these types of safety margins specific to overcoming temporal variation are likely not necessary. For example, if a state requires that a developer offset their stormwater nutrient load from a new housing development, this offset requirement is likely to be estimated using average runoff estimates. In this case, compliance is not estimated annually, but rather estimated based on an average. Thus, credits generated based on similar estimation assumptions should adequately achieve the margin of safety.

efficiencies specific to the water quality trading market region. However, it is likely that the resources involved to do this exercise would still be less than those required to directly monitor the effects of each individual nonpoint source BMP, and costs would decrease over time following the initial exercise of establishing set efficiencies for each BMP (Willamette Partnership et al. 2012). Because effectiveness estimates rely on values from published scientific studies, they are subject to the same scientific uncertainties inherent in direct monitoring. In cases where estimated impacts of nonpoint source BMPs are derived based on a small body of literature values, there is greater uncertainty about the actual range of BMP effectiveness.

In the Chesapeake Bay watershed, the University of Maryland (UMD) completed a multiyear literature review on the nutrient and sediment reduction efficiencies of urban and agricultural BMPs (Simpson and Weammert 2009). The report only included studies that took place in the Bay watershed, or in some cases, in similar climatic and geologic regions. A panel of experts from the Chesapeake Bay used the results of the meta-analysis to develop average efficiencies for BMPs, which were then incorporated into the Chesapeake Bay Watershed Model. BMP efficiencies adopted by the panel often vary in effectiveness based on hydrogeomorphic region and land use. In addition, for all Chesapeake Bay BMP effectiveness estimates, averages and ranges were set conservatively in order to account for variations in effectiveness depending on location, weather, temporal lags, and installation and maintenance issues, thereby reducing the uncertainty around these issues (Simpson and Weammert 2009). (See Box 2 for more information on temporal compliance uncertainty.)

As a result of this comprehensive and conservative exercise to estimate BMP effectiveness, Maryland's and Pennsylvania's nutrient trading programs use these BMP efficiencies for estimating at least some of the nonpoint source credits in their trading programs. Moreover, because of the widespread buy-in from U.S. EPA, states, and other stakeholders on the reliability of the estimates, Maryland and Pennsylvania programs determined that the BMP efficiency estimates developed through this process were suitably conservative and therefore do not apply any additional uncertainty ratios to nonpoint source trades whose credits were generated using these estimates (Maryland Department of Agriculture 2008; Pennsylvania Environmental Quality Board 2010). While conservative effectiveness estimates may alleviate uncertainty associated with BMP performance, there is a tradeoff in terms of credit supply in the market and the resulting credit price. Using carefully developed effectiveness estimates which account for biophysical and scientific uncertainty can provide consistency and predictability when estimating nonpoint source credits. On the other hand, using overly conservative estimates

Several different approaches to nonpoint source credit estimation have been adopted by water quality trading programs in the United States.

could unnecessarily reduce trading volumes and reduce the expected efficiency gains.

Estimation Tools and Models

Estimation tools and models can be useful mechanisms for estimating nonpoint source credits by allowing for more variables in credit calculations than BMP effectiveness estimates alone and by avoiding the need for directly measuring pollutant loads. By building or adapting site-scale models to account for natural fluctuations and variable BMP performance, models may reduce uncertainties around estimates of nonpoint source reductions. These tools and models help estimate the current nonpoint source pollutant loads coming from a given parcel. Models themselves might use BMP effectiveness estimates or might employ a more process-based method for determining BMP effectiveness under variable biophysical conditions. Tools and models are typically calibrated to real-world water quality data and thus, whether using effectiveness estimates or not, are linked to the quality and availability of scientific data.

There are several different approaches to nonpoint source credit estimation that have been adopted by water quality trading programs in the United States. These include the use of lookup tables, spreadsheet tools, and process-based models. These approaches are described in more detail below.

LOOKUP TABLES. Virginia's Nutrient Credit Exchange Program currently uses lookup tables, which provide average nutrient loading rates based on the Chesapeake Bay Watershed Model's average land use loading rates and average BMP efficiencies. This approach is simple and has the advantage of providing assurance to the landowner that the specific load reductions credited to a practice are constant and known for each watershed and do not require estimation on the part of the landowner. However, because the nutrient reduction values are based on average watershed load values, it is likely that there is a high degree of interfarm variability that is not accounted for. Thus at the farm scale, this approach can introduce uncertainty regarding the accuracy of the values.

SIMPLE MODELS. Using simple models or spreadsheet-based tools is another approach used by several water quality trading programs. In particular, the Great Miami River Watershed Trading Pilot uses the U.S. EPA Region 5 spreadsheet tool to estimate phosphorus credits from agriculture (Selman et al. 2009). This tool uses a simplified version of the Revised Universal Soil Loss Equation (RUSLE) to estimate soil loss, and subsequently phosphorus loss, before and after treatment with BMPs. Effectiveness estimates are used to estimate the BMP load reductions. The spreadsheet is simple and easy to use, and provides some on-farm specificity by using RUSLE as well as soil information.

PROCESS-BASED MODELS. Dynamic models are also being explored as tools that can help predict agricultural nutrient and sediment losses based on site-specific data. For example, USDA's Nutrient Tracking Tool (NTT) (used in Maryland, and being piloted in several water quality trading programs in the Northwest and the Chesapeake Bay) uses the Agricultural Policy Extender (APEX) model to estimate agricultural reductions from modeled farm loads based on on-farm characteristics such as soil type and weather, in addition to current and planned farm management characteristics such as tillage operations, fertilizer applications, and crop rotations (Texas A&M University 2013). By accounting for location-specific characteristics such as soil and weather, biophysical variability can be accounted for. However, the degree to which biophysical uncertainty is reduced depends on the quality of data and science underlying the model, and the degree to which the model has been calibrated to real-world results. The use of process-based models may cause some users to question the nonpoint source estimate results, because models may appear to lack transparency about their assumptions and processes. Only through adequate testing, refinement and calibration of these models, and review and buy-in from stakeholders, will these uncertainties be overcome. Some trading program administrators have suggested that model uncertainty could be quantified by estimating the potential for model error. A confidence interval could then be used to determine if an uncertainty ratio is warranted for the modeled results and if so, what magnitude is appropriate (Fox 2013).

When models are used to quantify the environmental impacts of BMPs, they have their own set of uncertainties associated with them. Model uncertainties generally pertain to the accuracy and reliability of the estimates, or output. Model uncertainty can be addressed through various mechanisms, such as the use of implicit assumptions and the quantification of the standard deviation of modeled results.

Trading Ratios

Trading ratios are a policy mechanism for explicitly addressing any remaining scientific and biophysical uncertainties that have not already been addressed through the credit quantification process. The following sections examine two common types of trading ratios applied in existing water quality trading programs: the uncertainty ratio, applied to generally address uncertainties of quantification, and the retirement ratio, applied to ensure that the trade benefits water quality.

Uncertainty Ratios

Uncertainty ratios "account for the variability in effectiveness of nonpoint source BMPs based on scientific uncertainty or random weather fluctuations" (Branosky et al. 2007). Although definitions vary by program, uncertainty ratios are typically used to ensure that an adequate reduction (in the case of nutrients) from a nonpoint source is achieved to offset the exact reduction required of the point source (Vogel and Szeptycki 2012). They serve as a margin of safety that, in light of uncertainties associated with nonpoint source reductions, aims to prevent the possibility of a trade degrading water quality. While common, uncertainty ratios are not used by all programs. For those programs that do use them, the most common ratio is 2:1, meaning that two units of nonpoint source pollution reduction are needed to offset one unit of pollution from a regulated point source (National Wildlife Federation 1999). The range of uncertainty ratios currently used in water quality trading programs nationwide varies and can go as high as 3:1 (Vogel and Szeptycki 2012).

The Great Miami River Watershed Nutrient Trading Program adjusts its uncertainty ratio requirements based on the regulatory status of the buyer and the status of the point source's receiving body of water. For example, buyers who wish to purchase credits before any regulations are in place requiring that reductions be made, and who discharge into fully attaining waters, do not have to apply an uncertainty ratio presently or for subsequent permits; they are able to trade with nonpoint sources on a 1:1 basis (i.e., no uncertainty ratio). On the other end of the spectrum, if a wastewater utility buyer needs to trade in order to be in compliance, and the utility discharges into impaired waters, trades with nonpoint sources receive an uncertainty ratio of 3:1 (Water Conservation Subdistrict of The Miami Conservancy District 2005).

If a water quality trading program utilizes a nonpoint source credit estimation methodology that employs conservative factors or is able to adequately model and account for biophysical variation, uncertainty ratios might be set lower than the typical 2:1 ratio (Horan and Shortle 2005; Vogel and Szeptycki 2012). Identifying certain situations in which uncertainty may be greatest, and uncertainty ratios most appropriate, could help to maintain a trading program's cost effectiveness while also ensuring water quality goals are met.

Retirement Ratios

While retirement ratios play similar roles to the uncertainty ratio in the sense that they help to guarantee water quality is not compromised by a point-nonpoint source trade in the face of nonpoint source BMP uncertainty, they are generally designed to serve a slightly different need. Retirement ratios can be applied to transactions in order to retire a certain number of credits for a net improvement in water quality. Maryland's program uses a retirement ratio of 1.1:1 in which 10 percent[2] of all credits purchased by a buyer are retired to the state to ensure the program achieves a net water quality benefit (Maryland Department of Agriculture 2008).

Mechanisms for Addressing Risk From Extreme Events

Centralized Credit Reserve/ Insurance Pool

Some water quality trading programs have established centralized credit reserves that can hedge against BMP failure as a result of weather or other "acts of God" (Branosky et al. 2011). This reserve is generally not meant to insulate against the risk of the landowner or aggregator not implementing BMPs as promised, but rather against unforeseen and extreme events that cause BMP failure. In Pennsylvania, the credit reserve is established by applying a 10 percent reserve ratio that "allocates a portion of each credit [sold] into a credit insurance pool" (Branosky et al. 2011). In the event of a BMP failure, a regulated source would be allowed to draw from the credit reserve to replace credits in proportion to his loss for that compliance year. In this way, regulated sources are insulated against risk of noncompliance related to BMP failure as a result of weather conditions or other unforeseeable circumstances.

The Ohio River Basin Water Quality Trading Project also uses a reserve pool. The Electric Power Research Institute (EPRI), which develops and oversees the trading program and facilitates the pilot trades, sets aside 20 percent of all credits it acquires for the reserve pool. The reserve pool would be used if the BMP fails to generate the estimated credits—because the model's credit estimates were later determined to be inaccurate through verification or the BMP failed as a result of flooding, for example (Fox 2013). In creating these credit reserves, the price of credits will increase, as with any trading ratio.

Mechanisms for Addressing Behavioral Uncertainty

Behavioral uncertainty regarding whether or not the practice is actually being implemented and maintained as promised can increase perceived risk to potential credit buyers. While buyers may believe these risks of moral hazard are real, most water quality trading programs have multiple mechanisms in place to address this form of uncertainty. These mechanisms include using aggregators as intermediaries, verifying that practices are in place, and mitigating risk through contract provisions for shared liability.

Aggregators

Aggregators are commonly used as intermediaries between buyers and sellers in water quality trading markets. Aggregators pool together credits from multiple projects so that the credits can be bundled and sold as a larger package than would otherwise be possible when acting individually. In many instances, an aggregator acts as a third-party agent who purchases rights to develop credit-generating projects on a landowner's property and sells the credits the project generated. Because landowners sell rights to access their land and implement BMPs, rather than sell credits, landowners do not face the capital risks inherent in developing and marketing credits, particularly from structural practices with high up-front costs.

Aggregators may often create a diverse portfolio of projects and credits which provides greater protection from one project defaulting. From the buyer perspective, diversified sources of credits may be seen as less risky than relying on a single project. In addition, buyers can reduce risks by working through an aggregator because an aggregator will often absorb the risk of an agricultural producer not complying with his contract by assuming liability for the credits, thereby creating a credit guarantee for the buyer (Nguyen et al. 2006).

Environmental Banc & Exchange (EBX), an aggregator working with agricultural producers primarily in Maryland, Virginia, and North Carolina, addresses the construction, credit yield, and operational risks of behavioral uncertainty. When EBX starts working with landowners, it pays for, manages, and controls the construction of the BMP(s) that is

Aggregators are commonly used as intermediaries between buyers and sellers in water quality trading markets.

being implemented to generate credits. By setting up the design specifications and overseeing construction, EBX can have assurance that the BMP(s) is implemented properly.

Self-Insurance

Using intermediaries for credit transactions alleviates uncertainty for the credit generators and credit buyers, but the uncertainty about the nonpoint source credits is transferred to the intermediary, who becomes the entity responsible for ensuring the point source receives the credits it needs. To protect themselves from the risks involved with bearing this liability, aggregators may have their own self-insurance policy. A self-insurance policy would create a reserve pool of credits that the intermediary can use in the event of project failure. For example, when EBX develops a project, it will hold approximately 20 to 30 percent of the credits back as insurance, depending on the degree of risk associated with that practice (i.e., structural practices carry greater risk). Ultimately, the cost of aggregator's self-insurance policy will be passed onto the buyer as a transaction cost.

Verification

Verification is done in most water quality trading markets to confirm that a practice is installed and maintained to meet design specifications. Rigorous verification policies can help reduce the perceived behavioral risks on the part of the seller by creating a system of transparency, accountability, and consequences for noncompliance on the part of landowners and project developers. Verification activities provide certainty to credit buyers that the credits meet the program standards, and they provide certainty to program administrators and the public that offsets are "real" and trades are not compromising water quality (Willamette Partnership 2009).

Verification may be conducted by certified third parties, a state agency or other program administrator staff, or the project developers themselves. Some trading programs, like the Tar-Pamlico and Great Miami River basin, only spot-check a small percentage of all projects. Other programs, including the Lower Boise (ID) and Red Cedar (WI), require third-party verification of all credit-generating projects on an annual basis (Morgan and Wolverton 2005). Verification tends to occur after projects are first installed and then annually, or every few years, thereafter. The process involves ensuring the credits were calculated using the appropriate methodology, and that the estimates are relatively accurate, checking the project's eligibility, and monitoring installed BMPs for specifications and functionality (Willamette Partnership et al. 2012).

The Willamette Partnership has a robust framework for verifying credits in the Rogue River basin. It requires third-party verification by accredited verifiers in the first year of the project to confirm project eligibility, accurate credit quantities, and appropriate plans and funds for long-term maintenance. Verifications occur annually thereafter through the life of the project. Annual verification activities include monitoring that the practices are in place and reporting on their performance. Every fifth, tenth, and twentieth years, full verification is required—including a site visit. When the verifier estimates the amount of credits that the generating project is producing, the estimate must be within 15 percent of the project developer's estimate in order for the project to be

Shared financial liability arrangements may generate feelings of ownership for both the buyer and the producer, resulting in both parties taking responsibility over the project's success.

successfully verified. The 15 percent threshold allows room for variation in calculation and sampling methods (Willamette Partnership 2009).

Shared Financial Liability

Under the Clean Water Act, a regulated point source cannot transfer regulatory liability. Thus, in a water quality trading program, a regulated entity that purchases credits in good faith only to have those credits become void as a result of BMP failure is still held liable for noncompliance (U.S. EPA 2009). Inability to transfer liability is a considerable risk to a regulated buyer, both in terms of potential regulatory exposure and financial exposure (from fines resulting in noncompliance). As a result, regulated buyers may be wary about entering into trades with nonpoint sources who are exempt from regulatory enforcement. Likewise, the producer selling the credits may not perceive any responsibility for the quality of the credits generated (Nguyen et al. 2006). Mechanisms within buyer contracts that allocate financial liability between both buyer and seller could be an effective tool for mitigating risks associated with behavioral uncertainty (Shortle and Horan 2008).

With shared liability, the producer shares financial liability for regulatory noncompliance with the regulated buyer. Under a shared liability agreement, the credit seller is exposed to financial risk if CWA requirements are not met as a result of credit default (Willamette Partnership et al. 2012). Such an arrangement is used in the Chesapeake Bay and Colorado trading programs, where through contractual agreements, financial liability is split between the two parties and enforced through penalties and fees (Morgan and Wolverton 2005).

A similar shared financial liability arrangement exists between The Freshwater Trust, an aggregator of temperature credits, and the City of Medford (Oregon). The city and the trust have in their credit purchase agreement that if any fines are imposed on Medford for water quality violations related to credit failure, both the city and the trust are responsible for the fines (Willamette et al. 2012). These arrangements may generate feelings of ownership over the project for both the buyer and the producer, resulting in both parties taking some responsibility for the ultimate success of the BMPs and the transaction as a whole. However, arrangements in which farmers who are otherwise largely unregulated must assume partial financial responsibility for achieving pollutant reductions could be a deterrent to farmers who enter into trading programs voluntarily.

Mechanisms for Addressing Regulatory Uncertainty

While changes in the policies governing water quality markets, environmental targets, and agricultural policy are likely unavoidable, water quality trading program guidance can be designed to alleviate concerns over what these changes will mean for credits that have already been certified or transacted. Mechanisms for addressing regulatory uncertainty may include grandfathering, agricultural certainty programs, and developing consistency and standards among water quality markets.

Grandfathering

In the event of changing regulations, grandfathering recognizes already certified credits, or already sold credits, as valid if regulations change that would affect the credit calculation. For example, if the eligibility requirements for generating credits were to change, credit-generating projects that were implemented and certified under previous requirements would not be impacted. In this way, grandfathering reduces risk to early actors (both buyers and sellers) in the market.

Maryland has implemented a grandfathering clause in its water quality trading program. Maryland uses a performance-based eligibility requirement for nonpoint sources that is derived from the Chesapeake Bay Watershed Model agricultural land-use loads (Maryland Department of Agriculture 2008). It is understood that this model will be updated every few years and that the agricultural land-use loads may change. In addition, it may be that the load allocation for agriculture under the Chesapeake Bay TMDL may change in future years. Updates to the model and/or to the agricultural load allocation will likely necessitate changes to the agricultural eligibility requirement. With this in mind, Maryland's policy stipulates that once credits are certified and sold, they remain valid for the life of the contract. Once the contract is over, the producer would have to reassess the credit generation potential of his activities. In the case of credits that have been certified but not yet sold, the producer would have to recalculate the amount of credits that his planned activities can generate (Payne 2012).

Grandfathering of already certified and/or sold credits provides a guarantee to both buyers and sellers that the credits transacted will remain viable for the life of the contract. Grandfathering may encourage early actors in the trading program, which could result in more environmental benefits over time. There is a risk, however, that grandfathering might uphold credits that new science or policy decisions deem to no longer be credible, leading to the potential compromising of water quality goals as long as those credits are upheld.

Agricultural Certainty Programs

Agricultural certainty programs can be used to complement water quality trading programs by recognizing precompliance credit-generating activities as sufficient for meeting future regulations. In 2011, USDA and U.S. EPA released a document that provides a general concept for a certainty program. The document stated that if agricultural producers meet a series of criteria—such as developing conservation plans, implementing BMPs in accordance with water quality goals, and verifying practices—the producer's activities could count toward TMDL load allocations or other watershed cleanup goals, prevent any animal feeding operations from being classified as confined animal feeding operations (which could subject them to more regulations), and/or qualify them to be prioritized for cost-share funding. The document also stated that states could design these programs to function with trading programs (USDA NRCS 2011).

According to the Maryland Department of Agriculture, which is exploring the use of certainty to accelerate BMP implementation, "certainty is a voluntary approach supported by both the USDA and the U.S. EPA to provide 'assurances' to the agricultural community so that farmers may conduct business in a predictable regulatory setting in exchange for the implementation of additional best management practices (BMPs) to reduce nutrient runoff and erosion" (2012). Agricultural producers who demonstrate compliance with water quality requirements and agree to monitor and report additional BMP activities will be certified as meeting regulatory requirements for the life of the agreement. By receiving this certification that they're meeting requirements, they also become eligible to trade in Maryland's nutrient trading program.

A certainty program would allow agricultural producers to enter the trading market free from worry about how regulatory measures might affect their operations in the near future. This arrangement could motivate early adopters to participate in the trading program, resulting in more conservation on the ground that could improve water quality. Similarly to grandfathering, however, exempting landowners that enroll in the certainty program from future regulations may create significant loopholes if certainty requirements are significantly weaker than future policies or regulations affecting landowners. Where certainty programs are linked to trading program baseline requirements, a certainty program with little connection to current or future water quality goals might result in pollution loads not being properly offset.

Standards for Water Quality Trading Program Design and Implementation

Many water quality trading programs are facing legal challenges due to public interest concerns about water quality degradation resulting from trades. In turn, this concern about the public interest has resulted in considerable uncertainty in the market among buyers, sellers, and administrators. While U.S. EPA provided a water quality policy in 2003, this policy lacked firm guidance about how trading programs might be designed and implemented in ways that provided reasonable assurance that the conditions of the point source permits are being met. As a result, water quality trading programs vary significantly and provide varying levels of rigor in terms of ensuring additionality, verification, credit tracking and registration, and credit estimation methods.

In order to better assure the public, new policy, regulations, or best practices might be developed by U.S. EPA or other agencies. These standards or best practices would create consistency as well as shared expectations for program design, implementation, and transparency. This in turn would reduce uncertainty among participants in programs designed using approved standards or best practices as well as reduce the risk of litigation.

Mechanisms for Addressing Market Uncertainty

Because market uncertainties center on supply and demand dynamics, they are generally beyond the realm of the trading program and therefore can be difficult to address. For example, producers may be uncertain about whether trading will make economic sense if crop prices increase next year. There are, however, some mechanisms that can be used to help mitigate the risks associated with market uncertainty.

Preimplementation Certification

Agricultural producers who are interested in trading may be uncertain about demand. Will there be sufficient demand for the generated credits? Will buyers' willingness to pay be enough to cover costs and generate profit? Trading programs that allow credits to be certified for sale before the proposed credit-generating practice is actually implemented can lower the risks for agricultural producers who may be hesitant about paying to install practices without being guaranteed that the generated credits will be sold. By certifying credits before implementation, sellers are certified for credits that they're proposing to generate, not for credits that have already been generated.

Maryland allows for credit certification on proposed credit generation projects (Maryland Department of Agriculture 2008). Interested sellers can use the state's Nutrient Trading Tool to assess their existing nutrient loads, run a future scenario that simulates the nutrient reductions that would be achieved if additional BMPs were implemented, and estimate the credits those reductions would generate. At that point, the interested seller can submit the results of the tool to the state for review and certification. Once certified, the credits can be marketed to buyers and would be classified as credits that are "planned, contingent on sale." This approach prevents sellers from investing resources in generating credits before they are certain they will be purchased. Preimplementation certification may result in a perceived increase in risk to buyers facing permit limits, as there may be more uncertainty around preimplementation credits as compared to credits generated from a project already in place. Projects already in place reduce the potential for a buyer to default on his permit if a project is not implemented due to a lack of funds, bad weather, or some other circumstance that prevents the credit seller from following through on his or her agreement.

Credit Bank/Clearinghouses

In the context of environmental markets, a credit bank is "a private or public entity that creates and sells or brokers sale of credits" (Commonwealth of Virginia 2011). Banks typically serve as clearinghouses for credits and function as intermediaries between credit buyers and credit sellers. Entities that wish to buy credits can purchase credits from the clearinghouse which holds credits, or potentially pay into a centralized fund or bank who will use those funds to purchase credits from other sources (e.g., the agricultural sector or other point sources). The latter arrangement is similar to an in-lieu fee system.

Credit banks may offer regulated entities an attractive option for obtaining credits because they prevent entities from having "to locate and purchase credits on their own, thereby lowering their transaction costs and mitigating their risk"

In order to better assure the public, new policy, regulations, or best practices might be developed by U.S. EPA or other agencies.

(Selman et al. 2009). Agricultural nonpoint sources may also find this arrangement to be beneficial because, similarly to working with an aggregator, a credit bank would serve as the intermediary. In a 2012 study, Nguyen et al. found that a clearinghouse—that is, an entity that serves as an intermediary to transact all trades between buyers and sellers—versus a bilateral exchange—a one-on-one exchange between buyer and seller—was generally a more efficient design for conducting point source to nonpoint source trades (Nguyen et al. 2012). Below are examples of how credit banks have been used to reduce risk in water quality trading programs.

Agricultural nonpoint sources may find a clearinghouse arrangement to be beneficial because, similarly to working with an aggregator, a credit bank would serve as the intermediary.

PENNVEST is an example of a nutrient credit clearinghouse in Pennsylvania. It holds auctions at which permitted wastewater treatment plants can purchase credits to meet their nitrogen and phosphorus permit limits. PENNVEST outlines how its operation benefits buyers by remitting regulated entities of "adhering to regulatory procurement requirements, search costs, negotiation costs, evaluation counterparty credit-worthiness, [and] contract enforcement" (PENNVEST 2011). For credit sellers, PENNVEST "can facilitate an increase in demand that makes undertaking credit-generating projects more viable." PENNVEST, as an intermediary that is contracted with both the buyer and the seller, also assumes default risk and enforcement responsibility in its contracts. As such, the PENNVEST clearinghouse not only reduces transaction costs but also greatly reduces risk exposure to both buyer and seller.

North Carolina's Ecosystem Enhancement Program (EEP) offers an in-lieu fee system. Developers who are required to offset their nutrient loads from stormwater can opt for a "buy-down option" in which they pay an in-lieu fee to EEP. EEP, once it collects sufficient fees to create an economy of scale, issues a request for proposals for private sector turnkey mitigation projects. The North Carolina model reduces buyer uncertainty, as the buyers have a guaranteed option for meeting their offset obligation at a known price. On the other hand, this model has been criticized for its potential to negatively impact market dynamics. If in-lieu fees are low, they can interfere with the market's setting of credit prices, driving prices down and hindering supply (Kelly 2013b).

The Ohio River Basin Water Quality Trading Project uses a revolving bank model. The bank is administered by EPRI and operates through local soil and water conservation district offices. Private investment dollars are being used to fund conservation practices on local farms and generate credits. Those credits will then be sold to buyers in the watershed, and the proceeds used to fund additional offset projects. This model minimizes market uncertainties for buyers and sellers. In addition, the revolving bank model serves a role similar to that of aggregator, reducing risks to the buyers because they are able to consolidate risk by purchasing from a single entity (the bank) instead of several (individual farmers).

Government Guarantee Program

Attracting private capital to the markets can be challenging, particularly in the early stages of water quality trading programs. Some have argued that the government could help play a more active role to stimulate water quality trading market demand and supply. One way to do this could be for the government to create a federal credit guarantee program that protects early actors by agreeing to purchase credits that go unsold.

Senator Ben Cardin introduced legislation in 2009 that included a "Chesapeake Bay Nutrient Trading Guarantee Pilot Program" with

It is important that program designers and administrators understand the types of uncertainty and risk that participants in their program are likely to face and implement solutions that maintain environmental integrity and minimize transaction costs to participants.

the goals of encouraging innovative practices on agricultural land, accelerating restoration, leveraging public funds to provide capital to the private sector for accelerating restoration, and supporting Bay-wide nutrient trading. Although the bill was not passed, the pilot program would have included a $20 million guarantee fund to be available for the first five years of an interstate nutrient trading program, providing a federal guarantee for any unsold credits until the market matured (Chesapeake Clean Water and Ecosystem Restoration Act 2010).

The advantage of a credit guarantee program is that it establishes a known cost for risk mitigation. However, such a program has the potential to be abused because its safety net could serve as an incentive for individuals to implement projects that are not, in essence, good investments and may not have otherwise gone forward.

IV. CONCLUSION

Many mechanisms are available for mitigating risks that buyers and sellers perceive when evaluating whether to participate in a water quality trading market. It is important to note that each mechanism for addressing uncertainty comes at a cost. For instance, using trading ratios will increase the cost of producing a credit and may have an impact on supply. Mechanisms like verification, use of aggregators, and credit banks also increase transaction costs in the market. It is important that program designers and administrators understand the types of uncertainty and risk that participants in their program are likely to face and implement solutions that maintain environmental integrity and minimize transaction costs to participants. On the following page, Table 1 summarizes the findings presented in this paper: the five main types of uncertainty, the available mechanisms for addressing them, the pros and cons of each mechanism, and an estimate of the level of cost that is typically involved.

When deciding which mechanisms to use, program designers should assess the forms of uncertainty that are present in a potential trading program. Next, they should identify all of the available mechanisms for addressing those forms of uncertainty. Programs can employ these mechanisms in tandem or individually, depending on the program’s goals, needs, available resources, and other circumstances. The benefits and drawbacks of each option should be carefully considered along with region-specific factors such as available data, tools, and resources, and the presence of policies that may impact or guide the trading program.

In addition, more research and analysis on the various mechanisms, and the science and policies on which they’re based, should be conducted. To better quantify nonpoint source loads, and therefore reduce scientific and biophysical uncertainty, more research is needed on the hydrology of natural systems and the effects of BMPs, and modelers must continue to refine tools and models to reflect the best available science. Program designers must weigh the costs of the mechanisms to address behavioral, regulatory, and market uncertainty against the benefits provided. And finally, more research is needed on how to best combine these mechanisms to ensure all aspects of uncertainty are adequately addressed, without unnecessarily compromising the efficiency of a trading program. In the end, program designers should establish water quality trading programs that minimize uncertainty so that water quality goals can be achieved in a cost-effective manner.

TABLE 1

TYPES OF UNCERTAINTY AND MECHANISMS FOR REDUCING UNCERTAINTY RISKS

Type of Uncertainty	Mitigating Mechanism	Pros	Cons	Cost
Scientific and Biophysical	Direct measurement	■ If conducted properly, may be most accurate credit estimation method	■ Is labor intensive ■ Is technically challenging ■ Has attribution challenges	high
	BMP effectiveness estimates	■ Can rely on available data ■ Achieves consistency among trades	■ Rely on averages, aren't site specific	low*
	Estimation tools and models	■ Can be site specific	■ Have their own degrees of uncertainty	varies*
	Uncertainty ratio	■ Communicates easy-to-understand margin of safety ■ Can be adapted to specific BMPs or circumstances	■ May be duplicative if other mechanisms in place	varies
	Retirement ratio	■ Assures water quality is not compromised	■ May be duplicative if other mechanisms in place	varies
Extreme Events	Centralized Credit Reserve	■ Pools risk	■ May be duplicative if other mechanisms in place	varies
Behavioral	Aggregators	■ Transfer liability and absorb risk ■ Diversify credit sources	■ Cause some costs to be lost to intermediary	low
	Self-insurance	■ Can be adapted to specific BMPs or circumstances	■ May be duplicative if other mechanisms in place ■ May not be as efficient as a pooled-risk insurance policy	varies
	Verification	■ Provides easy-to-understand assurance for the public	■ Is labor intensive	low
	Shared liability	■ Encourages shared financial risk	■ Encourages shared financial risk ■ Still attributes sole regulatory risk to buyer	N/A

TABLE 1

TYPES OF UNCERTAINTY AND MECHANISMS FOR REDUCING UNCERTAINTY RISKS, CONTINUED

Type of Uncertainty	Mitigating Mechanism	Pros	Cons	Cost
Regulatory	Grandfathering	■ Encourages early action ■ Provides market certainty	■ Risks compromising water quality in light of new regulations or information	N/A
	Certainty programs	■ Encourage early action ■ Provide market certainty	■ Risks compromising water quality in light of new regulations or information	low
	Water quality trading design standards and best practices	■ Provide guidance and clear standards for program design	■ May not deter litigation unless standards are endorsed by regulatory agencies	low
Market	Preimplementation certification	■ Encourages project planning without upfront investments	■ May increase buyers' perceived risks	N/A
	Credit banks	■ Provide more efficiencies than bilateral exchanges ■ Centralize risk	■ Cause some costs to be lost to intermediary ■ Use of price-setting means can interfere with market dynamics ■ May stifle third-party actors who transact sales	low
	Government guarantee	■ Provides assurance that credits generated will be sold	■ Relies on public funds to artificially stimulate market	high*

*Costs typically borne by government agencies or other program developers rather than market participant.

REFERENCES

Abdalla, C., T. Borisova, D. Parker, and K. Saacke Blunk. 2007. “Water Quality Credit Trading and Agriculture: Recognizing the Challenges.” *Choices* 22(2): 117–124. Available at: http://www.choicesmagazine.org/2007-2/grab-bag/2007-2-06.pdf.

Branosky, E., C. Jones, and M. Selman. 2011. “Comparison Tables of State Nutrient Trading Programs in the Chesapeake Bay Watershed.” Washington, DC: World Resources Institute. Available at: http://www.wri.org/publication/comparison-tables-of-state-chesapeake-bay-nutrient-trading-programs.

Chesapeake Clean Water and Ecosystem Restoration Act, S. 1816, 111th Cong., 2d Sess. (2010).

Commonwealth of Virginia. 2011. “Expansion of the Use of Nutrient Credits in Virginia Pursuant to Senate Joint Resolution 334 (2011).” Richmond, VA. Available at: http://leg2.state.va.us/dls/h&sdocs.nsf/fc862b17a1cf388852570f9006f1299/ca941f936de26c6c8525797c005a0f91/$FILE/SD6.pdf.

Faeth, Paul. 2000. *Fertile Ground: Nutrient Trading’s Potential to Cost-Effectively Improve Water Quality*. Washington, DC: World Resources Institute. Available at: http://pdf.wri.org/fertile_ground.pdf.

Fox, Jessica. Personal communication. EPRI, February 27, 2013.

Hart, R. and U. Latacz-Lohmann. 2005. “Combating Moral Hazard in Agri-Environmental Schemes: A Multiple-Agent Approach.” *European Review of Agricultural Economics* 32(1): 75–91.

Horan, R.D. and J.S. Shortle. 2005. “When Two Wrongs Make a Right: Second-Best Point-Nonpoint Trading Ratios.” *American Journal of Agricultural Economics* 87(2): 340–352.

Hughes, Peter. Personal communication. Red Barn Trading Company, May 2, 2011.

Kelly, George. Personal communication. EBX, February 19, 2013(a).

Kelly, George. Personal communication. EBX, March 25, 2013(b).

Maryland Department of Agriculture. 2008. “Maryland Policy for Nutrient Cap Management and Trading in Maryland’s Chesapeake Bay Watershed, Phase II A—Guidelines for the Generation of Agricultural Nonpoint Nutrient Credits.” Annapolis, MD: Maryland Department of Agriculture. Available at: http://www.mdnutrienttrading.com/docs/Phase%20II-A_Crdt%20Generation.pdf.

Maryland Department of Agriculture. 2012. “MDA Receives More Than $1.1 Million in Federal Conservation Innovation Grants.” Press release, August 29. Available at: http://news.maryland.gov/mda/press-release/2012/08/29/mda-receives-more-than-1-1-million-in-federal-conservation-innovation-grants/.

Morgan, C. and A. Wolverton. 2005. “Water Quality Trading in the United States.” Working Paper #05–07. National Center for Environmental Economics.

National Wildlife Federation. 1999. “A New Tool for Water Quality: Making Watershed-Based Trading Work for You.” Available at: http://water.rutgers.edu/TMDLs/Trading/newtool.pdf.

Nguyen, N.P., J.S. Shortle, P.M. Reed, and T.T. Nguyen. 2012. “Water Quality Trading with Asymmetric Information, Uncertainty and Transaction Costs: A Stochastic Agent-Based Simulation.” Resource and Energy Economics 35(1): 60-90.

Nguyen, T.N., R. Woodward, M. D. Matlock, A. Denzer, and M. Selman. 2006. “A Guide to Market-Based Approaches to Water Quality.” Washington, DC: World Resources Institute, Texas A&M University, and University of Arkansas. Available at: http://edu.nutrientnet.org/docs/NNGuide.pdf.

Northwest Environmental Advocates. 2013. “Oregon cheating on water quality trading program.” Available at: http://northwestenvironmentaladvocates.org/2013/03/oregon-cheating-on-water-quality-trading-program/.

Payne, Susan. Personal communication. Maryland Department of Agriculture, February 26, 2012.

Pennsylvania Environmental Quality Board. 2010. “Rules and Regulations: 25 PA. Code CH. 96. Water Quality Standards and Implementation.” Available at: http://www.pabulletin.com/secure/data/vol40/40-41/1927.html.

PENNVEST. 2011. “Overview for Purchasing/Selling Nutrient Credits in PENNVEST’s Nutrient Credit Clearinghouse.” Available at: http://www.portal.state.pa.us/portal/server.pt/community/nutrient_credit_trading/19518/nct_documents/1075305.

Ross & Associates Environmental Consulting, Ltd. 2000. “Lower Boise River Effluent Trading Demonstration Project: Summary of Participant Recommendations for a Trading Framework.” Prepared for the Idaho Division of Environmental Quality. Available at: http://yosemite.epa.gov/r10/oi.nsf/Webpage/Lower+Boise+River+Effluent+Trading+Demonstration+Project/$FILE/summary.pdf.

Selman, M., S. Greenhalgh, E. Branosky, C. Jones, and J. Guiling. 2009. “Water Quality Trading: An International Overview.” Washington, DC: World Resources Institute. Available at: http://www.wri.org/publication/water-quality-trading-programs-international-overview.

Shortle, J.S. and R. D. Horan. 2008. “The Economics of Water Quality Trading.” *International Review of Environmental and Resource Economics* 2: 101–133.

Simpson, T. and S. Weammert. 2009. “Developing Best Management Practice Definitions and Effectiveness Estimates for Nitrogen, Phosphorus, and Sediment in the Chesapeake Bay Watershed.” College Park, MD: University of Maryland Mid-Atlantic Water Program.

Texas A&M University. 2013. “Agricultural Policy/Environmental eXtender.” Available at: http://apex.tamu.edu/.

U.S. Department of Agriculture Natural Resources Conservation Service. 2011. “Certainty Framework.” Available at: http://www.mn.nrcs.usda.gov/partnerships/mstc/2011_Oct25/Certainty%20Framework%20FINAL%20july%2019%202011.pdf.

U.S. Environmental Protection Agency. 2009. “Water Quality Trading Toolkit for Permit Writers.” Washington, DC: U.S. EPA Office of Wastewater Management Water Permits Division.

U.S. Environmental Protection Agency. 2010. Water Quality Assessment and TMDL Information: National Summary of State Information. Available at: http://ofmpub.epa.gov/waters10/attains_nation_cy.control.

Vogel, J. and L.F. Szeptycki. 2012. “A Survey of Trading Ratios Used for Generation of Credits in Water Quality Trading Programs.” Charlottesville, VA: University of Virginia School of Law Environmental Law and Conservation Clinic.

Water Conservation Subdistrict of The Miami Conservancy District. 2005. “Great Miami River Watershed Water Quality Credit Trading Program Operations Manual.” Available at: http://www.miamiconservancy.org/water/documents/TradingProgramOperationManualFeb8b2005secondversion.pdf.

Wheeler, Tim. “Environmental groups sue to block Chesapeake pollution trading.” The Baltimore Sun, October 3, 2012. Available at: http://articles.baltimoresun.com/2012-10-03/features/bal-bmg-environmental-groups-sue-to-block-chesapeake-pollution-trading-20121003_1_pollution-diet-environmental-groups-patuxent-riverkeeper.

Willamette Partnership. 2009. “Verification Protocol: Willamette Ecosystem Marketplace, Pilot Version 1.0 General Crediting Protocol.” Available at: http://willamettepartnership.org/Verification%20Protocol%201.0.pdf.

Willamette Partnership, Pinchot Institute for Conservation, and World Resources Institute. 2012. “In It Together: A How-To Reference for Building Point-Nonpoint Water Quality Trading Programs.” Available at: http://willamettepartnership.org/in-it-together/In%20It%20Together%20Part%202_2012.pdf.

ENDNOTES

1. Uncertainty categories and nomenclature were created by the World Resources Institute.
2. Since publication of Maryland’s guidelines, the retirement ratio was changed from 5 percent to 10 percent.

ABOUT THE AUTHORS

Sara Walker is an associate at WRI whose works focuses on NutrientNet, WRI's online water quality trading tool, and cost-effective and market-based approaches to reducing nutrient pollution.
Contact: swalker@wri.org

Mindy Selman is a senior associate at WRI who leads the organization's work on water quality. She is a leading expert in water quality trading and other market-based mechanisms for improving water quality.
Contact: mselman@wri.org

ACKNOWLEDGMENTS

This publication was made possible by USDA's Office of Environmental Markets (OEM).

We would like to thank the following WRI staff for reviewing this publication: David Tomberlin, Erin Grey, Rebecca Gasper, Michelle Perez, and Todd Gartner. We would also like to thank Chris Hartley (USDA OEM), Marc Ribaudo (USDA Economic Research Service), Bob Rose (U.S. EPA), and Bobby Cochrane (Willamette Partnership) for reviewing this publication.

Special thanks also go to the following individuals who shared their expertise over the course of writing this publication: George Kelly (Environmental Banc and Exchange), Sonja Biorn-Hansen (Oregon Department of Environmental Quality), Bobby Cochrane (Willamette Partnership), Peter Hughes (Red Barn Consulting) and Jessica Fox (Electric Power Research Institute).

PHOTO CREDITS

Pg. 8, Justin Hobson; pg. 11, Keith Weller; pg. 17, Tim McCabe, USDA Natural Resources Conservation Service.

ABOUT WRI

WRI is a global research organization that works closely with leaders to turn big ideas into action to sustain a healthy environment—the foundation of economic opportunity and human well-being.

Our Challenge

Natural resources are at the foundation of economic opportunity and human well-being. But today, we are depleting Earth's resources at rates that are not sustainable, endangering economies and people's lives. People depend on clean water, fertile land, healthy forests, and a stable climate. Livable cities and clean energy are essential for a sustainable planet. We must address these urgent, global challenges this decade.

Our Vision

We envision an equitable and prosperous planet driven by the wise management of natural resources. We aspire to create a world where the actions of government, business, and communities combine to eliminate poverty and sustain the natural environment for all people.

Our Approach

COUNT IT

We start with data. We conduct independent research and draw on the latest technology to develop new insights and recommendations. Our rigorous analysis identifies risks, unveils opportunities, and informs smart strategies. We focus our efforts on influential and emerging economies where the future of sustainability will be determined.

CHANGE IT

We use our research to influence government policies, business strategies, and civil society action. We test projects with communities, companies, and government agencies to build a strong evidence base. Then, we work with partners to deliver change on the ground that alleviates poverty and strengthens society. We hold ourselves accountable to ensure our outcomes will be bold and enduring.

SCALE IT

We don't think small. Once tested, we work with partners to adopt and expand our efforts regionally and globally. We engage with decision-makers to carry out our ideas and elevate our impact. We measure success through government and business actions that improve people's lives and sustain a healthy environment.

WORLD
RESOURCES
INSTITUTE

10 G STREET NE
SUITE 800
WASHINGTON, DC 20002, USA
+1 (202) 729-7600
WWW.WRI.ORG

ISBN 978-1-56973-820-7