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LESSONS FOR TRADING PROGAM DESIGN TO PROTECT WATER QUALITY: A SYNECTIC ANALYSIS OF AIR AND WATER QUALITY PROTECTION PROGRAMS

presented by

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has been accepted towards fulfillment
of the requirements for

M.S. degree in Resource Development

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Date 11/6/00

LESSONS FOR TRADING PROGRAM DESIGN TO PROTECT WATER QUALITY: A SYNECTIC ANALYSIS OF AIR AND WATER QUALITY PROTECTION PROGRAMS

By

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A THESIS

Submitted to
Michigan State University
In partial fulfillment of the requirements
For the degree of

MASTER OF SCIENCE

Department of Resource Development

2000

ABSTRACT

LESSONS FOR TRADING PROGRAM DESIGN TO PROTECT WATER QUALITY: A SYNECTIC ANALYSIS OF AIR AND WATER QUALITY PROTECTION PROGRAMS

By

Elaine Marie Brown

This research focused on gaining new insights for protecting water quality through a literature review and comparative analysis of the United States (U. S.) air quality protection and market incentive-based trading programs that have benefited air quality. Sulfur dioxide (SO_2) emissions have been reduced by 50 percent and at an estimated $7 billion less since air quality policy shifted from a traditional regulatory command-and-control system to an emissions allowance market. Given the performance in the SO_2 allowance trading programs, analysts have explored the opportunities for using similar market incentive-based systems for water pollution control. However, despite some six efforts nationally to implement point-nonpoint trading programs, there have been few trades to date.

Economic theory offers the situation, structure, conduct and performance (SSCP) analytical framework in which to evaluate why and how markets function. The comparative analytics of synectics is used to test for similarities between two different markets–air emission allowances and water effluent credits. This analysis indicates that there are institutional differences between air and water quality policies that limit how an effluent trading program can be designed.

This work is dedicated to my parents, Frank and Micky Chapko, for always believing in me and being there when I needed them. And to my sons, Jason, Jeffrey, and Joseph Brown, in the hope that through out their lives they will always have the courage to risk failure in pursuit of their dreams and the wisdom to continue to explore and grow and learn.

ACKNOWLEDGEMENTS

I could not have completed this task without the intellectual, collegial, and moral support of my advisor, Dr. Patricia E. Norris, and Dr. Sandra S. Batie. Both provided invaluable research references and guidance. Dr. Scott G. Witter provided excellent guidance and direction for the water quality aspects of this effort. I also appreciate the willingness of the Director, Dr. Jon F. Bartholic, and Associate Director, Dr. Frank M. D'Itri, of the Institute of Water Research to support staff scholarship and research endeavors. Finally, I want to acknowledge all the encouragement and assistance received from family, friends and colleagues.

This research was support by grants from the Elton R. Smith Endowment at Michigan State University and the Michigan Great Lakes Protection Fund.

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LIST OF ABBREVIATIONS

BACT .... Best Available Control Technology
BAT .... Best Available Technology (economically achievable)
BMP .... Best management practice
BPT .... Best Practicable Control Technology
CEMS .... continuous emission monitoring system
CRP .... Conservation Reserve Program
ERC .... emission reduction credit
H_2S .... hydrogen sulfide
H_2SO_4 .... sulfuric acid
LA .... load allocation
MI DEQ .... Michigan Department of Environmental Quality
mmBtu's .... millions of British thermal units
NAAQS .... National Ambient Air Quality Standards
NPDES .... National Pollution Discharge Elimination System
NO_2 .... nitrogen dioxide
NSPS .... New Source Performance Standards
POTW .... publicly owned treatment works
ppb .... parts per billion
ppm .... parts per million
PSD .... prevention of significant deterioration
RACT .... Reasonably Available Control Technology
RECLAIM .... Regional Clean Air Incentives Market Program
SIP .... State Implementation Plan
SO_2 .... sulfur dioxide
TMDL .... total maximum daily load
tonnes .... metric tons
US EPA .... United States Environmental Protection Agency
WLA .... waste load allocation

INTRODUCTION

Water resource protection is an evolving science. Many years of research have given society a better understanding of the complexities of the natural environment and better strategies to manage anthropogenic impacts. Since enactment of the Clean Water Act in 1972, many millions of dollars have been spent, federal and state programs have been implemented, and improvements in water quality have been made. However, much remains to be done to advance our understanding of the unique nature of each watershed and of human impacts on the water resources that support our lifestyles and livelihoods.

This research is focused on gaining new insights about protecting water resources through a literature review of U. S. air quality protection and market incentive-based trading programs that have benefited air quality. Beyond the literature review, a synectics analysis—using analogy to ascertain if the model developed for one problem can be applied to another—will also be employed (Gordon, 1961). For this analysis, the air quality protection and emissions trading programs are used as a direct analogy for water quality protection and pilot nutrient trading programs to obtain lessons that will benefit water quality protection programs when implementing market incentive-based nutrient trading programs. This synectics analysis will use the "situation, structure, conduct and performance" economic framework for comparison of air and water protection public policies (Thompson, Matthews, and van Ravenswaay, 1994).

Chapter 1

PROBLEM IDENTIFICATION AND RESEARCH DIRECTION

Background of the Problem

Despite billions of dollars spent annually on water pollution control regulations, permits and conservation subsidies, there is evidence that water quality in the United States is declining. Even with major investments by all levels of government in waste water treatment over the past 20 years, 44 percent of the nation's river miles, 57 percent of the lake acres, and 44 percent of estuary water do not fully support their designated uses (i.e., they are not fishable and swimmable) (Faeth, 1996). The trend in recent budgets for federal regulatory programs and farm conservation subsidies have been cutting back from historical levels which may now exacerbate these problems. These environmental problems are not unfamiliar or new. The U.S. has a history of water quality problems and programs to address these problems (e.g., NPDES and CRP to address nutrient and sediment problems). The U.S. has a longer history of air pollution problems and programs; therefore much can be learned from innovative, successful, environmental protection approaches in another medium such as air emissions trading programs for air quality protection.

Emissions trading in air quality programs represents the first formal application of market incentive-based approaches to environmental policy. The regulatory command-and-control[1] approach of the original federal Clean Air Act produced environmental benefits but at a higher cost than might have been necessary under a more flexible policy framework (Tietenberg, 2000). After much debate and many legislative proposals, the Clean Air Act was amended in 1990 to allow more flexibility in meeting emissions controls for sulfur dioxide (SO_2). Specifically, a SO_2 emission allowance trading program was implemented (McLean, 1997). The history of this new market incentive-based program of emission allowance trading is short. However, market observers have noted that fewer allowance trades have occurred than expected and at a lower cost than expected. Evidence suggests that the flexibility afforded (i.e., the ability to chose the most appropriate methods for reducing emissions) by the changes in the Clean Air Act enabled dischargers to adopt less costly, innovative treatment and discharge control technologies, thereby reducing the demand for emission allowance trading. Nevertheless, analysts have concluded that, with the changes in the Clean Air Act, SO_2 emissions have been reduced by 50 percent and at an estimated $7 billion less than the anticipated cost of the regulatory command-and-control system (Burtraw, 1996a).

The potential for credit trading programs in water quality policy is a logical extension of the results observed in the air quality arena. In fact, nutrient credit trading programs in water quality have been developed in several regions around the United States. Because much of the on-going impairment of surface water

[1] The command and control approach means mandated technologies and/or standards.

has been attributed to nonpoint sources of pollution, trading programs which incorporate both point and nonpoint discharges are of particular interest. While point-point trading programs, like air emissions credit programs, have been fairly successful, the effectiveness of point-nonpoint trading programs is more problematic. Although point-nonpoint trading programs have been developed targeting agricultural nonpoint sources in at least five locations, and research has shown that nonpoint controls can be implemented at lower cost than point controls (Hoag and Hughes-Popp, 1997), only two point sources have implemented discharge reduction credit trades with agricultural nonpoint sources (Klang, 2000)[2].

The State of Michigan has been a national leader with market incentive-based environmental protection programs, including its state-level air emissions trading program. More recently, Michigan has attempted to build on those successes with a similar market incentive-based approach for water quality protection. Together with the World Resources Institute and Michigan State University, the Michigan Department of Environmental Quality (MI DEQ) examined the economic feasibility of nutrient credit trading in the Saginaw Bay watershed. The 1997 study determined that environmental and economic benefits could be gained from trades of nutrient credits between point and

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[2] Both point sources implemented trades as part of multi-year agreements with the Minnesota Pollution Control Agency that are incorporated into the sources' NPDES permits.

nonpoint sources. The study also concluded that the economic feasibility of nutrient credit trading is watershed dependent; factors critical to success—such as geophysical features, meteorological conditions, land use patterns, distribution of discharges between point and nonpoint sources, and economic growth—vary widely between watersheds (Faeth, 1997). In addition, the MI DEQ conducted a review of pilot water pollution credit trading programs in other states, specifically program structures and trading activities (Batchelor, 1997). Typically, different environmental media, such as air and water, are regulated by different divisions of state and federal regulatory agencies and thus have considered market incentive-based programs rather independently for each media. However, this is not the case for Michigan. The model used for air emissions trading is also being used for water pollution credit trading, since the same staff specialist has been developing both media's rules. There also appear to be similarities between the pilot water trading programs and the air emissions trading program (e.g., caps on total discharges, trading ratios).

In no case has the following question has been addressed: **Do current difficulties with water quality trading program design arise because of fundamental differences between air and water media and/or because of fundamental institutional barriers inherent in the Clean Water Act (barriers which have been eliminated from the Clean Air Act with the 1990 amendments)?**

Statement of the Problem

Currently Michigan's *Water Quality Trading Work Group* is developing a set of recommendations to the MI DEQ for the development and implementation of a statewide water pollution reduction credit trading program. However, the U.S. Environmental Protection Agency (US EPA) which must approve the program and has been critical of the group's efforts to date. The research proposed herein would provide answers to the question posed above, thus contributing to the success of Michigan's and other states' efforts to develop trading programs for water quality protection while also contributing to the knowledge base.

Research Directions

The proposed research will address the question: Do current difficulties with water quality trading program design arise because of fundamental differences between air and water media or because of fundamental institutional barriers inherent in the Clean Water Act (barriers which have been eliminated from the Clean Air Act with the 1990 amendments)? This research effort is unique, as a review of the literature indicates that a comparative analysis of market incentive-based trading programs for air and water media has not been completed.

Focused Research Questions

Historically, air quality has been treated as a free public good and air property rights were not an issue until air pollution began to cause serious health problems[3]. In the US, the first federal air pollution act was enacted in 1955 as a public health program for air pollution research, training and technical assistance (Boubel, et. al., 1994, pg. 11). The air pollution act was gradually modified and became the Clean Air Act of 1970. However, society has always valued highly the property rights to water. For example, early concerns with rights to commerce resulted in congressional enactment of the Rivers and Harbors Act of 1899. This statute was the forerunner of the Federal Water Pollution Control Act Amendments of 1972 (known as the Clean Water Act) that established a complex set of rules now governing the rights to use water for waste discharges (Braddock, 1995). This historic difference and situational and structural conditions suggest that the following focused questions may be useful in addressing the research question posed above:

1. **Media Similarities between Air and Water.** Are the differences in media and pollutant biogeophysical processes between sulfur dioxide emissions in air and nitrogen/phosphorus discharges in water a limiting factor in establishing environmentally and economically sound market incentive-based nutrient trading programs?

[3]The linkage between air and human health was recognized in policy efforts in the early 1800's. In 1848, Great Britain enacted the first public health act to control smoke and ash (Boubel, et al, 1994. Pg. 6).

2. **Property Rights and Institutional Structure**

   A. Differing Property Rights Structure. Does the history of differing property rights structures in the air and water media make implementing air emissions trading policies more feasible and less costly than implementing water pollution nutrient trading policies?

   B. Air and Water Institutional Frameworks. Does the institutional framework established in the U.S. to protect and manage air quality make designing and implementing environmentally and economically effective air emissions trading programs more feasible and less costly than the institutional framework established in the U.S. to protect and manage water pollution nutrient trading programs?

3. **Economic and Environmental Benefits of Market Incentive-based Trading.** Are the economic and environmental benefits of market incentive-based point-nonpoint nutrient credit trading programs sufficient to warrant changing the institutional framework for water pollution nutrient trading program design?

Each question is intended to frame the policy issue and guide the research process. These questions do not comprehensively address all the factors (political, socioeconomic) which could influence the effectiveness of market incentive-based trading programs as water quality protection programs. Rather they are used to guide the literature review and synectics analysis of public policy within the situation, structure, conduct and performance (SSCP) framework. Each question fits into the SSCP public policy analysis framework. Question 1 addresses the physical media or situation to which policy is applied. Questions 2 A and B address the structure or the rights and institutions under which decisions are made. Question 3 addresses the conduct (decisions made) and performance (impact of the decisions on the media) components of the SSCP framework.

Using a synectics approach (Gordon, 1961), if the four components of the SSCP framework (Thomason, et al, 1994) are the same for both the air and water quality protection, than the successes in the air emissions credit trading program should be applicable to water quality nutrient trading programs. However, since the situation and structure lead to conduct, which leads to performance, then differences in situation and structure could explain differences in conduct for each market incentive-based program. If there are differences between the air and water situation and structure component(s), than other outcomes may occur. Recommendations may be made regarding institutional changes or additional research that may be needed to duplicate the success of the air quality program in water quality protection. Through the research process, these focusing questions may prove to be less valuable for testing and questions that are more appropriate may be generated for further testing and research.

Chapter 2

LITERATURE REVIEW

Introduction

This chapter is divided into four sections. It follows the policy analysis framework described by Thompson, et al (1994) that is more elaborately characterized in Chapter 3. The situation, structure, conduct and performance (SSCP) of U. S. air and water protection programs are presented including pollution market incentive-based trading programs. The first section presents the discussion of the situation or physical conditions in the air and water media. Section 2 presents the discussion of the structure that frames the air and water programs. Components that researchers find essential to successful market incentive-based programs are presented along with the evolution of air and water property rights and institutional policies. Finally, Section 3 addresses the conduct and performance of air and water pollution market incentive-based trading programs while Section 4 presents a discussion of the findings from the literature review.

The literature and policy review in this chapter are the foundation used to compare the similarities and differences in the SSCP policy framework for the air and water media. The findings from the literature and policy review are then applied in Chapter 3 in a synectics analysis of the case studies. The details of the SSCP policy framework and synectics analysis are presented in Chapter 3.

As stated in Chapter 1 the fundamental research question[4] is: Do current difficulties with water quality trading program design arise because of fundamental differences between air and water media and/or because of fundamental institutional barriers inherent in the Clean Water Act (barriers which have been eliminated from the Clean Air Act with the 1990 amendments)?

The question is explored based on the focused research questions described in Chapter 1. The current United States policies and programs for sulfur dioxide emissions and phosphorus and nitrogen effluent discharges will be examined using the framework of the focused research questions.

Section 1: Situation—Media Similarities between Air and Water

Using the SSCP policy analysis framework, the situation is the physical characterization of the resource and the biogeochemical processes that occur within that media. This section addresses these characteristics for the air and water media.

[4] There may be other important causes for difficulties in water quality trading program design. For example, social acceptance, overcoming the inertia of the status quo, and the sequence of events and time it takes to adapt new policy approaches. The research presented here focuses on the media and the institutional framework.

The biophysical characteristics of air and water as waste assimilating media, specifically for the sulfur dioxide assimilative capacity of air (Harte, et al, 1991, Boubel, et al, 1994 and Turco, 1995) and the nitrogen and phosphorus assimilative capacity of water (Manahan, 1991), are evaluated below. Within the airshed and watershed context, the minimum environmental protection standards are identified (EPA and State regulations). The methods for measuring and monitoring compliance with discharge and ambient standards are also identified (standard methods manuals). Issues that may exist regarding enforcing, regulating and monitoring compliance within a nutrient credit trading program are also presented.

Biogeochemical Cycles

The natural environment has processes for managing most elements and compounds found within it. Elements necessary for life such as carbon (C), nitrogen (N), phosphorus (P), and sulfur (S) move through the atmosphere, lithosphere, hydrosphere, and biosphere in biogeochemical cycles. These cycles describe how elements such as sulfur (S) and compounds such as sulfur dioxide (SO_2) move through the spheres that combine to create the environment (Turco, 1997). The physical processes and chemical changes that occur in each phase determine when and to what extent each element or compound is available to react in the environment (Manahan, 1991). To compare sulfur dioxide emissions in air to nitrogen and phosphorous discharges in water, it is important to understand the biogeochemical cycles for each element and the biophysical nature of each media.

The Sulfur Biogeochemical Process

In the sulfur (S) biogeochemical cycle, sulfur is found primarily as sulfate minerals, which are used as fertilizers for plants. The critical compounds found in the atmosphere include sulfur dioxide (SO_2), sulfuric acid (H_2SO_4), hydrogen sulfide (H_2S), carbonyl sulfide (COS), and dimethyl sulfide [$(CH_3)_2S$] (Turco,1997). This literature review focuses on the first three compounds.

Sulfur is found in its most reactive forms SO_2, H_2SO_4, and H_2S in the atmosphere (see Figure 1). These compounds are the result of natural and anthropogenic activities. The major anthropogenic source of SO_2 emissions is fossil fuel combustion. This source contributes more than natural sources to the emission of SO_2, 100 metric tons (here after tonnes) per year versus 90 tonnes per year from all natural sources (Turco, 1997). The SO_2 reacts with the hydroxyl radical (OH) and is converted to H_2SO_4 which is cycled back to the earth's surface primarily by precipitation.

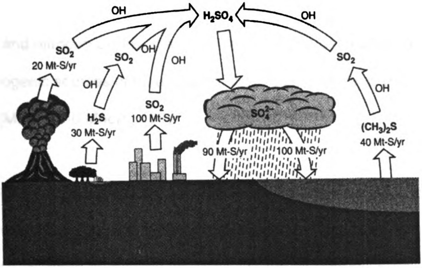

Figure 1 The Sulfur Biogeochemical Cycle

Source: *Earth Under Siege: From Air Pollution to Global Warming* p. 301.
Used with permission of R. P. Turco, Author

A detailed discussion of the chemical characteristics of sulfur dioxide is found in Appendix A: Physical Characteristics of Air and Water Media and Biogeochemical Processes for Sulfur, Nitrogen and Phosphorus, beginning at page 152.

Biophysical Properties of Air

Air is a mixture of gases that make up the atmosphere. It is essential to support life on this planet. Air provides oxygen for animal respiration and carbon dioxide for plant respiration. It also filters out ultraviolet radiation from the sun and acts as a sink and filtration system for anthropogenic pollutants (Turco, 1997). Air is composed almost entirely of nitrogen and oxygen (about 99 percent). Compared to nitrogen and oxygen, argon and carbon dioxide are minor components of the atmosphere and, with the *trace elements*[5] including sulfur dioxide and nitrogen oxides, make up less than one percent of the air. Yet anthropogenic sources of thousands of trace elements have an impact on air quality (Moore and Moore, 1976).

Air quality and pollutant dispersion are also determined by the physical characteristics of large air mass movement, weather and climate conditions, and local air movement. A detailed discussion of the biophysical properties of air and local air movement are found in Appendix A: Physical Characteristics of Air and Water Media and Biogeochemical Processes for Sulfur, Nitrogen and Phosphorus, beginning at page 153.

What is an Airshed?

The term "airshed" is sometimes used when describing air management programs. Workers in water resources who think of managing water resources on a watershed basis coined the term airshed. In air quality, an airshed is a geographic area requiring unified management to achieve air pollution control. However, airshed is not an accurate comparison for managing air since air does not flow in a single direction like water. This name is more appropriately used in areas with valleys or basins. Because much of the United States is flat, a better term is air quality control region. The air quality control regions are geographic

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[5] Trace elements are a tiny fraction of all gases present with concentrations of less than 20 ppm.

areas agreed upon by the state agency that administers air quality programs and the US Environmental Protection Agency (US EPA) (Boubel, et al, 1994).

Sulfur Dioxide Human Health and Environmental Standards

The US EPA sets emissions limits for sulfur dioxide (SO_2) that the states are required to enforce. The SO_2 limits are set to protect human health and welfare. The primary standard is established to protect human health while the secondary standard is set to protect welfare (visibility, buildings and environmental damage). The US EPA is required by statute to periodically review the adequacy of the standards and make revisions as new evidence merits changes. The national ambient air quality standards for SO_2 are as follows: (40CFR50; Harte, et al, 1991; Boubel, et al, 1994).

Primary: annual average: 80 $\mu g/m^3$ or 0.03 parts per million (ppm)

24-hour average: 365 $\mu g/m^3$ or 0.14 ppm

Secondary: 3-hour average: 1300 $\mu g/m^3$ or 0.50 ppm

Methods of Measuring and Monitoring SO_2 Emissions in an Air Quality Management Region

Ambient air monitoring of SO_2 is required under the Clean Air Act. A federal, state and local partnership system has been established across the country for ambient air monitoring of regulated pollutants. The ambient air monitoring system is used to determine changes in air quality such as improvements in non-attainment areas and deteriorating conditions in pristine or attainment areas. Deteriorating conditions would require states to modify the state implementation plan (SIP) and permitting practices to reverse the trend. This national ambient air quality monitoring system collects data that is held in several databases. The US EPA Office of Air Quality Planning and Standards (OAQPS) maintains and manages these databases (OAR, 2000). A brief discussion of ambient SO_2 monitoring is presented in Appendix A: Physical Characteristics of Air and Water Media and Biogeochemical Processes for Sulfur, Nitrogen and Phosphorus, beginning at page 157.

Biogeochemical Cycle of Water

Water is a unique compound and, like sulfur, nitrogen and phosphorus, has a biogeochemical cycle called the hydrological cycle. Though the water cycle or hydrological cycle is often illustrated by a simple diagram as found in Figure 2 below, the reactions that occur in each sphere are critical to life on earth.

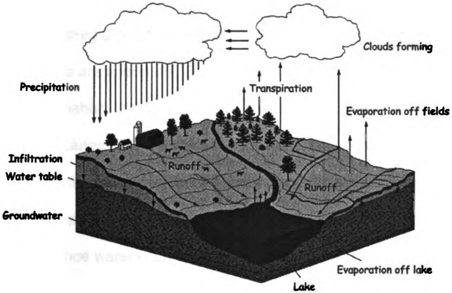

Figure 2 The Hydrologic Cycle

Source: MSU Institute of Water Research/Center for Remote Sensing and GIS

Hydrology is the study of the movement and storage of water in the environment (Black, 1996). A detailed discussion of water hydrology and the biophysical properties of water are presented in Appendix A: Physical Characteristics of Air and Water Media and Biogeochemical Processes for Sulfur, Nitrogen and Phosphorus beginning at page 157.

Biophysical Properties of Water

Water is an excellent solvent that easily dissolves substances such as nitrates and sulfates. This property gives water the ability to assimilate excess amounts of these materials. The ability to form ionic bonds makes it an active molecule in reactions as a vapor and a liquid. The heat capacity property influences weather and water body circulation patterns. See Table 13 Important Properties of Water in Appendix A at page 159 for more details.

For the purposes of this study, the three elements sulfur, nitrogen and phosphorus are important. These three are commonly found in water in various forms (Manahan, 1991). Table 1 on the following page summarizes the behavior and significance of these elements in water. The significance of this table with regard to this research is that all three elements are naturally found in water which is capable of assimilating or moving these elements through the hydrologic system. Since water is an excellent solvent and all three of these elements are found in nature, water can assimilate or move the elements. The problem arises when anthropogenic sources of these elements are added into the natural system. At some point, these human additions overload the system and negatively impact water resources. This human impact may result in the development of new policies to protect the hydrologic system.

Element	Sources	Behavior and Significance
Nitrogen (N)	Minerals, decayed organic matter, pollution	Among most important molecules in water. Inorganic N exists as NO^-_3 where oxygen (O_2) is present and as NH^+_4 in the absence of O_2. Nitrate is an algal nutrient. NH^+_4 is a weak acid that is bound to soil. Organic nitrogen is bound to various pollutant organic and biological compounds.
Phosphorus	Minerals, fertilizer runoff, domestic wastes (i.e., detergents)	Occurs in natural waters as anions of orthophosphoric acid, H_3PO_4 (i.e., $H_2PO^-_4$ and HPO^{2-}_4) in normal pH ranges. Algal nutrient.
Sulfur	Minerals, pollutants, acid mine water, acid rain	Sulfate ion, SO^{2-}_4 predominates in aerobic conditions; hydrogen sulfide, H_2S is produced in anaerobic waters. H_2S is toxic; SO^{2-}_4 is harmless at moderate levels.

Table 1. Occurrence of Sulfur, Nitrogen and Phosphorus In Water

Source: Manahan, 1991. Page 36. Used permission of Lewis Publishers, Inc.

Physical Characteristics of Water Movement in a Watershed

A watershed is an area of land in which all the precipitation that falls on the land moves to a drain or ditch channel and flows downhill to a common outlet from which it enters into a stream, lake, river, wetland or the ocean (Black, 1996). There are two key characteristics found in this definition that are important to this research. One, the boundary of a watershed and therefore the land area that the water body drains can be delineated. The second is the physical fact that water flows downhill.

There are many possible sources of pollution for surface water and many kinds of pollutants that can affect ground and surface water. Pollutants arise from point and nonpoint (diffuse) sources. Permitted discharges, parking lot runoff, and agricultural and silvicultural runoff all contribute pollutants that can impact water quality. This study focuses on two of those pollutants, nitrogen and phosphorus.

Chemical Characteristics of Nitrogen

Nitrogen is the most abundant gas in the atmosphere, but in that form it is not biologically available until it is converted into a more active compound such as oxides of nitrogen (NO_x[6]) or ammonia (NH_3). This conversion occurs in the atmosphere through lightening or combustion reactions (Berner and Berner, 1987). Nitrogen goes through many conversions as it moves through its biogeochemical cycle (see Figure 3 on the following page).

[6] The symbol NO_x is used to denote several forms of the compound e.g., NO_2 or NO_3.

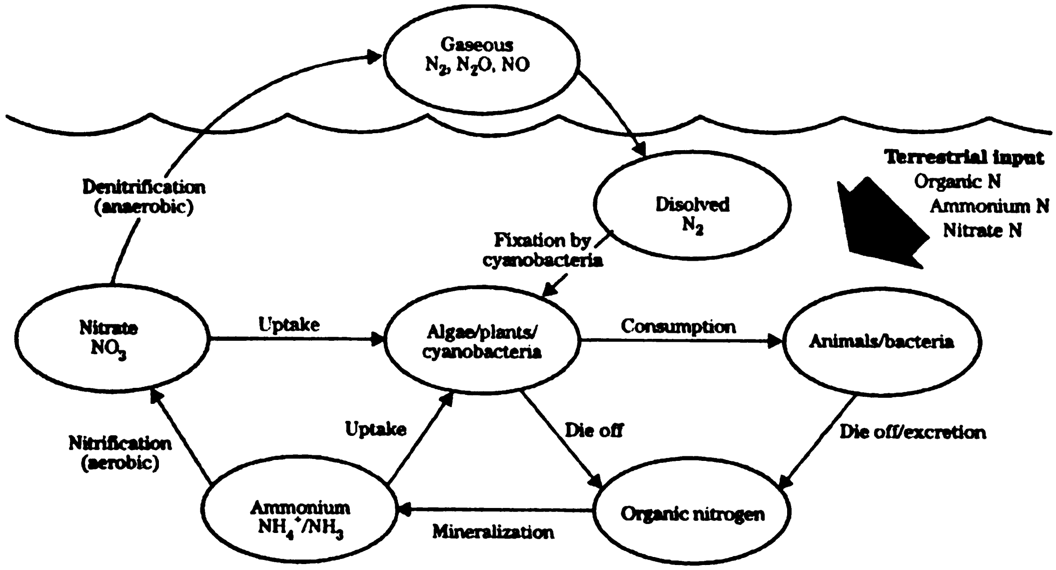

Figure 3 The Nitrogen Cycle

Source: USDA NRCS Procedure to Estimate the Response of Aquatic Systems to Changes in Phosphorus and Nitrogen Inputs. Appendix B.

Nitrogen compounds are critical to the life processes of all plants and animals. Nitrates (NO_3^-) are fertilizers that plants need to produce protein. Ammonia and ammonium compounds are applied to soils as fertilizers, which plants readily break down to produce protein (Sawyer, et al, 1994).

Both natural and anthropogenic sources of nitrogen compounds contribute to the nitrogen cycle. Nitrate enters rain through lightening, photochemical oxidation, chemical oxidation, soil production in microbial processes, fossil fuel combustion and forest burning. About 25 percent of the nitrogen compounds come from natural sources while the remaining 75 percent are anthropogenic sources. About 50 percent of the anthropogenic sources come from fossil fuel combustion in automobile engines and power plants. The total anthropogenic contribution of nitrogen compounds from both atmospheric emissions and land application of fertilizers is about 50 percent (Berner and Berner, 1987).

Chemical Characteristics of Phosphorous

Phosphorus also has a complex cycling process in the biosphere (see Figure 4 below). It is typically the least available of the nutrients needed for life processes and is therefore frequently the limiting factor for biological growth in a fresh water system. Soluble orthophosphate is quickly assimilated by plants (Wetzel and Likens, 1997).

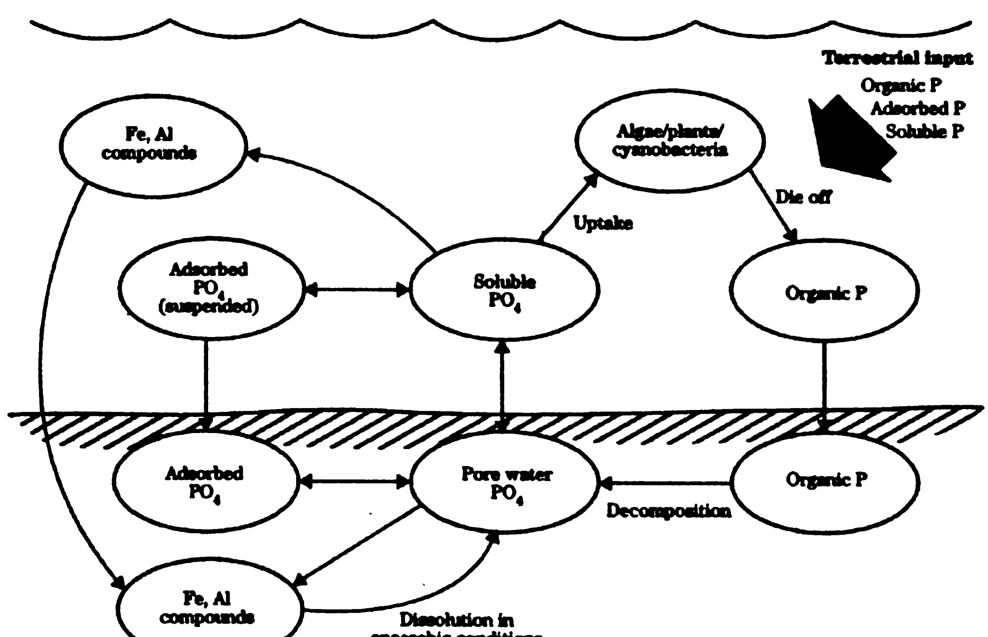

Figure 4 The Phosphorus Cycle

Source: USDA NRCS Procedure to Estimate the Response of Aquatic Systems to Changes in Phosphorus and Nitrogen Inputs. Appendix A.

Phosphorus, like nitrogen, must be present in a simple inorganic form to be taken up by plants. Studies of phosphorus (P) cycles in lakes estimate that for every 1 milligram of P delivered from all sources, 0.2 milligrams are insoluble and unreactive. The balance is available for plant growth (Berner and Berner, 1987). The inorganic phosphates that plants use are called orthophosphates ($H_2PO^-_4$, HPO_4^{2-} and PO_4^{3-}) (Manahan, 1991). When an abundance of orthophosphates is available in a river or lake, they contribute to excess algal growth.

Unlike nitrogen, which is very soluble in water, only inorganic or orthophosphate is water soluble and therefore available for plant growth. Polyphosphates or organic phosphates can be hydrolyzed in water to become available orthophosphates but are usually a minor consideration as they are precipitated as solids or adsorbed onto sediments[7]. Algae may grow at PO_4^{3-} levels as low as 0.005 mg/l or 5 µg/l during summer conditions (Sawyer, et al, 1994). Inhibiting algal growth requires an inorganic phosphate level below 0.5 mg/l. Since typical municipal wastewater contains 25 mg/l of total phosphorus, the efficiency of wastewater treatment must be very high to prevent algal growth. For fresh water environments, inorganic phosphates are sometimes called the limiting nutrient for plant growth, as excess inorganic or orthophosphates will accelerate euthrophication of lakes and streams (Manahan, 1991; Berner and Berner, 1987).

[7] If the soil is saturated with phosphorus compounds than the compounds may run off and become available to aquatic plants.

The phosphorus cycle has also been influenced by anthropogenic activities. Deforestation has increased runoff and, therefore, phosphorus deposition into water courses. Increased use of fertilizers in agricultural production and soluble phosphorus in detergents and domestic and industrial wastes have all contributed to an increase in phosphorus in water courses. It is estimated that half of the soluble phosphorus now in rivers is from anthropogenic sources, and in polluted rivers in North America anthropogenic sources contribute 10 times as much soluble phosphorus as natural sources (Berner and Berner, 1987).

Nitrogen and Phosphorus Compounds in Water

Water acts as an oxidizing or reducing agent depending upon the amount of oxygen available. Water in the aerobic (with-oxygen state) can break down or transform the macronutrient elements such as nitrogen and phosphorus into non-poisonous inorganic forms, nitrate and phosphate respectively, that are readily assimilated by plants (Moore and Moore, 1976).

Environmental problems occur when there are excess (N and P) nutrients, which then encourage excess plant growth and accelerate the eutrophication process. Both the oxidation of macronutrients and the eutrophication process can remove oxygen from water. Accelerated eutrophication may result in *algal blooms.* This process occurs when excessive nutrient levels enhance rapid algal growth until the supply of one or more macronutrients is exhausted. At that point the algae die and cause a rapid depletion of oxygen. The oxygen is consumed in the decomposition of the dead algae, which then causes fish to die of asphyxiation resulting in massive fish kills (Moore and Moore, 1976).

Human Health and Environmental Standards for Nitrogen and Phosphorous

The primary effect of concern with nitrates is their conversion into nitrites[8]. Nitrites in the human body cause methemoglobinemia. This condition occurs when the nitrites absorbed in the body react with hemoglobin (the molocule in the blood that carries oxygen to the cells) and convert it to methemoglobin, which cannot transport oxygen. When blood methemoglobin reaches 10 percent, the skin appears blue; at 20 percent oxygen to the brain is reduced; and at 60 percent coma and death can occur (Harte, et al, 1991).

Most cases of methemoglobinemia are the result of drinking well waters high in nitrates (greater than 100 milligrams per liter). Most fatalities occur in infants (thus the blue baby syndrome). The best prevention is avoiding water with high nitrate levels. Therefore, the US EPA has established a drinking water standard for nitrates. The maximum permitted level in drinking water is 10 mg/l or 10 ppm (Harte, et al, 1991).

[8] A recent study in Oregon indicates that above a certain level NOx can also kill tadpoles.

Phosphorus compounds do not have a human health standard. Phosphorus is not a *pollutant* with a national standard, rather elemental phosphorus has a national water quality criterion[9] of 0.10 μg/l to protect marine and estuarine organisms from bioconcentrations, which may become toxic. Currently, there is no ambient water quality standard for inorganic phosphates that contribute to eutrophication (US EPA, 1998). However, states are required to submit plans as to how they will protect water resources from plant nutrients (nitrates and inorganic phosphates) to protect designated uses. Therefore, the states may set discharge limits for plant nutrients. For example, in Michigan phosphorus is limited by Administrative Rule 323.1060 as follows ". . . plant nutrient shall be controlled from point source discharges to achieve 1 milligram per liter of total phosphorus as a maximum monthly average effluent concentration unless other limits. . . are deemed necessary . . ." (Dell, 2000).

Experience has shown that algal blooms do not occur in fresh water when phosphorus is limited. An attempt was made in 1976 to establish a water quality criterion for phosphates in fresh water. To prevent excess eutrophication, the total phosphate content as P was recommended not to exceed 50 μg/l in any tributary to a lake or reservoir and 25 μg/l within the lake or reservoir (Faust and Aly, 1981). A phosphorus criterion has yet to be established nationally, though the US EPA recently proposed a National Strategy for the Development of

[9] Water quality criteria are the narrative and numerical terms used to determine if a water body is meeting its designated uses (e.g., fishable and swimmable, recreational uses, etc.).

Regional Nutrient Criteria (US EPA 1998). During summer growing conditions, the critical level of inorganic phosphorus to avoid an algal bloom has been established as near 0.005 mg/l or 5 μg/l (Sawyer, et al, 1994).

Methods of Measuring and Monitoring Nitrogen and Phosphorous Discharges in a Watershed

Nitrogen is found in various forms in water. Some forms are readily available for photosynthesis, while others are not available without going through natural reactions. Nitrogen sampling and analysis can be done relatively simply. A Van Dorn Sampler, which is simple to operate, is typically used to collect the sample. The water sample is assumed to be properly collected so that contaminants will not skew the analysis results. One of the complexities of testing for nitrogen is its presence in various organic and inorganic forms (Wetzel and Likens, 1979). The procedure for determining the amount of available inorganic or orthophosphate is a water sample is appropriate for the range of 1 to 500 μg/l of water. One procedure for each nutrient (testing for nitrate-nitrite nitrogen and inorganic-orthophosphate) is presented under procedures for nitrate-nitrite nitrogen and inorganic-orthophosphate testing in Appendix A: Physical Characteristics of Air and Water Media and Biogeochemical Processes for Sulfur, Nitrogen and Phosphorus, beginning at page 160.

Summary of Biogeochemical Factors for Sulfur Dioxide, Phosphorus and Nitrogen

Section 1 presented the biogeochemical factors for air and water and how that physical situation affects the natural movement of sulfur dioxide, phosphorus, and nitrogen through the medium. The nature of the three pollutants was also presented including how they become available to cause environmental problems, and how they are measured and monitored. This information is summarized in the table below.

Biogeochemical Factors for Sulfur Dioxide, Phosphorus, and Nitrogen

Characteristic	**Sulfur dioxide in Air**	**Phosphorus in Water**	**Nitrogen in water**
Complex cycling	Yes	Yes	Yes
Dispersion in media	Wide area	Downstream	Downstream
Easy to monitor ambient conditions	Yes	No	No
Easy to monitor pollutant discharge	Yes - major stationary sources	Yes - point source No – nonpoint source	Yes –point source No – nonpoint source
Non uniform mixing	yes	yes	yes

Table 2. Summary of Biogeochemical (Situation) Factors for Sulfur Dioxide, Phosphorus, and Nitrogen

As Table 2 indicates, all three compounds have complex cycling through the medium, dispersion processes that are relatively predictable in an air quality management area or downstream, and have non uniform mixing (i. e., hot spots could develop as the pollutant is dispersed into the media). However, differences occur in the ease of ambient monitoring. It is relatively easy and inexpensive to monitor ambient SO_2 emissions, while monitoring for phosphorus or nitrogen in the water media requires more time, expertise, and resources to properly gather samples and analyze them. Similarly, SO_2 sources are equipped with continuous monitoring devices that track and record emission relatively easily, while nutrient point sources are monitored as required but with more labor and resource intense methods. Finally, it is difficult to monitor nonpoint sources of nutrient pollutants not only because of their numbers and spatial distribution but also because simple methods have not been developed that allow easy measurement of differences of in-stream water quality as a result of nonpoint source discharges or new control of nonpoint sources of nutrients. Ambient monitoring is typically a cost born by government agencies. When funding reductions become necessary, ambient monitoring is often one of the first programs to be reduced in scope. Despite this historic trend, ambient monitoring has not been a responsibility of the regulated community. Therefore, the differences in human ability to measure and monitor water discharges and ambient conditions particularly for nonpoint sources of pollutants may be a limiting factor in establishing environmentally and economically sound market incentive-based nutrient trading programs.

Section 2A: Structure—Property Rights and Institutional Framework

This section is divided into two parts. Part one presents a discussion of the structure (property rights and institutional framework) necessary for an effective market incentive-based trading program based on review of the literature. The second part is a discussion of the observed structure for U.S. air and water quality programs. The later part will address existing property rights as formed and modified by federal and state policies.

Property Rights—An Overview

Property rights, in economics, define Person A's right to use the benefit stream of a resource or property, exclude Person B from using the resource benefits, and allow Person A to sell the rights to the benefits (Dales, 1968; Bromley, 1991). Government sets the ownership rules and defends the rights of Person A to the benefit stream. Person B has an obligation to respect the property rights of Person A. Person B has no ability to change the rights to the benefits of Person A unless they produce harmful externalities that affect the rights of Person B to his/her property or resources. This classic description of property rights works well for a private property regime where individuals own the property or instruments. However, it becomes a more complex scenario when state property or nonproperty (open access resource or public good) is involved (Tietenberg, 1996, p. 49).

Property rights are described as either non-attenuated or attenuated. Non-attenuated property rights have four characteristics: rights are clearly specified (universality), benefits and costs accrue to the owner (exclusivity), rights are transferable (transferability), and rights are protected from seizure or encroachment by government (enforceability) (Tietenberg, 1996, p. 41). When any one of these four characteristics is not met the rights are described as attenuated (i.e., not fully implementable). Rights are clearly specified when statutes, regulations, and/or entitlements clearly describe Person A's right to a benefit stream. All costs and benefits accrue to the property owner when s/he directly or indirectly obtains the benefits of the property. When property rights are transferable, Person A's right to use and sell the benefits stream of a resource or property are clearly specified. Finally, rights are enforced when by law or institutional structure government protects Person A's rights to use and sell a resource or property.

Bromley (1991) describes four property regimes in which property rights are implemented. In a state property regime, such as parks or wildlife refuges, the users have a duty to abide by the use and access rules of the managing agency and the agency has the right to set the rules. The private property regime gives an individual the socially acceptable use of a benefit stream and the duty to refrain from unacceptable uses while non-owners (others) have a duty to accept appropriate uses and the right to expect only those uses to occur. For the common property regime, such as a condominium community or a hunting club, the group of owners has the right to exclude non-owners and non-owners have a duty to abide by that rule. In a nonproperty regime with a public access resource, such as some fisheries or air, there is no defined group of owners or users and the benefits are available to all. Users have privileges but no right regarding use rates or maintaining the resource. Tietenberg (1996, p. 51) elaborates on

Bromley's nonproperty regime of a public access good when addressing complex environmental resources. He describes such resources as a public good. A public good has two characteristics nonexcludability (once made available no one can be excluded from using it) and indivisibility (one person's use does not limit the amount available to another). A good example is air which could be call a public access good or a public good.

Key Components of Market Incentive-based Trading Programs

The environmental economics literature has discussed the theoretical concept of market incentive-based programs for pollution control and abatement for more than 30 years (Dales, 1968; Tietenberg, 1985; Klier, Mattoon, and Prager, 1997). However, this concept has been slow to be adopted into environmental policy and regulatory program applications (Tietenberg, 1998; Stephenson, Shabman and Geyer, 1999). The following literature review briefly describes the components of market incentive-based credit trading that are key to an economically efficient and environmentally sound pollution trading program.

There are institutional, design and implementation components that are essential to a successful market incentive-based trading program. The institutional components include: clearly defined property rights (including the rights, liability and responsibilities of the participating parties) (Schmid, 1987; Dales,1968); an institutional framework that supports implementation of the program (Stavins 1997 and 1995; Apogee Research, Inc, 1992); the choice of open or closed trading systems (who may or must participate) (Batchelor, 1997), program goals (Solomon, 1999), internal (ability to make internal operations' changes) and external flexibility (alternatives for reaching the performance goal) for participants (Tietenberg, 1990; Stephenson, Shabman, and Geyer, 1999); and opportunities to respond to financial incentives for pollution prevention (Shabman and Stephenson, 1998). Design components important to market incentive-based trading programs include: a standard unit of the pollutant to trade (Tietenberg, 1990); reasonable trading ratios (Hoag and Hughes-Popp, 1997); opt-in provisions (ELI[10], 1997; McLean, 1997), and banking (the ability to purchase or save credits for future use or sale) (Tietenberg, 1998; Stavins,1997). The implementation components include: initial transaction costs (among trading parties with limited government regulation of the transaction) (Solomon, 1999), information costs (ease of finding trading partners and other information necessary to trade) (Stavins,1997), and monitoring and enforcement costs (Hoag and Hughes-Popp, 1997).

Institutional Components

Who has property rights and who has obligations as a result of those rights must be clearly defined (Schmid, 1987 p. 41). Typically these rights and obligations are established through an institutional framework of statutes, regulations, judicial decisions, and cultural norms (Dales, 1968 p. 58). For example, under Title IV of the Clean Air Act (CAA) of 1990 (42USC 7651), a new

[10] Environmental Law Institute will be denoted in citations as ELI.

system of property rights was created (McLean, 1997). Based on five to ten years of scientific and policy research[11], this institutional framework, the Clean Air Act, gave the largest generators of SO_2 emissions, utility companies, an absolute emissions cap. This cap meant that 263 power generating units[12] were required to reduce emissions and 182 additional units that decided to "opt-in" to Phase I (McLean, 1997). The trading program limited the amount of discharges or "allowances" that these 445 power generating units could emit into the atmosphere, bank for future use or sell to other utilities needing additional emissions allowances. Each allowance was a use right that could be sold to or bought from other utilities or in the open market. The public has benefited from cleaner air and monitoring the sales and use of emissions through a tracking system instituted in the program.

An institutional framework that supports implementation of a market incentive-based trading program is critical to its success. The administering agency must have clear legal authority to implement the program including allocating trading rights, and implementing and enforcing the program (Tripp and Dudek, 1989). Without such authority, potential participants are left with uncertainty that limits the likelihood of participation. The uncertainty could involve

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[11] This five to ten year timeframe to study the policy issues with all the stakeholders at the table and improve the scientific understanding of sulfur dioxide emissions and controls is likely undervalued for the contribution made to changing sulfur dioxide emissions policy.

[12] A power generating unit is a fossil-fueled boiler or combustion turbine used to produce electricity.

perceived risks to future capital investments or a greater potential for lawsuits. Both uncertainties are risks that most facilities will avoid. Ultimate responsibility for pollution reduction must be clearly stated and certainty of conditions must be known (Kerns and Stephenson, 1996).

The Clean Air Act provides several examples of an institutional framework that encourages more cost effective pollution control through market incentive-based approaches. In 1986, the US EPA officially published an air emissions trading policy (Tietenberg, 1990). This policy (51CFR 43829), within the context of the command and control requirements of the Clean Air Act, allowed licensed sources[13] of pollutants more flexibility in meeting pollutant control requirements than they previously had. Any source that over-controls emissions at a particular point of emissions could get a certified emission reduction credit (ERC) that could be used to meet emissions standards for other points of discharge in the same facility or sold to another pollutant source.

The ERC can be used under several CAA policies. The *bubble* policy allows existing plants with multiple emissions points or a group of plants to be regulated as a single source (Powers, 1998). Under this policy, emitting facilities in the bubble attain required emissions control by over-controlling the most economical sources in order to create ERCs for use on other sources. The US

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[13] Sources means the places from which pollutants emanate (Boubel, et al, 1994, pg. 29).

EPA emissions trading policy formally recognized several other emissions control alternatives including offset, netting and emissions banking policies. The *offset* policy requires major new or expanding sources in areas that are not meeting air quality standards (called non-attainment areas) to obtain ERCs from existing firms to offset their emissions. The *netting* policy allows existing sources that are modifying or expanding to use in-facility ERC generated to remain below the level of emissions that would trigger a more stringent new source review process. Thus the level of ambient air quality remains the same or improves (Tietenberg, 1990).

An open or closed system describes the base-line conditions under which the program is conducted. An open trading system is typically voluntary with its basis in existing regulations and supplementary to the regulatory program. For example, in an air emissions trading program, stationary, area, and mobile sources could participate. Open trading may be used to retain ambient environmental standards for air or water quality. Open systems also provide a less costly means of meeting technology-based standards (Batchelor, 1997). A closed trading system is often called a 'cap and trade' program. It designates which sources must participate and the maximum pollutant level they may release (the cap) for a geographic area. The level of pollutant that each source may release is allocated among the group of sources required to participate (Stephenson and Shabman, 1996).

The goals established for any market incentive-based nutrient trading program are critical to the success of the program. Clearly defined goals or objectives are essential for obtaining participant and citizen support (Tripp and Dudek, 1989). The stringency of the goal determines the institutional design. In cases with substantial and permanent reduction requirements (i.e., the Acid Rain Program and RECLAIM) the goal has driven agencies to select a cap and trade program to achieve substantial pollution reductions. With a modest environmental goal, there appears to be no advantage of an open trading system over a closed trading system (Solomon, 1999). In the case of water quality programs, the goal has been used by dischargers to determine the cost-benefit of additional controls to meet effluent limits. And, the goal serves as a base to measure the effectiveness of the trading program in achieving the reductions (Apogee Research Inc, 1992).

Participant flexibility, in identifying economic opportunities and source compliance flexibility both internal and external to the participant's facility, is necessary in an effective market incentive-based trading program. Tietenberg (1990) describes opportunities to respond to financial incentives for pollution prevention as one of the first principles in creating effective market incentive-based programs. This approach allow the participants in the market who know the costs of pollution controls to achieve environmental objectives while minimizing costs and perhaps generating credits through over-control of pollutants. Compliance flexibility is the ability of a program participant to decide how best to meet pollution reduction requirements. It can be achieved through changing internal operations to meet program requirements or through seeking additional allowances outside the program participant's operations (Stephenson, Shabman, and Geyer, 1999). Internal flexibility lets the operator of the source chose the most cost effective means of achieving pollution reductions. Such flexibility leads to innovation in control strategies and further savings and pollution reductions (Powers, 1998). However, internal flexibility may also reduce initial interest in trading because it allows sources to find new internal methods for compliance (Burtraw, 1996).

External flexibility allows sources of pollution to alter their compliance responsibilities by trading or transferring responsibility to another party. Or they may save their own pollution reductions for use in a future timeframe to meet pollution reductions. This is called banking and allows a pollution source to essentially trade with itself in another timeframe. As external flexibility increases, it creates more opportunities to sell or bank pollution reductions or allowances and generates financial incentives for additional pollution reductions (Stephenson, Shabman, and Geyer, 1999).

Design Components

Several design components that were introduced above are presented in more detail here. A key design component is a standard unit of pollutant to trade (Tietenberg, 1990). Pollutant trading programs have adapted the unit of trade as more practical experience has been gained with market incentive-based programs. The original air emissions trading program was a system of credits that a facility could earn by reducing a source of emissions in units per year. Once used an emissions reduction credit was gone. More recently the implementing authority assigns allowances based on fixed units such as a ton of SO_2 as a unit of trade. These allowances are assigned in advance as the maximum pollutant load the source can release. With allowances, sources can more effectively plan for capital improvements and future allocation needs (Tietenberg, 1998). Allowances also facilitate the establishment of a market in which allowances may be bought and sold.

When pollutant sources are physically different or under different regulatory requirements, such as point and nonpoint sources of nutrients or air emission sources in zones having varying impacts on a resource, then trading ratios may be part of the program design to address these differences (Powers, 1998). Trading ratios define the number of units of a nonpoint source pollutant that is equivalent to a point source unit of pollutant for the purposes of trading. Point and nonpoint sources of nutrients (phosphorus and nitrates) have different discharge cycles. While point sources tend to consistently deliver a typical volume of flow in each season, nonpoint sources are more cyclical with more flow and concentration in the spring or during high runoff storm events. Additionally, while there are thousands of permitted point source dischargers across the country, these sources are identified, regulated and monitored, unlike nonpoint sources, which are spatially distributed across the watershed, small, too numerous to inventory and monitor, and unregulated. These differences and the differences in impact to a water body can be addressed in trading ratios. Trading ratios address uncertainty about pollution control and create safety components to address this uncertainty. Trading ratios increase the marginal costs of trades and therefore, reduce the likelihood of trades (Hoag and Hughes-Popp, 1997).

Other design components that improve the effectiveness of market incentive-based trading programs are opt-in provisions and banking. Most of the existing programs do not require all sources of the pollutant to participate. Typically, major sources (e.g., most polluting electric utilities) or those sources with emissions above a threshold value (e.g. RECLAIM and the four tons per year minimum emissions of SO_2 and/or NO_x) are required to participate in a program. However, other sources of similar pollutants are not required to participate. This restricted number of participants limits the trading opportunities available and thus the economic gains that can be achieved from a trading program[14] (Tietenberg, 1998). Under Title IV of the Clean Air Act, 182 additional units opted-in to Phase I of the program (McLean, 1997). Sources joining the program before compelled to under Phase II allowed the units that were eligible to opt-in to accumulate additional transferable and bankable allowances through earlier program participation. These additional allowances can be used during

[14] Though any one may purchase emissions allowances in the sulfur dioxide and RECLAIM program, the limitation on the number of entities required to participate does limit the economic and environmental gains that can be obtained from a market incentive-based program.

Phase II when all individual source allowances have been reduced (Tietenberg, 1998). The SO_2 emission allowances are issued into the future for the participating units. This tactic allowed the units to bank allowances and thus more quickly reduced emissions. However, banking does extend the timeline for achieving the program-wide emissions reduction goal (McLean, 1997). A disadvantage of an opt-in program is the high transaction cost for the source (e.g., an SO_2 source would be required to install a monitoring system) (ELI, 1997).

Implementation Components

While design components describe how a program will be administered, they also impact implementation components that ultimately determine the costs incurred through participating in the market incentive-based program. The three implementation components introduced above are explained as follows.

Transaction costs are generally defined as the expenses that a source incurs to participate in the market. If these expenses are high compared to perceived benefits they will limit trading. If they are low, they enhance the likelihood of market participation and therefore achievement of the desired environmental goal at a lower cost (Stavins, 1995). Three activities determine if transaction costs will limit trades in a market incentive-based program. The first is the initial transaction costs of participating in the exchange. This participation cost can be as simple as documenting and recording the transaction in a program such as SO_2 trading or as complex and time consuming as getting case-by-case approval and NPDES permit revisions to implement a trade. The more time and resources required to prepare for a trade, the less likely that trading will occur.

Another type of transaction costs is information costs. Information costs refer to the ease of finding willing trading partners. Before trading can occur there must be willing buyers and sellers; the more participants in the market, the more easily the transaction will occur (Stavins, 1995). In air emissions trading, allowances are listed on a registry that buyers and sellers can easily access to reduce information costs. However, in pilot nutrient trading programs, there are no registries and finding a trading partner with sufficient nutrients to meet the needs of the buyer is more difficult and complex. There may also be the need for a point source to trade with multiple nonpoint sources to achieve the desired offset, as is the case in the Minnesota pilot program. Once a buyer and seller have found each other, they may then need to spend additional time and resources bargaining. Negotiating and completing the trade may require legal, brokerage, and insurance fees. One method for reducing costs is to establish an auction market, which allows participants to determine reasonable exchange rates and more readily obtain allowances (Tietenberg, 1998).

A third type of transaction costs are monitoring and enforcement costs. Once a trade is executed, it is the role of the responsible government authority to assure that what has been agreed to has occurred (Stavins, 1995). In the SO_2 and RECLAIM programs, the participants were required to install a continuous emission monitoring system (CEMS). The CEMS documents actual emissions and verifies that the participant is operating within its allocated allowance level (Stavins, 1997). The allowance tracking program that US EPA initiated for the SO_2 program is a publicly available database that allows the public and market participants to verify the compliance of any participant (McLean, 1997). The quality of the monitoring system and the high penalty for non-compliance with the SO_2 program reduce the monitoring and enforcement costs. In the SO_2 program, there has been 100 percent compliance and no need for enforcement actions through 1996 (ELI, 1997). Lower enforcement costs increase the likelihood of market incentive-based program success (Hoag and Hughes-Popp, 1997).

The above discussion is summarized in Table 3 on the following page. Essentially, the institutional and design components (columns 1 and 2) are the framework (structure) of the program that determines how a program will be implemented. Column 3 includes the list for the implementation (how the program is conducted) or transaction costs of participating in the program. The components in this column are the procedures that are required for a trade to occur. When the key institutional and design components (structure) are present than the implementation of this market incentive-based trading program can be implemented with relatively simple, inexpensive, and straightforward procedures that facilitate trading. Conversely, if one or more of the institutional or design components is missing, trading is less likely to occur because the resulting procedures will be more time-consuming and/or expensive to implement.

Institutional	**Design**	**Implementation**
Property Rights and Institutional Framework	Trading Unit	Initial Transaction Costs
Goals	Trading Ratio	Information Costs
Open or Closed System	Opt-in Provisions	Monitoring Costs
Economic Incentives	Banking	Enforcement Costs
Compliance Flexibility		

Table 3. Key Components for Successful Market Incentive-Based Trading Programs

With the existing air emissions programs, there has been a division of the implementation costs between government agencies and emitters. Both have experienced some increase in costs for implementing successful trading programs. However, the benefits and cost savings of implementing the program appear to (as compared to the command-and-control approach) have exceeded the increased expenses incurred by either government agencies or polluters.

All twelve of the key components in Table 3 will be used in a comparative analysis of existing national, and regional or pilot programs. The assumption is that if the institutional and design components are present and implementation costs are low, than the program is a successful trading program. And, therefore, the market incentive-based trading program is reducing environmental pollution at less cost than would be achievable under the historic command and control approach to environmental protection. This framework will be used to evaluate the national sulfur dioxide trading program in this chapter as well as the case study programs presented in Chapter 3.

Although who bears the cost of implementation and liability are important, they are not addressed in Table 3. In the air allowance trading programs, monitoring costs are born by the regulator and the participating sources. Each source is liable for its own performance regarding creating and using allowances. In the pilot nutrient trading programs where trades have occurred, the point source has the liability for obtaining, maintaining, and monitoring the nonpoint source discharge reduction as part of its NPDES permit requirements. The state has also increased BMP and ambient monitoring as a result of the trading program.

Section 2B: Observed Structure—U.S. Air and Water Property Rights and Institutional Frameworks

While the previous section (2A) focused on property rights and institutional structure as developed in the literature, this section will focus on observed property rights and institutional frameworks for air and water quality programs in the U.S. The observed property rights are formed by the public policies developed through statutes, rules and administrative procedures that form the institutional framework for each program.

The air and water property rights structure review will examine the history of air and water pollution program development and describe the similarities and differences between air and water property rights. The literature review will be discussed in narrative form. In addition a summary table for each media will be developed, indicating who has rights, who has obligations, whether the property rights are non-attenuated, and if the property rights are attenuated, which of the four required conditions for non-attenuated rights is not met.

The air and water institutional frameworks review will use the statutory, regulatory, and agency guidance documents, existing program literature, and research literature to identify the similarities and differences between the statutes with regard to the existing institutional framework[15]. In addition to the narrative, a summary matrix will be developed for media protection goals, ambient standards, emissions standards, the regulatory agencies, and regulatory requirements for compliance for each statute specific to sulfur dioxide and phosphorus/nitrogen for air and water respectively.

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[15] Judicial review and action have also contributed to the evolution of the air and water institutional framework. However, a review of case law is not undertaken in this research.

Evolution Property Rights to Air

Air emissions have been a problem since before the industrial revolution (Boubel, Fox, Turner and Stern, 1994). The smoke from burning coal for home heating and industrial processes like smelting lead, firing pottery kilns, and smoking fish all caused smoke and ash air pollution. During the industrial revolution, Great Britain took the lead in addressing the problem. Smoke and ash abatement was considered to be a responsibility of the health agency in Great Britain as evidenced in the first Public Health Act in 1848 and later Acts in 1866 and 1875 (Boubel, et al, 1994).

The United States took a different tact, though it also considered air pollution to be a public health issue. Smoke abatement, as air pollution control was then called, was considered a municipal responsibility. The first municipal ordinances were enacted in the 1880s and focused on non-domestic sources such as industrial, locomotive, and marine activities. In Meuse Valley, Belgium (1930), Dorora, Pennsylvania (1948), and London, England (1952) air inversions trapped polluted air over communities and resulted in many deaths (Kupchella and Hyland, 1993). These events triggered more research and efforts to control and regulate anthropogenic sources of air pollution. The first state to enact an air pollution regulation was California in 1947 (Boubel, et al, 1994).

As smog problems worsened in Los Angeles and began to appear in other major cities, the United States enacted the first federal air pollution statute. This 1955 legislation provided support for research, training and technical assistance and was administered by the Public Health Service. In 1970, the Environmental Protection Agency became the administering agency for air pollution control. The statute was amended and extended several times from inception through 1977 (Boubel, et al, 1994).

U. S. Air Property Rights and Regulatory Program Development

Since the formation of the nation, air has been considered a public good available for breathing and for emission releases from domestic, industrial and agricultural sources. It is only in the last half of this century, because of crises such as deaths and illness from temperature inversions over smog-laden cities, that society has demanded better air quality and government has responded with regulations that define property rights to the air.

The air resource is a good example of an open access or public good regime. Individuals, industry and municipalities have the right to discharge pollutants into the air and no other users have the right to prevent it, unless the pollutants cause externalities that infringe on rights or health. Each polluter has privilege and the others have obligations.

With the passage of the Clean Air Act in 1970, the federal government often through agreements with state agencies has required certain industries (e.g., power plants, manufacturing companies, and incinerators) to obtain licenses to discharge pollutants into the air[16]. Therefore, these industries have the right to discharge up to the level on their permit and all others have the duty to accept that pollutant and the right to expect the pollutant to be the type licensed and to be only as permitted by license. In a dynamic process, the licensed polluters have the power to change the relationship with others and others have the liability of having to accept that change (Bromley, 1991).

Simultaneously, however, other polluters (i.e., individuals, vehicle drivers, and unlicensed industries such as gravel pits, lawn care companies, and agriculture) are free to emit pollutants into the air without a license. This open access or public good situation is the policy choice at this time. It is the result of many social factors and high administrative costs (Dales, 1968). It occurs, in part, because the transaction costs (information, monitoring, and enforcement costs) to permit individuals and small companies tend to be prohibitive (Stavins, 1995). As the technology to monitor and enforce emissions control at smaller scales improves, this situation may change. Today, these unlicensed air polluters have the privilege to pollute, but they have no right regarding the use rate of the resource, while others have no right or recourse to prevent air emissions (Bromley, 1991).

[16] Prior to the CAA of 1970, some state did some regulate air emissions in highly polluted areas (i.e., Los Angeles).

History of Water Property Rights and Regulatory Program Development

Water use property rights evolved differently from air rights. While air is essential for life, and perhaps because it is difficult to exclude users, it has been treated as an open access or public good resource available to all users. While water is essential for both animal and plant survival, it is also critical for commerce, industrial production and transportation.

The federal government has the authority to enact legislation to regulate water based on the *commerce clause* (Article 1, section 8, Clause 3) of the United States Constitution, which authorized the federal government to regulate activities that effect interstate commerce (Braddock, 1995). Congress has a 100-year history of legislation to protect water use. In 1899, Congress passed the Rivers and Harbors Act protecting the nation's waters to preserve navigation. (Shipping was the primary means of transporting people and supplies at that time.) Only in the past fifty years has Congress enacted water quality protection legislation.

The initial response of the federal government to water quality problems was to enact legislation to facilitate state activities to protect water quality. In 1948, the federal government enacted the Water Pollution Control Act that gave state and local governments technical assistance funds to promote activities to protect water quality. At that time water pollution was viewed as a state and local government problem so there were no federal goals and objectives, or even limits or guidelines. The Water Quality Act of 1965 made states responsible for setting water quality standards for interstate navigable waters (Copeland, 1999).

With regard to water use rights in the United States, the eastern half of the country (east of the Mississippi River) adopted a reasonable-use policy called the riparian doctrine. The western half of the United States adopted the prior appropriation doctrine. The assumption under both of these doctrines is that the water quality will be such that each user can use it as desired without incurring additional costs to improve the quality because of an upstream user (Braddock, 1995). For a more detailed discussion of water use (water quantity) rights see Riparian and Prior Appropriations Doctrines in Appendix B: Structure of U.S. Air and Water Programs beginning at page 162.

As with air quality protection in 1970, the federal government took another giant leap toward environmental protection with the passage of the Clean Water Act of 1972 (33USC 1251-1321). This statute did not maintain the components of the previous laws; instead, it set up new laws that established a federal program for protecting and restoring water quality. The statute was ambitious and set lofty goals of eliminating discharges to the nation's waters by 1985 and achieving fishable and swimmable water quality by 1983 (33USC1251). The 1972 statute (P.L. 92-500) made it illegal to discharge a pollutant without a permit, strengthened the water quality standards system, encouraged the use of best achievable pollution control technology (BAT) that is economically achievable, a

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and provided billions of dollars for construction of sewage treatment plants (Copeland, 1999b).

The 1972 statute also introduced section 208 to address areawide planning and plans to control nonpoint sources[17] of pollution from agriculture and silviculture. The law required state to identify problem areas (i.e., stream reaches not meeting designated uses because of nonpoint source pollution), US EPA approval of control plans, creation of 208 planning organizations, and implementation funding from the federal government. When the federal funding was cut in the early 1980s, the program lost support and interest until additional funding was added with the 1987 amendments (Black, 1996).

The 1987 Clean Water Act Amendments (P.L. 95-217) strengthened requirements on toxic pollutants and allowed states to assume responsibility for federal programs. The Act focused on point sources of pollution (i.e., wastes discharged from identifiable sources such as pipes and ditches). Little attention was focused on nonpoint sources despite evidence that it represented over 50 percent of the water pollution problems (Copeland, 1999a).

The 1987 Clean Water Act Amendments (P.L. 100-4) authorized activities to address nonpoint sources of pollution and directed states to develop nonpoint

[17] Nonpoint sources of pollution include runoff from agricultural and forest lands, as well as construction site and urban runoff.

source management programs under section 319 (33USC1329). Federal financial assistance is provided to states to administer the program and provide funds for planning, demonstration projects, and nonpoint source pollution control activities. The grants may cover up to 60 percent of the implementation costs (Copeland, 1999a).

The Clean Water Initiative was released in February 1998 to improve and strengthen water pollution control efforts. The Initiative identifies over 100 actions to improve point and nonpoint pollution control and received $121 million in FY 1999 to increase nonpoint source pollution grants under section 319 (Copeland, 1999b).

U. S. Water Property Rights and Obligations for Industries, Agriculture and Individuals

In the United States the right to discharge pollutants into a water course is controlled by the Clean Water Act. It is unlawful to directly discharge pollutants into the waters of the nation unless the discharge is authorized by a permit. This permit process is established under section 402 of the Clean Water Act through the National Pollutant Discharge Elimination System (NPDES) program (33USC1342). Nationwide some 65,000 industrial and municipal (i.e., publicly owned treatment works) dischargers must obtain permits. Nonpoint sources of pollution are not subject to the NPDES permitting requirements. Any permitting that may be required for nonpoint sources of pollution, either urban (stormwater permits) or agricultural (confined animal feeding operations), are addressed by sta

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state programs for runoff planning and management under section 319 of the Clean Water Act (Copeland, 1999a). Therefore, point source dischargers have a use right to discharge through an NPDES permit, while nonpoint sources of pollution have a privilege to discharge without a permit. Citizens and all other entities are obligated to recognize these permitted and un-permitted rights that may limit their right to a designated use of the water resource. Therefore, the rights of the citizens to clean water are diminished to the extent that permitted or un-permitted discharges occur.

The point and nonpoint sources of pollutants have differing rights or privileges in part because of the nature of the pollutant source. The nonpoint source discharges are so numerous and diffuse that it is difficult to identify and quantify individual nonpoint sources. Point source discharges can be measured at the end of the pipe, while nonpoint sources can be measured in the water body. Under the current state of the science, models and calculations of edge-of-field runoff are used to determine the environmental impacts of installing best management practices to control nonpoint source discharges or runoff into a water body.

More importantly, the difficulty resides in the inability to monitor and enforce controls of nonpoint sources. Since the methods of control are management-based rather than technology-based (as is the case for point sources), the control is achieved through land management practices and local ordinances (Black, 1996). The number of nonpoint sources (e.g., fields, parks, lawns, parking lots, construction sites, etc.) that would need to be regulated also make monitoring and enforcement too costly.

Table 4 presents in summary form the property rights structure for SO_2 emissions in air for permitted and non-permitted sources (column 2) and for P and N in water for permitted and non-permitted sources (column 3). The four characteristics of property rights as listed in column 1 determine if a person has full or non-attenuated property rights, or if rights are attenuated because at least one of the four criteria are not met.

Property Rights Criteria	**Air Resources (SO_2)**		**Water Resources (P & N)**	
	Permitted	**Others**[a]	**Permitted**	**Others**[b]
Rights specified	Yes	No	Yes	No
All benefits/costs accrue	Yes	No	Yes	No
Transferable	Yes	No	No[c]	No
Enforceable	Yes	No	Yes	No

Table 4. Summary of Property Rights for Air (SO_2 emissions) and Water Resource (P and N discharges) Users

a—unpermitted sources such as motorized vehicles, small generators
b—nonpoint sources such as rural (agricultural) and urban (stormwater runoff)
c—Permitted in this table refers to dischargers with P and/or N discharge limits and not to prior appropriation doctrine users regarding selling a quantity of water for other uses.

Property Right Matrix for Air and Water Resource Users Regarding SO_2 Emissions and Nutrients (P and N discharges)

In the case of permitted sulfur dioxide emissions, all four criteria are met. The right to emit some level of SO_2 is specified and all benefits and costs for this property right come to the permitted source. The permitted sources may transfer the right to emit SO_2 through sales (allowance trading) or use the allowance in another timeframe (banking). Finally, the right to emit is enforceable, that is, emissions are continuously monitored and use of more allowances then what is in the permit results in fines and penalties. Therefore, permitted SO_2 sources have unattenuated property rights. Non-permitted sources have none of these rights with regard to SO_2 emissions. Though non-permitted sources have the privilege of emitting without a permit, these rights are not specified, and all benefits and costs do not accrue to them (breathers pay the cost of polluted air). The non-permitted sources cannot transfer rights that have not been assigned, and there is no enforcement (or monitoring) of the privilege to pollute.

Permitted dischargers of N and P have attenuated rights because they cannot sell or bank effluent discharges. They are permitted to discharge to a certain level but cannot transfer that right to another party. Therefore, their property rights are attenuated. This lack of transferability applies to permitted sources under either the riparian or prior appropriations doctrine for water quantity use. As is the case with others for air emissions, non-permitted sources of N and P discharges have the privilege to discharge without a permit. These privileges are not specified, all benefits and costs do not come to the polluter, the privilege is not transferable and there is no enforcement or monitoring of the privilege.

Since permitted SO_2 emitters have unattenuated property rights, they have the ability to participate easily in a trading program that is designed to reduce transaction costs. Sources in the SO_2 trading are in essence point sources of pollution and they trade allowances with other point sources (though anyone may purchase an allowance from the market). However, N and P dischargers that want to participate in a trading program are in a different property rights situation. Under current practices, even the permitted point source dischargers have attenuated property rights because discharges are not transferable. Further, nonpoint sources of N and P pollution have the privilege to pollute to the point where it becomes an offsite impact that causes others to take legal action. Therefore, the point-point trading model for SO_2 may not be suitable for point-nonpoint N and P dischargers.

Government Agencies' Roles and Responsibilities for Air Quality Protection Programs

The 1970 Clean Air Act Amendments created procedures for the US EPA to set national standards for air quality, required reduced automobile emissions, required use of best available control technology (BACT) for new sources, regulated air toxics, and expanded federal enforcement authority. The 1977 Clean Air Act Amendments substantially expanded the statute and added the Prevention of Significant Deterioration program to protect high quality air that exceeds the national standards (McCarthy, Parker, Schierow, and Copeland, 1999).

Title 42, Section 7401 of the US Code describes the Congressional findings and purpose of the Clean Air Act as follows: The findings relate to expanding pollution problems in urban areas, the related links to public health, and the roles of state and federal government. The section states the purposes and goal as protecting air quality and protecting public health, advancing pollution prevention programs and the role of all levels of government. A more detailed listing of the CAA findings, goal, and purposes are in Appendix B: Structure of U.S. Air and Water Programs, beginning at page 163.

The 1990 Clean Air Act Amendments

The Clean Air Act as amended in 1990 is divided into six Titles: air pollution prevention and control, emission standards for moving vehicles, general, acid deposition control, permits, and stratospheric ozone protection (42USC 7401-7671). Those sections pertinent to sulfur dioxide emissions trading are summarized below.

Section 109 of the Clean Air Act (42USC7409) requires the U.S. EPA to set National Ambient Air Quality Standards (NAAQS) for pollutants that are found across the country. These standards are set for six air pollutants: sulfur dioxide (SO_2), particulate matter, nitrogen dioxide (NO_2), carbon monoxide (CO), ozone (O_3), and lead. These are called criteria pollutants and the US EPA sets standards to limit emissions. The primary standards are established to protect public health while secondary standards protect welfare (e.g., environmental and property damage) (EPA, 1993).

Under the authority of section 110 of the Clean Air Act (42USC7410), each state submits a state implementation plan (SIP) detailing how it will proceed with air pollution prevention and control in the state, including how it will attain and maintain the standards set forth by the US EPA. This task is accomplished through inventorying sources and modeling emissions to determine if air quality violations will occur. If the models predict emissions in excess of the standards, then the state must impose additional controls on existing sources, and proposed new sources must obtain construction permits that show how they will avoid exceeding the standard for that pollutant. If an area has air pollution that exceeds the primary NAAQS for a criteria pollutant, then new sources and modifications to old sources must offset their emissions with reductions from existing sources (McCarthy, Parker, Schierow, and Copeland, 1999). If a state fails to submit or implement a SIP, the US EPA may impose sanctions that limit development or withhold federal highway grants. The plans must be approved by the Environmental Protection Agency or it can take over the program for that state by developing a Federal implementation plan (FIP) (EPA, 1993).

New Source Performance Standards (NSPS) must be established by the US Environmental Protection Agency under section 111 of the Clean Air Act (42USC7411). The NSPS are nationally uniform, technology-based standards that are set for categories of new industrial facilities. The maximum emissions level under the NSPS is based on the best *adequately demonstrated* continuous control technology available while still considering costs. This standard applies to major stationary sources such as power plants, steel mills and smelters (McCarthy, Parker, Schierow, and Copeland, 1999).

Another policy that affects SO_2 emissions is the prevention of significant deterioration (PSD) program as described in sections 160-169 of the Clean Air Act (42USC7470-7479). The purpose of the program is to protect air quality that is better than the required NAAQS, even if the new air pollution source would not violate the standards. The program divides clean air areas into three classes for management, and no state has established the program to date[18]. Only three of the criteria pollutants, sulfur dioxide, nitrogen dioxide, and particulate, have PSD standards. New sources in a PSD area must install best available control technology (BACT) that may be more restrictive than that required by the NSPS (McCarthy, Parker, Schierow, and Copeland, 1999).

Title I of the Clean Air Act Amendments of 1990 (42USC7413-7414) provides for federal enforcement, inspections and monitoring. Section 113 authorizes the Agency to issue orders requiring compliance and to impose penalties for violations of the act. New authorities added under the 1990 Amendments include raising some penalties from misdemeanors to felonies;

[18] If the state fails to implement the program in a timely manner, the US EPA would likely take an administrative action or citizen lawsuits would force government action.

allowing for administrative penalties, and authorizing a $10,000 award to persons providing information that leads to convictions under the Act (42USC7413). Section 114 authorizes the Agency to require sources to a) submit reports, b) monitor emissions, and c) certify compliance with the Act's requirements. In addition, US Environmental Protection Agency staff is authorized to conduct inspections (42USC7414). Like most federal environmental statutes, the Clean Air Act is enforced primarily by states and local governments that issue permits, monitor compliance, and conduct inspections. The federal government is a buttress for and has the authority to review state actions or to act independently in cases for which it concludes the state acted inadequately (McCarthy, Parker, Schierow, and Copeland, 1999).

Title IV of the Clean Air Act Amendments of 1990 (42USC7651-7651o) addresses acid deposition control and will be addressed in detail below. The other title that affects sulfur dioxide emission is Title V, Permits, which was added under the 1990 amendments (42USC7661-7661d). Prior to these amendments, only new sources or major modifications of major stationary sources (i.e., power plants and steel mills) were required to get construction permits under section 165 (42USC7475). Sources subject to permit requirements include major sources that emit or could emit 100 tons per year of any regulated pollutant (i.e., sulfur dioxide, nitrogen dioxide, etc). The permit indicates what air pollutants the source is allowed to emit. The source must submit a compliance plan and certify compliance for the permit, which must be renewed every five years. Holding a permit protects sources somewhat, as a permit provides that a source cannot be held in violation if it is complying with explicit requirements found in its permit (McCarthy, Parker, Schierow, and Copeland, 1999).

A summary table and discussion describing the statutory requirements for SO_2 emissions may be found in Appendix B: Structure of U.S. Air and Water Programs, beginning at page 164.

The United States Statutory Program for Sulfur Dioxide Allowance Trading

The statutory authority to implement a national sulfur dioxide allowance trading program is found under Title IV, Acid Deposition Control, of the 1990 Clean Air Act Amendments, Sections 401 through 416 (42USC 7651-7651o). (Hereafter called Title IV of the Clean Air Act.) The findings and purpose of Title IV recognize that acid deposition is an environmental and health risk that should be reduced. The goal is to reduce SO_2 emissions to 10 million tons below 1980 levels by 2010. (A detailed presentation of the Title IV findings and goal are presented in Appendix B: Structure of U.S. Air and Water Programs, beginning at page 165.) These reductions will occur by setting compliance requirements for specific sources[19] by certain deadlines. These reductions can be met through an emission allocation and transfer system (i.e., an allowance trading program).

[19] Sources in this context may include more than one affected unit generating SO_2 emissions.

The national sulfur dioxide allowance trading program is unique, detailed and complex. It involves complex calculations to determine the allocation of allowances for each affected unit[20] listed in a table for both Phases I (1995-1999) and II (2000 and beyond) (42USC7651c(e)3 and 7651d(g)2). This program is a significant departure from the command and control approach to environmental policy and regulation. Though market incentive-based approaches have been tried on a limited basis for transitional air quality programs and within the context of the command and control approach, this national trading program is the first United States statute to take this approach (Tietenberg, 1998).

Since 70 percent of the total SO_2 emissions in the United States come from electric utility emissions, the allowance trading program targets those emitters (Soloman, 1998). The first phase, from January 1, 1995-December 31, 1999, is targeted at the largest fossil-fuel burning units (electricity generating power plants that have more than 100 megawatts of capacity and are emitting SO_2 at a rate higher than 2.5 pounds per million Btu's of energy output) (42USC7651c). Phase I requires 263 burning units to participate and reduce emissions to 2.5 pounds per million British Thermal Units (mmBtu's). However, because affected units that would be required to participate in Phase II could opt-in to Phase I, 445 affected units participated in the program in 1995 (McLean, 1997). Phase II, which began on January 1, 2000, will affect more than 2000

[20] Affected unit means a unit that is subject to the emission reduction requirements or limitations of Title IV of the 1990 Clean Air Act (42USC7651a(1).

units and require all units to reduce SO_2 emission to 1.2 pounds per mmBtu's (McLean, 1997; Kerr, 1998).

The structure for the SO_2 allowance trading program is also established by Title IV of the Clean Air Act. Each operator of an affected unit is given a permit that allows emissions up to the allowance calculated and allocated by the US EPA. The goal of the program is to cap by 2010 total SO_2 emissions such that they are 10 million tons below the 1980 level of 25.9 million tons (McLean, 1997). Phase I begins the reduction process, and the statute requires that the reduction be pro rated among affected units. In 2000, the US EPA will allocate a maximum of 8.90 million allowances annually to assure that the goal is achieved (42USC7651b(a). Each affected unit must be permitted under Section 408 in Title IV of the Clean Air Act and, through that five-year permit, obtain allowances to cover actual emissions for each year (42USC7651g(a). The affected units are subject to the requirements of the other titles of the 1990 Clean Air Act including demonstrating that each unit can meet primary or health-based NAAQS, new source performance standards, and Prevention of Significant Deterioration provisions (McLean, 1997). Annual emissions in excess of allowances will result in a fine of $2000 per ton of SO_2 emissions over the permitted level and deduction of that number of allowances for the next year (42USC7651j). This fine does not limit the ability of the US EPA or a state or local permitting and regulatory authority to levy other fines authorized in Title I of the Clean Air Act (42USC7407).

In addition to the allocated allowances, an operator of an affected unit may obtain SO_2 allowances through three other sources. The US EPA withholds 2.8 percent of the allowances from the allocation process. Some are sold at $1500 per allowance in direct sales, and others are hold at an annual auction (42USC7651o) on the Chicago Board of Trade. Title IV of the Clean Air Act also provides for issuing bonus allowances for conservation and renewable energy efforts, using flue gas desulfurization system (e.g., scrubbers), and for early reduction credits (McLean, 1997). Finally, operators of affected units (or anyone else) may buy and sell allowances from other allowance holders. If an operator knows that actual unit emissions will be less than the allowances held, than excess allowances may be sold, traded, or banked for future use (42USC7651b(b).

If public health and the environment are to be protected, then the US EPA must be able to monitor emissions and enforce the requirements of the Clean Air Act. This issue is addressed through the continuous emission monitoring system (CEMS) required in section 412 (42USC7651k) and detailed in regulations issued in January 1993 and finalized to streamline and simplify the program on November 20, 1996 (40 CFR 75). Each operator is required to install, operate and assure the quality control of a CEMS for its affected units, keep records and report this information to the US EPA. Failure to do so would result in fines on uncontrolled emissions (42USC7651k).

Since there is a cap on total emissions from all affected units that must reduce emissions to meet the cap, there is a value and a market for allowances. Any person may buy an allowance that an affected unit may choose to sell. In addition, as new affected units come on line after January 1, 2000, they will need SO_2 allowances to operate. These new affected units are not allocated allowances like existing units. Rather, under Title IV of the Clean Air Act, they must obtain allowances from any entity that holds them (42USC7651b(e).

Regulatory Program for Sulfur Dioxide Allowance Credit Trading

Though the US EPA administers Title IV of the Clean Air Act, the primary implementation and regulation of permitted sources is carried out by state and local governments. As has been the policy of the federal government since the need for air pollution control was identified, the federal government sets the standards and provides technical assistance and funding to state and local government programs. Only with the passage of the Clean Air Act Amendments of 1990 has the federal government mandated permits for the operation of major sources of air pollutants (which is a state government implemented program) and pursued administrative penalties in enforcement actions for non-compliance with the Statute (McCarthy, Parker, Schierow, and Copeland, 1999).

Each state, as part of its state implementation plan (SIP) under Title I of the Clean Air Act must also submit a plan describing how the state will implement the SO_2 allowance trading program (42USC7661a). A state may establish a program with stricter standards and requirements than the federal Clean Air Act; however, it may not have a program with lower standards and requirements. The SIP must include how it will fund the program, including permitting, compliance and ambient air quality monitoring and enforcement provisions. Under section 114 of the Clean Air Act, the US EPA administrator or an authorized representative has monitoring and compliance authority for any permitted facility (42USC7414). This authority includes the right to enter any facility, examine and copy air permit required records, as well as access to inspect monitoring equipment and sample any emissions that the operator is required to sample. Each state can submit a procedure to carry out these functions and if the procedure is approved the state is delegated the authority to carry out this section (42USC7414).

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Key Components	**Title IV SO_2 Trading Program**
Institutional	
• Property rights and institutional framework	Clearly defined for affected units
• Goals	Lower SO_2 by 10 million tons[a]
• Open or closed system	Closed system w/emission limit
• Economic Incentives	Yes
• Compliance Flexibility	Yes Internal and External
Design	
• Trading unit	One ton of SO_2 = one allowance
• Trading ratios	No
• Opt-in provisions	Yes for defined sources
• Banking	Yes internal or traded
Implementation /Transaction Costs	
• Initial transaction Costs	Yes new rules of exchange
• Information Costs	Yes registry and auctions
• Monitoring Costs	Yes initial expense and reporting
• Enforcement Costs	Yes minimal[b] 100% compliance

Table 5. Market Incentive-based Program Components Comparison to the Title IV Sulfur Dioxide Allowance Trading Program

a = SO_2 emissions were to be reduced by 10 million tons below the 1980 levels of 25.9 million tons. b = Costs were present but minimal for inspections, audits of allowance systems, etc.

Comparing the Title IV Sulfur Dioxide Allowance Trading Program to Key Components of a Market Incentive-based Program

The key components of a market incentive-based trading program, as found in the environmental economics literature, were discussed earlier in this chapter. Essentially, the institutional and the design components are all part of the structure that determines how a program will be implemented. The implementation/transaction cost components are the procedures that are required to achieve a trade under that structure. The components are summarized in the left column of the table below and the sulfur dioxide trading program is compared to each component. The above table lists the key components required for a successful market incentive-based program in column 1 and indicates how well the SO_2 emissions trading program matches those components.

The SO_2 allowance trading program meets all five institutional components. For the sources participating in the program, property rights are unattenuated and the institutional structure is clearly define in the federal statute. The goal is a permanent reduction of SO_2 emissions by 10 million tons per year below 1980 levels, which is sufficient to create a need to participate among sources. This closed system provides economic incentives to participate (allowances have an economic value) and compliance flexibility. Since each source is given a performance standard instead of a technology standard to meet, there is an incentive to continuously reduce emissions. Both internal flexibility (choice of operational practices/technologies to reduce emissions) and external flexibility (choice to buy, sell, or bank allowances to optimally plan for upgrades and future allowance needs) increase the options available to economically achieve more environmental benefits.

The SO_2 allowance trading program also meets all five design components. A clearly defined trading unit or allowance facilitates ease of trading as does no trading ratios. (As noted previously, trading ratios increase the cost of trades and therefore decrease the likelihood of trades). The opt-in provisions, though limited to stationary sources, do expand the number of required participants in the market and therefore enhance the likelihood of trades. Banking adds more flexibility to the sources' ability to achieve emissions reductions through either banking credits for use internal to the source or for external sale at a future date to other sources or new sources that need allowances to operate.

With all of the above components in place, the sources have an institutional framework that facilitates program implementation. While there are transaction costs for participating in the SO_2 market, these costs are minimal because of the supportive framework of the program. There are some initial costs in learning and implementing the new rules of exchange. These costs are born by the SO_2 sources. There are information costs for the SO_2 sources, but these information costs are reduced because the trading system is tailored to the needs of the sources targeted to participate in the program. The information costs include using a registry for the buying, selling, and using allowances. The monitoring costs are born by both sources and regulatory agencies. The sources must install continuous emissions monitoring systems and report the results to the regulatory agency. The regulatory agency has the cost of establishing the recording system for the source monitoring data and ambient monitoring data (to determine the environmental impacts as a result of the program). This monitoring expense has been relatively minimal compared to the command-and-control approach. Enforcement costs are born by the regulatory agency. These costs have been minimal because of the transparency of the trading system (anyone can check and see what allowances a company has and can emit) and 100% compliance with the program.

Government Agencies' Roles and Responsibilities for Water Quality Protection Programs

Under the Federal Clean Water Act (33USC1251-1387), the US EPA is charged as the chief administering agency regarding pollutant discharges. One exception is for discharges of dredge and fill materials in a wetland, which are regulated in section 404 (33USC1344(a)1). In that case, the US Army Corps of Engineers is the lead agency, subject to environmental guidance and veto power vested in the US EPA (33CFR§320.2).

The Clean Water Act is a technology-based statute that requires regulated sources to use prescriptive technologies to control discharges. The concept of best practicable control technology (BPT) is used primarily for controlling conventional pollutants such as suspended solids, biochemical oxygen demanding materials (e.g., phosphorus, nitrogen, and organic matter), fecal coliform and bacteria, and pH. Conventional pollutants are those that are naturally occurring in the environment and that deplete the dissolved oxygen supply in the water that is necessary to support fish and other aerobic aquatic life. In the case of industrial sources after 1989, the act requires greater than BPT pollutant abatement. This higher technology standard is termed best available technology (BAT) that is economically achievable. The BAT control level focuses on toxic substances (Copeland, 1999b). Publicly owned treatment works (POTW) are required to meet similarly high standards by installing secondary treatment systems that break down organic pollutants and remove 80 to 90 percent of the oxygen demand and suspended solids before discharge to the environment (Moore and Moore, 1976).

A higher level of pollution control is required as technology improves to reduce discharge into the waters of the United States (Copeland, 1999b). For example, some POTWs now have tertiary treatment systems that chemically treat the effluent, reducing the oxygen demand of the effluent by removing inorganic materials such as phosphorus and nitrogen, before it is discharged. This higher standard may be required for a POTW to expand in a watershed where degraded waters are not currently meeting designated uses or to produce high quality waters for use as a public water supply downstream (Moore and Moore, 1976). While secondary treatment removes up to 50 percent of total nitrogen and 30 percent of total phosphorous, tertiary treatment can remove 90 to 95 percent of the phosphorus through precipitation techniques and up to 86 percent of the nitrogen through a denitrification process (Manahan, 1991).

Though the NPDES permitting process has improved water quality, it is a prescriptive process in that US EPA approves the technologies to be installed, with no incentive for innovation to reduce discharges. NPDES permits include the control technology to apply to each pollutant, the numerical effluent limitation[21] a point source discharge must meet, and the deadline for compliance. Permitted sources must also maintain records and regularly monitor discharges. For new sources, the effluent limit is called the standard of performance.[22] Permits are issued for five years and must be renewed to continue to discharge. As of January 1999, 43 states have been delegated authority to administer the NPDES permit program. The US EPA issues permits for the remaining seven states (Copeland, 1999b).

The governor of a state may submit a proposal for administering the NPDES program under state law or interstate compact to the Administrator of the US EPA. The State water pollution control agency administers the program to meet the requirements of sections 1311, 1312, 1316,1317 and 1343 and the permit requirements of section 1318 of the Clean Water Act (33USC1342). The proposal describes the state program, procedures and statutory authority that will be used to administer the NPDES program.

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[21] Effluent limitation is a restriction established by US EPA on the quantities, rates, and concentrations of chemical, physical, biological or other constituents discharged from a point source, other than new sources, into water (40CFR401.11(i).

[22] Standard of performance is any restriction established by the US EPA under section 306 of the Clean Water Act on quantities, rates, and concentration of chemical, physical, biological, or other constituents which are or may be discharged from new sources (40CFR401.11(k).

U.S. Statutory Requirements for Nitrogen and Phosphorous Discharges

The US EPA considers nitrogen and phosphorus to be *pollutants* that may need to be regulated to protect water quality (US EPA, 1998a, p. 12). As such these plant nutrients are the focus of the proposed new water quality criteria that would be used for determining if water bodies met designated uses and for Total Maximum Daily Load determinations (US EPA 1998b). Nitrate nitrogen has an ambient standard of 10 mg/l to protect drinking water supplies. While there is no ambient standard for inorganic phosphorus to protect water quality, there is a discharge standard for total P. The total P standard is 1 mg/l maximum monthly average for the effluent discharge[23]. For nitrogen, the discharge limit for nitrates is addressed through an unionized ammonia criterion of 320 μg/l for cold water and 420 μg/l for warm water resources[24].

Each point source discharge is required to obtain and comply with the requirements of the NPDES permit issued by the state regulatory agency. This requirement includes complying with the limits established in the permit and the monitoring and reporting requirements. The permit requires monitoring of the volume of discharge flow per day and of the amount of the pollutant released. Records of the day, date and time samples are taken, the methods and

[23] MDEQ administrative rule 323.1060.
[24] Telephone conversation with Sylvia Heaton, MDEQ Surface Water Quality Division, 5/15/2000.

procedures used for the analysis, and results of sample analysis are required. All monitoring records must be kept a minimum of three years, and the results of the monitoring must be reported at least annually to the regulatory agency (MDEQ, 2000). A person who submits false data for an NPDES application, form, or report and/or who fails to comply with the terms and conditions of the NPDES permit is subject to enforcement action i.e., fines and penalties (MDEQ, 2000).

There are several critical observations regarding the information in Table 6. Though the US EPA and a designated state agency regulate and/or administer programs for point sources of N and P discharges, nonpoint sources are not regulated. The nonpoint sources of P and N discharges have no emissions standards, permit requirements, compliance requirements, monitoring requirements, or enforcement actions (the exception is an environmental problem like a fish kill from runoff pollution). Therefore, as indicated earlier, nonpoint sources of P and N have the privilege to pollute. At the same time, point sources have a regulatory program with emissions standards, permit requirements (NPDES through water quality standards), and compliance, enforcement and monitoring requirements (NPDES permits). This dichotomy in property rights limits the ability of a government agency to implement a consistent control policy for all P and N discharges. This difference in property rights (structure) implies that different control programs (implementation strategies) are being used for point and nonpoint sources of P and N. Therefore, establishing a point-nonpoint nutrient trading program may require different strategies than the point-point SO_2 allowance trading program implemented under Clean Air Act.

Statutory Conditions	Phosphorus	Nitrogen
Ambient Standards	None for inorganic P	10 mg/l for nitrates[a]
Emissions Standards	Point Sources: 1 mg/l max. monthly average Nonpoint sources: None	Point sources: 320 µg/l in cold water; 420 µg/l in warm water Nonpoint sources: None
Regulatory Agencies	US EPA Delegated State Agencies (i.e., Depts. of Environmental Protection or Quality, Pollution Control Agencies	US EPA Delegated State Agencies (i.e., Depts. of Environmental Protection or Quality, Pollution Control Agencies
Permit Requirements major sources and POTW	Point sources: NPDES permit WQ standards Nonpoint sources: none	Point sources: NPDES WQ Standards Nonpoint sources: none
Compliance Requirements	Point sources: NPDES permit requirements Nonpoint sources: none	Point sources: NPDES permit requirements Nonpoint sources: none
Monitoring Requirements	Point sources: NPDES permit sampling and analysis rules Nonpoint sources: none	Point sources: NPDES permit sampling and analysis rules Nonpoint sources: none
Enforcement Actions	Point sources: NPDES permit subject to actions Nonpoint sources: none	Point sources: NPDES permit subject to actions Nonpoint sources: none

Table 6. Summary of U.S. and State Statutory Requirements for Phosphorus and Nitrogen Point and Nonpoint Source Discharges

a = safe drinking water act public health protection standard

Statute Program Policy for Nitrogen and Phosphorous Discharge Credit Trading

There is no federal statutory authority to implement nitrogen or phosphorus trading programs. For water quality programs to reap the benefits of market incentive-based trading, an institutional structure must exist, in essence, to create a market incorporating the key components identified earlier in this section. The US EPA has approved trading principles for specific water pollution problems on a limited basis (Jarvie and Solomon, 1998). In 1996, the US EPA issued the Effluent Trading in Watersheds Policy Statement. The statement supports trading *within the regulatory context* of the Clean Water Act (US EPA, 1996a). Later in 1996, the US EPA issued the Draft Framework for Watershed-based Trading (US EPA, 1996b).

The US EPA framework has identified eight principles for effluent or nutrient trading which are listed below (US EPA, 1996b). A summary of each principle is presented in Appendix B: Structure Of U.S. Air and Water Programs, beginning at page 166.

Principle 1. Trading participants must meet the minimum applicable Clean Water Act (CWA) technology-based standards.

Principle 2. Trades must be consistent with water quality standards throughout the watershed as well as meet the requirements of the CWA, other federal and state laws, and local ordinances.

Principle 3. Trades are developed within a TMDL or other equivalent analytical and management framework.

Principle 4. Trades must occur within the current regulatory and enforcement mechanisms.

Principle 5. Trading boundaries generally coincide with watershed or water body segment boundaries, and trading areas are a manageable size.

Principle 6. Trading will generally add to existing ambient monitoring.

Principle 7. Careful consideration is given to types of pollutants traded.

Principle 8. Stakeholder involvement and public participation are key components of trading.

Both the CWA and EPA regulations require public notice and comment procedures or hearings for various aspects of the effluent trading process. Involving stakeholders and the public in the process of establishing a trading program advances better management approaches and more effective environmental protection.

Regulatory Program for Nitrogen and Phosphorous Discharge Credit Trading

There is no national regulatory program for discharge credit trading, only guidance documents. Several states, such as Michigan and those with the trading programs presented in Chapter 3, are in the process of developing or have developed rules to establish state discharge trading programs. Since these programs complement existing point source regulatory programs, they may use existing compliance requirements and enforcement actions (Jarvie and Solomon, 1998).

Comparing Key Components of a Market Incentive-based Trading Program and Nitrogen and Phosphorous Discharge Credit Trading

A comparison of the institutional framework in the Draft Watershed-based Trading guidance (applicable to both P and N) to the key components for a successful market incentive-based trading program is provided in Table 7.

Key Components	**Draft Framework for Watershed-based Trading (Phosphorus Nitrogen)**
Institutional	
• Property rights and institutional framework	Defined for NPDES dischargers; not defined for Nonpoint sources
• Goals	Water quality standards
• Open or closed system	Open system w/effluent limit
• Economic Incentives	Yes
• Compliance Flexibility	No
Design	
• Trading unit	Not defined
• Trading ratios	Defined case-by-case
• Opt-in provisions	No
• Banking	No
Implementation /Transaction Costs	
• Initial transaction Costs	Yes high; modify NPDES permits
• Information Costs	Yes hard to find partners
• Monitoring Costs	Yes increased expense & reporting
• Enforcement Costs	Yes

Table 7. Market Incentive-based Program Components Comparison to the Draft Framework for Watershed-based Trading

Beginning with the institutional components the comparison shows that, the property rights and institutional framework are defined for point sources of P and N discharges but not for nonpoint sources. There are economic incentives for point-nonpoint source trading but they are based on the difference in cost of installing discharge controls between point and nonpoint discharges as compared to economic incentives in the program framework that create economic incentives. There is no compliance flexibility for either point or nonpoint sources. The watershed based trading program is designed to complement the existing technology-based regulatory program and therefore provides no internal compliance flexibility. External flexibility is also eliminated because there is no incentive to reduce emissions below those prescribed by permit or economic incentives to create a market.

Regarding design components, there are no national standards for trading units or trading ratios as no programs have been established through federal statutes. Trading ratios have been established on a case-by-case basis in pilot studies. Further, there are no opt-in or banking provisions in the Draft Framework for Watershed-based Trading.

Since all the key components in the structure of a successful market-incentive based program (institutional and design components) are not present, the implementation components or transaction costs under the Draft Framework for Watershed-based Trading are impacted as well. Initial transaction costs are very high because NPDES permits need to be modified, which is a time consuming process, to accommodate trading. Information costs are also high because it is difficult for a point source interested in trading with a nonpoint source to find a willing nonpoint source trading partner upstream from the point source. No registry or other mechanism exists to identify potential nonpoint source trading partners or the amount of nutrient they may be eligible to trade.

In the case of a trade, monitoring costs would also be higher. The point source would be required to increase monitoring at the nonpoint source location and report the results along with assuring the maintenance of the nonpoint source control measure. The regulatory agency would be doing more monitoring of the ambient conditions around the point and nonpoint source discharge to assure that degradation or problem conditions did not develop. Enforcement costs also increase compared to the command-and -control approach. For the regulator, the costs include identifying the nonpoint source control practices that are acceptable in a trade, determining the nutrient reduction that can be achieved along with the trading ratio for each trade, approving the trade, and modifying the point source NPDES permit. The point sources may be required to inspect the nonpoint source controls as well as do additional compliance monitoring. Because f the Draft Framework for Watershed-based Trading is not consistant with the key components of a successful market incentive-based program, it is unlikely that an economically and environmentally effective watershed-based trading program could be implemented under this guidance document. Several pilot projects, which will be examined in some detail in Chapter 3, have been initiated under this framework. Their level of success should be indicative of this problem.

Comparison of Federal Statutory Framework for Air and Water Quality Protection Programs

Another factor that is a critical part of the institutional framework for these programs is the national policies espoused in federal statutes with the goals, regulatory requirements for pollutants and state regulators, planning requirements, and the implications for trading programs. The following table provides a brief summary of those policies. In comparing the policies of the two statutes, clearly, the policy differences have implications for successfully implementing market incentive-based trading programs.

Comparison of U.S. Air and Water Institutional Frameworks

Factor	**Clean Air Act**	**Clean Water Act**
Goal	Protect public health	Minimum = fishable and swimmable waters Ideal = zero discharge
Regulates Pollutants	Yes. SO2 = Criteria pollutant	No NPDES permit standards for P and N (nutrient criteria)
Requires a plan	Yes. One state plan	Yes. Multiple plans by program
Regulator	One regulatory agency	Multiple regulatory agencies
Trading program	Yes	No. Guidance Document

Table 8. Comparison of U.S. Air and Water Institutional Frameworks

The first obvious and significant difference in the federal air and water statutes is that the goals are very different. Since its inception, the Clean Air Act was premised on the belief that air pollution was a public health and welfare issue. The purpose was always to enhance or protect public health and welfare, but no specific goals were set. On the other hand, since 1977, the Clean Water Act has had a very specific goal that calls for ceasing practices that may have been in place for many years. Ideally, the statute requires zero discharge into the waters of the country. This is a very lofty goal and one that would appear to eliminate all water pollution. At a minimum, the Clean Water Act sets a goal of all waters being fishable and swimmable. This is translated to mean that pollutant discharges cannot be such that the designated uses of full body contact recreation and a safe, viable fishery are impaired. Given the present state of the nation's water quality, this is a substantial goal that will require better management of both point and nonpoint sources of water pollution. The difference in goals alone is an indication that there may be differences in the programs implemented to achieve the goals.

The Clean Air Act regulates SO_2 as a criteria pollutant, while the Clean Water Act does not have an NPDES permit standard for phosphorus and nitrogen discharges. Rather N and P are controlled as "criteria pollutants" that are only included in an NPDES permit where required to meet a designated use. This difference in standards indicates that technology standards as opposed to performance standards for N and P discharges are in use. It would be difficult to implement performance standards when no performance standards exist.

Though each statute requires a plan for managing pollutants, each statute has a different approach. The Clean Air Act requires one plan for the entire state as to how it will address a criteria pollutant. However, the Clean Water Act requires multiple plans by program. For example one division in MDEQ develops a plan to implement the NPDES program while another division is delegated authority to plan and implement the wetlands permitting program. The same agency may administer several programs that regulate N or P discharges (i.e., NPDES for POTWs, pretreatment permits for industrial dischargers, and 319 plans with BMPs implemented to control nonpoint sources), but these programs are not required to integrate information and there is no single comprehensive watershed plan to address all water protection issues.

This piecemeal approach is reflected in state and local planning and management efforts. One program calls for remedial action plans while another calls for a nonpoint source management plans. Locally, drain commissioners may be implementing drainage plans in the same area where another local agency administers a soil and sedimentation control program, and yet another develops sewage treatment and stormwater management plans. This lack of coordination and integration complicates water protection and management.

The final significant difference in these statutes is that the Clean Air Act explicitly authorizes the implementation of a SO_2 allowance trading program, while the Clean Air Act has no such language to implement nutrient or effluent trading programs. In fact, only a US EPA draft guidance document exists with regard to nutrient/effluent trading. This omission significantly impacts the ability of state or local governments to implement P and N trading programs because it calls into question the first criteria for non-attenuated property rights—clearly specified rights of participants.

Summary of Findings regarding the Structure in U.S. Air and Water Protection Programs

Based on the review of property rights and institutional structure found in economics literature and the observed structure of the U.S. air and water Protection Programs, several observations can be made about the property rights and institutional frameworks of these programs. First, there has been a historical difference in property rights development. Air has been regarded as an open access or public good resource to be protected for human health and welfare purposes, while water has been highly valued for many uses (navigation, fisheries, recreation, water supply, waste treatment). This historical difference has resulted in different protection policies regarding each media. The 1977 Clean Water Act calls for zero discharge of pollutants into the water and at a minimum achieving fishable and swimmable standards for all water resources.

Reviewing the air and water institutional frameworks in more detail again reveals that there are differences in these frameworks that impact how an air or water quality trading program can be designed. Given the clear authority to implement a SO_2 allowance trading program in the Clean Air Act, a program that matches the key components found in the literature (Table 3, page 44) to achieve an economically and environmentally effect allowance trading program has been successfully implemented. Since the same authority to implement an effluent or nutrient trading program is not part of the Clean Water Act, the ability to implement an economically and environmentally effective program is limited. Additionally, the property rights for point and nonpoint sources of P and N discharges are not the same, therefore, the ability to implement a program that parallels the SO_2 program is limited. These differences in property rights structure and institutional frameworks for air and water media appear to make a nutrient trading program more difficult to implement.

Section 3: Conduct and Performance—Economic and Environmental Benefits of Market Incentive-based Trading

Introduction

This section of Chapter 2 addresses the conduct and performance of air and water pollution market incentive-based trading programs. It focuses on the economic and environmental outcomes from the Title IV sulfur dioxide trading program and pilot effluent trading programs.

Economic Benefits of Market Incentive-based Sulfur Dioxide Allowance Trading

Multiple studies have been completed on the economic benefits of SO_2 allowance trading, ranging from studies by government and industry (before the program was created by Title IV of the 1990 Clean Air Act Amendments) to analysis of the initial year of implementation and projections for the future (Burtraw, 1998, 1996; Bohi and Burtraw, 1997; McLean, 1997; Solomon, 1998). Regardless of the study, all reports show savings from the trading program when compared to the traditional *command-and-control* regulatory approach (Burtraw, 1998).

The economic benefits to the utility companies that are required to participate are the result of several factors. With allowance trading, participants have flexibility in determining how they will use allowances to cover their SO_2 emissions. The allowances may be allocated to them through the statute, purchased or sold on the market, or purchased from the annual US EPA auction on the Chicago Board of Trade. In addition, because each participating source is given the flexibility to determine how it will meet its emissions reduction requirements, it will choose the least-cost option based on the marginal cost of emissions control at the source. These options range from installing SO_2 scrubbers, to changing to low sulfur coal, or optimizing management practices to reduce SO_2 emissions.

For example, a study by economist Richard Schmalensee at the Massachusetts Institute of Technology concludes that because of the flexibility of the trading program, the cost of installing scrubbers is 40 percent lower than estimated in 1990 (Kerr, 1998). Burtraw reviewed many studies for his 1998 Resources for the Future discussion paper and determined the best estimate of annual saving from the trading program as compared to the command-and-control program to be about $780 million dollars annually (in 1995 dollars) or about 42 percent below the cost of the command and control approach.

By the year 2010, with full implementation of the SO_2 emissions reduction, projected economic benefits are expected to be $12 to $40 billion per year in benefits to public health and $3.5 billion annually from improved visibility (McLean, 1997). Several studies have tried to quantify the benefits to human health and the environment. For 2010, and using midpoint estimates of benefits, the majority of the economic benefits is attributed to reduced mortality due to exposure to sulfates ($69.25 per affected capita compared to $6.19 in costs per capita) (Burtraw, 1998). The primary study that was the basis of these estimates addressed only the 31 Eastern States in the United States (U.S. EPA Office of Air and Radiation, 1995). Therefore, it does not take into account substantially affected cities such as Los Angeles, California and Denver, Colorado.

However, the task of determining economic benefits is more difficult for environmental resources. There are not adequate economic or other social science methods for valuing all environmental benefits. Given inadequate methods, benefits have been calculated for aquatics, recreation, and residential visibility at $.72, $3.90 and $6.79 per affected capita, respectively for 2010 in 1995 dollars (Burtraw, 1998).

Environmental Benefits of Market Incentive-based Sulfur Dioxide Allowance Trading to the Public and the Environment

A US EPA study completed in 1995 (as required for Title IV of the Clean Air Act) on the human health benefits of reducing anthropogenic SO_2 emissions by 40 percent from 1980 levels indicates that the benefits will be substantial. The study made many assumptions and addressed only the 31 eastern states of the United States. However, at the means, the benefits appear significant. For 1997, 2,568 premature deaths are avoided; 3,864 new cases of chronic bronchitis are prevented; and 1.6 million asthma symptom days would be prevented. This study does not include the chronic symptoms of skin, eye and nose irritation that all humans experience when exposed to haze and smog produced by SO_2 emissions. The figures for 2010 are even more significant: avoided premature deaths, 9,678; prevented cases of chronic bronchitis, 14,564; and prevented asthma symptom days, 5.9 million.

The sulfur dioxide program is reducing emissions into the air but the benefits are hard to quantify. Study results announced by the US Geological Survey in June 1996 indicate that for large portions of the eastern United States, the amount of sulfur in the air has decreased by as much as 25 percent. Ambient concentrations of SO_2 have declined by 17 percent nationally between 1994 and 1995, and similar reductions are anticipated for 1996 (Lynch, Bowersox, and Grimm, 1996). Though acid rain and its effects on sensitive environments such as the Adirondack Mountains were a driving force for implementing the 1990 Clean Air Act amendments, there is little observable scientific evidence of reduction in lake pH and reduction of impacts to sensitive forests and soils. However, by 2010, the evidence suggests that no lakes will reflect an increase in acidity from anthropogenic sources of SO_2 outside of the sensitive Adirondack region of New York (McLean, 1997).

Economic Benefits of Market Incentive-based Nitrogen and Phosphorous Nutrient Trading

Given that market incentive-based programs for nutrient trading are in a case-by-case implementation and development stage, it is difficult to assess the full economic benefits that could be achieved from broader implementation. If a national statute enabled a program like sulfur dioxide emissions trading, more economic benefits could be achieved and assessed.

The opportunities for cost savings through trading are significant. One source estimates that the cost of point source reduction is 65 times higher than nonpoint source reduction (Bacon, 1992). For example, New York City estimates that it will cost $6-8 billion to upgrade its drinking water filtration system. By spending $5,000 on each of the 550 farms in the watershed ($2.75 million) to install the most advanced BMPs, New York could save billions of dollars. The

EPA (US EPA, 1993b) believes that if background pollution from agriculture were reduced, tertiary water treatment could be avoided at a savings to the nation of $15 billion (Faeth, 1996).

Economic benefits may also be obtained for the public. If a community is able to avoid or reduce public water supply treatment costs, as in the examples above, then citizens benefit with reduced costs or fees for public water supply services.

Environmental Benefits of Market Incentive-based Nitrogen and Phosphorous Trading

Trading can result in environmental benefits such as protection or expansion of wetlands, riparian corridors, and wildlife habitat. If point/nonpoint trading occurs, then nonpoint sources could put into place BMPs to produce such environmental benefits. This environmental benefit would not occur under the tradition regulatory approach to point source pollution controls. The benefits also depend upon the BMPs used (Podar and Kashmanion, 1998). For example, in the Rahr Malting Company trading case, riparian buffers and wetlands are being created as an offset for a downstream increase in BOD discharge. These new practices likely provide environmental benefits, however the benefits have not been calculated.

Section 4: Summary of Literature Review Findings

Using the situation, structure, conduct, and performance policy framework, several findings are apparent from the literature review. First, though air and water are different media with different attributes (situation), the pollutants of interest in this study, sulfur dioxide in air and phosphorus and nitrogen discharges in water, are found in the natural environment. The air and water media are capable of moving and assimilating these pollutants. The degradation that occurs in either media is the result of anthropogenic and natural causes that release excess amounts of sulfur dioxide emissions and phosphorus and nitrogen discharges in to the environment.

Air and water protection programs (structure) have evolved differently over time. The property rights structure for the two media has historically evolved differently. Air pollution has historically been viewed as a public health and welfare issue, while water pollution has been viewed as an environmental protection and public health issue. The stronger interest in water resources protection since the 1970's is because of the multiple, sometimes competing, uses for water resources and the desire to protect public health and the environment through specific environmental goals and policies. These historic policy differences have shaped the institutional framework for each media.

Both the air and water protection programs became much more environmentally proactive in the 1970s. These new policies set into place new command-and-control regulatory programs to permit and regulate major sources of pollution with technology-based standards in both media. These policies have persisted in both media through the 1990s. However, in 1990 the Clean Air Act was amended and, through Title IV, sulfur dioxide emissions became the first national performance-based regulatory program. The SO_2 emissions allowance trading program success has resulted in the use of the concept for other environmental program applications such as effluent or nutrient trading. However, since the U.S. Clean Water Act statute has not been changed to address trading program authorization, and the differences in point and nonpoint sources property rights, implementing a point-nonpoint nutrient trading program will be more difficult.

The success of the Clean Air Act policy change to permit SO2 trading (conduct and performance) has been well documented, while documentation for P and N nutrient trading is not as readily available. The economic benefits of SO_2 trading clearly exceed the benefits that could be achieved through the command-and-control approach. Similarly, the public health and environmental benefits exceed that which could be achieved under the command-and-control approach. The application and success of N and P nutrient trading programs has been much more difficult to determine. Since there is no national program, the evidence to date is based on modeling studies and a few pilot case studies that show environmental benefits but this evidence may not be sufficient to warrant a change in the national water protection institutional framework.

Chapter 3

RESEARCH DESIGN

Overview

The analysis uses the approach of synectics, a research method designed to promote the recognition of analogous problems. Synectics refers broadly to the investigation of similarities. Dunn (1994) pointed out that "people frequently fail to recognize that what appears to be a new problem is really an old one in disguise." If, as Tietenberg (1998b) has proposed, current difficulties being experienced by early water quality trading programs are similar to those experienced early in the air quality trading program, then investigating similarities between air and water programs will be useful for water program design and implementation. The research will also draw from natural and physical sciences, since similarities (or differences) may exist between air and water as two environmental media being used to receive waste discharges, or they may exist between the life cycles of air and water quality policy.

In addition to situation, structure or institutional factors will be considered in evaluating the similarities and differences between the air emissions credit trading and water pollution nutrient credit trading programs. For example, economic factors (e.g. transaction costs, number of participants, abatement costs, trading ratios) may explain why point-nonpoint trades had not occurred

(Hoag and Hughes-Popp, 1997) prior to 1997. In fact, there exist a number of institutional barriers to a successful point-nonpoint trading program for water quality (Shabman and Stephenson, 1998).

Section 1: Using a Synectics Approach to Policy Analysis

The original research work in synectics was to develop a creative process in problem-stating, problem-solving situations where new inventions were the result (Gordon, 1961, p.33). This creative problem-solving process uses four operational mechanisms that facilitate creative thinking by using the concept of making the familiar strange to get a better understanding of the problem. The four mechanisms are personal analogy, direct analogy, symbolic analogy, and fantasy analogy (Gordon, 1961, p. 36-56). These operational mechanisms can be and have been applied to public policy (Hayes, 1978 and Dunn, 1994). For the purposes of this research, the most appropriate mechanism is direct analogy. This analogy is the comparison of parallel facts, knowledge and technology.

Three procedures are used in synectics analysis: analysis, generalization and model-seeking or analogy. Analysis is examining the component parts of the problem. Generalization is identifying important similar patterns within the component parts. Model-seeking or analogy is using a similar model or experience to apply to a given problem (e.g., air emissions trading as a model for water pollution nutrient credit trading) (Prince, 1967).

This policy analysis will use direct analogy to compare the statutory language, program design features, and experiences of the sulfur dioxide emissions trading program in air quality to the point-nonpoint water pollution (nutrient) credit trading programs being developed and tested in water quality. The sulfur dioxide emissions trading program is the most successful example of a market incentive-based approach to environmental protection (McLean, 1997) and therefore the best direct analogy example to apply to the water quality program application.

Based on the key components for a successful market incentive-based program identified in the literature research in Chapter 2 (Table 3, page 44), analogies will be made between the most successful regional air emissions allowance trading program (RECLAIM) and the five existing point and agricultural nonpoint source water pollution (nutrient) trading programs. These five programs are: the Tar-Pamlico River Basin in North Carolina, the Dillion and Cherry Creek Reservoirs both in Colorado, the Fox River in Wisconsin, and the lower Minnesota River in Minnesota. Similarities will be identified, along with the merits of continuing those policies from a qualitative perspective. Important differences, in terms of both environmental protection and economic viability, in the statutes and programmatic design features also will be identified. The standards for important differences will be based on quantitative environmental protection criteria and qualitative socioeconomic factors identified in the literature research.

The Synectics direct analogy test will be applied at each level of the situation, structure, conduct, and performance framework. Situation includes those features of the world that must be taken as a given. In this research, the physical differences between air and water media and the characteristics of these goods and the services provided are the situation. Structure is the rights and obligations that policies produce to control or influence behavior with regard to the use of goods and services. This study will examine the property rights, the regulated exchange of air and water rights, the structure of the rights, and the enforcement of rights. Conduct is how people behave under a given policy structure. Who is allowed to participate within the policy structure? What are the incentives to follow the rules? What are the opportunity sets? Given the policy structure of air emissions credit trading and water quality nutrient trading, behavior or conduct can be examined. Performance is how well goals have been met by the public policy. In this analysis, are air and water quality goals achieved under a trading regime? At what cost and what benefits are the goals achieved? What performance measures and monitoring techniques are appropriate for air emissions credit trading and water quality nutrient credit trading?

Situation, structure, conduct, and performance will be evaluatied for the RECLAIM SO_2 air emissions allowance trading program and five water quality phosphorus/nitrogen nutrient trading programs. If the synectics direct analogy test shows that the situation is the same and the structure is the same, than one could reasonably expect the conduct and performance to be the same. However, if the analogy does not hold for all variables, then other institutional policies may be more appropriate to achieve the desired performance.

Section 2: Case Studies

REGIONAL CLEAN AIR INCENTIVES MARKET (RECLAIM): AN AIR EMISSIONS TRADING PROGRAM

Situation

Historically air pollution has been a problem in Los Angeles County[25]. The 1988 California Clean Air Act required all air districts with serious air pollution to adopt best available retrofit control technology (BARCT) for existing stationary sources. The statute also required all districts to achieve a five percent reduction in emissions. To address this requirement, the South Coast Air Quality Management District (SCAQMD) began the process of creating a market incentive-based program (Aplet and Meade, 1995).

Air pollution is still a severe problem in the South Coast Air Basin (SCAB). The basin includes the greater Los Angeles metropolitan area, including all or portions of Los Angeles, Orange, Riverside and San Bernardino Counties. Some 15 million people reside in the area and breathe some of the most polluted air in the country (SCAQMD, 2000).

[25] California created the first air pollution control district for Los Angeles County in 1946 legislation.

The area is frequently in violation of air quality standards for PM10, which can be emitted directly to the air or formed as a secondary pollutant in chemical reactions of SO_x, NO_x[26] and VOCs[27]. A 1993 South Coast Air Quality Management District (SCAQMD) study, using 1992 data, indicated that this air basin had higher annual average PM10 concentrations than any other area in the country (Johnson and Pekelney, 1996). In addition, at the time of the study, the area had been experiencing a serious recession, so any effort to improve air quality needed to be sensitive to the economic impacts of an emissions control program.

Structure

In October 1993, the SCAQMD Governing Board adopted the RECLAIM program. The program goal is to add flexibility in meeting emission reduction requirements and lower the cost of compliance. The RECLAIM program is designed to meet federal and state clean air program requirements(SCAQMD, 2000).

The RECLAIM program requires stationary sources that release more than 4 tons of NOx or SOx emissions per year to participate in the program (with several exceptions, such as essential municipal services). Each facility has an emissions cap for the entire facility instead of a permit for each source of NOx or

[26] Both SOx and NOx are short hand terms to denote more than one form of the compound e.g., NO_2 and NO_3.
[27] VOCs are volatile organic carbons e.g. benzene.

SOx (bubble policy[28]). Each facility also has a declining allowance. From 1994 through 2003 emissions from SOx sources are required to be annually reduced by 6.8 percent from 1992 base year levels (ACAQMD, 1993).

From concept development through rules development, the program took three years to develop. As was the case in the ten-year development process for the 1990 CAA Amendments, the RECLAIM program had input from citizens, industry, state and federal government, and environmental groups. At the start of the program, most environmental groups were not supportive[29] (Aplet and Meade, 1995). Since its implementation, the principle framework has not changed. However, RECLAIM has been modified to conform to federal air quality statutes for items such as an offset ratio of 1.2 to 1 for new sources of SOx and NOx emissions and use of Best Available Control Technology for new or modified sources with emissions increases (SCAQMD, 2000). Other emitting facilities below the threshold to mandate participation may opt into the program and have the advantage of one permit for all sources at the facility (bubble policy benefit).

The universe of stationary sources of NOx and SOx for the program began at 394 and 41 respectively. The 1998 annual audit report (SCAQMD,

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[28] The bubble policy allows existing plants with multiple emissions points or a group of plants to be regulated as a single source.

[29] The groups were concerned that the cap was not sufficient and that the safeguards were not adequate to prevent increased health risks in some areas. These concerns have not been the case under the RECLAIM program.

2000) indicates that 331 facilities were under RECLAIM in 1998. Of that total, 37 are facilities[30] participating in the SOx market. Each facility is issued an annually declining allocation of emission credits ("RECLAIM Trading Credits" or "RTCs") that constitutes an annual emissions budget. RECLAIM trading credits may be bought or sold as the facility deems appropriate. Facilities may also use emissions reductions credits generated by stationary sources not in the RECLAIM program, and mobile source emission reduction credits[31] may also be converted to RECLAIM credits up to the limit of the facility for that year (SCAQMD, 1998).

The South Coast Air Quality Management District is responsible for annually auditing the program, allocating RTCs, assuring that all facilities are complying with their emissions limits, and establishing a continuous emissions monitoring systems (CEMS) data storage system. The District also drafts revisions to the RECLAIM rules and monitors ambient conditions in sensitive areas to assure that degradation does not occur (SCAQMD, 1998). Finally, existing state laws and health and safety code regulations (sections 42400 through 42408) give the South Coast Air Quality Management District a range of civil and criminal actions including orders for abatement or injunctions, fines and penalties for violation of air regulations, and suspension and revocation of permits (SCAQMD, 1992).

[30] These facilities may also be participating in the NOx portion of RECLAIM.
[31] These credits would be comparable to a nonpoint source credit, if such credits existed in water quality trading programs.

Conduct

As a group, the facilities in the RECLAIM program have reduced actual emissions more than 6.8 percent required each year. These facilities have actively participated in the RTC trading and have installed SOx emissions reduction technologies. By participating in the program, each facility reduces the number of permits that it must submit and monitor and operates as a single source under a "bubble" for all facility SOx emissions. Emissions caps are lowered annually through 2003; after that they remain at the 2003 level. Facilities are developing more sophisticated means of monitoring and tracking actual emissions compared to allocated emissions and providing that data to the SCAQMD. Through annual audits of RECLAIM facility records, the SCAQMD has identified facilities that reduced emissions below four tons per year and were therefore no longer required to participate. Other stationary sources of emissions have been added to those required to participate in RECLAIM because of expansion activities, and some facilities have decided to opt-in to the program (SCAQMD, 1998 and 2000).

Performance

The RECLAIM program has been in operation since 1994. Annual audits and progress reports measure the accomplishments of the program and compare them to criteria identified in the development process. These program evaluation criteria include emissions reductions at or below what would occur under the air quality management plan and the traditional command and control regulatory approach; average annual price and availability of RECLAIM trading credits

(RTC); employment impacts; compliance issues; and air quality and public health issues (SCAQMD, 2000).

The findings from five years of annual reporting indicate that the program has been successful. Actual emissions have been below aggregate allocations of emissions each year (SCAQMD, 2000). These actual emissions were below the projected emissions in the state approved Air Quality Management Plans of 1994 and 1997. This reduction in emissions occurred at a lower cost than projected for the command and control approach (SCAQMD, 1998).

Since program inception, the average annual prices for SO_2 trading credits have fluctuated. However, these prices and availability of RECLAIM trading credits have remained well below the maximum levels established at the onset of the program (SCAQMD, 2000).

RECLAIM has had a minimal impact on employment. In the 1998 compliance year, three facilities attributed to RECLAIM the creation of one job. Of the eleven facilities that shut down or went out of business that year, only one indicated that RECLAIM was a cause for closing the operation (SCAQMD, 2000).

Compliance has not been a serious problem in the program. Of the 331 facilities in the RECLAIM program in 1998, 27 exceeded their allocations (about 8 percent). Failing to reconcile actual emissions with RTCs held (sloppy paper work) was a leading cause of the problem (SCAQMD, 2000). From 1994 through 1996, only a few facilities exceeded their allocation. Much of the problem relates to miscalculations, lack of understanding of the proper use and application of RTCs, missing data rules, or problems with electronic submittal of data. As a result of these problems, more reliable emissions monitoring techniques have been implemented (SCAQMD, 1998).

Air quality has improved with the implementation of RECLAIM. From 1989 through 1998 (the last year that a report is available), the SOx emissions have declined. The pattern of emissions has not shifted; nor has the geographic distribution of emissions changed. Opponents of the program feared that the flexibility to buy RTCs would shift the seasonal and/or geographical distribution of emissions and increase health risks in some areas. This has not occurred (SCAQMD, 2000).

Continuous emissions monitoring systems (CEMS) or their equivalent have been put into place at RECLAIM facilities to assure proper performance and compliance of each facility. All RECLAIM facilities are required to report, monitor and maintain records to verify their emissions. Major sources of SO_x emissions must use the CEMS and report emissions daily. The monitoring system is evaluated by the SCAQMD to further assure compliance with emissions caps. Based on sophisticated annual audits of each facility, no SO_x emitting facilities exceeded their allowance in 1998 (SCAQMD, 2000).

POINT/NONPOINT SOURCE NUTRIENT TRADING PROGRAMS

A 1992 study, commissioned by the US Environmental Protection Agency (Apogee Research, 1992) to analyze the incentives for including market incentive-based trading when reauthorizing the Clean Water Act, identified nine conditions or criteria necessary for a successful[32] program:

1. The waterbody must be a watershed or segment of a watershed (have physically defined boundaries);
2. Both the point and nonpoint sources must contribute a significant part of the total pollutant load to the watershed;
3. The water quality goal for the watershed must force actions;
4. Data must be accurate and sufficient to establish target goals and measure reductions;
5. Point sources must meet the technology-based discharge standards of the Clean Water Act;
6. For a significant portion of the pollutant load the marginal cost (per pound reduced) of nonpoint source controls must be lower than the costs of upgrading point source controls;
7. Point sources must be faced with either upgrading treatment capabilities or trading for nonpoint source reductions to meet water quality standards;
8. An institutional structure for facilitating trading and monitoring results must exist; and
9. Implementation mechanisms including enforcement mechanisms must be a part of the trading system.

The case studies used in the 1992 study included three point/nonpoint nutrient trading programs that were initiated in the 1980's—the Tar-Pamlico River Basin in North Carolina and the Dillon and Cherry Creek Reservoirs in Colorado. A brief description of each is provided below using the situation, structure, conduct and performance public policy analysis framework.

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[32] Successful in this case means that the program is efficient and cost effective because it achieves ambient water quality objectives at lowest cost. Costs include point and nonpoint source controls and administrative costs. This study also assumes that funding alone will cause nonpoint sources to participate in trading.

TAR-PAMLICO RIVER BASIN CASE STUDY

Situtation

The Tar-Pamlico Basin includes over 11,650 km^2 (about 4500 sq. miles) and parts of 17 counties. Its waters are valued for commercial and recreational fishing, boating, swimming, and it serves as the drinking water supply for eight cities and towns (Research Triangle Institute, 1993). The upper part of the basin is free flowing fresh water while the lower portion (about 991 sq. miles) is estuarine (salt water). The majority of the land in the watershed is forested or agricultural, and the population is about 365,000. The NC Department of Environmental Management (DEM) has registered 246 swine, dairy, chicken and poultry operations with over 2.6 million animals in the basin (Green, 1996). There are seven major and twelve minor municipal dischargers, two major industrial dischargers, and 127 nonmunicipal dischargers. Eighteen dischargers have a flow of more than .5 million gallons per day. (Jacobson, Danielson, and Hoag, 1994). The sources of nitrogen and phosphorus in the basin are as follows (note that most nutrient sources are nonpoint sources):

Source	Estimated Percent N	Estimated Percent P
Point Sources	28	8
Agriculture & Livestock	44	44
Forestry	5	9
Urban Areas	3	2
Wetlands	2	4
Atmospheric Deposition (Water)	17	31

Table 9. Sources of Nitrogen and Phosphorus in the Tar-Pamlico River Basin

Source: Jacobson, Danielson, and Hoag. Tar-Pamlico River Basin Nutrient Trading Program. 1994.

Structure

The Tar-Pamlico River Basin program began in September 1989 when the North Carolina (NC) Environmental Management Commission classified the river basin as a Nutrient Sensitive Waters (NSW) because of excess nutrients (nitrogen and phosphorus) entering the system. The excess nutrients led to extensive algal growth that depleted oxygen in the water and resulted in record fish kills. The NSW classification required the development of a basinwide plan to achieve a nutrient reduction goal that would relieve eutrophic conditions in the estuary (Green, 1996).

In February 1992, the NC Environmental Management Commission (EMC) approved a revised NSW implementation strategy. This strategy is a signed agreement that implements the NSW basinwide plan. Phase I of the strategy was initiated in 1990 and ended in 1994. The Phase I agreement was signed by the NC DEM and EMC, the NC Environmental Defense Fund, the Pamlico-Tar River Foundation, and the Tar-Pamlico Basin Association. Phase II was adopted in December 1994 and began in January 1995. The phase II agreement was signed by the NC DEM and EMC and the Tar-Pamlico Basin Association (NC DEM Report, 1995).

The purpose of Phase I was to establish and achieve a nutrient reduction goal for the estuary. The strategy also described the conditions to be met by the Tar-Pamlico Basin Association. (The Association is made up of 13 municipal wastewater treatment facilities (POTWs) and one nonmunicipal discharger). The remaining point sources have individual permits with nitrogen and phosphorus effluent limits. The tasks that were to be completed under the agreement included: development of an estuarine hydrodynamic computer model, engineering evaluation of the wastewater treatment facilities, annual monitoring reports on nutrient loading, and minimum payments for administration and implementation of agricultural BMPs (NC DEM Report, 1995). The unique feature of this agreement was that the Association as a whole, rather than individual treatment facilities, was given a nutrient loading limit. If the Association exceeded the loading limit, then it must pay for agricultural BMPs to reduce the nutrient load (Green, 1996).

Based on an estuarine water quality model, the goal of a 30 percent reduction in total nitrogen from 1991 levels was established as an interim goal for Phase II. The final target goal is no chlorophyll-a[33] samples above 40 microgram/liter (40 µg/l) and no water quality standard violations (NC DEM Report, 1995).

The model supported the belief that nitrogen was the most appropriate nutrient to limit in order to avoid excessive algal growth. As with most systems models, the basin was modeled to examine delivery of nutrients to a particular point in the basin. In this case, the town of Washington at the beginning of the estuary is that delivery point. The area has experienced significant algal growth

[33] Chlorophyll-a is found in algae and is proportionally related to the amount of nutrients available to the algae.

problems. However, phosphorus may become the limiting nutrient with a successful reduction in nitrogen so a reduction in both elements that maintains an appropriate ratio of total nitrogen to total phosphorus was determined. Phase II established the following loading for total nitrogen and total phosphorus for the Tar-Pamlico Basin. The interim goal for total nitrogen is 30 percent below 1991 conditions. Therefore, the Total Maximum Daily Load (TMDL) at Washington for total nitrogen was set at 1,944,000 kg/yr from both point and nonpoint sources. The total phosphorus load was set at 180,000 kg/yr for all sources. As calculated in the Phase II agreement, the Association's portion of the total nitrogen load is eight percent or 405,256 kg/yr aggregated for all Association members, while total phosphorus loading is 69,744 kg/yr. Both of these figures became a cap for the Association. If the cap is exceeded in 1995, then for the purposes of trading, the Association must pay for nutrient reduction by funding nonpoint source controls at $29/kg of nitrogen per year (NC DEM Report, 1995).

Trading options were established in the Phase II agreement. In addition to the flat fee for a kilogram of nitrogen, credits were assigned a life span. Structural BMPs have a ten-year life, while non-structural BMPs have a three-year life. Based on the BMPs grant funding obtain in Phase I[34], a 22,660 kg/yr credit, with a ten year life, wasl be available to the Association as of January 1995.

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[34] The project received a grant from EPA to fund some of the basin modeling costs and nonpoint source BMP costs.

Conduct

The NSW strategy involves the point source dischargers that are members of the Tar-Pamlico Basin Association and impacts other point and nonpoint sources of nutrients that did not sign the agreement. The DEM, which is the regulatory agency for pollution control and a party to this agreement, is impacted as well.

The Tar-Pamlico Basin Association[35] is given responsibilities beyond those required by other point source nutrient dischargers and unique privileges under this agreement. Phase I required the Association to fund a model to determine what the nutrient loading should be for the basin. (The modeling effort was funded in part through a US EPA grant.) They were also required to provide a payment each year for agricultural BMP implementation. The Association contributed $150,000 and obtained an EPA grant for $750,000, which was used for agricultural BMP credits in Phases I and II.

The Association was also required to conduct an engineering evaluation of each operation to seek low cost improvements in efficiency of operations and effluent reductions (NC DEM Report, 1995). This report, completed in March 1991, indicated that 160,000 kg/yr in nutrients could be removed through low cost, operational improvements (Green, 1996). The Association members are

[35] The Association has fourteen dischargers equaling about 90% of all point source flows to the river (Tar-Pamlico Nonpoint Source Strategy and Nutrient trading Program http://h2o.enr.state.nc.us/nps/tarp.htm last visited 3/13/2000).

required to monitor their effluent discharge for total nitrogen and total phosphorus weekly and report the results to the NC DEM annually (NC DEM Report, 1995).

As with the Association members, the other point source dischargers have to remain within the limits of their NPDES permits. However, the Association members were assessed as a group for the nutrient caps set in the Phase II agreement, which gives them the freedom to re-allocate some of the load among the members if needed to meet the cap. The advantage that the group has over other NPDES dischargers is that though they must individually monitor and report nutrient discharges; they do not have individual nutrient discharge limits in their permits. The NCDENR does ambient monitoring below discharge points and if a water quality problem is detected, they may take action against an association member (within the constraints of individual NPDES permits) (Gannon, 2000).

The Department of Environmental Management has been renamed the Department of Environment and Natural Resources and the Division of Water Quality now monitors the Tar-Pamlico Basin Plan. This division is responsible for reporting progress on achieving the 30 percent reduction goal by 2004. It is also responsible for drafting new rules regarding nonpoint source reductions in nutrients requested by the NC EMC based on lack of progress to reduce nonpoint sources of nutrients (NC DENR, 1999).

Ninety-two percent of the nutrient loading comes from nonpoint sources. Their total in-stream reduction target is 766,228 kg/yr. Some participation in reducing the nutrient load is funded through various voluntary programs for BMP installation that provide some level of matching funds and some is attained through required programs (NC DEM Report, 1995; Green, 1996). Since the nonpoint discharge reduction is primarily implemented through existing resources and voluntary programs, this effort is not achieving its goal as rapidly as desired. In July 1998, after two years of implementing this *voluntary* nonpoint source approach, the EMC determined that progress was inadequate and called for development of rules to achieve the nonpoint source reduction goals by 2000. Rules have been drafted but are not likely to take effect until late 2000 (NC DENR, 1999). Though the nonpoint source reductions through installation of BMPs are lagging behind the levels desired for 2000, the state and the basin are taking steps to address the complex issues of measuring nonpoint source impacts (NC DENR, 1999).

Performance

Since the cap for the Association has never been exceeded in the history of the program, no trades or purchases on nonpoint source controls have occurred and the credits accrued during Phase I remain to be used. The Association has met the performance goals of the agreement to date, at less cost than would have been required if the NC DENR had simply placed greater restrictions on point source dischargers. Malcolm Green, chairman of the Tar-

Pamlico Basin Association, estimates a seven-to-one savings with the Tar-Pamlico nutrient trading approach compared to conventional upgrading of municipal wastewater treatment facilities (Green, 1996).

Though no trades have occurred the Association has had a unique opportunity through this program. Because they were required to participate in the operational evaluation, individual members were able to reduce discharges through low cost operational changes rather than the seven-fold increase in costs that would have been incurred for conventional upgrading of facilities. In addition to these internal modifications, the Association has a single cap for nutrient discharges, rather than individual discharge limits. Therefore, the sources can agree among themselves as to which can most economically reduce nutrient discharges and over control to aid another facility that has higher costs to control nutrient discharges. In essence, the Association has a nutrient discharge "bubble" to maintain and more external flexibility with regard to meeting their individual discharge limits.

Trading has not occurred for the Association because it has not exceeded its nutrient caps. The model indicated that excessive algal growth would not occur if the nutrient levels were reduced by 45 percent. However, some parties thought the figure was too high based on the model and the data that were available to establish the projected impact curves. They also believed that the figures could be adjusted at the end of Phase II to take into account five years of modeling and monitoring data and adjusted accordingly (NC DEM, 1995; Green, 1996). The environmental groups opted out of signing the Phase II agreement because they were not satisfied with the 30% goal and they felt that the point source cap should be lower (NC DENR, 1999).

DILLON RESERVOIR CASE STUDY

Situation

The Dillon Reservoir is a high quality reservoir that in 1984 served over half of the water supply needs for the city of Denver, Colorado. It is a human-made reservoir with a surface area of 1800 acres and a popular recreational area (CDPHE[36], 1997). The concerns were that phosphorus loading from urban nonpoint discharges (since the area was growing) would create taste and odor problems for public water supply use and affect recreational uses (CDPHE, 1997). The primary source of nonpoint phosphorus loading is runoff from towns and ski areas (US EPA OWOW, 1996). Additionally, four municipally owned wastewater treatment plants would have to install advanced treatment systems to further reduce phosphorous loads (Apogee Research Inc, 1992, pg. 20). The sources of phosphorus loading in Dillon Reservoir in 1982 were:

[36] The abbreviation CDPHE is used for the Colorado Department of Public Health and Environment.

Source	**Percent of Phosphorus load to Dillon**
Natural Background	32
Nonpoint Sources (human-induced)	11
Industrial Wastewater	6
Municipal Wastewater	29
Groundwater	1
Atmospheric Deposition	21

Table 10. Sources of Phosphorus Loading in Dillon Reservoir 1982

Source of Data: Zander, B. Practical Case Studies of Actual Water Pollutant Trading Programs, 1996.

Structure

In 1984, the US EPA contracted a study to evaluate the relative costs of point and nonpoint control options for the Dillon Reservoir. The study determined that economic incentives existed for the point sources and that a trading ratio of 2:1 or less would produce 51 percent savings compared to the costs of upgrading treatment works with a no-trading option. Based on that study, the first nutrient trading program in the country was established (Apogee Research Inc., 1992, p 20.).

In 1982, the State of Colorado established an ambient water quality standard for Dillon Reservoir of 7.4 µg/l of phosphorus in the top 15 meters during the growing season and set a cap or total maximum daily load for phosphorus of 4,610 kg/year based on 1982 loading (Zander, 1996). The regulation that established the framework for trading was initiated in 1984. This regulation established phosphorus discharge limits for the major and minor sources of discharge and the rules by which they could change the discharge limit through trading with a nonpoint source (CDPHE, 1997). These point sources could control phosphorus from nonpoint sources at a rate of one pound of credit for two pounds of phosphorus controlled. The nonpoint source to be controlled had to exist before 1984 and the amount of credit would be determined using site-specific data and with the review and approval of the CDPHE Water Quality Division. These changes in where phosphorus was controlled were incorporated into the point source NPDES permits. However, this framework was contingent on the local governments in Summit County adopting regulations that required BMPs or other methods of phosphorus control mitigation for all new nonpoint sources (CDPHE, 1997). The Summit County Water Quality Committee coordinates the trading program and reports on progress and trends to the State (Zander, 1996).

Conduct

The point sources reduced their phosphorus loading from 3,738 kg/yr in 1981 to 529 kg/yr in 1991 through improving operating efficiency (US EPA OWOW, 1996b). By 1991, point source discharges made up only two percent of the total phosphorus load (down from 35 percent of the total Phosphorus load in 1981) to the reservoir (Apogee Research Inc., 1992).

Performance

The phosphorus loading to the Dillon Reservoir has remained at or below the 7.4 μg/l standard from 1982 through 1991 despite a growth in population of over 60 percent in the same timeframe (Zander, 1996).

As a result of being well below their annual loading allocation, point source dischargers have no economic incentive to initiate trades. Similar to the Tar-Pamlico Case Study, because of the ambient water quality standard and total maximum daily load set for phosphorus, the point sources have an incentive to reduce discharges or face increased costs from trading or upgrading the facility. This improved operating efficiency substantially reduced phosphorus loading to the reservoir at lower costs to the point source dischargers than would have been the case with a full upgrade.

No trades between point sources and nonpoint sources have occurred. Though the town of Breckenridge created a credit for its wastewater treatment facility by extending a sewer line to a subdivision using septic tanks (US EPA OWOW, 1996b), no trades between separate entities have occurred. In fact, the focus of phosphorus control has shifted to reducing nonpoint source discharges, and trades of nonpoint/nonpoint discharges[37] to offset new nonpoint sources

[37] For example, a resort paid for sewer lines into an area with individual septic systems and the reductions were used to offset future resort development (UA EPA, 1996).

have occurred (US EPA OWOW, 1996; Apogee Research Inc., 1992 p. 21; Batchelor, 1997, p. 25).

CHERRY CREEK CASE STUDY

Situation

The Cherry Creek Reservoir is located near Denver and is a primary recreational area. The reservoir was constructed in 1950 for flood control and attracts more than 1.5 million visitors each year (US EPA OWOW, 1996a). In the 1980's the area began to experience strong development pressures and anticipated a population increase of over 300 percent (Apogee Research Inc., 1992). To protect this high quality recreational resource, the Cherry Creek Basin Authority (CCBA) established a total maximum daily load for phosphorus. The allocations for total phosphorus from all sources in the Basin were as follows:

Sources	**Allocation in lbs/year**
Nonpoint Sources	10,290
Background Sources	1,170
Point Sources	2,310*
Industrial Sources	50
Individual Sewage Systems	450
Total Phosphorus	14,270

Table 11. Sources of Phosphorus in the Cherry Creek Basin
Source: CDPHE Cherry Creek Reservoir Control Regulation No. 72
* excluding industrial sources.

Structure

The Cherry Creek Reservoir program is a collaborative effort among the state and several local governments to control total phosphorus in the basin. The Colorado Water Quality Control Commission established a phosphorus standard of 0.035mg/l for the Reservoir in 1984 based on water quality data and hydrologic conditions of 1982 (CDPHE, 1985). The total annual phosphorus load for point and nonpoint sources is 14,270 pounds per year. Allocations were assigned to all point source dischargers based on the control of nonpoint sources that constitute over 70 percent of the phosphorus load for the Reservoir. A 50 percent reduction in nonpoint source phosphorus must be achieved across the board before trading can be implemented between point and nonpoint sources (CDPHE, 1985).

The Cherry Creek Basin Authority (CCBA) Board has representation from county and municipal governments, as well as water and wastewater special districts. These same groups are responsible for implementing BMPs to limit nonpoint source pollution in the Basin as described in several Basin plans (US EPA OWOW, 1996a). However, no regulatory loading reductions are required of these nonpoint sources, beyond discharge permit requirements for stormwater (CDPHE, 1998).

The CCBA has many responsibilities for Cherry Creek Basin water quality management, including assigning nonpoint source reduction credits and charging assessments and fees to support monitoring programs and capital projects authorized by state legislation in 1988. The CCBA has implemented four nonpoint source improvement projects that generate phosphorus reduction credits for the trading program (US EPA OWOW, 1996a). In addition, the CCBA approves point-nonpoint source trades for phosphorus and establishes the trading ratio for each trade on a case-by-case basis. The ratio may range from 1.3:1 to 3:1 (i.e., 1.3 pounds to three pounds of phosphorus most be removed for the point source discharger to be awarded one pound of phosphorus credit). The trade cannot occur until the CDPHE amends the permit of the point source discharger (CDPHE, 1998).

Conduct

Urban nonpoint sources were required to reduce loading by 50 percent before point/nonpoint source trading can occur. To date, some nonpoint source pollution reduction projects have been implemented by the CCBA to develop trading credits. Wastewater treatment plants have not met their TMDL limits for phosphorus. The state regulation requiring 50 percent reduction in nonpoint source loading has been extended several times as the deadlines have not been met (CDPHE, 1998).

Performance

Since nonpoint source reduction requirements have not been achieved, no trades have occurred between point and nonpoint sources of phosphorus. Also, the phosphorus load in the Cherry Creek Reservoir has not reached the TMDL limit established in 1984. When the TMDL limit is reached, point source effluent limits will depend on nonpoint sources reductions. If nonpoint sources have not been reduced, point sources will not be able to increase loading to accommodate new growth in the area, or they will be required to reduce their effluent limits to compensate for the nonpoint source loading (Apogee Research, Inc., 1992).

FOX RIVER CASE STUDY

Situation

The Fox River is part of the Wolf-Fox Basin of some 6600 sq. miles. The entire Fox-Wolf basin in Wisconsin is a major contributor of phosphorus loading to the Green Bay of Lake Michigan. Analysis, modeling and monitoring activities have been carried out in this watershed for some time, as it is part of a Remedial Action Plan for poly-carbonated bromides (PCB) contamination in Lake Michigan as well as a source of nutrients and sediments (White, 1994). In addition, the lower Fox River has more paper mills than any other river in the country (WDNR, 1998). Dissolved oxygen violations occur in Green Bay due to phosphorus loading from the forty watersheds of the Fox-Wolf Basin. Though point sources are a substantial contributor of phosphorus, studies indicate that nonpoint sources, mostly cropland runoff, account for 76 percent of the phosphorus loading. A load estimation study by Fox-Wolf Basin 2000, a nonprofit group, has indicated twelve of the forty watersheds contribute nearly 85% of the total phosphorus load reaching Green Bay (WDNR, 1999).

Structure

In early March 1981, the Wisconsin Department of Natural Resources (WDNR) approved regulations to allow dischargers to transfer permits by approved contracts for point sources such as municipal wastewater treatment facilities and paper mills along the Fox River. Ten pulp and paper mills and four municipal wastewater treatment facilities discharge into a 22-mile reach of the lower Fox River (O'Neil, et al, 1983). The WDNR developed the program because existing technology controls were not enough to assure compliance with water quality standards. To date only one trade has occurred between two point sources. A paper mill shut down its treatment operations and traded its allocation to the municipal facility that began taking the mill's wastewater (Apogee Research, Inc., 1992).

In 1997, the Wisconsin Legislature passed Act 27 to provide regulated facilities another avenue to achieve water quality. The WDNR is directed by s.283.84 Wis. Statutes to develop at least one pilot project for trading water pollution credits. Under this law, a point source can discharge pollutants at levels higher than authorized in the WPDES discharge permit, while another entity removes additional pollutants. This increase in point source discharge can only occur if agreements are reached between the dischargers, the WDNR, or other units of government (WDNR, 1999). As before the statute was enacted, the

WDNR must approve the discharge trades and modify the permits, which could be a lengthy process (Apogee research, Inc., 1992).

Conduct

Currently WDNR is developing a framework for the trading process and evaluating of the costs and associated phosphorus loading reductions for nonpoint source best management practices. The Fox-Wolf Basin is one of three watersheds under consideration as a pilot project (WDNR, 1999). A non-profit organization, Fox-Wolf Basin 2000, is working to facilitate public policies and private actions that achieve and maintain high quality waters in the Basin including seeking funding for research.

Performance

No schedules for phosphorus removal or final rules for trading have been established. A TMDL for phosphorus has not yet been set for this Basin. However, the Remedial Action Plan for Green Bay calls for 50 percent reduction in phosphorus. This level of reduction cannot be achieved without reductions in both point and nonpoint sources of phosphorus (White, 1994).

LOWER MINNESOTA RIVER CASE STUDY

Situation

The Lower Minnesota River is the last watershed of the Minnesota River Basin. This 1760 sq. mile watershed includes a 50-mile stretch of the river and encompasses parts of ten counties. It drains into the Mississippi River at St. Paul. The lower 25 miles of the river have been dredged for barge navigation, and in the summer during low flow the river can experience lake-like conditions and retention times that can result in substantial algal growth from excess phosphorus loading (MPCA, 1999). While there is no water quality standard for phosphorus, from 30 to 70 percent of the samples taken from three points in the lower Minnesota Watershed exceed the mean concentration of 0.25 mg/l total phosphorus in the Minnesota River. The lower Minnesota River also generates about 32 percent of the total phosphorus load for the entire basin. Until 1994, about one-third of the phosphorus load in the watershed was generated by two municipal wastewater treatment facilities. However, in recent years, they have improved operations and reduced the phosphorus discharge by 60 to 70 percent (UMN, 1999).

Phosphorus loads to the entire river vary with flow conditions in the Minnesota River. The estimated phosphorus load from point sources is 284 tons per year. During low flow 72 percent of the phosphorus load is attributed to point sources while during high flow only 10 percent on the total load is attributed to point sources. The relative proportions of total phosphorus loading over the long-term average[38] is 26 percent from point sources, with the remaining 74 percent coming from nonpoint, background and sediment sources (MPCA, 1999b, p. 6).

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[38] The average is based on an average total load from 1979-1993 of 1080 tons of total phosphorus at Jordan, MN.

In the lower part of the river, phosphorus concentration ranges from 300 to 325 parts per billion, well above concentrations known to cause problems in lakes.

Structure

Minnesota has put into place a strategy to reduce phosphorus loading to the river and therefore algal growth and low oxygen problems in the lower Minnesota. The Minnesota Pollution Control Agency (MPCA) has put into place a strategy to reduce phosphorus from point sources by placing phosphorus limits in discharge permits. For nonpoint sources, the MPCA has placed new regulations for water quality on animal feedlots and implemented a revolving loan program to upgrade septic systems. Through a cooperative effort, nonpoint sources of agricultural runoff are encouraged to participate in conservation programs to reduce sediment, and therefore phosphorus, entry into the river (MPCA, 1999b).

A TMDL of 53,000 pounds per day of Chemical Biological Oxygen Demand (CBOD) was established for the last 25 miles of the Minnesota River in 1988. This load was fully allocated among point sources dischargers in this reach of the river and upstream loading from point and nonpoint sources (Senjem, 1997).

The Rahr Malting Company is a point source in the lower Minnesota River that wanted to put into operation its own wastewater treatment plant. To implement this operational change the company worked with the MPCA to implement a point-nonpoint trade for nonpoint phosphorus reductions upstream in exchange for CBOD increases (Senjem, 1997).

In Minnesota, water effluent trading means substituting nonpoint source load reductions for point source load requirements of a discharger that is permitted under the NPDES program. The MCPA has several policy guidelines for trading: there must be a significant cost differential between point and nonpoint sources, the water quality problem must be chronic, and the pollutant being considered must be conservative[39].

The Rahr Malting Company NPDES permit, completed in January 1997, includes inter-pollutant trading in addition to the first phosphorus limits for a permit on the Minnesota River (Senjem, 1997; MPCA 1999b). The terms of the trade are incorporated into the NPDES permit.

One of the most unique features of this effort is the inter-pollutant trade. River studies were conducted to determine the relationships of phosphorus to chlorophyll and chlorophyll to CBOD. These studies were used to derive the trading ratio of one pound of phosphorus upstream for eight pounds of CBOD discharged into the TMDL segment of the river (Senjem, 1997).

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[39] Conservative means that the pollutant's potency does not change substantially over time and distance.

Several other requirements were part of this unique trade. Only five categories of best management practices were accepted for trading. They must be visible and able to be tracked and monitored (MPCA, 1997). These BMPs must also be secured through land purchase, easements or other contractual agreement for the duration of the discharge. Rahr Malting Company has an incentive to operate below its discharge limit because it is required to offset only the amount of CBOD it actually discharges (Senjem, 1997).

The MPCA also has obligations under this unique NPDES permit. It must inspect potential nonpoint sources sites, review estimates of phosphorus reduction, and approve the BMPs submitted under the permit (Senjem, 1997; MPCA, 1997).

Additional difficult tasks have been faced by the MPCA. Developing the linkage between the two pollutants was a time-consuming process. First, establishing equivalence and an acceptable trading ratio, given the impacts of flow on phosphorus loading to the river, was a potential obstacle to a successful program. The final difficult task was measuring nonpoint source load reductions. This task has been addressed by developing estimates for the approved BMPs (Senjem, 1997).

Conduct

The Rahr Malting Company has been working to meet the compliance schedule of its 1997 NPDES permit. To reduce transaction costs, the company has worked with the Coalition for a Clean Minnesota River to identify sites and secure easements. It has also established a non-profit corporation to sponsor river cleanup projects that satisfy its permit requirements (Senjem, 1997). Any nonpoint sources above the site of the Rahr Company are eligible to participate in the trading program. The Company has been entering into agreements with the owners of the most cost effective sites on which to implement and maintain the BMPs (MPCA, 1997).

Performance

Several trades have occurred. By summer 1997, the Rahr Malting Company had trading agreements with four landowners and others were added in 1998. These offsets are maintained for the life of the point source discharge (Klang, 2000). Additional sites for implementing acceptable BMPs have been identified. It appears likely that the company will be able to offset its entire CBOD load in the near future (Senjem, 1997; Klang, 2000).

Maintenance and monitoring of the BMPs installed for phosphorus reduction is required through the Rahr Company NPDES permit. The company must also annually report to the MPCA regarding these practices (Senjem, 1997). Enforcement is also implemented through the NPDES permit. If the company failed to meet its discharge limit for CBOD through excess discharges or lack of maintenance of the BMPs, it would be subject to the penalty provisions of the state and federal Clean Water Act. Based on the contracts that the company has made for BMPs, some improvement in water quality has occurred. The economic benefits are much more difficult to determine.

SUMMARY OF CASE STUDY FINDINGS

Table 12 on page 132 summarizes how well the six case study trading programs reviewed above meet the key components of a successful market incentive-based program (described in Chapter 2 Table 3, page 44). The RECLAIM program, as did the national sulfur dioxide allowance trading program, effectively meets all the components of a successful market incentive-based trading program.

Of the five nutrient trading programs, the Tar-Pamlico program comes closest to meeting all the key components. Beginning with the institutional components, the Tar-Pamlico case meets all but the compliance flexibility. With regard to compliance flexibility, the Association members had flexibility only within the Association "bubble" to determine the most economic way to remain under their total discharge cap. Similarly, regarding the design components, the Association could allow other POTWs to join the group (opt-in) and the Association has been allowed to bank the credits earned in Phase I for use in Phase II. Hence, the implementation components or transaction costs are high for initial transaction costs. The Association had significant costs to negotiate the creation of the Association and the Phase I and II agreements regarding their role in the Tar-Pamlico program (initial costs). In addition the Association had substantial costs through supporting the operational analysis at each member facility and partially funding the modeling effort to determine the loading to the estuary and their share of that nutrient loading (information costs). Therefore, though the Tar-Pamlico program most closely meets the components for a market incentive-based trading program, it does not meet the conditions necessary for an effective trading program.

The remaining four nutrient trading programs meet fewer of the components than the Tar-Pamlico case study[40]. With regard to institutional components none of the remaining four programs have economic incentives or compliance flexibility. All dischargers are required to participate in trading within the context of NPDES permit revisions. Because none of the four programs have opt-in options or banking provisions, they provide reduced flexibility in the implementation phase. All four programs have high initial costs and high information costs. Interestingly, despite these costs, and a lack of all the key institutional and design components, trades have occurred under the Minnesota program. The Rahr Malting Company has implemented several trades with upstream nonpoint sources to be able to increase CBOD discharges. However,

[40] However, the Dillon Reservoir Case, like the Tar-Pamlico case, did give the point sources an incentive to reduce nutrient discharges through an operational analysis of each source that substantially reduce their P discharge to the reservoir. In both cases, it appears that setting a cap or TMDL induced point source nutrient reductions to avoid additional compliance or upgrading costs.

this process has required ten years of research and negotiation, along with modification of their NPDES permit. Therefore, none of these programs meet the meet the conditions necessary for an effective market incentive-based trading program as defined in the economics literature.

Key Components	RECLAIM	Tar-Pamlico	Dillon Res.	Cherry Creek	Fox[a] River	Minn. River
Institutional						
Property rights and institutional structure[41]	Yes	Yes	Yes	Yes	Yes[b]	Yes[b]
Goals	Yes	Yes	Yes	Yes	No	Yes
Open or closed system	Closed	Closed	Closed	Closed	?	Closed
Economic Incentives	Yes	Yes	No	No	No	No
Compliance Flexibility	Yes	Yes - internal	No	No	No	No
Design						
Trading unit	Yes	Yes	Yes	Yes	No	Yes
Trading ratios	Yes	Yes	Yes	Yes	No	Yes
Opt-in provisions	Yes	Yes limited	No	No	No	No
Banking	Yes	Yes limited	No	No	No	No
Implementation/ Transaction Costs						
Initial transaction Costs	Yes	Yes-H	Yes-H	Yes-H	Yes-H	Yes-H
Information Costs	Yes	Yes-H	Yes-H	Yes-H	Yes-H	Yes-H
Monitoring Costs	Yes	Yes	Yes	Yes	Yes	Yes
Enforcement Costs	Yes	Yes	Yes	Yes	Yes	Yes

Table 12. Comparison of the Key Components for Successful Market Incentive-based Trading to the RECLAIM and Five Pilot Water Trading Programs

(a = still developing rules. b = policy guidelines only. H = high costs.)

[41] Though property rights and institutional structure are defined in each case, the property rights of point sources and nonpoint sources of nutrient discharge are different.

Section 3: Synectics Analysis of Market Incentive-based Trading Programs for Sulfur Dioxide and Nutrients (P and N) Pollutants

Using a synectics direct analogy test to compare the successful SO_2 allowance trading programs to the pilot nutrient (P and N) trading programs much can be learned from the similarities and differences in the air and water market incentive-based trading programs. If the situation and structure are similar, than the conduct and performance of the policy should be similar. However, if the situation or structure is different, than the conduct and performance of the policy will likely be different.

The air and water media for SO_2 emissions and N and P discharges are similar and can effectively be used in direct analogy of the situation for this policy analysis. The only complicating factors are human inability to easily and cost effectively measure nutrient discharges from both point and nonpoint source discharges and monitor ambient water resource conditions for N and P nutrients.

There are important differences in structure, property rights, and institutional framework for air and water quality protection programs. First, air and water policy statutes have different goals, which affects how protection policies are implemented. Until 1990 both air and water quality protection programs were technology-based programs. Since the passage of the 1990 amendments to the Clean Air Act, SO_2 is regulated using a total emissions cap, a performance standard for major stationary sources, and a single permit for a facility. This program gives regulated sources an incentive to reduce emissions and creates a market for emission allowances. This same program structure applies to the successful RECLAIM program.

Meanwhile the Clean Water Act remains a technology-based program that provides no economic incentive to improve discharge controls beyond those required in the command-and-control program. Like the Clean Air Act, the Clean Water Act regulates point (major) sources. However, with regard to N and P nutrients, these regulations are applied on a technology basis and without discharge standards except where waterbodies are not meeting designated uses or may become impaired. In that case, water quality standards may be applied to point sources. These complexities make implementing a market incentive-based program much more difficult.

Unlike the Clean Air Act, the Clean Water Act has no statutory authority to implement market incentive-based programs. The national water protection policy is a draft guidance document that encourages watershed-based trading within the context of the NPDES permit process. Finally, the pilot projects evaluated in this research examine nutrient trading efforts between point and nonpoint sources discharges, which is encouraged in the draft guidance document. However, point and nonpoint sources of P and N discharges have differing property rights. Given these differences in property rights and institutional framework, it is not surprising that the structure of SO_2 allowance trading and P and N nutrient trading programs are not similar.

Therefore, the conduct and performance of the participants in the five pilot nutrient trading programs has been very different than the participants in the RECLAIM program. The five nutrient trading programs are not economically viable and serve to address a case-by-case water quality problem. These pilot efforts have resulted in environmental benefits. But benefits are not from trading, nor from more flexibility. Rather environmental benefits result from threats of more costs and/or controls. With a cap on nutrients or a TMDL, the point sources participating in the five pilot projects have had an incentive to re-evaluate existing practices and reduce discharges without incurring the full cost of upgrading treatment practices. However, the structure for these pilot nutrient trading programs makes it highly unlikely that a viable market incentive-based program can be implemented. Transaction costs, including modifying the NPDES permit, finding trading partners, and increasing monitoring requirements, are high for the point source that initiates the nutrient trade. These differences in conduct and performance can provide insights that may improve environmental protection policy.

Chapter 4

RESEARCH POLICY ANALYSIS FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

Overview

Synectics analysis uses analogy to see if the model developed for one problem can be applied to another. In this case, air emissions trading is evaluated as a model for water quality (nutrient) trading programs. If the situation is similar and the structure is similar, then the conduct and performance should be similar and, one would observe a direct analogy between these air and water protection programs. However, in this study the analogy does not hold.

Section 1: Findings and Conclusions

Media Similarities between Air and Water

Both air and water have long been used and regulated as media for disposal of pollutants. The biogeophysical processes of the three pollutants, sulfur dioxide, nitrogen and phosphorus, are all part of the natural hydrologic cycle. The three pollutants are assimilated into the media at reasonable levels. Environmental degradation problems occur when anthropogenic and natural causes of the pollutant are produced in amounts that cannot be transported or assimilated by the media.

Though air and water flow regimes are different, they both have patterns that are modeled and somewhat predictable. Both regional and local air patterns in the atmosphere are understood as well as the flows and mixing zones in the hydrosphere.

Standard methods of measuring and monitoring each pollutant have been developed and implemented, though these methods are more difficult to implement for measuring point and nonpoint source discharges to water. Similarly, ambient monitoring is more costly and difficult to implement in water. The differences in the media and the pollutants do not appear to represent limiting factors in establishing environmentally and economically sound market incentive-based incentive trading programs.

Air and Water Property Rights and Institutional Frameworks

Differing Property Rights Structure

In 1990 the Clean Air Act gave marketable allowance rights to large stationary sources of sulfur dioxide emissions and capped the total amount of those emissions. These allowance rights can be used, banked, or sold to other regulated sources or other parties. This change in rights facilitates emissions reduction and therefore the rights of the public to cleaner air. However, the 1990 amendments did not remove the privilege that unpermitted sources of sulfur dioxide emissions have to pollute.

Though both air and water were open access resources, water rights have evolved differently than air rights. In the United States, more effort was placed on controlling the quantity and access rights than the protection of water quality. Two different use (quantity) rights systems developed in the U.S. The eastern half of the country (east of the Mississippi River) adopted a reasonable-use policy (riparian doctrine) while the western half adopted the prior appropriation doctrine. The assumption under both of these doctrines is that the water quality will be such that each user can use it as desired without incurring additional costs (Braddock, 1995). A national program to protect water quality was not implemented until decades after use rights. The program created under the Clean Water Act places discharge requirements on point sources but it does not cap total discharges nor does it authorize a nutrient trading program to reduce discharges. Additionally, as with the Clean Air Act, the property rights on point and nonpoint sources of pollution are different. Point sources are required to control P and N discharges in waterbodies where water quality is impaired or threatened to be impaired in the near future. Nonpoint sources have the privilege to pollute unless a TMDL or similar water quality protection cap has been applied to the waterbody. These differing property rights in the air and water media do make it easier to implement air emissions trading than water pollution nutrient trading policies.

Air and Water Institutional Frameworks

Though both statutes have advanced the reduction and control of pollutants, the goals and implementation of the acts have taken different approaches. The purpose or goal of the Clean Air Act is to reduce harmful air emissions to protect public health and the environment and to achieve attainment of national ambient air quality standards across the country. The goal of the Clean Water Act is zero discharge of pollutants in the waters of the nation. At a minimum, the purpose is to achieve water quality standards across the country such that all waters are *fishable and swimmable.*

Since the goals are so different, it is understandable that the implementation approach would also be different. The air emissions program has taken the approach of allowing the states to implement the program on an airshed or air management area basis, such that one state implementation plan for air quality is implemented and updated on a regular basis. This plan is approved by US EPA and is the basis for program funding. The goals for the state and the management areas are clear and there is an extensive network of ambient air monitoring both at the state and federal level to monitor and evaluate the effectiveness of the state plans based on changes in ambient conditions. All sources of emissions, stationary and mobile, are under the same regulatory requirements to reduce emissions and the credits from emissions reductions from various programs may actually be used in trading (e.g., RECLAIM credits).

Unlike the air quality program, the water quality program has not been as holistic. Each state submits an implementation plan for its water quality programs but program implementation is much more fragmented. Plans for program implementation may be carried out by different divisions or even agencies. Without coordination and understanding of the goals and purposes of each program, this multiplicity of programs may inadvertently be implemented at cross-purposes while trying to protect the watershed and the aquatic and terrestrial resource systems it supports.

The 1990 Amendments to the Clean Air Act were carefully crafted to address a national air quality problem. The sulfur dioxide emissions program was effectively targeted at the largest producers of sulfur dioxide, large stationary power plants. It was tailored to the address the most polluting sources with an allowance cap that required changes in operations (while giving the flexibility to meet a performance standard in the most economical manner) and a market mechanism that makes finding trading partners and transacting trades easy to accomplish. Finally, the program was designed to be transparent. That is sources participating in the emissions reduction program must record the use and trading of all allowances, there is a board of trade that allows buyers and sellers to track the volume and cost of allowances, and that information is publicly available.

The Clean Water Act has not been substantially amended in decades. It uses a technology-based command-and-control program to control discharges without the ability to control the total amount of discharge unless a state program has recognized some severe water quality impairment that limits total discharges (as is the case in some of the pilot nutrient trading programs). One of the most difficult policy issues is the zero discharge goal. If the explicit goal of zero discharge is to be achieved, than a trading program is not the appropriate program strategy to achieve zero discharge. However, if the performance goal of meeting the standard of fishable and swimmable water resources is the desired goal, than a market incentive-based program could help to achieve that goal—if the Clean Water Act authorized a market incentive-based trading program like Title IV of the Clean Air Act Amendments of 1990. This lack of institutional framework severely limits the possibility of capitalizing on the economic and environmental benefits that a well-designed market incentive-based incentive program may provide. The institutional framework established in the U.S. to protect and manage air quality does make it easier to design and implement environmentally and economically effective air emissions trading programs.

Economic and Environmental Benefits of Market Incentive-based Trading

Studies across the country have assessed the economic and/or environmental benefits of point-nonpoint nutrient trading (e.g. World Resources Institute, Apogee Research, Inc., Tar-Pamlico Basin Studies, and New York City water supply studies). However, given the current structure (property rights and institutional framework), there is little opportunity or incentive for participating in effective programs (conduct) that could bring substantial benefits (desired performance). The transaction costs of altering an NPDES permit, finding acceptable nonpoint trading partners, installing and assuring that the nonpoint source practices to reduce discharges are maintained, and the added monitoring that is required by the regulatory agency make it difficult to participate in the pilot nutrient trading programs. The exception is the incentive to improve internal operations of point sources (Tar-Pamlico and Dillon case studies) when a TMDL or total cap on nutrients is implemented. Even in those two case studies, a targeted, tailored and transparent program was not created to effectively address the pollution problem.

Therefore, though the economic and environmental benefits of market incentive-based point-nonpoint nutrient credit trading programs appear to be substantial, they may not be sufficient to bring about changing the institutional framework for water pollution nutrient credit trading program design. (Other factors not studied in this research may also contribute to changing the institutional framework, such as lawsuits, change in public opinion about the importance of protecting water resources from nonpoint sources of pollution.)

Answering the Research Question

Based on the research evidence, current difficulties with water quality trading program design do not arise because of fundamental differences between the air and water media (the situation). The difficulties arise because of the (structure) institutional barriers in the Clean Water Act. Some of these barriers have been eliminated through Title IV of the Clean Air Act and lessons such as targeting, tailoring, and making programs transparent can be applied to the nutrient trading programs. However, given the difference in the property rights among point and nonpoint sources, the lack of national nutrient standards, and a goal of zero discharge, there are other important policy issues to address if the Clean Water Act is amended to authorize nutrient trading.

Section 2: Lessons Learned

Findings Regarding Market Incentive-based Trading for RECLAIM and Five Pilot Water Trading Programs

Comparing the RECLAIM trading program and five pilot water trading programs yields similar findings to the previous sections. The RECLAIM program parallels the Title IV SO_2 trading program as an effective model of market incentive-based trading to achieve environmental benefits at a lower cost than with previous command-and-control regulatory programs. As with the national SO_2 trading program, the regional RECLAIM program takes advantage of the key institutional factors to implement a program that caps SO_2 and NO_x emissions in the Los Angeles metropolitan area at less cost than the regulatory program. The RECLAIM program's adherence to the design factors enables the participating sources to easily buy and sell RECLAIM trading credits at the 1.2:1 trading ratio required by federal standards for nonattainment areas. The opt-in option for facilities emitting less than 4 tons/year of SO_2 or NO_x gives participating sources more flexibility to meet the declining emissions cap for the valley. The banking provision allows participating sources to more economically plan and implement emissions reduction technology to meet the declining cap and maintain the total emissions cap.

The implementation/transaction cost factors have not been obstacles to implementing RECLAIM. Participating sources have experienced increased monitoring costs because of the requirement to install new continuous emissions monitoring systems and to annually report emissions and allowance usage to the SCAQMD. The SCAQMD has also experienced additional costs for ambient air quality monitoring. However, these costs have not been significant enough to deter program implementation.

The five pilot water effluent trading programs parallel the framework of the Draft Framework for Watershed-based Trading document. The pilots were experiments encouraged and facilitated through US EPA support and guidance, and are a foundation for the Framework document. Thus the pilot water effluent trading programs suffer from similar failings. With regard to institutional components, the only program that created an economic incentive was the Tar-Pamlico program. By treating the point sources in the Association as a "bubble" (the concept originally developed for air emissions), the participating POTWs were able to avoid the total phosphorus and nitrogen caps that would have required purchase of nonpoint source BMPs. The Association had the additional incentive of a study that identified operational improvements and avoided the need to implement a costly plant upgrade to control nutrients. Of the five pilot programs, only Tar-Pamlico meets all the design components for a successful market incentive-based program. However, its opt-in option is limited to point sources and banking is limited to those credits created in Phase I of the program. Finally, though the Tar-Pamlico program had high initial transaction costs and information costs, obtaining grants from the US EPA kept those transaction costs lower for the point sources and the state regulatory agency. Through the agreement with the state to create a "bubble" for total nutrient load and to find and facilitate nonpoint sources implementation of BMPs (if the Association exceeded its total effluent load), the Association reduced initial transaction and information costs. Despite the economic incentives, no trades have occurred because the cap for the point sources was set high and the Association has yet to exceed the cap and thus trigger the trading portion of the program.

Lessons Learned from the RECLAIM Program that would Benefit the Five Watershed-Based Trading Programs

Several lessons can be learned in the RECLAIM program that would be beneficial to the pilot water pollution trading programs.

1. A successful market incentive-based program needs to have the statutory and regulatory authority to minimize the uncertainty of participation. Who has the right or obligation to participate must be clearly defined.
2. Similar to the Title IV program that invested ten years of research and public policy involvement to become law, the RECLAIM program spent three years

from concept to development of the regulations for the program. Many interest groups participated in the discussion and initial policy ideas were modified to accommodate various constituency concerns. Additionally, since its inception, the RECLAIM program has gradually evolved and enhanced some aspects of the program to facilitate ease of trading and monitoring activities. Annual audit reports and tri-annual progress reports document the problems and the opportunities that the program has encountered and addressed. The pilot program for effluent trading would benefit from the same research and development activities, a clear statutory and regulatory framework, and a targeted, tailored and transparent program design.

3. The RECLAIM program has a strong measurement, monitoring and enforcement program. Until similar ease of discharge measurement for both point and nonpoint sources, a broader, easier and less costly long-term ambient monitoring program are initiated for water quality programs, and the ability to enforce nonpoint source controls are instituted, it will be difficult to document the benefits and improve water effluent trading programs.

Section 3: Recommendations for Future Research

No research project is as thorough as the author initially thinks it will be, as the research itself raises more issues and questions than it addresses. Several areas would benefit from further research.

More research needs to be done to address the market incentive-based trading policy development timeframe. Tom Tietenberg wrote an article in the mid-80s tracing the evolution of the air emission trading policy from the 1970s through 1984. It would contribute to the policy discussion if the evolution of the air emissions policy could be updated through 2000. Further insights could be gained into the evolution of water quality nutrient trading programs if that history was also traced and compared to the air emissions policy evolution through 2000. Perhaps water quality nutrient trading programs are just beginning the bubble policy stage of market incentive-based trading.

Point-nonpoint nutrient trading is a more complex policy arena then permitted sources allowance trading for air emissions. Given the large number of nonpoint sources, their spatial distribution, and irregular contribution to pollution problems, nonpoint sources are and will continue to be treated differently than point sources. Some researchers have suggested that a multi-tiered approach is needed. The largest nonpoint sources (e.g., agricultural operation runoff and stormwater runoff) would be permitted like point sources, smaller nonpoint sources (e.g. parks and commercial areas) could be encouraged to reduce discharges through economic incentives, and individual citizens and residences could be encouraged to reduce runoff through education and behavioral changes. For any of these approaches to work, nonpoint sources of pollutants must be recognized by the public as a serious environmental problem.

Since there are never enough resources to completely address an environment issue, prioritizing efforts to control nonpoint sources will be needed. Just as funds for controlling point sources such as POTWs were funded through a prioritizing system, a similar program makes good economic sense for nonpoint sources. There will come a point when the costs to control out weigh the benefits to be gained in controlling nonpoint sources. Clearly, there is a need for more research into the area of a multi-tiered approach. Perhaps a dialogue of all stakeholders could begin, in conjunction with the research needs identified here, to reach a consensus about the pollutant control goals, needs, methods that should be included in the next revision of the Clean Water Act

Another research issue that has been raised by economists is the number of firms that are impacted by a point-nonpoint trading program. Finding and quantifying the discharges of many nonpoint sources is a large challenge. Yet another challenge is understanding the impacts of the differences in the timing of pollutant releases between point and nonpoint sources of nutrient discharges.

There is also the need to understand the spatial relationship between point and nonpoint sources that could be potential trading partners. Are there enough nonpoint sources upstream of a point source to avoid a “small numbers” economic problem and create a viable market incentive-based trading program?

More research also needs to be done in the area of quantifying water pollutant discharges from both point and nonpoint sources for compliance and ambient monitoring purposes. Most nonpoint source reductions are calculated based on the BMPs that are put into place and the benefits they provide. There are no easy methods for tracing and measuring runoff. Most NPS monitoring is done in the waterbody and trends are documented. Better methods or models are needed to reduce the cost and improve the accuracy of that monitoring.

Another area to consider is the difference that including participants with differing property rights makes in implementing a program. Unlike the sulfur dioxide trading program with participants under the same structure, the pilot nutrient trading programs included point and nonpoint sources of pollution. This difference in property rights has not been studied in detail in either the air or water media (though some studies for creating emissions credits from retiring mobile sources of pollutants have been done). More research in this area and investigation of other policy programs that have dealt with differing property rights structure are needed.

APPENDICES

APPENDIX A

PHYSICAL CHARACTERISTICS OF AIR AND WATER MEDIA AND BIOGEOCHEMICAL PROCESSES FOR SULFUR, NITROGEN AND PHOSPHORUS

Chemical Characteristics of Sulfur Dioxide

Sulfur dioxide is a colorless, odorless gas. In high concentrations, it has a pungent, irritating odor. Sulfur dioxide has been used for many years as a fumigant for grapes and wine barrels and as a preservative, bleach and steeping agent for grapes, apricots and other fruits and vegetables (Harte, Holdren, Schneider, and Shirley, 1991).

Sulfur dioxide is created through natural processes, such as volcanic eruptions and emissions from living organisms and decaying organic matter, and through anthropogenic processes, such as power generating plants, industrial plants, and automobile fuel combustion (Boubel, Fox, Turner, and Stern, 1994). In each process, sulfide compounds (e.g., FeS_2, $(CH_3)_2S$, H_2S) are being oxidized or combustion reactions are occurring. These sulfide compounds react with oxidants[42] and particles to form sulfates and sulfuric acid particles. Sulfuric acid is the main component of acid rain (Harte, et al, 1991). Sulfur dioxide remains in the atmosphere for one to two weeks before being removed by wet deposition or precipitation. This cleansing of the SO_2 from the atmosphere results in the production of acid rain, which contains the sulfate ion (SO_4^{2-}) (Turco, 1997). The cleansing process can be described by the following chemical equations (Boubel, et al, 1994):

[42] Oxidizing agents (e.g., diatomic oxygen found in the air) induce chemical changes (Manahan, 1991. Pg. 410).

$H_2S + 2/3\ O_2 ==> SO_2 + H_2O$

$SO_2 + 1/2\ O_2 ==> SO_3$

$SO_3 + H_2O ==> H_2SO_4$

The sulfate ion (SO_4^{2-}) is also one of the major anions occurring in natural waters. It has corrosive attributes that affect steel and other metals, as well as sewer pipes and building materials (Sawyer, McCarty, and Parkin, 1994).

Detailed Biophysical Properties of Air

Three factors determine the structure and stability of the atmosphere: the earth's gravity, the amount of atmospheric gas and the temperature of the gas. Unless a molecule has enough velocity to escape the force of gravity, it remains in the atmosphere where it is continuously colliding with other molecules and particles. The atmosphere has a total mass of 5×10^{15} tonnes, which seems like a huge amount. However, that mass is spread in a thin layer around the earth which has a mass of 1.2 million times the mass of the atmosphere (not including the 1.4×10^{18} tonnes of mass in the oceans) (Turco, 1997). Temperature varies by altitude and season around the earth, but meteorologists and climatologists have determined average temperatures for various regions in the atmosphere (i.e., troposphere, stratosphere, etc.).

Most of the mass of air is found in the lowest layer of the atmosphere, called the troposphere. This layer extends 10-16 kilometers above sea level and is quite homogeneous, though water vapor content in this layer varies considerably, due to constant mixing by circulating air masses (Manahan, 1991). These circulating air masses are caused when the sun warms the earth's surface, which warms the lower air and causes it to rise. This vertical motion is called convection and redistributes the heat from the earth's surface throughout the atmosphere. Weather conditions are created by this motion and the horizontal movement of air masses called wind (Turco, 1997).

Meteorology is the study of atmospheric events, including movement of air masses and physical forces in the atmosphere such as wind, heat and water transitions (i.e., vapor to liquid). Atmospheric events affect and are affected by the chemistry of the atmosphere (Manahan, 1991). These atmospheric events determine the dispersion of a pollutant from a smokestack: Will it be dispersed high in the atmosphere or in the local vicinity of the stack?

Wind systems are caused primarily by the heating caused by sunlight on the earth's surface, the rotation of the earth and the friction of the atmosphere. Other contributing components are the evaporation and condensation of water and the radiant heat given off by the atmosphere and the earth's surface (Turco, 1997). These factors combine variably to drive the wind system and occur on two scales, local and regional winds and large scale wind systems, such as the jet stream and prevailing westerlies, that move air around the earth (Boubel, et al, 1994).

Short-term variations in the atmosphere are call weather, which is determined by temperature, clouds, winds, humidity, horizontal visibility, type and amount of precipitation, and atmospheric pressure. Some basic physics properties apply to weather. Cold air holds less water; warm air rises; and air flows from high pressure to low pressure regions to create wind (Manahan, 1991).

Physical Characteristics of Local Air Movement

Local wind systems interact with large scale-wind systems, and are important for transporting and dispersing air pollutants. Several local wind systems exist: sea and land breezes, mountain and valley winds, rural-urban circulation, and flow around structures (Boubel, et al, 1994, Turco, 1997). Due to different rates of heating and cooling in water and land, breezes are created on a daily basis. Since the land absorbs radiant heat more quickly than water, the air over the land heats faster and rises creating a low-pressure zone. The high-pressure zone, characterized by cooler air over the water, then causes the air to move to the low-pressure zone over the land, creating a breeze. In the evening, the opposite phenomenon occurs and the breeze moves from the land to the sea. Mountain and valley winds interact in several ways with the terrain, depending on the orientation of the ridgeline (east-west or north–south) and the direction of the wind (perpendicular or parallel) relative to the ridgeline. The interactions tend to create circular pooling of the wind (eddies) along the heated walls of the mountains, producing an upslope wind during the day and a downslope wind in the evening. If the wind is perpendicular to the ridgeline, then stationary eddies can fill the valley and trap pollutants (Boubel, et al, 1994, Turco, 1997).

The rural-urban circulation condition results from the heating of the surface in cities more quickly than rural areas near-by. With a light local wind, the urban area becomes a *heat island* by creating convection currents that circulate air around the urban area. If a regional (stronger) wind allows an outflow to take place, any pollution is moved in the prevailing direction (Boubel, et al, 1994, Turco, 1997).

Finally, the flow around structures themselves can affect wind patterns. As wind moves around a building, some of it is lifted past the building but some of it is diverted downward forming eddies the size of the building. This effect is multiplied in urban settings causing wind tunnels, turbulence and inversions (Boubel, et al, 1994, Turco, 1997). Predicting wind direction and movement is not an easy task. When several of the above local conditions are combined the process is further complicated.

Ambient SO_2 Monitoring

Ambient SO_2 monitoring is often done by collection of ambient air for absorption analysis. A specialized sampler is used with a sorption medium[43]. This method has a 99 percent collection efficiency as long as the medium does not become over saturated. The analysis method is the reaction of two specific reagents[44]. Interfering compounds such as NO_2 and H_2S are treated after sampling. Automated sampling and analysis techniques can also be used on a discrete or continuous monitoring basis for several gases including SO_2 (Boubel, et al, 1994).

The Hydrologic Cycle

Hydrology is the study of the movement and storage of water in the environment (Black, 1996). Water cycles through the atmosphere, hydrosphere, and lithosphere. For the purposes of this study the focus will be on the hydrosphere and the lithosphere. Water evaporates from the land and sea surface and transpires from plant surfaces to enter the atmosphere. It leaves the atmosphere and returns to the lithosphere and hydrosphere as precipitation that can be in the form of rain, hail, snow, or fog. Through this continuous closed-system process, the finite water on the planet is moved and recycled.

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[43] The sampler is typically a midget impinger with a fritted rubber using a ten (10) ml sodium tetrachloromercurate sorption medium. The air flow is 2-3 liters per meter and the minimum sample size is 2 liters.

[44] dicholor-sulfitomerecurate and formaldehyde-pararosaniline reaction analysis

The total volume of water on the planet is estimated at 1.033×10^{15} acre-feet, of which 96.8 percent is found in the oceans (Black, 1996). The remaining 3.2 percent is freshwater, of which almost 75 percent is in the polar ice and glaciers and a little less then 25 percent is in ground water. The less than 1 percent left is found in the lakes, rivers, air and soil (Black, 1996). This small fraction is most affected through anthropogenic impacts, and society strives to manage it though planning and pollution control programs.

Biophysical Properties of Water

Within the discipline of hydrology, the study of fresh water is called limnology. Limnology address the biological, chemical and physical properties of water (Manahan, 1991). The unique properties of water are often taken for granted. The properties that are essential to life and due, in part, to the ability of the water molecule to form hydrogen bonds are listed in the Table on the following page.

Important Properties of Water

Property	Effects and Significance
Excellent solvent	Transports nutrients and waste products, making biological processes possible
Highest dielectric constant in solution	High solubility of ionic substances
Highest surface tension of any liquid	Controlling factor in physiology; governs drop and surface phenomena
Transparent to visible and longer-wavelength fraction of ultraviolet light	Colorless, allowing light required for photosynthesis to reach considerable depths in water bodies
Maximum density as a liquid at 4° C	Ice floats; vertical circulation restricted in stratified water bodies
Highest heat of evaporation	Determines transfer of heat and water molecule between the atmosphere and water bodies
Higher latent heat of fusion than any other liquid except ammonia	Temperature stabilized at the freezing point of water
Higher heat capacity than any other liquid except ammonia	Stabilization of temperature of organisms and geographical regions

Table 13. Important Properties of Water

Source: Manahan, 1991 Page 24. Used with permission from Lewis Publishers, Inc.

The most important property of water with regard to P and N discharges is that it is a solvent for nutrients and transports nutrients throughout the hydrologic system. Additionally, water is transparent to visible light, which allows photosynthesis to occur at some depth in water either using up available nutrients or causing water quality problems when excess nutrients are available.

Procedures for Nitrate-Nitrite Nitrogen and Inorganic-Orthophosphate Testing

The best method for testing for nitrate and nitrite nitrogen in water is the reduction of the nitrate in an alkaline-buffered solution to nitrite. This reaction occurs when the sample is passed through a column of copperized cadmium metal filings. The nitrite concentration is then measured by using a diazotization method that gives reliable results up to 500 micrograms (µg) of nitrate or nitrite nitrogen per liter (Wetzel and Likens, 1979).

The procedure for determining the amount of plant available inorganic or orthophosphate in a water sample is appropriate for the range of 1 to 500 µg/l of water. The sample is combined with a reagent of molybdate, ascorbic acid, and trivalent antimony. The molybdic acid formed in the reaction is then converted by reducing agents into a blue-color complex and the intensity of the color is measured to determine the amount of plant available inorganic phosphate. This procedure is specific to the elements in periodic charter group Va so it cannot distinguish between an arsenate compound and phosphate. This is normally not a problem in natural waters (Wetzel and Likens, 1979).

APPENDIX B

STRUCTURE OF U.S. AIR AND WATER PROGRAMS

Riparian and Prior Appropriation Doctrines

Under the riparian doctrine, no one person has exclusionary rights to a certain volume of water, and it is expected that a riparian landowner will return the water in a reasonable condition such that the next riparian landowner will also be able to use the water. This approach gives some flexibility in use without requiring agreement of all users (Schmid, 1987 p. 97-98). In riparian doctrine, all riparian users have the right to use the water but not to consume or sell it. The rights to the water are associated with the land and are not transferable (Tietenberg, 1996 p. 205). The other users have the same privileges to use the water and all users have a duty to use the water such that it is available to the next user.

West of the Mississippi, where water is less abundant, the policy of prior appropriation is applied to water use rights. Historically, the first owner of the right to a specified volume of water has the right to consume it or sell it to another lower priority user without regard to down stream or lower priority users access to water. However, that right has been limited through an increasing role of government, which has been given ownership rights and has been taking a more active role in protecting in-stream uses. The initial owners were given usufructory right (the right to use rather than an ownership right which was given to the state) (Tietenberg, 1996 p. 205).

With prior appropriation, the first user has more property rights than the remaining users. She may use the volume allotted for whatever purpose or sell it to any one at the price the market will bear within the constraints of the usufructory right. These property rights give the first owner privileges to the water and obligate other owners and all other persons with the duty to recognize those privileges with no right to change them.

Clean Air Act Findings, Purposes, and Goal

Title 42, Section 7401 of the US Code describes the Congressional findings, purpose, and goal of the Clean Air Act as follows:

Findings: 1) most of the population is in metropolitan areas, 2) growing amounts and complexity of air pollution caused by urbanization, industrial development and using more motor vehicles impacts on public health and welfare, 3) air pollution prevention and control at its source is the primary responsibility of the States and local government, and 4) the role of federal government is financial assistance and leadership for intergovernmental cooperation to prevent and control air pollution. The section continues and describes the purpose as: 1) to protect and enhance the quality of air to promote public health and welfare; 2) to continue and enhance a national research and development program to obtain prevention and control of pollution; 3) to provide technical and financial assistance to State and local governments as they develop and implement pollution prevention and control programs; and 4) to encourage the development of regional pollution prevention and control programs. Finally, Section 7401 states that the goal of the chapter is to encourage and promote government actions for pollution prevention.

Summary of U.S. Statutory Requirements for Sulfur Dioxide Emissions

Statute Requirement	**How Implemented for SO_2 Emissions**
Ambient Standards	Nonattainment Areas Attainment Areas
Emissions Standards	Existing Stationary Sources New/Modifying Stationary Sources
Regulatory Agencies	US Environmental Protection Agency Delegated State Agency (i.e., Department of Environmental Protection or Quality, Pollution Control Agency
Permit Requirements major sources or sources that could emit 100 tons per day of pollutant	Nonattainment Areas- New sources NSPS, offsets 1.2:1 ratio Attainment Areas- PSD standards for SO_2
Compliance Requirements	Reporting, monitoring, five year renew
Monitoring Requirements	Reporting, emissions monitoring
Enforcement Actions	Inspections, administrative penalties, fines

Table 14. Summary of U.S. Statutory Requirements for Sulfur Dioxide Emissions

Table 14 summarizes the statutory requirements for SO_2 emissions. Ambient air standards are set and result in two classifications for air quality control regions. Nonattainment areas are not meeting the ambient air quality standard and therefore stricter controls are placed on SO_2 emissions to bring the area back up to the ambient air standard (it becomes an attainment area).

Emissions standards are the maximum amount of SO_2 that a permitted stationary source can emit. If the source is already existing it must comply with the standard. The standards become stricter when a new source is built or an old source is modified.

Permit requirements vary depending on if the source is in an attainment or nonattainment area with stricter requirements in the later (e.g., 1.2 to 1 offset ratio for new sources). All sources emitting or capable of emitting 100 tons per day of pollutant are required to participate in the sulfur dioxide trading program.

The US EPA is the responsible federal agency for protecting air quality. The states that chose to administer the program also select on department to administer the air quality protection program for the state through one state implementation plan for each criteria pollutant, i.e., SO_2.

Compliance, enforcement, and monitoring requirements are the same for attainment and nonattainment areas. Permits are renewed every five years and there are reporting and monitoring requirements. Regulatory agencies perform inspections and can issue administrative penalties and fines.

Clean Air Act Title IV Findings and Goal

For Title IV of the Clean Air Act the congressional findings and purpose (42USC7651) are summarized as follows: Congress finds that 1) acidic compounds and their precursors in the air and their deposition are a threat to the natural and human environment and public health; 2) the key sources of acidic compounds are sulfur and nitrogen oxide emissions from combustion of fossil fuels; 3) the problem is of national and international importance; 4) control strategies and technologies exist that are economically feasible; 5) present and future generations will be adversely affected by delays in addressing the problem; 6) reduction in total loading of sulfur dioxide and nitrogen oxides protects the public health and welfare and the environment; and 7) control measures on steam-electric generating units should be initiated immediately. The purpose of Title IV of the Clean Air Act is to reduce effects of acid deposition by reducing sulfur dioxide emissions to 10 million tons below 1980 levels and reducing nitrogen oxide emissions by about 2 million tons below 1980 levels in the continental United States.

US EPA Principles for Effluent or Nutrient Trading

The US EPA has identified eight principles for effluent or nutrient trading which are summarized below (US EPA, 1996b).

Principle 1. Trading participants must meet the minimum applicable Clean Water Act (CWA) technology-based standards.

In the case of point sources, such as wastewater treatment plants and industrial dischargers, this assures that all trading partners meet the minimum standards of the CWA. It promotes fairness by allowing only those that already meet a baseline of water quality protection to benefit from trading.

Principle 2. Trades must be consistent with water quality standards throughout the watershed as well as meet the requirements of the CWA, other federal and state laws, and local ordinances.

Trades cannot affect water quality to limit designated uses for the water body. Any trade must first demonstrate that it will meet water quality standards throughout the watershed. A trader may not discharge a higher level of pollutants than what is allowed in permits or rules. Traders must meet assigned waste load allocations (WLAs) and load allocations[45] (LAs) even if trading helped to develop the total maximum daily load (TMDL) for the watershed to meet the anti-degradation and anti-backsliding policies of the CWA.

Principle 3. Trades are developed within a TMDL or other equivalent analytical and management framework.

Since TMDLs give estimates of pollutant loading from all sources, with a margin of safety, and a prediction of ambient pollutant concentrations, data from the TMDL can be used to forecast discharge effects on water quality. Other appropriate frameworks would include Lakewide Area Management Plans and Remedial Action Plans used in the Great Lakes. These frameworks facilitate successful trading by allocating responsibilities among covered dischargers and predicting the general effect of proposed trades. The cost of administering a trading program also needs to be built into the process as does reasonable

[45] WLA and LAs are the portion of the waste load that is assigned to individual point sources and nonpoint sources respectively. These loads along with a margin of safety and background loading from nature determine the TMDL or maximum amount of the pollutant that the water body can assimilate without negative effects on its designated uses.

assurance mechanisms such as performance bonds, memorandums of understanding, contracts, etc.

Principle 4. Trades must occur within the current regulatory and enforcement mechanisms.

All point source dischargers must comply with the CWA and nonpoint dischargers must comply with state or locally specified BMPs for each source category as a minimum measure to protect water quality. Therefore, there is no internal flexibility in trading.

Principle 5. Trading boundaries generally coincide with watershed or water body segment boundaries, and trading areas are a manageable size.

Segment boundaries are usually specific hydrologic units as defined by federal or state agencies or by the physical presence of a dam or the confluence of two rivers. Trading involves shifting the location of a discharge within a water body. Implementing this principle assures protection of the water body as a whole and guards against having adverse localized effects (i.e. poor mixing). The trading zone could be a few hundred feet, across the lake, or a mile upstream.

Principle 6. Trading will generally add to existing ambient monitoring.

Predicting the effectiveness of a trade requires obtaining data on numerous factors in the trading zone. Factors such as spatial, temporal, chemical, weather pattern, and geographic characteristics can all affect the level of control achieved by effluent trading. Ongoing ambient and effluent monitoring data are used to determine whether trades are meeting and maintaining water quality standards and traders are meeting their applicable limits.

Principle 7. Careful consideration is given to types of pollutants traded.

The potential impacts of discharging a pollutant to a new segment of the watershed must be evaluated to avoid localized violations of water quality standards. Typically, like pollutants have been traded such as nitrogen for nitrogen and phosphorus for phosphorus. Given the nature of toxic pollutants, they are unlikely candidates for trading, unless the environmental benefits can be definitively demonstrated.

Principle 8. Stakeholder involvement and public participation are key components of trading.

Since effluent trading occurs within a watershed context, all dimensions need to be considered. As Dixon (1985) described watershed problems, they result from a mixture of biophysical, economic, social, political, and institutional conditions. Previous efforts to effectively manage pollution on a watershed basis have failed because they have focused too heavily on biophysical factors and ignored the often more complex socioeconomic factors such as stakeholder buy-in to assure effective implementation of voluntary management practices or local ordinances.

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