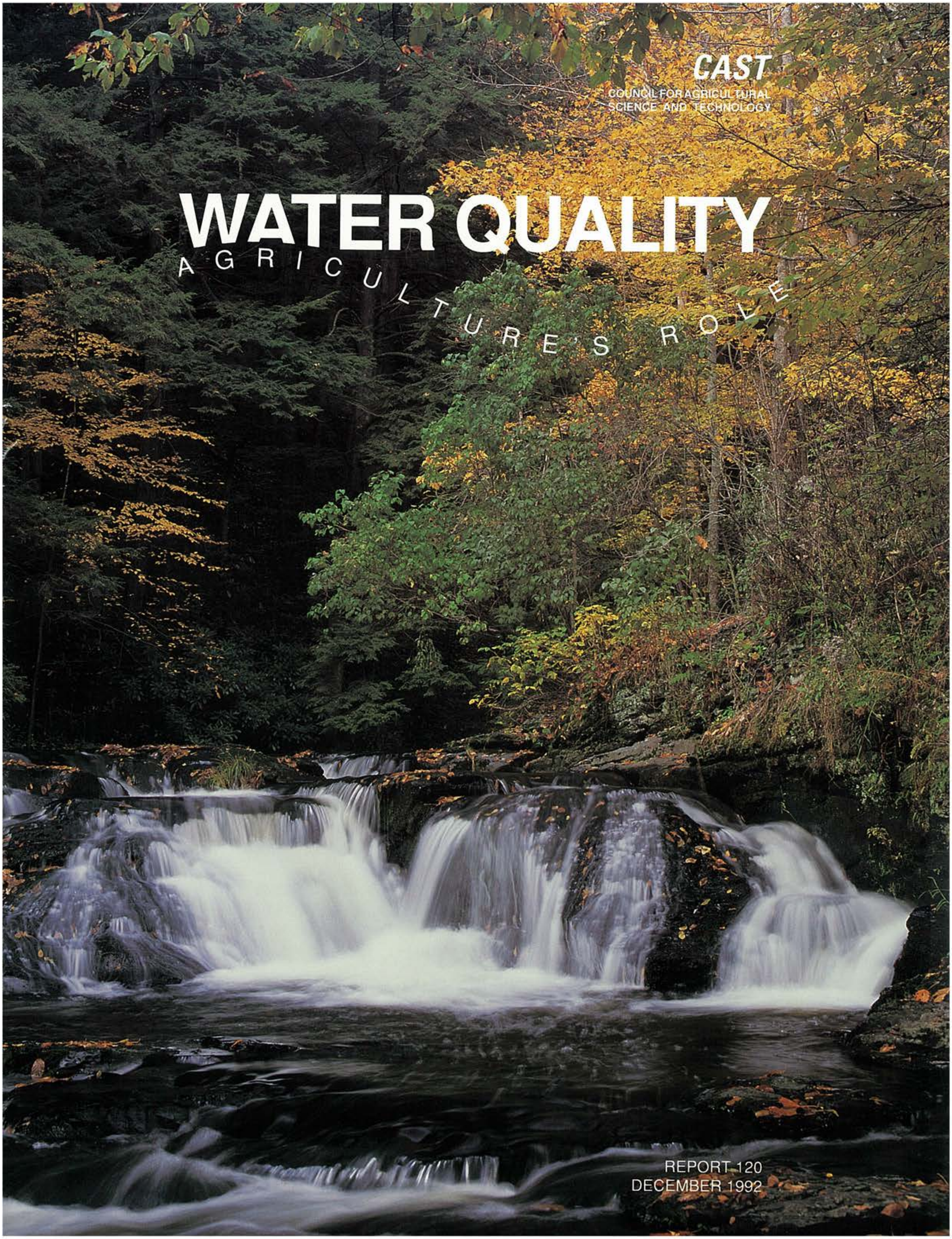

CAST
COUNCIL FOR AGRICULTURAL SCIENCE AND TECHNOLOGY

WATER QUALITY

AGRICULTURE'S ROLE

REPORT 120
DECEMBER 1992

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The Science Source for Food, Agricultural, and Environmental Issues

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The Council for Agricultural Science and Technology (CAST) is a nonprofit educational organization comprised of 29 member scientific societies and many individual, company, nonprofit, and associate society members. CAST's Board of Directors is composed of 46 representatives of the scientific societies and individual members, and an executive committee. CAST provides scientific information on key national issues in food and agriculture to policymakers, the news media, and the public.

The primary mission of CAST is the publication of task force reports written by scientists from many disciplines. The National Concerns Committee screens proposals from all sources and recommends to the Board certain topics for approval as task force projects.

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Task Force Report

No. 120 December 1992

Council for Agricultural Science and Technology

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Foreword

The CAST National Concerns Committee recommended to the board of directors that CAST prepare a report addressing issues related to agriculture and water quality. The topic was approved by the CAST Board of Directors at the February 1989 board meeting.

Dr. Frank J. Humenik, professor, in charge of Extension, Biological and Agricultural Engineering, North Carolina State University, Raleigh, was selected to serve as chair. Members of the task force were chosen to write the first draft of the report. A writing committee was then formed and met; they synthesized and supplemented the original draft. The complete task force includes highly qualified scientists with expertise in agronomy, animal sciences, biological and agricultural engineering, crop science, economics, forestry, pharmacology and medicine, policy analysis, soil and environmental sciences, toxicology, and water hydrology.

The authors were responsible for writing sections of the first and second drafts, revising all subsequent drafts, and reviewing the proofs. The CAST Executive and Editorial Review committees reviewed the final draft. The CAST staff provided editorial and structural suggestions and published the report. We acknowledge the entire CAST staff, in particular Kay Gardner and Lorie Silverthorn, for the many hours they contributed to make this report possible. The chair and authors are responsible for all scientific content in the report.

On behalf of CAST, we thank the authors who gave of their time and expertise to prepare this report as a contribution of the scientific community to public understanding. Also, we thank the employers of the authors who made the time of the authors available at no cost to CAST. The members of CAST deserve special recognition for their unrestricted contributions that support the preparation and publication of all CAST reports.

This report is being distributed to members of Congress, the U.S. Department of Agriculture, the Environmental Protection Agency, the Food and Drug Administration, the Agency for International Development, Office of Technology Assessment, Office of Management and Budget, media personnel, and to institutional members of CAST. Individual members of CAST may receive a copy upon request. The report may be republished or reproduced in its entirety without permission. If copied in any manner, credit to the authors and CAST would be appreciated.

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Abbreviations

AB2021	Pesticide Contamination Prevention Act (California)
ACP	Agricultural Conservation Program
ADI	Acceptable Daily Intake
AFA	Agricultural and Food Act (1981 farm bill)
ARS	Agricultural Research Service
ASCS	Agricultural Stabilization and Conservation Service (USDA)
BAT	Best available technology
BMP	Best management practice
CDFA	California Department of Food and Agriculture
CEC	Cation exchange capacity
CEEP	Conservation Environmental Easement Program
CEEPES	Comprehensive environmental management model
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act (also known as Superfund)
CES	Cooperative Extension Service
CFR	Code of Federal Regulation
CRP	Conservation Reserve Program
CSGWPP	Comprehensive State Ground-Water Protection Program
CSRS	Cooperative State Research Service
CTA	Conservation Technical Assistance
DALS	Department of Agriculture and Land Stewardship
DCPA	Dacthal
DWEL	Drinking Water Equivalent Level
ECARP	Environmental Conservation Acreage Reserve Program
EEG	Electroencephalogram
EPA	U.S. Environmental Protection Agency
ERS	Economic Research Service
ES	Extension Service
EXTOXNET	Toxicological information system
FACT	Food, Agriculture, Conservation, and Trade Act (1990 farm bill)
FHA	Farmers Home Administration
FIFRA	Federal Insecticide, Fungicide and Rodenticide Act
FSA	Food Security Act (1985 farm bill)
FY	Fiscal year
GAO	U.S. General Accounting Office
GPCP	Great Plains Conservation Program
GWDR	Ground water disinfection rule
HA	Health Advisory
HAL	Health Advisory Level
HEL	Highly erodible land
ICM	Integrated Crop Management
IPM	Integrated Pest Management
LD	Lethal dose
LDT	Lowest dose tested

LTA	Long-Term Agreement
MASTER	Midwest Agrichemical Subsurface/Surface Transport and Effects Research
MCHI	Mid-Continent Herbicide Initiative
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminat Level Goal
MCRP	Maryland Conservation Reserve Program
MI	Midwest Initiative
MSEA	Management Systems Evaluation Areas
N	Nitrogen
N_2	Dinitrogen
N_2O	Nitrous oxide
NO_3^-	Nitrate
NAL	National Agriculture Library
NAS	National Academy of Sciences
NAWDEX	National Water Data Exchange
NAWQA	National Water Quality Assessment Program
NEPA	National Environmental Policy Act
NOAA	National Oceanic and Atmospheric Administration
NOAEL	No-Observed-Adverse-Effect Level
NPDES	National Pollution Discharge Elimination System
NPS	Nonpoint source
OP	Organophosphorous
OPP	Office of Pesticide Programs
ORD	Office of Research and Development (U.S. Environmental Protection Agency)
OTA	U.S. Office of Technology Assessment
PCB	Polychlorinated biphenols
PIK	Payment In Kind
pfu	Plaque-forming units
PMZ	Pesticide Management Zone
PRZM	Pesticide soils leaching model
PWS	Public Water Systems
PWSP	Public Water Systems Program
RfD	Reference Dose
RUP	Restricted-use pesticide
RUSTIC	Pesticide ground water leaching model
SCS	Soil Conservation Service
SDWA	Safe Drinking Water Act
SMP	State Pesticide Management Plan
TCDD	Tetrachlorodibenzodioxin (dioxin)
TMDL	Total maximum daily load
TSCA	Toxic Substances Control Act
UF	Uncertainty factor
UIC	Underground injection control
U.S.	United States
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
VSS	Volatile suspended solids
WATSTORE	National Water Storage and Retrieval System
WHP	Wellhead Protection
WQI	Water Quality Initiative
WQIP	Water Quality Initiative Program
WRP	Wetlands Reserve Program

Summary

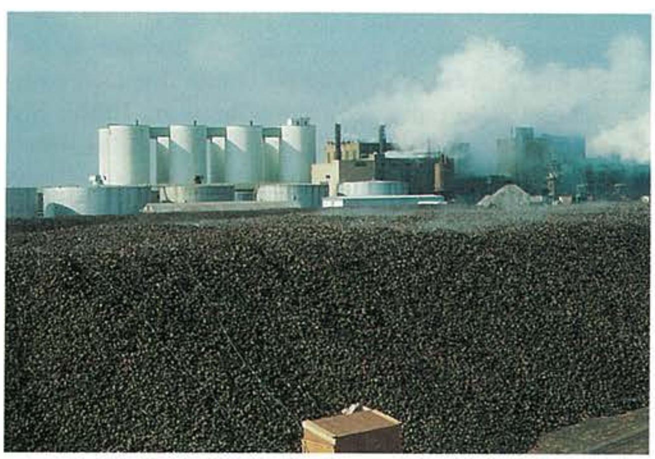
CAST produced the report, *Agriculture and Groundwater Quality*, in May 1985. That report was organized according to classes of substances that can affect ground water quality and the basic principles involved in causing and correcting water quality problems.

This report, *Water Quality: Agriculture's Role*, considers the total water resource. While there is continuing interest in ground water, surface water protection has gained renewed interest, and new programs are being developed to protect all water resources on a total watershed basis. The purpose of this report is to highlight current approaches to protect water quality from agricultural contaminants by reviewing the development of the modern agricultural system as influenced by legislation and policy. Contaminants associated with agricultural production are considered along with risk/benefit considerations, national drinking water standards, and water quality standards. Recent water quality surveys are reviewed and developing water quality programs are discussed. Major programs and activities to protect water quality from certain agricultural practices as well as environmental/conservation programs affecting U.S. farmers are reviewed in detail.

Agricultural Production and Its Impact on the Environment

The transformation of U.S. agriculture during the past 40 years parallels the rapid changes that have occurred in the nonfarm sector. The use of mechanization, hybrid seeds, mineral fertilizers, crop protection chemicals, and improved farming practices boosted agricultural productivity per work hour at twice the rate of that for manufacturing. As the United States began to fully experience the productivity advances supported by production oriented governmental policies and by science and technology, concerns were raised over the potential associated environmental costs. These concerns led to vigorous public policy debates over the appropriate course for U.S. agriculture.

For over 40 years, programs such as nonrecourse commodity loans and target prices have dominated farm policy. High loan rates acted as a market floor, encouraging farmers to produce in excess of demand. Traditionally, policymakers turned to acreage reduction programs to lower government surpluses and stimulate higher market prices, with varying degrees of success. These policies and practices led to excessive



The transformation and increased productivity of agriculture over the past 40 years. Photographs courtesy of F. J. Humenik, North Carolina State University, Raleigh.

government-held grain stocks, record federal expenditures on agriculture, and a deemphasis of conservation measures.

Dramatic proposals began to surface to fundamentally alter farm programs, driven by mounting federal deficits, massive surplus grain stocks, and growing concerns over the rural environment. The enactment of the 1990 farm bill (Food, Agriculture, Conservation, and Trade Act or FACT) reinforced agricultural policy that began with the acreage reduction program of the 1981 farm bill (Agricultural and Food Act or AFA) and expanded emphasis on environmental protection in the 1985 legislation (Food Security Act or FSA). The process that had begun to lower the number of eligible farm program base acres and thus reduce target price deficiency payments was continued in the 1990 farm bill. This bill began to encourage farmers to plant for the marketplace, instead of for government-supported payments. Previous conservation reserve programs, conservation compliance, alternative agriculture, swampbuster, sodbuster, and related provisions that add new environmental protection provisions were retained or expanded in the 1990 farm bill.

Agriculture will be increasingly directed by public concerns and environmental policies that are focused on water quality protection. Fortunately, the debate will benefit from increased understanding of the sciences, risks, benefits, and realities of agricultural production. The goals of U.S. agriculture and environmental policies that have often been at odds with one another recently have been moving toward greater harmony.

Water Quality: A Public Policy Perspective

Water pollution problems are fundamentally institutional problems. There are physical and biological dimensions in detecting contamination, tracing the source, defining treatment technologies, monitoring human health consequences, and dealing with polluters as well as consequences of polluted water. The means for reducing water contamination are institutional and include a mix of incentives, rights, and obligations confronting resource users. Policy is the process by which societal changes are made. Governments at all levels will act to protect citizens from the fact or fear of water contamination. Actions are taken when the hazards are apparent. However, policy changes in a democratic society are notoriously reactive, responding to evidence that failure to act could be disastrous. Changes are usually incremental, seldom revolutionary, and any change has winners and losers.

Various food policies have been enacted over the past 60 years to influence decisions by farmers and provide them with a measure of economic protection from poor or no yields. The character and distribution of U.S. agriculture are influenced significantly by these policies. By influencing production decisions, these policies indirectly affect water quality. Policies tending to increase the capital intensity of farming—substituting capital in the form of applied inputs for land and people in farming—place the water resources at greater risk. Land set-aside programs, whether for supply control or erosion reduction, encourage farmers to work their remaining land more intensively (Batie, 1987). When operated in conjunction with price and income support programs for eligible crops, the incentive for intensification is even greater. Little incentive exists for a farmer to unilaterally restrict applications of those inputs when the rules encourage greater intensification for that farmer's neighbors and competitors. To the extent that price and income support programs encourage farmers to plant more of the supported crops, such programs may discourage crop rotation, nonchemical weed and pest control, and other practices that protect water quality.

Rules guiding access to water also influence farmer actions that may affect water quality. With no regulation or price mechanism to guide allocation of water to competing users, there is no particular incentive to exercise stewardship in its use. Water is taken for granted, applied liberally, with only vague limits of reasonable use to guide distribution. In the western states, where water is allocated to land owners, little incentive exists for a user to apply less than the allocation. Programs that encourage farmers to irrigate otherwise unproductive land inevitably place additional stress on water quality. Increasing evidence of the hazards of sloppy waste disposal practices has led to policy change (Carriker, 1988). But these laws are highly specific to certain water sources, as in the Safe Drinking Water Act, or potentially dangerous residuals as in the Hazardous Waste Management Act or Federal Insecticide, Fungicide and Rodenticide Act. They do not deal comprehensively with water quality management. In summary, water contamination is a direct and predictable consequence of a complex fabric of rules and incentives guiding businesses and homeowners seeking legitimate personal or economic goals. In most instances these rules have other purposes—to stabilize farm incomes, to assure access to water, or to encourage economic growth. Changes in performance will require changes in the rules, adjusting the options available to competing water users and/or the direct user cost of specific options.

Change can be instigated in two basic ways: by eliminating certain options through regulation or by adjusting the anticipated cost or benefit (including nonmonetary effects) of an alternative. Taxes, penalties (financial penalties and inelegibility for public programs), and defined liability make those actions less attractive than other alternatives. Examples are provided in the full report. New data showing health consequences of water pollution can be an incentive for behavior modification. Examples of compensation for pollution-reducing behavior include (1) tax credits for land left open for ground water recharge, (2) special interest rates or tax incentives available to farmers who employ low-input or prescription management technologies, (3) subsidies to help offset uncertainties for a farmer willing to change production practices in the public interest, (4) cost-sharing to help water users invest in new technologies, and (5) government support for research and extension efforts by universities and other institutions to develop information that is compelling enough to encourage change. The most direct way to deter the actions that contaminate water is to declare those actions illegal.

New information about water quality problems can produce the support necessary for successful regulation or other policy change. More information is needed on health and environmental risks. More specific to water quality protection, analysis of the incentive structure is needed.

Effective, supportable water quality protection policies are emerging at every level throughout the United States. They are not coming fast enough for some, and success is elusive. Water quality can be protected or improved with significant changes in the ways we use that water, changes possible only through reasoned public policy.

Strip cropping and other management practices conserve soil and protect water quality. Photograph courtesy of Tim McCabe, Soil Conservation Service, U.S. Department of Agriculture.

Agriculture and Water Quality

In a 1986 EPA report (U.S. Environmental Protection Agency) to Congress, the nation's remaining water quality problems were largely attributable to pollution from nonpoint sources. The report noted at that time 76% of the impaired acres of lake water, 65% of impaired stream miles, and 45% of impaired estuarine square miles were affected by nonpoint source pollution. About 50 to 70% of the assessed surface waters were adversely affected by agricultural nonpoint source pollution due to soil erosion from cropland and overgrazing, and from pesticide and fertilizer application. State nonpoint source assessment reports show agriculture to be the greatest nonpoint source pollution problem in the United States. Similarly, the largest share of state nonpoint source management reports focus on agriculture. More specifically, livestock and nutrient management have been identified as the major nonpoint source problems of the immediate and short-term future.

When addressing agriculture's role in water quality, the total resource must be considered because of the continuum of water described by the hydrologic cycle. From this broader perspective, agriculture should promote practices that prevent or minimize pollution of all parts of the hydrologic cycle and avoid encouraging those that simply shift pollution from one medium to another.

The agricultural use of fertilizers and manure increases the availability of plant-essential elements, and thus increases the total yield and/or quality of crops. However, excess amounts of nitrogen and phosphorus from commercial fertilizer and manure, or pathogenic microorganisms from manure, may cause water quality problems. Based on the known health effects of nitrate and nitrite, a health based standard level was established at 10 mg/l (ppm) nitrate nitrogen. The nitrite standard for drinking water is 1 mg/l. Daily consumption of drinking water containing nitrate nitrogen levels at or below 10 mg/l would not be expected to cause nitrate/nitrite-related adverse health effects. This level is the legally-enforceable Maximum Contaminant Level (MCL) for municipal water supplies (U.S. Environmental Protection Agency, 1989b; 1990b). Nitrates in excess of the MCL can be a factor concerning methemoglobinemia in infants and may be a risk to humans due to nitrosamine formation. Water high in nitrate also can have detrimental effects on the health of farm animals, resulting in weight loss and poor feed conversion (Carter and Sneed, 1987). High and even low levels of nitrate can cause eutrophication (deterioration) of surface water bodies, especially estuaries. Eutrophication can occur in surface water at nitrate levels as low as 1 mg/l. Phosphorus can cause eutrophication of fresh water at even lower levels.

Salinity refers to the total concentration of a mixture of soluble salts present in all natural waters. Irrigated water is one of the major sources of increased salinity, which can result in crop yield reductions and water quality degradation. The irrigated area in the United States has increased from nearly 19 million acres in 1945 to more than 47 million acres in 1987 (U.S. Department of Commerce, 1987). Nearly 30% of the market value of products sold from farms was produced by irrigation. This production from irrigated farms came from only about 13% of the total cropland. Irrigation in arid or semiarid regions always degrades water quality and may deplete available ground water. To prevent soil salinity from reaching harmful levels, a portion of this concentrated soil solution must be leached (drained) below the crop root zone. Drainage from most hydrologic basins progresses from the uplands into rivers and eventually to the ocean. Some hydrologic basins, such as the Salton Sea and Kesterson Reservoir in California and the Stillwater Reservoir in Nevada, are closed and do not have an outlet to the ocean. Ocean disposal is nature's way of moving dissolved salts out of the landscape. Irrigation tends to accelerate this displacement process and increases the salt content of surface streams. Irrigation management procedures developed to prevent harmful accumulations of salt in the soil and for the proper application of irrigation water with various levels of salinity are discussed in the full report.

Pesticides include a large number of chemicals used primarily in agriculture for pest control and, consequently, may enter ground and surface water. Among the chemicals classified as pesticides are herbicides, insecticides, fungicides, nematicides, and rodenticides. Some of the more important pesticides and their associated toxicities, separate from drinking water exposure, are summarized in the full report. Given the numerous classes of chemicals used as pesticides, it is not surprising that human and animal exposure to them may result in a wide range of symptoms.

Ground water supplies over 100 million Americans with their drinking water. Private wells generally do not receive disinfection treatment for pathogenic microorganisms (DiNovo and Jaffe, 1984), and the EPA has estimated that approximately 72% of the public water-supply systems in the United States that use ground water do not disinfect (U.S. Environmental Protection Agency, 1990f). Based on survey data from the Centers for Disease Control, it has been estimated that waterborne infections caused by bacteria, viruses, or protozoan pathogens affect 940,000 people and are responsible for 900 deaths every year in the United States (Bennett et al., 1987). Sources of microorganisms included home septic systems, cropland being irrigated with sewage effluent, sanitary landfills, land application of sludge, sewage effluent, and manure. The report discusses the current and proposed EPA and state requirements and standards for protection of the ground water from microorganisms.

Many agricultural practices, such as land-applied manure or municipal waste, redistribute metals within the environment where they may enter the food chain or water resources. New rules were signed on November 25, 1992 and are to be published in final form (entitled Standards for the Use and Disposal of Sewage Sludge) as 40CFR Part 503 in the *Federal Register* in January 1993.

Pollution prevention must be looked at in a systems approach if effective loading reduction is to occur. For agriculture and rural areas, nutrient and chemical management, manure management, surface runoff and erosion control, ground water leaching, and septic tank placement in regard to wellheads must all be considered and addressed jointly. Urban or suburban areas should focus on land fills, septic tank maintenance, storm water management, and lawn and garden best management practices.

Risk/Benefit Considerations: Health, Environmental, and Economic

Risk/benefit considerations continue to be an important tool in establishing environmentally sound, cost-effective, scientifically accurate regulations and public policies. Risks or benefits can be classified as actual, projected, or perceived. Acceptance of the validity of risk/benefit calculations may be influenced by the values or needs of individuals or interest groups.

Health Risks

Evaluation of health risks is an integral part of the regulatory process for establishing drinking water standards and acceptable pesticide residues (tolerances) on food crops. Except in cases where there is a proven link between a chemical exposure and human illness, risk assessment may rely on mathematical models designed to help scientists predict potential adverse effects. Waterborne disease from microbial contamination is an actual risk that continues to occur when drinking water has not been adequately treated and protected. In contrast to actual health risks that can be documented and supported by data, other effects may be categorized as projected. For example, the number of human cancers that may result from exposure to a carcinogen in drinking water, based on data collected in laboratory animals, can only be estimated or projected.

There is a significant degree of uncertainty associated with projecting risks due to chemical exposure. Part of this uncertainty stems from the existence of different risk assessment models. The models used by the U.S. Environmental Protection Agency to establish water standards for carcinogenic chemicals are conservative, intending to provide a "worst case" risk projection.

Environmental Risks

Risk to the ecosystem can be real or projected, and like health risk data can be subject to controversy, scientific dispute, and may cause public uncertainty. A substantial number of agricultural practices cause adverse, sometimes irreversible, environmental changes and may increase water quality degradation. Some of the practices discussed in the report include the draining and conversion of wetlands for crop production; documentation of the adverse effects of certain chemicals; soil sediment eroded from cropland into rivers and lakes; and loss of submerged aquatic vegetation.

Experts disagree about the value of mathematical models to predict the future of dynamic, biologically sensitive ecosystems. Projecting risks to surface waters is complicated by natural events like flooding and droughts and the complexity of assessing all inputs on a total watershed basis. Projecting risks of ground water contamination requires extensive hydrogeological research.

Economic Risks

Economic analysis, particularly the effect of financial incentives or disincentives, continues to be a vital part of risk and benefit evaluations. Determination of economic efficiency, the balancing of costs and benefits, including social and environmental costs, is complicated by existing laws, court interpretations, and governmental institutional responsibilities. Changes in the rights and obligations of users, or in the economic and social cost of water-use options may be needed to reduce water pollution (Libby, 1990).

Perception of Risk

Public confusion may result from the scientific uncertainties associated with assigning risks. The scientific community's ability to detect chemicals is much more advanced than the understanding of the toxicology associated with such discoveries. The public understands that pesticides are not a natural component of drinking water and that pesticides were created to kill living things. They are generally unaware of the scientific basis for the debate over "safe levels of exposure" that surrounds establishment of pesticide tolerances for exposure in food or water.

Public perception can be a political catalyst that stimulates legislative and executive action. Public policies are a reflection of prevailing public values, attitudes, and perceptions of societal problems, and can be significantly shaped by the media. Trend information, such as similar questions asked of comparable groups at different times, is a more accurate indicator of public opinion than opinion polls. Public opinion trend information indicates that public support for environmental protection not only remains strong, but has continued to increase (The Conservation Foundation, 1982). People tend to accept risks if they are self-imposed or if they are familiar. However, pesticide contaminated drinking water involves an involuntary risk, one associated with a resource for which no substitutes exist (i.e., water). Public perception in the 1990s reflects concern about environmental protection and wise management of the entire ecosystem and agriculture is just one part of that ecosystem.

Current Approaches to Protecting Water Quality from Agricultural Contaminants

The existence of numerous efforts at all levels of government to protect water from agricultural contaminants necessitates development of an effective coordination strategy to avoid conflicts and duplication of efforts. Failure to recognize this need can lead to squandering of limited resources and may result in conflicting programs that may even increase contamination of ground water while trying to reduce contamination of surface water (or vice versa).

Approaches to protect water quality from agricultural contaminants can be categorized as nonregulatory/voluntary, regulatory, liability, or comprehensive protection. Many farmers have voluntarily adopted best management practices and other measures that will help protect water from contamination. Continued research, education by public and private entities, technical assistance on developing or implementing water quality protection programs and regulations, economic incentives, and product stewardship are necessary to increase water resource protection. Product controls and other regulatory standards and laws provide incentives, as does liability for the adverse environmental consequences of agricultural production. Resource-based protection, such as watershed management and comprehensive state ground water protection programs, is an example of comprehensive protection.

Future Water Quality Programming

The reaffirmation of the need to control nonpoint sources of pollution after a period of intensive activity on point source control and ground water quality provides a current focus for addressing future water quality programming in relationship to agriculture's role in water quality. A GAO report (1990) identified conflicts between some federal agencies' policies and states' water quality goals as significantly affecting state and local efforts to control nonpoint source pollution. A prime example of the problem is the USDA Farm Commodity Programs, which indirectly contribute to nonpoint source water pollution through policies that encourage maximum crop production goals without regard for natural resource protection. A key contributing factor associated with EPA resource constraints has been that available funds are overwhelmingly oriented toward point source control activities rather than nonpoint source. However, the EPA's own analysis of comparative risks posed by alternative pollution problems suggests that nonpoint source water pollution poses a level of health risks comparable with that presented by point sources and with substantially more serious ecological risks.

The reauthorization of the Clean Water Act will gain increased national attention, especially from those who feel better control of agricultural nonpoint sources is necessary to achieve water quality goals. This will result in directing increased attention to the technology, public policy, and regulations necessary to achieve national water quality goals. Defining a balanced and technically sound role for agriculture in maintaining water quality will be a very important cooperative and multidisciplinary challenge.

Toward a New Agricultural Ethic

Convergence of many concerns over the present agricultural system is facilitating an integration of agricultural and environmental policies. The environment, the farm sector, and the tax paying public would benefit from policies that simultaneously address the economic and environmental consequences of U.S. agricultural techniques and capacity. In the future, the EPA and USDA will have to work together in integrating agricultural and environmental policies.

The development of strong government regulatory programs alone will not solve the environmental problems that are linked to agricultural practices. Because these problems are so diverse and because agricultural practices vary so widely, the creative, voluntary participation of farmers from across the country will be necessary to achieve environmental goals. Farmers will make good partners in national and local pollution control programs because they are affected first by the problems and are the key for effective solutions.

Environmentalists need to recognize that there are limits on the speed and the degree to which agricultural programs can be altered to achieve environmental goals. It is equally important for the agricultural community to recognize the need to integrate agriculture and environmental policies in establishing a new ethic that places equal emphasis on production and environmental protection. The time is right for everyone to work toward a new agricultural ethic that will achieve both agricultural and environmental quality goals of a safe and affordable food supply, a prosperous farm sector, and a stable, productive ecosystem.

Development of National Drinking Water Standards and Guidelines

Drinking water regulations are to contain criteria and procedures that assure a supply of drinking water, which dependably comply with maximum contaminant levels (MCL), including quality control and testing procedures.

The Safe Drinking Water Act requires the EPA to establish primary drinking water regulations that will (1) apply to public water systems; (2) specify contaminants which, in the judgment of the EPA administrator, may have an adverse effect on the health of persons; and (3) specify for each contaminant a maximum contaminant level goal (MCLG) and either a maximum contaminant level (MCL) or treatment technique. A treatment technique requirement would only be set if "it is not economically or technically feasible" to ascertain the level of a contaminant in drinking water.

MCLGs are nonenforceable health goals and are to be set at a level at which, in the administrator's judgment, "no known or anticipated adverse effects on health or persons occur and which allow an adequate margin of safety." The MCLGs for carcinogens are to be set at zero.

MCLs must be set as close to the MCLGs as feasible. Feasible means "with the use of the best technology, treatment techniques, and other means, which the administrator finds, after examination for efficacy under field conditions and not solely under laboratory conditions, are available (taking costs under consideration)."

Health Effects Information for Drinking Water Standards and Guidelines

Nitrate/nitrite and alachlor were selected as examples of well-known chemicals that can be found in ground water or drinking water. Nitrate/nitrite is inorganic and representative of an input from natural sources, animal and human waste, and nutrients used for crop production. Alachlor is organic and representative of an agricultural chemical that is used primarily for crop production. Therefore, these two chemicals were used in the report to provide specific examples for the development of drinking water standards and guidelines.

Water Quality Standards

A water quality standard defines the water quality goals of a body of water, or portion thereof, by (1) designating the use or uses to be made of the water and (2) setting criteria necessary to protect those uses. States adopt water quality standards to protect public health or welfare, enhance the quality of water, and serve the purpose of the Clean Water Act.

If the EPA does not approve the state's water quality standard, it may promulgate federal water quality standards necessary to meet requirements of the Clean Water Act. States can develop more stringent standards than those required by the Clean Water Act.

If technology-based limits are insufficient to obtain or maintain quality standards, the state or EPA must determine the total maximum daily load (TMDL: the amount of a pollutant that may be discharged into a water body and still maintain water quality standards). The TMDL is the sum of the waste load allocation from point sources and the load allocation from nonpoint sources and background sources, plus a margin of safety.

Recent Water Quality Surveys

Results for the EPA National Survey of Drinking Water Wells, the National Alachlor Well Water Survey, and state surveys are presented in Appendix D.

The EPA survey estimated that about 10% of the nation's community drinking water wells and about 4% of the rural domestic wells would have detectable levels of at least one pesticide; however, less than 1% would exceed a standard or health guideline value. That survey estimated that about one-half of the wells contain nitrate, with about 1.2% of the community wells and 2.4% of the rural wells exceeding the 10 mg/l (nitrate as N) drinking water standard.

In the alachlor survey, less than 1% of rural wells had any detections of alachlor, and only 0.02% were projected to exceed the MCL.

Management of Agricultural Nutrients

Nitrogen is no more essential for crop production than any of the other 15 essential elements. However, the amount of nitrogen required is much larger than any other essential mineral element except potassium, for which the amounts required are essentially the same as for nitrogen. Nitrogen can be supplied from various sources, but it is necessary for adequate crop yields.

Nitrogen losses can be minimized by proper nutrient management practices and best management practices (BMPs) to reduce surface runoff and ground water infiltration losses. Agronomic management for high yields will promote efficient utilization of the available nitrogen in the soil plant system. Proper fertilization practices, nitrification inhibitors, water-nitrogen management, and legume rotations can be used to improve nitrogen use efficiency and reduce nitrogen losses.

Transport of phosphorus into waters is of concern primarily when erosion moves soil materials into surface waters. Except for very small areas of sands and organic soils that are almost completely devoid of clays, oxides, and carbohydrates that retain (absorb) phosphates, the phosphorus added in organic material or mineral fertilizers is retained in the soil. However, these small areas may have a high level of agricultural activity and be in sensitive ecological settings. An example is the concern over phosphorus enrichment of Lake Okeechobee in Florida from agricultural runoff. Techniques to control transport of bioavailable phosphorus in agricultural runoff are important because of the low levels of phosphorus (10 ppb) that can stimulate algal growth.

Phosphorus adsorbed on surfaces of soil particles that are transported by erosion can desorb as the soluble phosphorus is diluted and thus contribute to the accelerated eutrophication problem. If no soil materials are transported, the phosphorus stays where it can be used by crops, and fertilized croplands do not contribute to accelerated eutrophication of surface waters.

Major Programs/Activities to Protect Water Quality from Agricultural Contaminants

Numerous efforts are underway to protect water from agricultural contaminants. Among these are programs and legislation at all levels of government. Some of the numerous federal, state, regional, and local government efforts underway are summarized in Appendix F of the report.

Environmental and Conservation Programs Affecting U.S. Farmers

Conservation programs linked to farm program benefits eligibility, cost-share programs, and USDA programs affected by noncompliance are reviewed. Options for farmers to retain or lose eligibility for USDA Farm Program benefits and have other USDA programs open to them are outlined in Appendix G of the report.

1 Agricultural Production and Its Impact on the Environment

Modern Agriculture's Rapid Evolution

The transformation of U.S. agriculture during the past 40 years outdistances the rapid changes that have occurred in the nonfarm sector. U.S. agriculture today—influenced by international trade, government actions, world money markets, and rapidly advancing technological innovations—is comprised of some of the nation's most skilled managers and sophisticated business strategists. That sophistication has bred new generations of farmers who better understand the complexities and opportunities of their role in the national and international marketplace.

U.S. farmers have proven their ability to seize market advantage and to capitalize on government farm programs to maximize profits. They are doing this in a dynamic theater of farm policy and regulatory influence in which environmental and ecological protection have moved rapidly to center stage.

As policymakers focus on environmental issues that might influence the future of U.S. agriculture, it is important to understand the factors that led to our present-day food production system and the limitations inherent in establishing national environmental goals related to agriculture. It is equally important to discuss the ways in which agriculturally related policies can work at cross-purposes to the nation's stated environmental objectives.

Science Spawns The Green Revolution

Mechanization, hybrid seeds, commercial fertilizers, and agricultural chemicals, commonplace today, have been used to dramatically boost crop production only in the past few "moments" of agriculture's 10,000 year history. Before the 1870s, methods to control pest damage in crop production were primarily cultural and physical and included crop rotation, destruction of crop refuse, timing of planting dates to avoid high pest population periods, use of trap crops, pruning and defoliation, and isolation from other crops. However, additional pest management or controls were needed to lessen crop damage.

Chemical pest control in agriculture originated in the United States in 1870 with the development of Paris green to combat the potato beetle. Bordeaux mixture was first used in France in 1882 to control disease in grape culture. Scientists began extensive research into various methods of chemical pest con-

Mechanization is one component of the rapid evolution of modern agriculture. Photographs courtesy of F. J. Humenik, North Carolina State University, Raleigh.

trol throughout the early 1900s.

Much of this research matured during the 1950s and early 1960s. This period is considered the dawn of agriculture's Green Revolution—an era when new varieties of wheat, corn, rice, and virtually every other crop were combined with applications of mineral fertilizers and other agricultural chemicals to produce dramatic increases in crop yields. While the average farmer of the 1950s could produce enough food to feed 27 people, today one farmer feeds 120 people.

Agricultural and Environmental Policies Take Root

Well before the Green Revolution, the U.S. Congress enacted the Agricultural Adjustment Act of 1933. What was intended as a response to the needs of farmers during the Depression Era became the cornerstone of U.S. agricultural policy during the succeeding 50-plus years. On this cornerstone was built an elaborate structure of farm income support programs, acreage incentive and control schemes, guaranteed low-interest loans, crop disaster payments, and government-pegged target prices for various crops.

Yet, even in the midst of the Depression, the federal government demonstrated its interest in protecting our natural resources, declaring in 1935 that soil erosion was a national menace and directing the U.S. Department of Agriculture to establish the Soil Conservation Service. A dozen years later, regulatory supervision of pesticides began under the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) of 1947, although as recently as 1952, only about 10% of U.S. cropland was treated with herbicides. Today that figure stands at 90 to 95%.

Productivity Rises as Farm Population Drops

The use of mechanization, hybrid seeds, mineral fertilizers, crop protection chemicals, and improved farming practices boosted per work-hour agricultural productivity at twice the rate of that for manufacturing. If farmers today produced food using the same techniques available at the time of World War I, one out of every three people would need to leave his or her job and return to the farm.

Over the past 40 years, per-acre yields have risen dramatically: corn yields are up 125%, wheat yields have climbed 38%, soybean production is up 40%, and cotton harvests have risen 51% during the past four decades.

The bounty fostered by science and technology produced an agricultural heyday in the late 1960s and early 1970s. The United States is considered the breadbasket of the world, exporting vast quantities of grain to markets around the globe. U.S. grain exports climbed 340% during the past three decades until it supplied over one-half the grain traded throughout the world.

All this happened despite a continuing exodus from the farm. Forty years ago, there were more than 27 million U.S. farms. Today, there are fewer than 2.1 million.

Agriculture's Impact on the Environment

As the United States began to fully experience the productivity advances fostered by science and technology, concerns were raised over the potential environmental costs associated with these innovations. These concerns led to vigorous public policy debates over the appropriate course for U.S. agriculture.

At one extreme were those professing the Malthusian theory that population growth would vastly outpace the world's ability to feed itself, suggesting "full speed ahead" for agricultural production as the only priority. At the other end of the spectrum were those whose views, popularized in Rachel Carson's *Silent Spring* (Carson, 1962), reflected a small but growing body of concern over health, environmental, and food safety questions.

That debate, which continues today, formed the basis for several diverse and sometimes conflicting governmental policy choices influencing U.S. agriculture and our society at large.

The Rush to Produce

Production oriented policies coupled with mechanization and emphasis on large scale acreages put virtually every inch of cultivable land into production. Fences were removed, grass waterways, vegetative buffer strips, and shelter belts were plowed. Wetlands and swamps were drained with the encouragement and financial support of government programs. Ground water irrigation systems permitted more extensive farming. Governmental expansion of irrigation in the arid west occurred on lands with poor moisture-holding capacity or on lands with no natural or engineered drainage systems. The "go-grow" governmental policies encouraged agricultural production but increased soil erosion, water pollution, and loss of fish and wildlife habitat.

Soil: The Mounting Loss of a Vital Resource

During the past 40 years, the effects of production agriculture on soil productivity have been largely offset by improved technology—pesticides, hybrid seeds, fertilizers, equipment, tillage practices, higher plant populations, and irrigation.

However, water and wind erosion still hold threats to soil productivity. Erosion continues its relentless removal of the organic matter, fine soil particles, and plant nutrients from unprotected soil. While it may have taken up to 1,000 years for 1 inch of topsoil to form under natural conditions, this inch can be lost in as little as four years through erosion. Water supplies, in turn, can also be affected because soil sediment from the field may well be deposited in streams, lakes, rivers, and ditches. Millions of dollars are spent annually to dredge harbors and ship channels to clear them of erosion's deposits. Fish, wildlife, and reservoir capacity also are affected.

Fertilizers that promote and pesticides that protect crop growth, have become contaminants in some regions when carried into water supplies.

The use of irrigation has opened new lands to production and has afforded some of the highest crop yields on record. But in some locations, irrigation has led to accumulation of certain salts in soils, creating highly alkaline soils unsuitable for most agricultural crops. During the 1970s and 1980s, some 20,000 acres of cropland were eliminated each year due to salt problems, primarily in the arid and semiarid regions of the 11 western states.

In some locations, deterioration of soil structure and tilth also occurred. This resulted from a number of factors, including loss of organic matter, excessive soil tillage, and use of heavy equipment. Reduced water infiltration and water holding capacity resulted along with reduced crop productivity, increased erosion, and runoff of plant nutrients and pesticides.

Widespread use of applied nutrients and pesticides has raised concerns in some areas after surveys detected the presence of nitrate and pesticides in some lakes, streams, and underground drinking water supplies. Questions were raised also about the indirect effects on ecology, environment, and human physiology of long-term, low-level exposure to pesticides.

During America's history, agriculture has converted forests, marginal lands, swamps and other wetlands to crop production. These ecological changes produced the standard of living we enjoy today, but the changes are accompanied by erosion problems, reduced fish and waterfowl populations, and threatened wildlife habitats in many parts of the United States.

Agricultural Policy: Conflicting Signals on Production and Environmental Sensitivity

Practically since its inception, U.S. farm policy has been the focus of debate in the halls of Congress. The basic structure of farm legislation has been reestablished by Congress and signed into law by the president. But because the agricultural economy is so volatile, and because farm legislation has been written to respond to the near-term concerns of society, such policies have rarely been relevant for the duration of their stated term.

For over 40 years, programs such as nonrecourse commodity loans and target prices have dominated farm policy. High loan rates acted as a market floor, encouraging farmers to produce in excess of demand. As a result, in soft export periods, government-owned stocks burgeoned as producers chose to default on their loans.

Traditionally, policymakers turned to acreage reduction programs to lower government surpluses and stimulate higher market prices, with varying degrees of success. If farmers saw an opportunity to capitalize on potentially higher market prices while still gaining the protection of government support programs, they often idled the required number of acres (usually those that were traditionally less productive) and boosted their yield goals on the remaining acres.

Erosion continues its relentless removal of organic matter, soil particles, and plant nutrients from unprotected soil. Photograph courtesy of F. J. Humenik, North Carolina State University, Raleigh.

Since farm program benefits were tied to every bushel or pound of program commodities produced, farm policy offered little flexibility and no financial encouragement for farmers to plant anything other than their traditional crops or to employ systems such as crop rotations, which would benefit their resource base. These policies and practices led to excessive government-held grain stocks and record federal expenditures on agriculture.

A Decline in Agricultural Competitiveness

Dramatic proposals, driven by mounting federal deficits, massive surplus grain stocks, and growing concerns over the rural environment, began to surface, which fundamentally altered farm programs. At the time, policymakers had yet to fully experience the effects of worldwide recession, and many policies that were built on inflationary expectations were maintained. Beginning in the early 1980s, the glut of U.S. grain surpluses steadily mounted, as agricultural embargoes, unfavorable currency exchange rates, worldwide recessionary pressures, and growing competition in global grain markets choked export opportunity.

Barely two years into the 1981 farm bill (Agricultural and Food Act or AFA), the mistakes had become clear. Congress granted authority to the secretary of agriculture to implement, at his discretion, acreage reduction programs.

The dangers of locking automatic increases into the established loan rate became clear as price supports outpaced market-clearing levels and U.S. grain became less competitive on world markets. Attention turned away from fencerow-to-fencerow plantings and toward implementation of vast acreage reduction programs, creating record declines in planted acreage.

Farmers, who in 1980 relied on the government for only 5% of their net cash income, only six years later obtained one-half their income from Washington. Government expenditures on farm income support programs reached record proportions. Direct payments in 1983 were nearly five times what they had been only two years before (in 1981, $3.8 billion; in 1983, $18.6 billion). Then, payments nearly doubled within the next four years (to $33.4 billion in 1987).

In 1983, the secretary of agriculture announced a massive acreage reduction program, Payment In Kind (PIK), which withdrew a record 83 million acres from crop production. This reduction caused a ripple effect on the rural economy nationwide, as farmers cut their purchases of inputs, equipment, and other items. This was a major turning point in farmer participation in government programs.

Clearly, government policies had created a situation where farmers were induced to "farm" and "harvest" the benefits of agricultural policy rather than make decisions based on market signals.

A New Focus on the Environment

As efforts mounted to shift the agricultural machine into a lower gear, major advances in analytical chemistry and instrument sensitivity shifted the spotlight to the lingering effects of the "go-grow" period. And, for the most part, policymakers did not like what they saw.

Results of well sampling surveys for nitrates and pesticides began to suggest a potentially serious problem, particularly in regions of the country where sandy, porous soil or the presence of sinkholes provided easy paths through which nitrates and pesticides could contaminate ground water. Earlier assumptions that these chemicals would be filtered out or broken down proved not always to be true as traces of these contaminants were detected with increasing frequency in rural wells. Concerns rose, and several years passed before thorough studies put the issue into perspective. A review of recent water quality surveys is presented in Appendix D.

Studies of river water quality in watersheds draining agricultural regions revealed the presence of sediment, nitrate, phosphate, and certain pesticides, particularly during early spring rainstorms following field preparation but before plant growth shielded the soil (Figure 1.1). Education, conservation farming methods, and wellhead protection programs were seen as a key to preventing water contamination.

Shifting Legislative Priorities

In 1985, Congress enacted a five-year farm bill (Food Security Act or FSA), but this legislation was not business-as-usual for U.S. agriculture. The new law began to incrementally lower loan rates and target prices for various commodities; farmers were encouraged to plant nonprogram crops; acreage reduction incentives were built into the legislation; and export promotion measures were added to alleviate the oversupply of grain storehouses.

While the ratcheting down of support programs was a dramatic shift in farm policy, perhaps more significant was Congress' establishment of a comprehensive new conservation title in the bill. The conservation title created a new national Conservation

Reserve Program (CRP) in which farmers were compensated for removing highly erodible and other fragile lands from production for 10 years. Congress returned to policies of retiring land from production, policies that had been used in the past for management of production, but that were now focused on protection of soil and water.

In an additional program, Conservation Compliance, farmers in areas identified by the USDA as having highly erodible soils were required to submit a locally approved conservation plan for their farms by January 1991 or risk losing future farm program benefits. Full implementation of these plans is required by January 1, 1995. The bill also authorized research funds for alternative farming programs, with the goal of better integrating agriculture's use of nutrients (fertilizers, manures, and legumes) and pesticides with alternative production measures.

In an assessment of agriculture's potential impact on water quality, it is imperative that crops not included in federal commodity programs, such as fruits and vegetables, be given careful consideration. Although acreages of individual crops are relatively small, combined acreages are significant. In mild climate areas, these high-value crops are often produced year-round with irrigation and, perhaps, chemigation, on rich, porous soils. As a result, they are generally more intensively managed than program crops, and may require more nutrients, pesticides, and irrigation water. The risk is that irrigation-induced erosion, runoff, and leaching to shallow ground water aquifers will be enhanced. Management decisions affected heavily by climate, pest levels, and the resulting market economics are more difficult to influence without the requirements of federal commodity programs. Thus, efforts to improve production practices are best accomplished by strong grower educational efforts, such as those provided the USDA, EPA, grower associations, and private industry. However, the financial incentives cannot be contradictory.

Continuing the New Direction

The enactment of the 1990 farm bill (Food, Agriculture, Conservation, and Trade Act or FACT) reinforced agricultural policy thinking that began with the lessons learned from the 1981 farm bill and the new philosophies embodied in the 1985 legislation. In many ways, the 1990 bill could be viewed as something of a cease and desist order for the New Deal policies that have dominated agriculture since the 1930s. In addition, it represents the most environmentally sound farm bill ever written because of its expanded emphasis on environmental protection.

The 1990 farm bill initiated programs to encourage farmers to plant for the marketplace, not for government-set support payments. The process that had begun with the 1985 law (to lower the number of eligible farm program base acres and thus reduce target price deficiency payments) was continued in the 1990 law with a new "Triple Base." In addition to the normal base acreage and the typical 20% acreage set-aside for most crops, Congress added a "flexible plantings" designation for 15% of the base. Farmers do not get a deficiency payment on these acres, regardless of the crop grown; but farmers have the freedom to choose a more profitable (or prudent) crop for those acres. The legislation retains or expands previous CRP, conservation compliance, alternative agriculture, swampbuster, sodbuster, and related provisions and adds new environmental protection provisions (see Appendix F).

Turning the Tide: The Impact of New Policies and Practices

Much is riding on whether these new agroenvironmental policies and farming changes will succeed in protecting ecological resources. In many cases, adoption by farmers is hampered by large direct or indirect costs, lack of experience, and necessary cropping and equipment changes. But encouragement can be derived from recent trends. For example, no-till soybean acreage doubled in the years between 1987 and 1990, and the percentage of all farmed acres in America in conservation tillage has increased steadily (Table 1.1).

Recent studies indicate that siltation, nutrients, and pesticides, the most common agricultural nonpoint source contaminants, are reduced by conservation tillage and implementation of best management practices (BMPs). Furthermore, by reducing soil erosion, unwanted movement of soil-bound nutrients

Table 1.1. Percentage of all farmed acres in America in conservation tillage (Conservation Technology Information Center, 1992)

Crop year	Farmland in conservation tillage (%)
1989	25
1990	26
1991	28
1992	31

and pesticides is also reduced. Crop residue covering of the soil is an important part of these strategies (Tables 1.2 and 1.3; Figure 1.1).

Reduction of agricultural nonpoint source water pollution should become evident as farmers complete the implementation of their USDA conservation compliance plans. With a deadline for completion of 1995, this program affects at least 40% of all U.S. farmers and 98% of all highly erodible farmland in America—more than 130 million acres. On-farm changes include maintenance of high residues (conservation tillage), use of buffer strips around fields and along water supplies, contour planting, strip farming, and construction of terraces and grassed waterways to reduce runoff and erosion. Other USDA programs such as the Water Quality Incentive Program, Conservation Reserve Program, and Wetlands Reserve Program should further reduce adverse agricultural impacts on water quality if adequately funded.

The extent to which the fishable and swimmable goals of federal water quality legislation are reached will play an important role in determining the pace and extent of future shifts from voluntary programs to state and federal regulatory programs to protect water quality. Assessment of water quality (chemical, physical, and biological) will be the on-going basis for such decisions. As a result, an important issue is whether current monitoring programs are adequate to properly support assessments of progress being made toward water quality goals. A report of a special committee on water quality monitoring in North Carolina concludes, "First, the monitoring of nonpoint sources and ambient water quality conditions is woefully inadequate. Monitoring of these elements of water quality are inadequate to keep the public properly informed on the status and trends of water quality, and they provide inadequate information to guide the formulation and adoption of public policy. Second, results of existing monitoring programs are not effectively disseminated to oversight agencies and the public." (Camblos et al., 1991)

Table 1.2. Effect of conservation tillage on erosion reduction (National Soil Erosion Research Laboratory, 1992)

Residue covering of soil (%)	Erosion reduction (%)
20	50
30	65
40	75
No-till	94

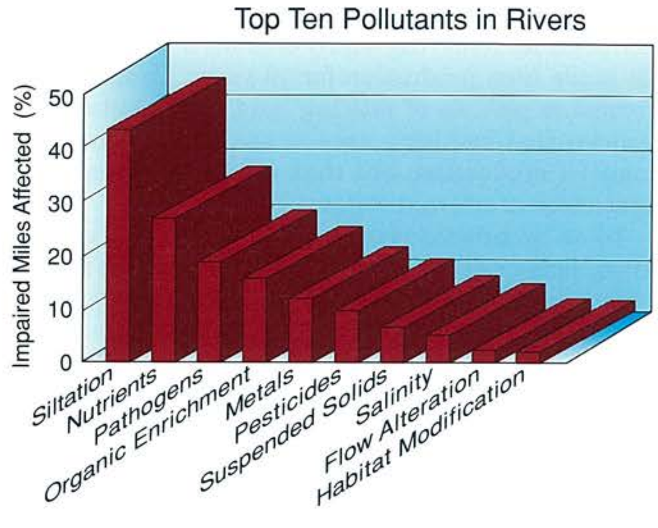


Figure 1.1. Ranking of river pollutants from the *1988 National Water Quality Inventory* (U.S. Environmental Protection Agency, 1990h).

Detecting and Assessing Contaminants

Agriculture in the 1990s—farming in the "decade of concern"—will be strongly influenced by public concerns and environmental policies focused on water quality protection. Fortunately, the debate will benefit from increased understanding of the sciences, risks, benefits, and realities of agricultural production.

Studies of water quality have come a long way in the past decade. Ever since new technology first permitted detection in parts per billion—and parts per trillion—accuracy has replaced sensitivity as the limiting factor. Proper design, conduct, and interpretation of analytical results have become increasingly critical. Strict sampling, handling, and analysis procedures were developed to avoid the introduction of significant bias when searching for the presence of minute quantities of contaminants.

When the more sensitive analytical procedures and instrumentation were employed in numerous local and regional studies, detections of pesticides, nitrates, and other contaminants occurred more frequently than before, raising concerns for widespread water contamination. This led to nationwide assessments, further development of new analytical techniques, and recommended best management practices. The EPA began assessing impacts on ecosystems and developing drinking water standards and health advisory guidelines. When complete, these will allow society to more fully gauge the significance of

Table 1.3. Total amounts of soil erosion, water runoff, and herbicide runoff with varying tillage systems in an Iowa small watershed, natural rainfall study (adapted from Baker and Johnson, 1979)

Tillage treatment	Soil erosion (tons/acre)	Water runoff (gal./acre)	Alachlor runoff (lb/acre)
1973			
Moldboard plow	7.3	43,700	0.013
Ridge-till	1.4	21,400	0.009
No-till	0.5	23,500	0.014
1974			
Moldboard plow	23.1	87,600	0.080
Ridge-till	10.1	58,800	0.040
No-till	0.8	40,600	0.009
1975			
Moldboard plow	7.7	37,400	0.002
Ridge-till	3.2	32,000	0.001
No-till	1.6	34,200	0.0002

contaminant detections in surface and ground water.

Assessing the Contaminant Threat

The 1990 EPA *National Survey of Pesticides in Drinking Water Wells* (U.S. Environmental Protection Agency, 1990b) concluded that 96% of our 10.5 million rural domestic wells are free of measurable traces of any of the 126 commonly used pesticides or breakdown products surveyed and more than 99% of all wells in the country contain no pesticide traces exceeding the EPA lifetime standard for safe drinking water. However, the EPA estimates that more than 50% of the nation's wells contain nitrates and about 1.2% of community wells and 2.4% of rural domestic wells have nitrate levels that exceed the drinking water standard. See Appendix D.

An often overlooked health threat to rural well water users is the presence of coliform (fecal) bacteria. Such bacteria from human and animal waste indicate the potential presence of pathogenic microorganisms, the most significant health risks associated with rural wells. Unfortunately, they are also the most commonly found contaminant. In Iowa, for example, over 45% of the rural wells tested by the state were dangerously contaminated with coliform bacteria (Iowa Department of Natural Resources, 1990). In one part of Iowa, coliform bacteria were detected in nearly 75% of the rural wells. Further testing and implementation of best management practices are needed to address this contaminant challenge.

The highest potential risk areas for rural water contamination include unsafe wells—those wells that have cracked casings or grouting; abandoned and improperly sealed wells; excessive use of nutrients or pesticides over vulnerable aquifers or on land with porous soils and shallow ground water; and sinkholes. Also, wells improperly located near septic systems or sources of animal waste can become unsafe. Farmers have begun to take management actions to help close these direct pathways to ground water contamination.

Many states are now using EPA analytical procedures and standards to assess the water quality of their streams, lakes, and rivers. The EPA's most recent report on the quality of our nation's waters (U.S. Environmental Protection Agency, 1992) estimates that 10% of assessed rivers and 21% of assessed lakes are impaired and not fully supporting state designated uses such as swimming, fishing, and water supply. Contamination results from many sources, both urban and rural. State assessments summarized by the EPA (representing 29% of total U.S. river miles and 41% of total U.S. lake acres) rank river pollutants, of which siltation, nutrients, pathogens, pesticides, salinity, and habitat modification are commonly referred to as agricultural inputs (Figure 1.1). The top ten pollutants for lakes were in approximately the same order; the major exception was that nutrients were first and siltation was second. The limited number of year-round studies to date indicates that agricultural contaminants are present in these rivers draining agricultural watersheds primarily in the spring. Heavy spring rainstorms wash soil, nutrients, and agrichemical contaminants from recently prepared and seeded cropland. Detected pesticide concentrations in rivers are most likely to peak immediately after spring storms, although concentrations of most commonly used pesticides may exceed water quality standards all year in some reservoirs and streams.

Assessment and reduction of soil sediment in surface waters from agriculture, forestry, land development, and other activities have become the top priorities of water quality programs because sediment and the chemical contaminants that sediment often carry, degrade the physical, chemical, and biological quality of receiving waters and impact fisheries and aquatic life.

A More Environmentally Sound Agriculture

Virtually every human activity produces some impact on the environment, and agricultural production is no exception. The very practice of agriculture requires human intervention in natural life cycles;

adjustment of soil structure, chemistry, and hydrology; and the integration of synthetic and natural resources. Thus, imbalances are likely to occur.

The lessons learned during the latter half of the twentieth century have helped farmers find ways to minimize this impact. More and more, farmers are employing innovations and practices that preserve the integrity of the ecological system on which they depend, while permitting ecological disturbances with the economies of scale necessary to feed society.

The goals of U.S. agricultural and environmental policies, which have often been at odds with one another, recently have been moving toward greater harmony. This compatibility has helped foster genuine changes in the way farmers till the land and in the types of products made available to them by agricultural suppliers.

Reductions in soil erosion losses and improvements in water quality barometers documented by the 10-year Rural Clean Water Program (U.S. Department of Agriculture, 1989; U.S. Environmental Protection Agency, 1990e) point the way for an environmentally sound agriculture, one that assures both abundant food and a safeguarded environment.

The continuing quest to meet the dual goals of agricultural productivity and environmental protection has been at the forefront of scientific research and public policy development. It also has played a role in the development of agricultural chemicals.

Examples of recent advances of products include herbicides that are effective on specific weeds at rates of only ounces per acre, yet are nontoxic to humans and wildlife and break down in a matter of days. New and safer insecticides and fungicides are also in development or already on the market. "Bulk" containers of these microdose pesticides are now very small plastic bottles, premeasured water-soluble pouches and bottles, as well as premeasured effervescent tablets in easy-to-use blister packs. These products are generally compatible with integrated pest management procedures. In addition, biological pest control agents are being developed to replace certain chemical pesticides.

Use of filterstrips, contour and conservation tillage, and other BMPs long recommended and encouraged, are now necessities for many farmers with highly erodible land. Photograph courtesy of F. J. Humenik, North Carolina State University, Raleigh.

More judicious use of mineral fertilizers and pesticides is commonplace today. Use of pesticides and fertilizers by U.S. farmers will continue to decline in coming years as new placement and timing techniques, reduced use rate recommendations, and new microdose pesticides are widely adopted.

A redoubling also is occurring in efforts to prevent soil erosion and contaminated runoff from farmers' fields. Use of filter strips, contour and conservation tillage, and other BMPs, long recommended and encouraged, are now necessities for the many farmers with highly erodible land as they implement and maintain their ASCS Conservation Compliance plans. Nearly 1.3 million compliance plans have been filed under this program, charting major changes in farming practices and land use to be completed by January 1995. By April 1, 1991, about 50% of all farms were in compliance with their Conservation Compliance Plan. Guidelines in the 1985 and 1990 farm bills in addition to the guidelines contained in the Federal Coastal Zone Management Act and many state regulations, also specify BMPs to achieve water quality goals. See Appendixes F and G.

2 Water Quality: A Public Policy Perspective[1]

Introduction: Context of the Issue

The most compelling and challenging environmental problems of the next decade are the unintended side effects of reasonably informed people making rational choices within the opportunity sets defined by law and custom. In the case of ground water contamination, many thousands of small decisions aggregate to a pattern of behavior that imposes serious risk on water consumers. The perpetrators are all around us, the neighbors trying to control weeds in their lawn or corn crop, the developer improving the local tax base while paving a recharge area, or the rural town trying to dispose of solid waste. Their intentions are honorable. They are neither callous nor stupid. They are behaving predictably within the formal institutional setting of their business or home.

Water pollution problems are fundamentally institutional problems. There are physical and biological dimensions, of course, in detecting contamination, tracing the source, defining water treatment technologies, monitoring human health consequences, and treating those damaged by polluted water. These are not trivial matters; they require scientific inquiry. But the real roots of the problem and, therefore, the means for reducing contamination are institutional, the mix of incentives, rights, and obligations confronting resource users.

Adjustments to the options available to resource users are the substance of policy. They redefine the consequences of action. Policy changes may create a legal obligation to use water differently or may shift the full cost of certain water uses back to the users. They may just help to inform the users that certain actions will hurt their own health or that of their neighbors. Information in this area is expensive, essentially beyond the means of a rational seeker of knowledge in that costs exceed likely returns to information. Data linking quality to a particular water use and quality change to changes in that use are difficult to find.

The institutional character of the water pollution problem needs clarification. The basic contention is that only changes in the rights and obligations of users or the economic and social cost of water use options will reduce pollution of that limited and vital natural resource. Policy is the process by which those changes are made. Governments at all levels will act to protect citizens from the fact or fear of water contamination. Actions are taken when the hazards are apparent. Policy changes in a democratic society are notoriously reactive, responding to evidence that failure to act could be disastrous. Changes are usually incremental, seldom revolutionary. Any change has winners and losers; there is inertia in an existing set of institutions that has its own winners and losers.

Why Public Action? The General Case

This country's elected and appointed representatives act to create, protect, or enhance the interests of people with political access. Governments generally help us deal with problems we cannot handle ourselves for one reason or another. Conflict is the beginning point of policy change, not an aberration or malfunction in a democratic society, but a fundamental prerequisite to change.

People may want a product or service for which exclusive rights are impossible. Little incentive exists for a business to provide something that becomes available to everyone whether they pay for it or not. In some instances use of the service by some does not diminish its availability to others (water quality data, for example), while in other cases this open access situation can lead to congestion or deterioration (an ocean fishery or ground water aquifer). The waste absorbing capacity of a ground water aquifer is essentially there for the taking. There is little incentive for an individual to curtail legal income or utility-producing uses of water if other users continue access and one person's reduced use has no obvious

[1]Adapted from L. W. Libby. 1990. A public policy perspective on groundwater quality. *J. Soil Water Conserv.* 45:190-193.


The public policy process provides opportunities for the protection or enhancement of people's interests. Photograph courtesy of F. J. Humenik, North Carolina State University, Raleigh.

effect on water quality. Given the physical and biological character of ground water, costs of excluding users of the waste absorbing capacity of the resource are very high. On the other hand, costs of recovering damaged aquifers may be even higher.

In other cases, government steps are demanded because actions by one person impose unreasonable or unacceptable burdens on others (pollution), or create uncompensated advantages for others (farms as open space). These third party, or spillover, impacts of private water use decisions bring requests for government to redefine the boundaries of individual discretion. Obviously we do not want government interfering in all situations where people's rights collide—spillovers are everywhere in a complex society. Unreasonable and unacceptable are moving targets, open to political definition. A special case of the above is the situation where a person is apparently motivated to act against his own long term interest. The social trap occurs when a person responds predictably to a situation that will bring him or her inevitable pain in the future. "Micro-motives are not consistent with what individuals who share a common preference want to obtain as a long term result" (Schmid, 1978). In the ground water quality case, rational polluters know that they should not destroy their long-term water supply, yet lack the micro-incentive to respond. Government can assemble information for the larger group and perhaps enforce mutually defined self-discipline to eliminate the social trap.

Other government actions are taken simply because people want it that way, without direct reference to spillovers or open access resources. Recent surveys indicate that people support environmental protection as a matter of principle, whether or not they are directly threatened by pollution. The concept of humans living in harmony with other parts of the ecosystem has popular support. People are willing to act on that support and ask government to take necessary steps to protect an appropriate natural harmony. Prevailing cultural values, perceptions of right and wrong, guide policy formation. Government should do more than referee battles among powerful interests—the public interest is more than the sum of private interests. Of course this aspect of policy development requires courageous leadership. There may be no immediate gainers to contribute to reelection campaigns and there may in fact be losers who aggressively complain.

Conflicts leading to policy change may have any of several logical roots—the above categories are not mutually exclusive. But there is a sort of wandering coherence to the policy process that can be observed, analyzed, and predicted.

Current Incentives Guiding Water Use by Farmers

The basic incentive driving agricultural users of water is the effect of the water on plant and animal growth, which represents a source of income. Residuals returning to the source are an unintended side effect. Plant nutrients, pesticides, fuels, and other inputs have a similar income generating purpose. Input decisions are made within an institutional structure designed to facilitate food production with acceptable quality by informed individuals earning an acceptable income.

Various food policies have been enacted over the past 60 years to influence decisions made by farmers and provide them with a measure of economic protection from the vagaries of global weather patterns. The character and distribution of U.S. agriculture are influenced significantly by these policies. By influencing production decisions, these policies indirectly affect water quality. In general, one may conclude that policies tending to increase the capital intensity of farming—substituting capital in the form of applied inputs for land and people in farming—place the water resources at greater risk. Land set-aside programs, whether for supply control or erosion reduction, encourage farmers to work their remaining land more intensively (Batie, 1987). When operated in conjunction with price and income support programs for eligible crops, the incentive for intensification is even greater. If the purpose of these programs is to bolster farm commodity prices, the farmer tries to squeeze more output from remaining land to sell at the supported price. That generally means more plant nutrients and water, increasing the potential for water quality problems. Little incentive exists for a farmer to unilaterally restrict applications of those inputs when the rules encourage greater intensification for that farmer's neighbors and competitors. Nitrogen fertilizer is cheap compared to the value of lost production if too little nitrogen is applied. Unless a farmer's own on-farm water supply is contaminated by on-site farm practices, the farmer would see little water quality impact from better management practices. To the extent that price and income support programs encourage farmers to plant more of the supported crops, such programs may discourage crop rotation and other mechanical means of weed and pest control in favor of more chemicals.

Rules guiding access to water also influence farmer actions that may affect water quality. With no regulation or price mechanism to guide allocation of water to competing users, there is no particular incentive to exercise stewardship in its use. Water is taken for granted, applied liberally, with only vague limits of reasonable use to guide distribution. In the western states, where water is allocated to land owners, little incentive exists for a user to apply less than the allocation. Even in eastern states like Florida, where use permits may be denied by water management agencies, the user must weigh the likelihood of restrictions against expected returns to greater application when a voluntary reduction to protect the aquifer makes little attributable impact. Programs that encourage farmers to irrigate otherwise unproductive land inevitably place additional stress on water quality.

Solid waste management has only recently become a policy area of national concern. The residuals of our complex industrial society have little direct consideration in market transactions. The cost of adequate disposal is generally passed along to taxpayers and does not affect the price of the product that leaves the residual. Many of those residuals eventually reach receiving waters, in some stage of decomposition perhaps, but still damaging to water quality.

Increasing evidence of the hazards of sloppy waste disposal practices has led to policy change (Carriker, 1988). But these laws are highly specific to certain water sources, as in the Safe Drinking Water Act, or potentially dangerous residuals as in the Hazardous Waste Management Act or Federal Insecticide, Fungicide and Rodenticide Act. They do not deal comprehensively with water quality management. States have undertaken waste management programs that encourage recycling, partly because there are no acceptable places left to bury the waste. But the throw-away society label still fits. Until recently there has been little real incentive in our system to shift to products with less waste or to reuse the residual of economic activity if there is clear personal cost from that action. In fact, proper disposal is expensive and often inconvenient for the individual.

Given the nature of farm production, disposal may be more expensive for farmers than for other businesses. But the farmer will live with a waste problem rather than cease using the product. No one should be surprised that farm wastes, including excess nutrients and pesticides, can create water contamination problems.

In summary, water contamination is a direct and predictable consequence of a complex fabric of rules and incentives guiding businesses and homeowners seeking legitimate personal or economic goals. In most instances these rules have other purposes—to stabilize farm incomes, to assure access to water, or to encourage economic growth. Changes in performance will require changes in the rules, adjusting the options available to competing water users and/or the direct user cost of specific options.

The Policy Choices

The essential purpose of water quality policy is to change water use behavior. For the most part, people do respond to evidence that a failure to change could be painful. There is, however, the inevitable momentum of the past; it may be more difficult to depart from a current pattern of action than to adopt a different pattern initially. Also, change entails uncertainty, which can influence the decision as well. Persistent, stubborn pursuit of a lost cause in the face of compelling evidence is not uncommon.

Change can be instigated in two basic ways, by eliminating certain options through regulation or by adjusting the anticipated cost or benefit (including nonmonetary effects) of an alternative. Policy must intervene someplace in the decision process.

Raising the Cost of Actions That Tend to Pollute

A water user unwittingly imposing risk or cost on other users by permitting contamination may be forced to internalize that possibility through a higher cost. Taxes, penalties, and defined liability make those actions less attractive than other alternatives. The right to use water remains with the individual, but the consequences change.

A specific tax may be imposed on the polluting action (Braden, 1988). Iowa requires agrichemical producers and dealers to pay a pesticide registration tax and levies a $0.75/t fee on nitrogen fertilizers (Batie and Diebel, 1989). Revenue collected is earmarked for addressing contamination problems. While little evidence exists that the added cost to users offsets the cost to those affected by contamination, the general idea is to force those who may pollute to pay part of the cost up front. Effect on chemical use is unclear. If the additional return on inputs exceeds the tax, use will likely continue.

Alternatively, a tax may be based on pollution reduction necessary to achieve a predefined standard. The goal is to reduce use of the target inputs sufficiently to retain a defined measure of water quality (Braden, 1988). Success requires knowing how chemical users will respond to a higher input cost of specific magnitudes and how reduced use of target chemicals will actually affect water quality. This approach assumes that the standard selected is appropriate. If the quality standard is too high it could further the "license to pollute" with little useful result. If it is too restrictive, it could impose an unwarranted burden on water users. Standard setting is always equal parts of science, politics, economics, and philosophy on risk bearing. A nondegradation standard asserts that any impurity is too much, that society must be protected from all possibility of harm from polluted water (at least from controllable sources), and that farmers and other potential polluters and ultimately consumers must bear all costs of absorbing risk. A recent U.S. General Accounting Office report concluded that nearly all public water systems achieve federal drinking water standards but that water to replenish sensitive aquatic systems should (in their opinion) actually be cleaner than the water we drink. Thus by that logic, widespread reliance on EPA drinking water standards would be inadequate to protect water for other uses—a surprising result for those who assume that human consumption would be the most limiting water use (U.S. General Accounting Office, 1988).

Financial penalties, rather than taxes, may be attached to water quality standards. This approach is similar to taxing, except that the required payment is a lump-sum fine for exceeding pre-defined limits on acceptable behavior rather than a marginal addition to cost meant to induce that level of water quality.

An additional method of increasing the cost of polluting activities is to declare the perpetrator ineligible for public programs. The 1985 Food Security Act establishes the cross compliance limitation on eligibility for USDA income support programs for those who destroy wetlands. The same could apply to those who may pollute water. If, however, the only cost of the potentially polluting action is loss of other program benefits, the success of this approach requires the water user to anticipate those other benefits. It also assumes that the added burden of avoiding pollution behavior will not exceed expected gains from cross-complied programs (Libby, 1985).

New liability regulations may increase the potential cost of certain water uses. In Connecticut, strict liability rules remove usual common-law negligence tests from water uses that cause contamination. The guilty party must provide an alternative source of clean water. "While designed to be a remedial policy, the strict liability rule can result in deterrence; a farmer has an extra incentive to be careful" (Batie and Diebel, 1989).

Finally, new information can create psychic or emotional cost for those who inadvertently pollute water. Data showing pollution and health consequences of certain actions can dissuade the user from those actions. Incentives to change behavior need not be monetary. An important rationale for collecting detailed data on water pollution sources and impacts along with the communication of results to involved parties, is to help polluters realize what they are doing to others. The concept of resource stewardship is founded on a personal value that destruction of natural systems is basically wrong. Because of the open access nature of water quality as discussed above, however, the guilt approach to changing user behavior is seldom enough. Even if one person agrees that his or her actions may hurt others, that person may be reluctant to bear personal cost if there is no assurance that other polluters will bear such cost as well. The "why me" syndrome is at work whenever the burden for avoiding those actions is inequitably distributed. Relying on voluntary behavioral change in response to education is wishful thinking in this and most other areas of policy. Education generates one set of incentives that may reinforce others in accomplishing meaningful change.

Compensating Those Actions That May Reduce Pollution

Bribes are often more effective than threats. If overall system gains result from changes in individual behavior, then a little creative social bribery may be in order. Whether a penalty is more fair than a subsidy in accomplishing a behavioral change is a matter of opinion. Individuals asked to forego opportunities in the interest of the broader public may well feel that they deserve to be compensated for that sacrifice. Others may think that they should not be rewarded for appropriate behavior anyway. One's position on the matter is generally determined by the stake that person has in the result—another predictable aspect of the policy process.

Compensation for pollution-reducing behavior may come in the form of tax credits for land left open for ground water recharge. Florida's Blue Belt amendment to the state constitution permits legislation to provide a property tax incentive for farmers and other landowners to protect recharge areas. Special interest rates or tax incentives may be available to farmers who employ low-input or prescription management technologies. A subsidy may help offset uncertainties for a farmer willing to change production practices in the public interest.

Cost-sharing can help water users invest in new technologies. Virginia farmers may be eligible for state funds to help in constructing manure storage facilities. In Arizona, Wisconsin, and other states, cost sharing is available for installing special best management practices to protect ground water.

Governments support research and extension efforts by universities and other institutions to develop information that is compelling enough to encourage change. Agricultural practices that cause less pollution result from this public investment, giving water users options that they would not have had otherwise. The reduction of excessive application of nutrients can save the farmer and the water supply (Hallberg, 1986).

Changing the Water Rights of Potential Polluters

The most direct way to deter those actions that contaminate water is to declare those actions illegal. Private property entails exclusive, though not absolute, right to enjoy the services of acquired resources. Distribution of the "bundle of rights" that defines property is a product of the policy process.

Local governments retain primary authority for regulating land use for various public purposes. Protection of a ground water aquifer is such a declared purpose in many states. The community of Crystal Lake, Illinois, for example, has established specific watershed management zones to control use of land in the interest of water quality (DiNovo and Jaffe, 1984). State regulation may establish water quality limits and declare illegal any actions that violate these standards.

Most ground water regulations are focused on specific contamination sources, like solid or hazardous waste sites, oil and gas production sites, underground storage tanks, even large concentrations of farm animals. Most states regulate application of pesticides. Enforceable water quality regulations are more difficult to establish when contamination sources are dispersed, as is true with much of agriculture. Regulations may prohibit certain farm practices that tend to pollute or mandate other practices that must be used to minimize damage. Best management practices have been defined and required for cases of point or nonpoint pollution of ground and surface water (Batie and Diebel, 1989). Special natural resource districts in several states have authority to restrict the water use options available to individual users. In Nebraska, for example, a district may require farmers to employ farm practices that limit contamination (Aiken, 1987). Florida Water Management Districts have broad authority to control water use (Carriker, 1985).

When rights to use water or land in particular ways are reassigned to protect water quality, there is an implicit assumption that any inconvenience to the user giving up those legal options is more than offset by gains to public health and safety. No compensation is required. In effect, government is simply reclaiming a right allocated to individuals to assure that health and safety are protected. Reasonableness of the restriction and links to a valid public purpose may be tested in court. The regulatory power of government is not absolute, and tests of the limits of regulation are part of the policy process.

Government entities may choose to purchase water use options from potential polluters rather than simply take them through regulation. A state or local government could buy ground water sensitive lands outright, thereby removing all land use options of the private owner at a price that compensates for the transfer. In cases where extreme measures are necessary, the government may invoke the power of eminent domain to protect the public interest with payment of "just compensation." Outright purchase removes that land from the local property tax rolls and puts the public in the land management business, both of which add to the cost of this policy approach. Purchase of just the right to develop land important to a ground water aquifer can be a less painful option for government. Land stays on the tax rolls, but its value is limited by the transferred right to develop. The owner retains all remaining rights that do not pollute water.

There are various other techniques by which rights or options available to individual owners or businesses may be redefined in the interest of protecting water quality. The key distinction between restrictions on property rights and other measures is that action is assured. Reliance on manipulating the enlightened self-interest of individuals whose actions may affect quality of the water is not required.

Conclusions

The policy development process should include the system by which good information is organized for collective and private choice. No participant in water policy debates should underestimate the physical and biological complexities of water quality protection. More information is needed about how contamination occurs, patterns of vertical and lateral water movement, soil and contaminant interactions, potential human health consequences of various contaminant concentrations, and the likelihood of those impacts being experienced by an individual. But this knowledge and the science behind it is important primarily for its impact on how people use water. Knowledge is useful only if it is sufficiently understood and used by people—business and household owners, community leaders, and government bureaucrats.

The policy development process is centrally concerned with defining incentives or rules that change how people act. An individual voter, taxpayer, or citizen reacts to policy options in terms of how they expand or narrow current opportunities in pursuit of a defined goal. For many voters or resource users, the best policy action may be no action, because the problem in question imposes fewer risks or burdens than the proposed solution. One's position on that matter is influenced by information and by individual willingness to take chances with the target problem. There are no absolutes in policy, just points of view.

New information about water quality problems can produce the support necessary for regulation or other policy change. Support is the essential prerequisite to effective policy; necessary, though not sufficient, for success. Current water quality policy includes (1) defining the relevance of the problem, (2) determining the options for adjusting behavior, and (3) distributing the impacts of those policy options.

In water quality policy, as in other areas, we must maintain healthy respect for the rights and intentions of individuals. The massive hypocrisy that the only path to enlightenment is zero flexibility for you and full freedom for me must be avoided.

The principle of diminishing marginal utility must be acknowledged. At some point more of anything inflicts more pain than gain (Boulding, 1973). Preserving every bit of wetland or absolute purity of water everywhere is not in the overall public interest and will not be supported. Each measurable increment of water quality enhancement must stand the "so what" test. In policy, clean water is an instrumental good, important only to the extent that it enhances the perceived quality of life.

Improved understanding of human behavior is essential to success in water policy. More information is needed on risk bearing behavior by different categories of people, particularly differences between risk voluntarily accepted and risk imposed by actions of others. More specific to water quality protection, analysis of the incentive structure is needed. Reasoned institutional change and, therefore, successful reduction of water pollution or other such problems, require a more definitive understanding of why people do what they do (Gladwin, 1989).

Policy is an observable predictable process. Opportunities exist for intervention in the evolution of a full-fledged policy problem (Hahn, 1988). Education plays an important role, affecting the basis for policy action. People as citizens, voters, or public officials need to understand the roots of a particular problem and likely impacts of options for dealing with it.

Effective, supportable water quality protection policies are emerging at every level throughout the United States. They are not coming fast enough for some, and success is elusive. But there is nothing insurmountable in these water quality problems; few profound absolutes stand in the way of progress. Water quality can be protected or improved with significant changes in the ways we use that water, changes possible only through reasoned public policy.

3 Agriculture and Water Quality

Introduction

In a 1986 report to Congress (U.S. Environmental Protection Agency, 1986b) the nation's remaining water quality problems were largely attributable to pollution from nonpoint sources. The report noted at that time 76% of the impaired acres of lake water, 65% of impaired stream miles, and 45% of impaired estuarine square miles were affected by nonpoint source pollution. About 50 to 70% of the assessed surface waters were adversely affected by agricultural nonpoint source pollution from soil erosion from cropland and overgrazing, and from pesticide and fertilizer application.

"Agricultural nonpoint source pollution includes pollutant losses in surface runoff and pollutant leaching to ground water. Agricultural pollutants include pesticides, sediment, nutrients, and bacteria from agriculture cropland, livestock production/waste mangement facilities, and grazing areas. Nonpoint source pollution has several defining attributes (Vigon, 1985):

1. Nonpoint source pollution is not easily associated with a defined process such as sewage treatment that creates effluent discharged through a pipe.
2. Nonpoint source pollution can be intermittent and is related to the intensity of an intermittent runoff event, making it difficult to quantify and even more difficult to control.
3. Nonpoint source pollution originates over a broad area making identification and assessment of sources difficult.
4. Nonpoint sources are usually the concern of several political jurisdictions.
5. Nonpoint sources are resistant to regulatory-based controls.

The EPA's definition of nonpoint source pollution is (U.S. Environmental Protection Agency, 1987c, p.2):

> NPS pollution is caused by diffuse sources that are not regulated as point sources and normally is associated with agricultural, silvicultural and urban runoff, runoff from construction activities, etc. Such pollution results in the human-made or human-induced alteration of the chemical, physical, biological, and radiological integrity of water. In practical terms, nonpoint source pollution does not result from a discharge at a specific, single location (such as a single pipe) but generally results from land runoff, precipitation, atmospheric deposition, or percolation. Pollution from nonpoint sources occurs when the rate at which pollutant materials entering water bodies or ground water exceeds natural levels.

"When runoff is collected and discharged through a pipe (e.g., in combined storm and sanitary sewers, or in cases of runoff from active mines), it is usually considered to be a point source. There are exceptions, however, such as the Clean Water Act's definition of irrigation return flow as a nonpoint source, despite the fact that the water is collected and returned to the stream through a discrete channel or pipe.

"Because of the difficulty in regulating nonpoint sources, there is an increase in the classification of concentrated nonpoint sources (such as feedlots) as point sources that makes them subject to regulation under a permitting system (Davenport, 1988; Novotny, 1988)." (Spooner et al., 1992)

In a U.S. General Accounting Office (GAO) publication, *Water Pollution—Greater EPA Leadership Needed to Reduce Nonpoint Source Pollution* (U.S. General Accounting Office, 1990), the first conclusion listed is "The magnitude and diversity of nonpoint source pollution makes it particularly difficult to control. Unless the problem is addressed, however, little progress will be made in obtaining the nation's water quality goals."

The January 25, 1991 *Environmental Reporter* notes that the EPA's newly reorganized Office of Water plans to focus on improving its nonpoint source pollution program and on controlling combined sewer overflows. It also noted that officials in the EPA's Office of Water felt priorities must be adjusted within the EPA's water programs to deal with nonpoint source pollution. Although nonpoint source pollution accounts for approximately 65% of the impaired river miles, the EPA's Office of Water officials said only 6% of the EPA's total 1990 funds for point and nonpoint source water pollution control were targeted at the nonpoint source problem.

Land use, and thus agricultural activities, can substantially affect the amount of nonpoint source pollution runoff. However, land use, and thus agricultural activities, can also affect ground water. When addressing agriculture's role in water quality, the total water resource must be considered because of the continuity of water as described by the hydrologic cycle. From this broader perspective, agriculture should promote practices that prevent or minimize pollution of all parts of the hydrologic cycle and avoid encouraging those that simply shift pollution from one medium to another (e.g., from surface water to ground water or vice versa).

Fertilizers

Fertilizers are added to croplands to increase the availability of plant-essential elements and thus increase the total yield and/or quality of crops. Sixteen elements are known to be essential for plants. Thirteen of these (boron, calcium, chlorine, copper, iron, magnesium, manganese, molybdenum, nitrogen, phosphorus, potassium, sulfur, and zinc) come mainly from the soil, and the other three (carbon, hydrogen, and oxygen) come from carbon dioxide and water. Nitrogen is a special case in the sense that it comes from the soil and also by biological fixation from atmospheric nitrogen. Fertilizers are used to supply nutrient elements when soil supplies are not sufficient to produce adequate yields of crops. The main deficiencies occur in nitrogen, phosphorus, and potassium; consequently, these are the main elements in commercial fertilizers. Most soils have adequate amounts of other elements, although small amounts of trace elements are required for some crops, and some acid soils of tropical regions require ground dolomitic limestone to supply adequate amounts of available calcium and magnesium.

Water quality problems originating from the use of commercial fertilizers result mainly from the application of nitrogen and phosphorus. Phosphorus creates a problem when soil materials are eroded into surface waters, and nitrogen creates a problem because nitrogen compounds can be transported in surface runoff and nitrate can be leached into ground water. With few exceptions, potassium does not leach to ground water because soils serve as effective chemical filters for this element. When soil materials are eroded into surface water, the potassium largely stays adsorbed on the sediment particles and the small quantities desorbed create no known quality problems. The amounts of other essential elements added to croplands are small, and the soil serves as an effective chemical filter for most of them.

Manures

Animal manures traditionally have been applied to soil. They are well recognized for their value as both soil conditioners and fertilizers. As soil conditioners, manures improve soil physical properties and increase biological activity. Examples of their influence are increased water-holding and nutrient-holding capacity, increased uptake of surface water, improved soil workability and aeration, and reduced soil loss by erosion. As fertilizers, manures have the advantage of containing at least low concentrations of all the nutrients required to grow the plants from which the residues are derived. In total, the value of the plant nutrients is great. For example, the value of the nitrogen, phosphorus, and potassium in the 47% of the livestock and poultry manure estimated to be collectible is about $1.5 billion per year (Van Dyne and Gilbertson, 1978).

Manures have some disadvantages as fertilizers: (1) they are dilute sources of nutrients in comparison with chemical fertilizers; (2) they are variable in composition; (3) their fertilizer value with regard to nitrogen, phosphorus, and sulfur depends in part upon the rate of release from organic compounds; and

Although animal manures have traditionally been applied to soil, new techniques are being developed to utilize manure in an environmentally sound manner. Photograph courtesy of F. J. Humenik, North Carolina State University, Raleigh.

(4) applications of animal manures to land near living sites may be objectionable because of odors and flies.

Animal feeding operations tend to concentrate relatively large quantities of manures in small areas. As a consequence, manures generally are applied to nearby soils, and the amounts of nitrogen added per acre may far exceed the amounts removed by crops. The specific components in manure that could become pollutants are nitrogen, phosphorus, inorganic salts, organic solids, and certain bacterial organisms. Aside from odors, the principal concern about this concentration process is an increase in the nitrate content of ground water. Of secondary concern is bacterial contamination of the ground water. Livestock production systems not properly managed can be a potential source of water pollution, primarily through uncontrolled runoff and/or leaching from (1) manured cropland, (2) livestock-grazed pasture, (3) confined open feedlots, and (4) earthen waste storage/treatment structures

Salinity

Salinity refers to the total concentration of a mixture of soluble salts present in all natural waters. Frequently found in ground water are calcium, magnesium, sodium, and potassium salts of chloride, sulfate, and bicarbonate. In addition, trace elements such as selenium, boron, and molybdenum, when present in ground water above critical concentrations, can limit production of certain crops (boron) or be detrimental to animals consuming plants (selenium and molybdenum). Many trace elements are beneficial biologically at very low concentrations but become toxic or otherwise detrimental to the health of organisms and plants at higher concentrations (Page et al., 1990). Many trace elements have low solubility in neutral and alkaline soils, which minimizes trace element toxicities to plants, but the uptake of certain trace elements by plants may be great enough to cause toxicity in domestic animals and wildlife that consume the plants. Numerous cases of livestock poisoning caused by elevated levels of molybdenum and selenium in forage have been reported worldwide. The main sources of salinity are irrigation water, soil and mineral weathering, fertilizers, amendments, crop residues, and animal manure.

Crop yield reductions may result from (1) osmotic stress caused by the total soluble salt concentration, (2) toxicities or nutrient imbalances created when specific solutes become excessive, or (3) a reduction in water penetration through the crop root zone caused by excess sodium inducing a deterioration of soil permeability. The key to managing salinity is leaching, the net downward movement of water through the crop root zone. Salts are leached whenever water applications, either rainfall or irrigation, exceed evapotranspiration, provided soil infiltration and drainage rates are adequate.

Irrigation in arid or semiarid regions always degrades water quality. As applied water moves down through the soil profile, salinity levels increase because of plant transpiration and evaporation from the soil surface. These processes selectively remove water, thus concentrating the salts in the remaining soil solution. To prevent soil salinity from reaching harmful levels, a portion of this concentrated soil solution must be leached (drained) below the crop root zone. In some instances, natural drainage is sufficient to meet this drainage requirement; in others, human-made drainage systems must be installed. In either case, the effluent must go somewhere. Depending on hydrogeology, the need for human-made drainage may not be evident for an irrigation season or two, or even decades. Regardless of the degree of management, drainage water from irrigated lands carries salt that requires disposal.

In areas where the ground water is deep or nonexistent, salts accumulated in the root zone can be forced downward by leaching if the substrata are permeable. Of course, this leaching process can continue only until the level of the ground water extends up into the crop root zone. In some irrigated areas, rainfall is sufficient to leach the salts below the root zone. In this case, application of extra irrigation water for leaching is not required and, in fact, will cause the water table to rise unnecessarily. Without sufficient drainage, the water table may remain in the root zone too long and reduce crop productivity.

In some instances, salinity in ground water results from geological deposits or seawater intrusion into coastal aquifers as a result of pumping. These conditions are important in some local areas but they are not discussed in detail here. Emphasis here is upon the major problem, which is salinity resulting from irrigation.

Drainage from most hydrologic basins progresses from the uplands into rivers and eventually to the ocean. Ocean disposal is nature's way of moving dissolved salts out of the landscape. Irrigation tends to accelerate this displacement process and increases the salt content of surface streams. Some hydrologic basins, however, are closed and do not have an outlet to the ocean. Well-known examples are the Dead Sea and Great Salt Lake, but there are many others such as the Salton Sea and Kesterson Reservoir in California and the Stillwater Reservoir in Nevada. In closed basins, drainage water collects at some terminus and evaporates, leaving its constituents behind. With time, these terminal water bodies increase in salt content, eventually lose all biological value, and become less attractive for recreation.

Until the 1987 amendments to the Federal Water Quality Act, the EPA did not regulate the disposal of agricultural drainage because it was considered a nonpoint source. States now need to establish plans for the control of nonpoint sources, including agricultural drainage. The California State Water Resources Control Board, in the aftermath of the ecological concerns at Kesterson Reservoir, directed the development of plans to regulate drainage in the San Joaquin River Basin. Present plans focus on selenium, boron, molybdenum, and salinity. The objectives for selenium and molybdenum are based on maintaining the aquatic environment of receiving-water while the emphasis for boron and salinity is for sustained use by agriculture. The experiences gained in this water quality control program will provide guidelines for others since basic issues should be similar.

Ways of minimizing the effects of irrigation on downstream water quality are known and practiced. More precise irrigation management to limit drainage to the amount required to maintain full crop production is one method to reduce the mass of salt discharged in drainage effluent (van Schilfgaarde et al., 1974). Use of drain water as a source of irrigation water is also possible in some instances (Grattan and Rhoades, 1990). The amount of irrigation water required also may be reduced by utilizing shallow ground waters to satisfy crop water requirements (Kruse et al, 1990). These techniques can impact the amount and solute concentration of drainage water, but they cannot eliminate the need for drainage. Drainage water must be transported out of the region, disposed of locally, or treated. The presence of trace elements in drainage effluent elevates the concern of water quality.

Extent of Irrigated Agriculture

Irrigation is practiced throughout the United States, but states in humid regions have only limited areas of supplemental irrigation. Most of the irrigated land is found in the arid, semiarid, and subhumid regions of the western United States. With some notable exceptions, such as in southern California and Utah, irrigation was not prominent in the United States until the federal government became involved through the Reclamation Act of 1902. Primarily through the efforts of various government agencies, the irrigated area in the United States increased rapidly early in the 20th century. By World War II, irrigation was well-established in the southwestern and mountain states and in the Pacific Northwest. Major expansion since that time has been primarily by the private sector, resulting in rapid expansion in the central Great Plains and in the southeastern states. Growth in irrigated areas has decreased considerably in recent years due to low farm revenue and increasing pumping costs because of declining ground water levels.

The irrigated area in the United States has increased from nearly 19 million acres in 1945 to more than 47 million acres in 1987 (U.S. Department of Commerce, 1987). The major reason for this marked increase in irrigated land is profitability. Nearly 30% of the market value of products sold from farms was produced by irrigation. This production from irrigated farms came from only about 13% of the total cropland. One factor in the high value of products from irrigated agriculture is that large proportions of the fruits and vegetables marketed in the United States are grown under irrigation. The distribution of irrigated farm lands in the United States is illustrated in Figure 3.1. The development of irrigation in western valleys and in areas of the Great Plains overlying the Ogallala aquifer, riceland irrigation in Arkansas and Texas, and irrigation of sandy soils in Florida show clearly the interrelations among crop water requirement, inadequate precipitation, and the importance of avail-

Irrigation is practiced throughout the United States because of increased productivity of alfalfa and grain and high value of irrigated fruits and vegetables. Photograph courtesy of Valmont Industries, Inc., Valley, Nebraska.

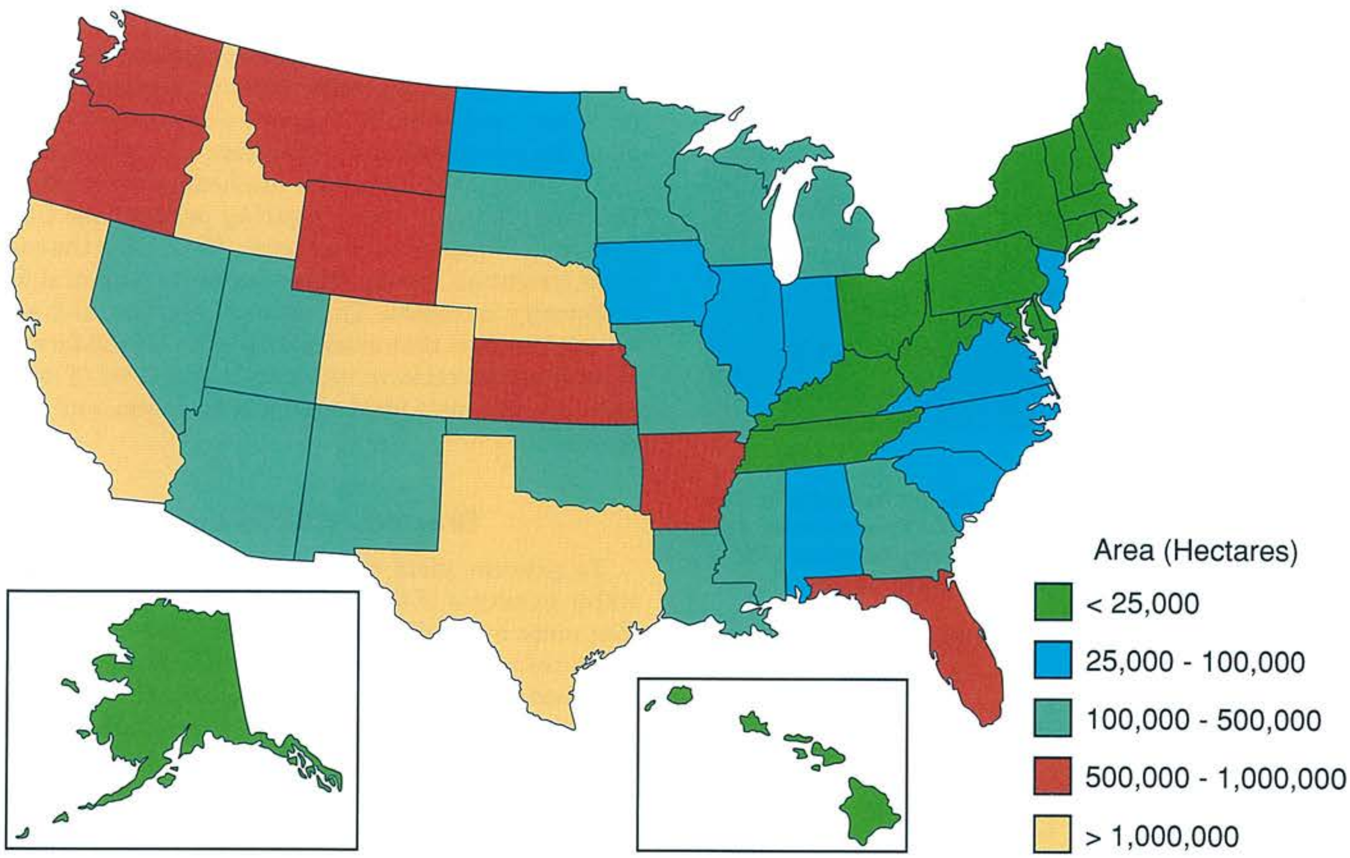


Figure 3.1. Irrigated farm land in the United States in 1987 by state (adapted from U.S. Department of Commerce, 1987).

able ground water. Another important force behind irrigation development is the need to support the livestock industry in mountain states by irrigating pasturelands and rangelands. Without a reliable source of forage, maintenance of a stable livestock base would not be possible during years of below normal precipitation.

Crop Response to Salinity

The predominant influence of water quality on plants is growth suppression caused by salinity. In many fields, the distribution of salinity in the soil is so variable that one area of a field can show distinctively different salinity symptoms from another area. Bare spots, poor spotty stands, and severely stunted plants are all signs of high salinity. Figure 3.2 illustrates the variability in plant growth caused by variability in the salt content of the crop root zone. However, moderate salinity levels often restrict plant productivity without any obvious injury symptoms.

Many crop failures on salt-affected soils result from growing crops that have low salt tolerance. Approximately a ten-fold range in salt tolerance exists among agricultural crops. Research results indicate that soil salinity does not reduce crop yield measurably until a threshold level is exceeded. Beyond the threshold, crop yields decrease approximately linearly as salinity increases (Maas and Hoffman, 1977).

Tolerance to salinity can vary with plant growth stage. Germination failures that occur on saline soils are not normally caused by crops being especially sensitive during germination, but rather to exceptionally high concentrations of salt where the seeds are planted. These high salinity levels near the soil surface are a consequence of upward water movement and evaporation in the absence of water applications. Many crops, however, are most sensitive during early seedling growth and then become more tolerant during later growth stages (Hoffman et al., 1990).

Plant response to soil salinity is considered to be independent of the irrigation method provided the space-time distribution of salinity in the root zone is determined properly. Thus, the criteria for judging the suitability of a saline water is applicable to all irrigation systems with the exception of foliar dam-

Figure 3.2. This photograph illustrates the variability in plant growth caused by variability in the salt content of the crop root zone. Photograph courtesy of G. J. Hoffman, University of Nebraska, Lincoln.

age from wetting crop leaves. With the appropriate determination of the average root zone salinity, one can use published crop salt tolerance data and leaching requirement criteria to make irrigation, drainage, and agronomic management decisions regardless of the irrigation method.

In special situations, toxicities and nutrient imbalance can occur if specific solutes in the irrigation water become excessive. Trees and other woody perennials may be specifically sensitive to chloride. Crop, varietal, and rootstock differences in tolerance of chloride depend largely upon the rate of transport of chloride from the soil to the leaves. The slower the transport, the more chloride-tolerant the crop. Boron concentrations as low as 0.5 g/m^3 in the irrigation water can be detrimental to sensitive crops. A wide variety of crops are sensitive to boron.

Although the concentrations of some salts in saline soils may be several orders of magnitude greater than the concentrations of some essential nutrients, plant nutritional disturbances are not common in salt-affected soils. A well documented exception, however, is the development of calcium deficiency under some saline conditions that results in blossom-end rot in tomatoes, internal browning of lettuce, and reduced corn growth.

Irrigation Management

Irrigation water is applied in discrete amounts and at specified times with most irrigation systems. Optimal irrigation management requires consideration of expected rainfall, timing of the next irrigation, and the amount of water the soil can hold at the time of irrigation. The desirable irrigation system is one that uniformly applies a specific amount of water over a field, and applies water at a rate low enough so that all of the water infiltrates. Farmers who have irrigation systems that have poor uniformity characteristics must balance over-irrigating parts of the field with under-irrigating other parts. Generally, the cost of an irrigation system increases as its potential for uniformity increases. The optimal systems and water applications that maximize profits for the farmer depend on the relative water costs, the level of management, the costs for the irrigation system, and crop prices.

Drainage Requirement

To prevent yield reduction from salinity, some water in excess of that required for evapotranspiration must be applied so that accumulated salts will leach below the root zone. The amount of leaching required depends on the salt concentration of the applied water and the salt tolerance of the crop. If leaching is inadequate, harmful salt accumulations can develop within a few cropping seasons. The fraction of the applied water that must pass through the root zone to prevent harmful salt accumulations in the soil is the leaching requirement. The optimum management strategy is to apply no more water than is necessary for full crop production and leaching of salts. This leaching requirement has been established for irrigation water of various levels of salinity and for irrigated crops of major importance (Hoffman, 1985). This management strategy dictates that the quality of the applied water will decrease as the water passes through the root zone but it is the only proven way of sustaining irrigated agriculture where salinity is a threat.

Leaching Frequency

Some irrigation waters are sufficiently low in salinity that, even without leaching, a number of irrigations can be applied before salinity accumulates to levels detrimental to crop yield. An additional consideration is the knowledge that the salt tolerance of many annual crops increases as the growing season progresses; this suggests that if soil salinity is low enough initially and adequate amounts of low-salt water are applied, soil salinity can be permitted to increase throughout the season. For the next crop, rainfall either singly or in combination with dormant season irrigations can leach accumulated salts. An important exception to this procedure is perennial crops, like trees, that form their buds for the next year during the latter half of the irrigation season. High salinity levels during bud formation will be detrimental to fruit production the following season (Hoffman et al., 1989). If irrigation waters are saline, rainfall and out-of-season leaching may not be sufficient and leaching during the irrigation season may be required to prevent yield loss.

Irrigation Interval

The interval between irrigations is one of the potential water management practices available for coping with saline conditions. The bulk of the experimental evidence does not support the proposition that the irrigation interval should be shortened under saline conditions. Most studies show no interactive effect of salinity and irrigation interval. Under some circumstances, increased frequency may even be detrimental.

Contaminants

The effects of agricultural chemicals on human and environmental health may be the result of a combination of factors. Characteristics of the chemical (persistence, soil binding properties), the site and setting in which it is applied (soil and weather conditions, proximity to bodies of water or wells), and management practices (use of protective clothing, timing, and rates of application) all contribute to the overall safety of chemical use. For the safety of human and environmental health, label directions regarding the correct use of agricultural chemicals must be strictly followed. Failure to do so can result in accidental overexposure to chemicals, dangerously high pesticide levels in foods and/or water, and destruction of nontarget species. There is a great deal of concern with regard to the long-term (chronic) health effects of pesticides; however, the only pesticide active ingredient currently recognized as a human carcinogen is arsenic and certain arsenic compounds. Numerous arsenic formulations have been used over the years as insecticides and herbicides (International Agency for Research on Cancer, 1987; Morgan, 1989).

A number of pesticides currently in use fall into the category of "Restricted Use Pesticides." These can be purchased or applied only by or under the direct supervision of a certified applicator. Restricted use status is applied to pesticides for which there is evidence of serious danger to human health, where there is strong animal evidence of undesirable health effects, or where misuse can have serious adverse environmental effects (Meister, 1990).

Nitrate

Nitrogen is a required plant nutrient. Therefore nitrogen sources are widely used in agriculture. As previously described in this report, ground water sampling programs have revealed the widespread presence of nitrate in ground water. While much of the nitrate found in ground water can be linked to agricultural practices (land application of manures, legume rotations, and nitrogen-containing fertilizers), it is essential to point out that there are many other sources of nitrate in the environment, including septic systems and naturally decaying organic matter, that can also serve as sources of ground water nitrate contamination. Nitrate is water soluble and moves readily through soil into ground water.

While there are multiple sources of nitrate that occur in the diet (e.g., celery, lettuce, spinach, cured meats [Wetzlich, 1991]), there are several areas of health concern associated with excessive consumption of nitrate. Nitrate is converted by bacteria in the mouth and digestive tract to nitrite; our diets likewise contain many other sources of nitrite, including cured meats. Infants are most susceptible to the best known condition caused by consumption of nitrate/nitrite—methemoglobinemia ("blue baby syndrome"). This disorder derives its name from skin color resulting from the compromised ability of the blood to reversibly interact with oxygen, thus depriving tissues of oxygen. Without proper intervention (typically injection of methylene blue), this condition can be fatal. Infants (up to 4 to 6 months of age) are particularly susceptible to methemoglobinemia because of the lack of acidity in their stomachs and possible gastrointestinal infection, allowing nitrogen-converting bacteria to flourish (Klaassen et al., 1986; Wetzlich, 1991). Water high in nitrate also can have detrimental effects on the health of farm animals, resulting in weight loss and poor feed conversion (Carter and Sneed, 1987).

Nitrate is among the chemicals for which drinking water standards have been established. Based on the known health effects of nitrate and nitrite, a health based standard level was established at 10 mg/l (ppm) nitrate nitrogen. The nitrite standard for drinking water is 1 mg/l. Daily consumption of drinking water containing nitrate nitrogen at levels at or below 10 mg/l would not be expected to cause nitrate/nitrite-related adverse health effects. This level is the legally-enforceable Maximum Contaminant Level

(MCL) for municipal water supplies (U.S. Environmental Protection Agency, 1989b; 1990b).

Nitrates in excess of the MCL can be a factor concerning methemoglobinemia in infants. Modern society has significantly reduced the risk of methemoglobinemia, commonly known as "blue baby" disease. From 1947 to 1949—a period long before significant agricultural use of commercial fertilizers—the state of Minnesota reported 139 cases of methoglobinemia and 14 deaths from the disease attributed to high nitrate levels in farm wells. Since 1960, only one blue baby fatality is known to have been reported in the nation and the cause was not attributed to fertilizer application but rather to a shallow farm well located too near a barnyard and septic system. While "blue baby" was a serious health threat to infants early in this century, occurrences are so rare today that major U.S. health organizations, including the National Institute of Health and the National Center for Disease Control, no longer keep statistics on it.

Another area of concern with respect to nitrate/nitrite exposure is the ability of nitrites to react with naturally-occurring functional groups in the foods we eat called secondary amines, forming a class of chemicals called nitrosamines (Menzer, 1991). Nitrosamines have been demonstrated to cause a variety of adverse effects when administered to laboratory animals in high doses. Among these adverse effects are liver and lung damage, convulsions, birth defects, and cancer (National Research Council, 1981; U.S. Environmental Protection Agency, 1987b). Although some of these effects can be eliminated by the presence of vitamins C and E (Archer et al., 1975; Kamm et al., 1977) and the human adult is assumed to convert only 10% of ingested nitrates to nitrites (U.S. Environmental Protection Agency, 1987b), the magnitude of the risk of adverse health effects in humans consuming nitrate-contaminated water due to nitrosamine formation is not known.

Even low levels of nitrate can cause eutrophication (deterioration) of surface water bodies, especially estuaries. Eutrophication can occur in surface water at nitrate levels as low as 1 mg/l.

Phosphorus

Phosphates, like nitrate, can enter ground and surface water from several sources, including phosphate-containing detergents, animal manures, commercial fertilizers, and natural sources. Unlike nitrate, phosphates tend to bind tightly to soils and therefore are much less likely to leach into ground water. Phosphates can be major pollutants of surface waters, however, as eroded soils are deposited in bodies of water (Klaassen et al., 1986).

Few, if any, adverse human health effects have been linked to exposure to high levels of waterborne phosphates (Klaassen et al., 1986). However, there are concerns over phosphorous pollution of surface water because of the accelerated deterioration of these waters and detrimental effects on related industries, including drinking water facilities, fisheries, and recreational areas. Phosphates contribute to surface water deterioration, termed eutrophication, by their role as an essential (and generally the limiting) nutrient for the growth of blue-green algae. Algae grow extremely rapidly in surface water containing phosphorous at levels of 50 μg/l (ppb) or greater. The subsequent decay of these algae deplete oxygen supplies in the water, resulting in the death of organisms in the water and release of more adsorbed phosphorous from sediments (Klaassen et al., 1986).

Yellow phosphorous and zinc phosphide, formulated for use as rodenticides, have been associated with human poisonings. Because of the caustic properties of these materials and their severe effects on the liver and lungs, therapy is supportive and poisonings are often fatal (Morgan, 1989; Klaassen et al., 1986). However, probably because of the lack of evidence of adverse health effects associated with consumption of phosphates in drinking water, no drinking water standards have been established for phosphates (U.S. Environmental Protection Agency, 1989c; 1990b).

Phosphorus can cause eutrophication (deterioration) of surface water at levels even lower than 1 mg/l.

Pesticides

The term pesticides includes a large number of chemicals used primarily in agriculture for pest control. Among the chemicals classified as pesticides are herbicides, insecticides, fungicides, nematicides, and rodenticides. With such a wide range of chemicals with so many uses, it is not surprising that thousands of very extremely diverse chemicals fall into this category. Pesticides applied to agricultural crops may act systemically (i.e., taken up by and incorporated into plant tissues) or simply by contact with the pest of concern on the surface of the crop. Therefore, a discussion of the toxicity of pesticides can be very complex. Some of the more important pesticides and their associated toxicities, separate from drinking water exposures, are summarized below.

Herbicides

Herbicides prevent unwanted plant growth. In an agricultural setting, a degree of selectivity is desired, so that the desired crops are not harmed; whereas weeds are either killed or prevented from germinating. Early herbicides included extremely nonspecific formulations such as arsenic salts. Most of today's herbicides are much more specific, and some function like plant hormones (e.g., 2,4-D [Meister, 1990]).

Given the numerous classes of chemicals used as herbicides, it is not surprising that human exposure to herbicides may result in a wide range of symptoms as exemplified below. Urea derivatives and the phenoxy herbicides (e.g., 2,4-D, 2,4-DP, 2,4,5-T, MCPA, dicamba) can be moderately to extremely irritating to skin and mucous membranes. The herbicide, 2,4,5-T (one of the active ingredients in "Agent Orange"), was also associated with the development of a skin condition called chloracne, resulting from low level contamination of this product with tetrachlorodibenzodioxin (TCDD, called "dioxin") (Kimbrough, 1990). Paraquat has resulted in fatal pulmonary edema following intentional and accidental overexposure (Klaassen et al., 1986; Morgan, 1989). Nitroaromatic herbicides (e.g., dinitrophenol, dinoseb, dinitrocresol formulations) affect cellular metabolism and have been associated with hyperthermia (high body temperature), rapid breathing, dehydration, liver and kidney degeneration, and neutropenia (low numbers of immune system cells called neutrophils) following overexposure (Morgan, 1989).

Insecticides

Insecticides have evolved greatly over the years. With the wide range of different chemicals used as insecticides comes a number of manifestations of toxicity. Often symptoms occurring minutes to hours following exposure of acute insecticide poisonings are quite similar: nausea, headache, vomiting, lethargy. Symptoms of chronic exposure can vary dramatically, and a number of insecticides are no longer registered for use in this country because of putative chronic health problems, including cancer, teratogenicity, and profound effects on the environment (U.S. Environmental Protection Agency, 1990g).

Beginning with the use of arsenic salt formulations with insecticidal activity in the mid-1600s (Hodgson and Kuhr, 1990), awareness of the toxicity of insecticides to both humans and insects has been a concern. Organic pesticides such as nicotine came into use in the late 1700s (Hodgson and Kuhr, 1990), and even today, the search for naturally occurring insecticides is a popular quest because of concern over the safety of a number of synthetic insecticides. Indeed, some botanicals, such as pyrethrum, show selectivity in toxicity, being much more poisonous to insects than to mammals (Hodgson and Kuhr, 1990); however, pyrethrins degrade rapidly in the environment (Morgan, 1989).

The insecticidal activity of DDT was discovered in 1939. Because it was inexpensive to produce, had a broad range of insecticidal activity, was persistent, and was relatively nontoxic to mammals, huge efforts went into the development of additional similar products. Undesired effects related to environmental persistence, insect resistance, and bioaccumulation in animal tissues necessitated bans or severe use restrictions of DDT and other organochlorine insecticides beginning in the early 1970s (Hodgson and Kuhr, 1990).

Organophosphorus (OP) and carbamate insecticides came into use in the 1940–1950 era; these compounds are still in widespread use today and are much less persistent and likely to bioaccumulate than the organochlorines (Hodgson and Kuhr, 1990). Hundreds of OP insecticides are currently registered for use in this country; among these are phorate (Thimet), disulfoton (Di-syston), parathion, fonofos (Dyphonate), dichlorvos (DDVT), acephate (Orthene), malathion, and diazinon (Spectracide). Among the more widely used carbamates are aldicarb (Temik), oxamyl (Vydate), carbofuran (Furadan), and carbaryl (Sevin) (Hodgson and Kuhr, 1990; Morgan, 1989). Both OP and carbamate compounds can be extremely acutely toxic because of their ability to interact with the enzyme acetylcholinesterase, a necessary enzyme for the normal functioning of the nervous system. Symptoms of poisoning by OPs and carbamates include excessive salivation and sweating, muscle twitching followed by weakness, constricted pupils (miosis), as well as more nonspecific symptoms such as headache, nausea, and dizziness. Treatment in both cases involves administration of atropine (to relieve symptoms of hypersecretion) and supportive therapy (because of the likelihood of convulsions and/or respiratory distress). In addition, because of the irreversible nature of the OP-acethylcholinesterase interaction, an agent to regenerate the inactivated enzyme (such as pralidoximine; also known as protopam or 2-PAM) will be given if medical help is sought within hours of poisoning (Klaassen et al., 1986; Morgan, 1989).

Recent studies suggest that prolonged exposure to organophosphate insecticides may also be associated with long-term nervous system deficits. Deficits reported in individuals with histories of repeated OP poisoning included abnormal electroencephalograms (EEGs), altered mood, polyneuropathy, and impaired memory and intellectual function (Duffy et al., 1979;

Table 3.1. Health effects of metals used in agricultural settings (International Agency for Research on Cancer, 1987; Morgan, 1989; Kay, 1991)

Metal	Use	Health effects
Arsenic	Multiple insecticide and herbicide formulations	Animal and human carcinogen; multisystem toxicant; interacts with protein thiols
Copper	Organocopper fungicide formulations; copper sulfate used as aquatic herbicide	Irritating upon contact with skin and mucus membranes, low solubility limits systemic exposure
Mercury	Multiple organomercury fungicide formulations	Readily absorbed from gastrointestinal tract; potent nervous system toxicants
Tin	Multiple organotin fungicide formulations	Irritating to skin, eyes, respiratory tract; nervous system toxicant, causing headache, dizziness, photophobia, convulsions
Cadmium	Cadmium chloride, sulfate, and succinate used as fungicides	Very irritating to respiratory and GI tracts; inhaled cadmium dust has been associated with pulmonary edema, persistent cough, labored breathing, and chest pain. Ingestion causes vomiting, diarrhea; chronic exposure associated with kidney and liver damage, anemia, and defective bone structure

Savage et al., 1988; Senanyake and Karalliedde, 1987).

Other classes of pesticides have different symptoms of poisoning associated with them. For example, pyrethrum is a potent dermal and respiratory allergen (Morgan, 1989). Some synthetic pyrethroids (molecules chemically similar to pyrethrum but with a longer life in the environment) have been associated with paresthesia (numbness) when liquid or volatilized materials contact human skin. Pyrethroids associated with this reaction include fenvalerate, flucythrinate, cypermethrin, and fluvalinate (Morgan, 1989).

Fungicides

Like other classes of pesticides, fungicides include a variety of very different chemicals. Historically, tragic epidemics of pesticide poisoning occurred because of accidental consumption of seed grain treated with organic mercury or hexachlorobenzene fungicides. Mercury-containing fungicides are among the most toxic pesticides ever developed. Epidemics of severe, and often fatal, neurologic disorders have resulted from the consumption of methyl mercury-treated seed grain and from consumption of meat from animals to whom mercury-treated seed grain had been fed. Some thiocarbamate fungicides have weak cholinesterase inhibiting activity. A number of fungicides are associated with respiratory and dermal irritation and/or sensitization (e.g. the ethylene bisdithiocarbamates, catafol, and organic copper and tin compounds) (Morgan, 1989). Most of the recently developed fungicides, i.e., systemics, sterol-inhibitors, benzimidazoles, etc., have specificity for certain plant pathogens and have little effect on animal species at recommended application rates.

Metals

Metals are neither produced nor destroyed by agricultural practices. However, many agricultural practices redistribute metals within the environment. Some of these metals find their way into ground water by means of their application as components of land-applied manure, municipal waste used as fertilizer, or by virtue of their pesticidal activities. Table 3.1 summarizes some metals of agricultural interest, their use in agriculture, and potential adverse effects. As has been mentioned previously, the only pesticide active ingredients that have been designated human carcinogens are arsenic and certain arsenic compounds (International Agency for Research on Cancer, 1987).

Regulations

Current EPA regulations governing land application of sludge address only cadmium and sludge concentrations of polychlorinated biphenols (PCB). Federal guidelines recommend that sludges containing 10 to 50 ppm of PCBs be incorporated in the soil (*Fed. Regist.*, 1979). Cadmium is limited to an annual application rate of 0.5 lb/acre and a cumulative loading rate based on soil pH and cation exchange capacity (CEC). Cumulative loading rates range from 5 (sandy soils) to 20 (clayey soils) lb/acre depending upon the soil CEC. It has also been recommended that maximum cumulative application of lead to the soil should not exceed 800 lb/acre (U.S. Environmental Protection Agency, 1981). In addition, 42 states currently have regulations or guidelines covering land application of sewage sludge, which set either a maximum allowable concentration and/or maximum pollutant loading rate for selected organic and inorganic pollutants. Most states limit the sludge nitrogen application rate so that it does not exceed the nitrogen needs of the particular crop being grown. This limitation severely reduces the potential for nitrate leaching into ground water in significant amounts. On an area basis, the potential problem with nitrate leaching into the ground water is minor. It is estimated that in most states less than 1% of the agricultural land would be required for application of sewage sludge in quantities that would supply 100 lb/acre of available nitrogen, a modest agricultural application rate (Sommers, 1977).

At annual sludge application rates, < 15 tons/acre, which are recommended for efficient crop removal of sludge-nitrogen, leaching of metals should pose little threat to ground water resources for all but those sludges with very high metal levels (Logan and Chaney, 1983).

Because of the strong retention of metals by soils, loss of metals by erosion and runoff transport of sediments might pose a greater threat to water supplies than leaching. Even if some erosion and transport of soil containing sludge-applied metals occurs, the low solubility of the metals will result in very low metal levels in the stream or lake. Proper site selection and sludge application management are necessary to protect water resources from metal contamination due to surface runoff and erosion.

The Office of Water Regulations and Standards of the EPA has reevaluated the existing regulations and criteria by which land application of municipal sludge is controlled in the United States. They used a risk assessment approach with the goal of developing regulations governing land application of sewage sludge that will protect terrestrial and aquatic ecosystems and minimize the health risk to animals or humans. A draft of the Proposed Standards for the Disposal of Sewage Sludge was published on February 6, 1989 (*Fed. Regist.*, 1989). These rules were signed on November 25, 1992 and are to be published in final form (entitled Standards for the Use and Disposal of Sewage Sludge) as 40CFR Part 503 in the *Federal Register* in January 1993. The new regulations encourage beneficial uses of sludge such as land application, composting, lime stabilization, and other distribution and marketing strategies.

Microorganisms

Ground water supplies over 100 million Americans with their drinking water; in rural areas, there is an even greater reliance on ground water as it comprises up to 95% of the water used (Bitton and Gerba, 1984). It has been assumed traditionally that ground water is safe for consumption without treatment because the soil acts as a filter to remove contaminants. As a result, private wells generally do not receive treatment (DiNovo and Jaffe, 1984), nor do a large number of public water supply systems. The EPA has estimated that approximately 72% of the public water-supply systems in the United States that use ground water do not disinfect (U.S. Environmental Protection Agency, 1990f). However, the use of contaminated, untreated, or inadequately treated ground water has been the cause of approximately 50% of the waterborne disease outbreaks in this country since 1920 (Craun, 1986a, 1986b; Craun, 1991; Herwaldt et al., 1992). The majority of the outbreaks were caused by pathogenic (disease-causing) microorganisms.

Between 1920 and 1990, 1,674 waterborne disease outbreaks were reported in the United States, involving over 450,000 people and resulting in 1,083 deaths (Craun et al., 1991; Herwaldt, 1992). The data are summarized for ten-year periods in Figure 3.3 (Craun, 1991). The number of reported outbreaks and the number of associated cases of illness have risen dramatically since 1971, as compared with the period from 1951–1970. During the period, 1971 to 1980, an average of 32.6 outbreaks per year were reported. From 1981 through 1990, the average was 27.4, as compared with averages of 11 and 13 for the periods 1951 to 1960 and 1961 through 1970, respectively (Craun, 1991). The increase in reported numbers of outbreaks may be due to an improved reporting system implemented in 1971, (Craun, 1985); however, it is still believed that only a fraction of the total number of outbreaks is reported (Lippy and Waltrip, 1984). Based on survey data from the Centers for Disease Control, it has been estimated that waterborne infections affect 940,000 people and are responsible for 900 deaths every year in the United States (Bennett et al., 1987).

When considering outbreaks that have occurred due to the consumption of contaminated, untreated, or inadequately treated ground water from 1971 to 1982, the most commonly identified causative agents were *Shigella* spp. and hepatitis A virus (Table 3.2). In almost two-thirds of the outbreaks, no causative agent could be identified, and the illness was listed

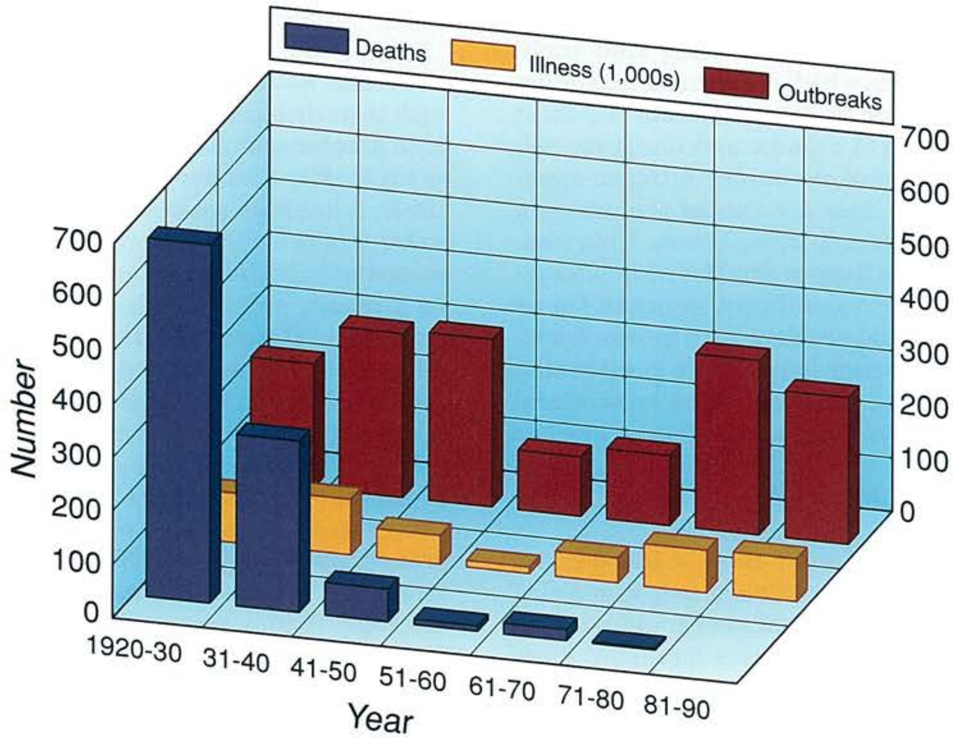


Figure 3.3. Waterborne disease outbreaks, illnesses, and deaths in the United States, 1920–1990. Note that the number of reported outbreaks and the number of associated cases of illness have risen dramatically since 1971, as compared with the period from 1951–1970. (Adapted from Craun, 1990, 1991 [Reprinted from *Water Sci. Technol.* 24:17–20, G. F. Craun, Causes of waterborne outbreaks in the United States, 1991, with permission from Pergamon Press Ltd., Headington Hill Hall, Oxford 0X3 0BW, UK]; Herwaldt et al., 1992 [Reprinted from *J. Am. Water Works Assoc.*, Vol. 84, No. 4, April 1992, by permission. Copyright© 1992, Am. Water Works Assoc.]).

as gastroenteritis of unknown etiology. However, more recent results suggest that the majority of these outbreaks were caused by enteric viruses and parasites such as *Giardia*.

In a nationwide study of rural drinking water supplies, including those in the open country and in places of less than 2,500 population, 29% of all households were served by water containing more than one coliform bacterium per 100 ml (one-fifth pint). Fecal coliform bacteria were found in the drinking water supplies of 12% of all rural households. "Households served by dug and bored wells, wells in which the water leaves the casing above ground level, wells with inadequate covers, inadequately maintained wells, and shallow wells all tended to have high coliform levels more commonly than those served by wells without those characteristics." (Francis et al., 1982).

The diarrhea that promotes methemoglobinemia in human infants whose formulas are made with well water contaminated with nitrate and bacteria may arise from infection with pathogenic bacteria contained in the water. In the survey by Francis et al. (1982), fecal coliform bacteria were found in the water supply of only 4.5% of rural households using community water systems. In the absence of bacterial contaminations, infants can tolerate relatively high concentrations of nitrate in their drinking water (Cornblath and Hartmann, 1984; Hegesh and Shiloah, 1982).

Table 3.2. Causative agents of waterborne disease in untreated or inadequately treated ground water systems, 1971-1982 (Craun, 1985)

Disease	Oubreaks (no.)	Total (%)
Gastroenteritis, unknown cause	132	64.7
Bacterial diseases	30	14.8
Viral diseases	23	11.2
Chemical poisoning	12	5.9
Parasitic diseases	7	3.4
Totals	204	100.0

Characteristics of Microorganisms

Bacteria are microscopic organisms, ranging from approximately 0.2 to 10 μm in length. They are distributed ubiquitously in nature and have a wide variety of nutritional requirements. Many types of harmless bacteria colonize the human intestinal tract and are routinely shed in the feces. One group of intestinal bacteria, the fecal coliform bacteria, historically has been used as an indication that water has been contaminated by human sewage. In addition, pathogenic bacteria, such as *Salmonella* and *Shigella*, are present in the feces of infected individuals. Thus, a wide variety of bacteria are present in domestic wastewater.

Viruses are obligate intracellular parasites; that is, they are incapable of replication outside of a host organism. They are very small, ranging in size from approximately 20 to 200 nm. Viruses that replicate in the intestinal tract of humans are referred to as human enteric viruses. These viruses are shed in the fecal material of individuals who are infected either purposely (i.e., by vaccination) or inadvertently by consumption of contaminated food or water, swimming in contaminated water, or person-to-person contact with an infected individual. More than one hundred different enteric viruses may be excreted in human fecal material (Melnick and Gerba, 1980). As many as 10^6 plaque-forming units (pfu) of enteroviruses (a subgroup of the enteric viruses) per gram and 10^{10} rotaviruses per gram may be present in the feces of an infected individual (Tyrrell and Kapikian, 1982). Thus, viruses are present in domestic sewage and, depending on the type of treatment process(es) used, between 50 and 99.9999998% of the viruses are inactivated during sewage treatment (Stewart, 1990).

A third group of microorganisms of concern in domestic sewage is the protozoan parasites. In general, protozoan cysts (the resting stage of the organism that is found in sewage) are larger than bacteria, although they can range in size from 2 μm to over 60 μm. Protozoa are present in the feces of infected persons; however, they also may be excreted by nonsymptomatic carriers. Cysts are similar to viruses in that they do not reproduce in the environment, but are capable of surviving in the soil for months or even years, depending on environmental conditions.

Diseases that may be caused by ingestion of these microorganisms are shown in Tables 3.3 and 3.4.

Table 3.3. Bacteria and parasites pathogenic to humans that may be present in sewage and sludge (Gerba, 1983)

Group	Pathogen	Disease/symptom caused
Bacteria	*Salmonella* (1,700 types)	Typhoid, paratyphoid, salmonellosis
	Shigella (4 spp.)	Bacillary dysentery
	Enteropathogenic *Escherichia coli*	Gastroenteritis
	Yersinia enterocolitica	Gastroenteritis
	Campylobacter jejuni	Gastroenteritis
	Vibrio cholerae	Cholera
	Leptospira	Weil's disease
Protozoa	*Entameoeba histolytica*	Amoebic dysentery, liver abscess, colonic ulceration
	Giardia lamblia	Diarrhea, malabsorption
	Balantidium coli	Mild diarrhea, colonic ulceration
	Cryptosporidium	Diarrhea
Helminths	*Ascaris lumbricoides* (roundworm)	Ascariasis
	Ancyclostoma duodenale (hookworm)	Anemia
	Necator americanus (hookworm)	Anemia
	Taenia saginata (tapeworm)	Taeniasis
	Trichuris (whipworm)	Abdominal pain, diarrhea
	Toxocara (roundworm)	Fever, abdominal pain
	Strongyloides (threadworm)	Abdominal pain, nausea, diarrhea
Fungi	*Aspergillus fumigatus*	Respiratory disease, otomycosis
	Candida albicans	Candidiasis
	Cryptococcus neoformans	Subacute chronic meningitis
	Epidermophyton spp. and *Trichophyton* spp.	Ringworm and athlete's foot
	Trichosporon spp.	Infection of hair follicles
	Phialophora spp.	Deep tissue infections

Table 3.4. Enteric viruses pathogenic to humans that may be present in sewage and sludge (Gerba, 1983)

Viruses	Number of types	Disease/symptom caused
Enteroviruses		
Poliovirus	3	Meningitis, paralysis, fever
Echovirus	31	Meningitis, diarrhea, rash, fever, respiratory disease
Coxsackievirus A	23	Meningitis, herpangina, fever, respiratory disease
Coxsackievirus B	6	Myocarditis, congenital heart anomalies, pleurodynia, respiratory disease, fever, rash, meningitis
New enteroviruses (Types 68-71)	4	Meningitis, encephalitis, acute hemorrhagic conjunctivitis, fever,respiratory disease
Hepatitis Type A (Enterovirus 72)	1	Infectious hepatitis
Norwalk virus	1	Diarrhea, vomiting, fever
Calicivirus	1	Gastroenteritis
Astrovirus	1	Gastroenteritis
Reovirus	3	Not clearly established
Rotavirus	2	Diarrhea, vomiting
Adenovirus	41	Respiratory disease, eye infections, gastroenteritis
Pararotavirus	Unknown	Gastroenteritis
Snow Mountain Agent	Unknown	Gastroenteritis
Epidemic non-A non-B hepatitis	Unknown	Hepatitis

Sources of Microorganisms

Microorganisms may be introduced into the subsurface environment in a variety of ways. In general, any practice that involves the application of domestic wastewater to the soil has the potential to cause microbiological contamination of ground water. This is because the treatment processes to which the wastewater is subjected do not effect complete removal or inactivation of the disease-causing microorganisms present. For example, expected removals of pathogenic microorganisms after various levels of wastewater treatment are shown in Table 3.5.

Viruses, enteric bacteria, and protozoa may be introduced into the subsurface environment in a variety of ways. Goyal et al. (1984) isolated viruses from the ground water beneath cropland being irrigated with sewage effluent. Viruses have been detected in the ground water at several sites practicing land treatment of wastewater; these cases were reviewed by Keswick and Gerba (1980). The burial of disposable diapers in sanitary landfills is a means by which pathogenic microorganisms in untreated human waste may be introduced into the subsurface. Vaughn et al. (1978) detected viruses as far as 408 m downgradient of a landfill site in New York. Land application of treated sewage effluent for the purpose of ground water recharge has also resulted in the introduction of viruses to the underlying ground water (Vaughn and Landry, 1977; 1978).

Septic Tanks

Home septic systems are reported to be a larger source of ground water contamination than farming (Council on Environmental Quality, 1980). Septic systems commonly used in the United States were designed for a rural setting, with low housing densities. This reflects the fact that septic systems by design release nitrate. Use of a septic system remains the primary sewage control method in most rural areas (Perkins, 1984).

The typical septic system is composed of three parts: septic tank, trenches or septic field, and the surrounding soil. Household wastes flow into the tank, where solid materials settle out and form sludge while grease and other floatable material form a surface scum. The wastes in the tank are attacked by anaerobic (growing without oxygen) bacteria. The decomposed materials are then transported to the septic field and released to the soil. Nitrogen enters the septic tank primarily as protein; it leaves the tank

Table 3.5. Pathogen removal in treated sewage (Stewart, 1990)

	Enteric Viruses	*Salmonella*	*Giardia*
Infective dose (particles)	1	$> 10^3$	25–100
Amount in feces	10^6–10^{10}/g	10^{10}/g	9×10^6/stool
Concentration in raw sewage (no./l)	10^5–10^6	5,000–80,000	9,000–200,000
Removal during:			
Primary treatment			
% removal	50–98.3	95.8–99.8	27–64
Number remaining	1,700–50,000	160–3,360	72,000–146,000
Secondary treatment			
% removal	53–99.92	98.65–99.996	45–96.7
Number remaining	85–47,500	3–1,075	6,480–109,500
Tertiary treatment			
% removal	99.983–99.9999998	99.99–99.999999995	98.5–99.99995
Number remaining	0.0007–17	0.000004–7	0.099–2,951

as ammonium. The tank and part of the septic field are anaerobic, preventing the formation of nitrate. However, once the effluent enters the soil, aerobic bacteria rapidly convert the ammonia to nitrate.

Recent estimates indicate some 22 million septic units are serving 25% of the housing units in the United States (U.S. Environmental Protection Agency, 1986c). The number of septic systems is increasing at the rate of one-half million per year (Scalf et al., 1977). With the rapid growth of housing in rural United States, septic tanks and cesspools are now responsible for the release of over 1 trillion gallons of wastewater per year (Council on Environmental Quality, 1980). Assuming four persons per household, an average septic system releases 190 gal. of effluent per day. This effluent contains an average of 65 mg/l of total N, 24 mg/l total P, 1×10^{11} total coliform, and 1×10^9 fecal coliform per liter. On a yearly basis this would translate to about 38 lb N per septic system. Some of this nitrogen would be lost to denitrification (the biological conversion of nitrate to nitrogen gas). However most ammonia converted to nitrate is leached.

Properly functioning septic systems may degrade water quality because nitrate is formed in the treatment process. Septic systems by design are expected to add some nitrogen to ground water. It is expected that the ground water will accept and dilute a small amount of nitrogen. Local ordinances control the site of septic systems relative to wells and by soil types. However, these ordinances are generally geared to ensure adequate loading of materials into soil and have lacked a consideration of ground water quality (Bauman and Schafer, 1985). Moreover, it is estimated that only 32% of the total land area of the United States is suitable for septic system installation. Many occurrences of properly sighted septic systems causing problems have been reported (Perkins, 1984). In

Table 3.6. Septic tanks and waterborne disease

Disease	No. of cases	Source of contamination	Reference
Gastroenteritis	1,200	Septic tank 150 ft from city well	Craun, 1981
Hepatitis A	98	Septic tank near water supply for commercial pellet ice operation	Craun, 1979
Hepatitis A	17	Septic tank 6 ft from a 100-ft-deep well	Vogt, 1961
Typhoid	5	Septic tank 210 ft from well	McGinnis and DeWalle, 1983
Gastroenteritis	400	Septic tank 50 ft above a spring	Craun, 1984
Gastroenteritis	?	Septic tank 100 ft from a 40-ft-deep well	Wellings et al., 1977

well-drained sands, nitrate exceeded 10 mg/l as N in wells as much as 295 ft down gradient from the system (Walker, 1973). Between 1971 and 1979, septic systems were deemed responsible for 45% of all waterborne disease outbreaks in the United States (Craun, 1981).

The number of septic systems within a given region is by far the most important factor controlling their potential to pollute ground water. The first 10 or 100 septic systems in a given area may have little effect. But at some input level, the ground water system will exceed nitrate limits for drinking water (Bauman and Schafer, 1985). Nitrate levels exceeded 8 mg/l as N on a regular basis for an unsewered 30 square mile area (5 people/acre) of Portland, Oregon (Cogger, 1988). Twenty-five years of ground water data for a sewered and nonsewered area (10 people/acre) in Long Island showed nitrate levels in the ground water of the sewered area were lower than levels under the septic systems (Katz et al., 1980). Computer models have been developed to project the effect of lot size (population density) on ground water contamination levels under septic systems (Perkins, 1984).

Septic tank effluent may be the most significant source of pathogenic bacteria and viruses in the subsurface environment. Septic tanks are the source of approximately one trillion gallons of waste disposed to the subsurface every year (U.S. Congress, 1984), and are frequently reported as sources of ground water contamination (U.S. Environmental Protection Agency, 1977). The overflow or seepage of sewage, primarily from septic tanks and cesspools, was responsible for 43% of the reported outbreaks and 63% of the reported cases of illness caused by the use of untreated water (Craun, 1985).

There have been several waterborne disease outbreaks documented to have been caused by the contamination of ground water with septic tank effluent (Table 3.6). These have been reviewed recently (Yates, 1985). For example, twelve hundred people in a town of 6,500 developed acute gastroenteritis after consuming tap water that had been contaminated by septic tank effluent (Craun, 1981). A dye tracer was used to show that the source of contamination was a septic tank located 49 m (161 ft) from the city's drinking water well. Effluent from a septic tank serving a household that had recently had infectious hepatitis contaminated a well used to make commercial ice, resulting in a 98-person outbreak of hepatitis (Craun, 1979). A drinking water spring contaminated with septic tank effluent was responsible for over 400 persons developing gastroenteritis caused by a Norwalk virus-like agent (Craun, 1984). More recently, 900 persons developed gastroenteritis caused by a Norwalk-like virus after consuming well water that had been contaminated by an onsite sewage treatment facility (Herwaldt et al., 1992).

Municipal Sludge

Another source of microorganisms to the subsurface is municipal sludge. Land application of municipal sludge is becoming a more common practice as alternatives are sought for the disposal of the ever-increasing amounts of sludge produced in this country. The sludge that is produced during the process of treating domestic sewage contains high levels of nitrogen and other nutrients that are required by plants. However, if not properly treated and land-applied it can degrade the soil and ground water quality. Sludge also contains pathogenic microorganisms at concentrations sufficient to cause disease in exposed individuals (Table 3.7).

Several studies conducted in the late 1970s suggested that viruses are tightly bound to sewage solids and are not easily released into the soil (Gerba, 1988). However, in a more recent study, viruses were detected in a 10 ft-deep well at a site where anaerobically digested sludge was applied to a sandy soil 11 weeks after sludge application.

Some examples of pathogen detection in ground

Table 3.7. Concentrations of microorganisms in digested sludges (adapted from Gerba, 1988)

Organism	Type of stabilization: Anaerobic (No. per g dry weight)	Type of stabilization: Aerobic (No. per g dry weight)
Enteroviruses	0.2–210.0	0–260
Rotaviruses	14.0–485.0	ND[a]
Salmonella	3.0–10^3	3
Total coliforms	10^2–10^6	10^5–10^6
Fecal coliforms	10^2–10^6	10^5–10^6
Shigella spp.	20	ND
Yersinia enterocolitica	10^5	ND
Ascaris	4.0[b]	
Trichuris	1.3[b]	
Toxocara	0.4[b]	

[a]ND = no data.
[b]Average of all types of digested sludge, percent viable.

water at sites where domestic waste was applied to the land are shown in Table 3.8.

Manure

Manures added to soils contain a vast array of microorganisms, some of which have the potential for causing human and animal disease. Reviews of the scientific literature (Ellis and McCalla, 1976; Reddy et al., 1981) indicate that microorganisms pathogenic to humans and animals do not survive well outside their hosts. The period of survival may vary considerably with the pathogen and the circumstances.

Fate of Microorganisms in the Environment

The fact that microorganisms remain infective long enough, and can travel far enough in the subsurface to contaminate drinking water and cause waterborne disease outbreaks has led to attempts to develop predictive models of microbial fate in the subsurface. To model the survival and transport of microorganisms in the subsurface, it is necessary to determine the factors that influence them. In addition to identifying these factors, it is necessary to quantify these effects in some way so that they can be used in the development of predictive models.

Once in the subsurface, there are two major factors that control microbial fate: survival and migration. The longer a microorganism persists, the greater the chance that it will still be capable of causing infection when it reaches the ground water after migrating through the soil.

In general, both the survival and migration are controlled by the specific microorganism type, the nature of the soil, and the climate of the environment. The susceptibility of microorganisms to different environmental factors varies considerably among different species as well as strains. The size and chemical composition of different microorganisms influence the extent to which they can travel in the subsurface. The soil properties play a major role in the survival and migration of bacteria and viruses. The texture of the soil, pH, organic matter content, and moisture content all influence how long microorganisms can survive and how far they can travel in the subsurface. Two aspects of climate are particularly important in determining microbial fate: temperature and rainfall. Microorganisms can survive for extended periods of time at low temperatures. Rainfall is important in that it can mobilize adsorbed microorganisms and promote their migration to the ground water.

Table 3.8. Viruses in ground water following land application of waste

Site	Reference
90 ft below cropland irrigated with secondary sewage effluent	Goyal et al., 1984
10 ft below sludge application site 11 weeks after application	Jorgensen and Lund, 1985
1320 ft downgradient from a sanitary landfill	Vaughn and Landry, 1977
40 ft below a septic tank at a well 108 ft away	Wellings et al., 1977

Regulations

The fact that microorganisms are responsible for numerous waterborne disease outbreaks led the EPA to propose Maximum Contaminant Level Goals (MCLGs) for viruses and *Giardia*, a protozoan parasite, in 1985 (U.S. Environmental Protection Agency, 1985b). Rather than require systems to monitor the water for the presence of these pathogenic microorganisms, the EPA proposed treatment technique regulations to ensure that the levels of pathogenic viruses and *Giardia* in the treated water would result in a risk of less than one in 10,000 infections per person per year. In June 1989, surface water treatment requirements that require a minimum of 99.9% removal of *Giardia* and 99.99% removal of viruses were finalized. The possible requirements of the ground water disinfection rule (GWDR) were published in June 1991 (U.S. Environmental Protection Agency, 1991a). Water utilities wishing to avoid disinfection will be given the option to demonstrate that their wells meet "natural disinfection" criteria that are being developed by the EPA. "Natural disinfection" criteria include horizontal setback distances, depth to well screen, thickness of the unsaturated zone, ground water travel time, and virus transport time. At this time, the "natural disinfection" criteria are being developed using an acceptable virus concentration of 2 viruses per 10 million liters of water at the well (to achieve the EPA's goal of limiting the risk of increased infections to one in 10,000 persons per year) (Regli et al., 1991).

The EPA has recently proposed new standards for the disposal of sewage sludge (*Fed. Regist.*, 1989). In the proposed rule, three classes of sludge are defined based on the pathogen reduction requirements. The specific levels of pathogen reduction required for Class A, B, and C sludge are presented in Table 3.9. The crop and access limitations to the land are dependent on the class of sludge applied, with the strictest controls on land receiving the least treated (Class

C) sludge.

In addition to federal standards, several states have laws and regulations designed to minimize the potential for pathogen contamination of drinking water. For example, most states have prescribed minimum setback distances between septic tanks and drinking water wells. Setback distances range from 25 feet in South Carolina to 400 feet in Rhode Island and Massachusetts.

Another practice regulated by many states is the reuse of treated sewage effluent. As stated previously, even tertiary treated sewage effluent may contain concentrations of pathogens high enough to pose a threat to human health. The state of California is in the process of revising the so-called "Title 22" regulations pertaining to the use of effluent for irrigation and other purposes. Reclaimed water is classified by the degree of treatment it has received: disinfected tertiary, disinfected secondary–2.2 (total coliform not to exceed 2.2/100 ml), disinfected secondary–23 (total coliform not to exceed 23/ml), or undisinfected secondary reclaimed water. The permitted uses of the water are dictated by

Table 3.9. Federal sludge regulations (*Fed. Regist.*, 1989)

Class	Pathogen reduction requirements	Access and use restrictions
A	Pathogen concentrations equal to or less than: *Salmonella* spp.–3/g VSS[a] Viruses–1 pfu/g VSS Protozoa–1/g VSS Helminth eggs–1/g VSS Sludge raised to 53° C for 5 days 55° C for 3 days or 70° C for 1/2 hour Indicator densities equal to or less than: Fecal coliform–2 log/g VSS Fecal streptococci–2 log/g VSS	No restrictions on access to or use of agricultural land. For nonagricultural land, access is restricted until a vegetative cover is established. Sewage sludge that is distributed and marketed must meet Class A requirements.
B	Treatment to reduce pathogen concentrations in the incoming wastewater by: *Salmonella* spp.–2 log/g VSS Viruses–2 log/g VSS or The resultant sludge has densities of indicator organisms less than or equal to: Fecal coliforms–6 log/g VSS Fecal streptococci–6 log/g VSS	Food crops that have harvested parts above the ground or that touch the soil cannot be grown for 18 months after application. Food crops with harvested crops below the ground cannot be grown for 5 years, unless no helminth eggs are present, then for 18 months. Food crops may not be harvested for 30 days after sludge application. Animals may not graze for 30 days after sludge application. Public access must be restricted for 12 months after sludge application.
C	Treatment to reduce pathogen concentrations in the incoming wastewater by: *Salmonella* spp.–1.5 log/g VSS Viruses–1.5 log/g VSS or The resultant sludge has densities of indicator organisms less than or equal to: Fecal coliforms–6.3 log/g VSS Fecal streptococci–6.7 log/g VSS	Food crops that have harvested parts above the ground or that touch the soil cannot be grown for 18 months after application. Food crops with harvested crops below the ground cannot be grown for 5 years, unless no helminth eggs are present, then for 18 months. Food crops may not be harvested for 60 days after sludge application. Animals may not graze for 60 days after sludge application. All access must be restricted for 12 months after sludge application.

[a]VSS = volatile suspended solids.

the level of treatment, with fewer restrictions being placed on the disinfected terti-ary reclaimed water, and the most restrictions on the undisinfected secondary reclaimed water (Kiado, pers. com., 1992).

States are developing regulations requiring buffer zones or separation distances for various activities, including agriculture, from streams in drinking water supply watersheds. Separation distances from receiving waters also are specified for land application of treated wastewater, sludge, and animal waste. Animal waste lagoons also have required separation distances and bottom sealing requirements to minimize leaching to ground water.

Pollution Prevention

Pollution prevention must be looked at in a systems approach if effective loading reduction is to occur. For agriculture and rural areas, nutrient and chemical management, manure management, surface runoff and erosion control, ground water leaching, and septic tank placement in regard to wellheads must all be considered and addressed jointly. Urban or suburban areas should focus on septic tank maintenance, storm water management, and lawn and garden best management practices.

4 Risk/Benefit Considerations: Health, Environment, and Economic

Introduction

During the past twenty years there has been an increase in research on a wide range of issues relating to health, environmental, and economic risks associated with surface or ground water contamination by agricultural chemicals.

During this same period, public concern about air and water pollution, waste management, soil erosion, exploitation of natural resources, and extinction of plant and animal species stimulated new environmental protection laws, regulations, and public policies. Public support for cleanup and prevention of pollution has continued to increase. The number of environmental, consumer, and health organizations has multiplied, reflecting increasing interest in food and drinking water quality, ground water degradation, surface water contamination, and sustainable agricultural practices.

Risk/benefit considerations continue to be an important tool in establishing environmentally sound, cost-effective, scientifically accurate regulations and public policies. It remains difficult to develop consensus among interest groups who evaluate risk/benefit considerations in disparate ways. Even the definition or basic concepts relating to risks and benefits can mean different things to different people.

Risk can be defined as the probability that an adverse effect will occur. Benefit can be defined as anything that contributes to an improvement in condition. Risks or benefits can be classified as actual, projected, or perceived. Acceptance of the validity of risk/benefit calculations may be influenced by the values or needs of individuals or interest groups.

Health Risks

Evaluation of health risks is an integral part of the regulatory process for establishing drinking water standards and acceptable pesticide residues on food crops (tolerances). Except in cases where there is a proven link between a chemical exposure and human illness, risk assessment may rely on mathematical models designed to help scientists predict potential adverse effects. The report, *Health Issues Relating to Chemicals in the Environment: A Scientific Perspective*, describes issues relating to toxicity and the basic scientific concepts involved in evaluating health effects of chemicals (Council for Agricultural Science and Technology, 1987).

There are a number of agricultural chemicals whose use and abuse have been associated with adverse health effects. Over-exposure to organophosphate and carbamate insecticides is associated with inhibition of an enzyme called acetylcholinesterase, resulting in symptoms of hyperstimulation. Pyrethrum and pyrethrin insecticides can act as dermal and respiratory allergens. Fatal pulmonary edema can result from overexposure to the herbicide, paraquat (Morgan, 1989). Exposure to high levels of nitrates in water has been linked to methemoglobinemia in infants; this condition results in a potentially fatal reduced oxygen-carrying capacity of the blood (Klaassen, 1986).

In contrast to actual health risks that can be documented and supported by data, other effects may be categorized as projected. For example, the number of human cancers that may result from exposure to a carcinogen in drinking water, based on data collected in laboratory animals, can only be estimated or projected.

Using laboratory data to predict possible human health effects depends on a process known as extrapolation—i.e., the application of information collected in one setting to other sets of circumstances. Table 4.1 contains some of the many extrapolation issues that may lead to uncertainty in projecting risk.

Projected health risks due to chemical exposures may be regarded by the public or some interest groups with a great deal of suspicion. Scientists and regulators charged with the task of determining potential long-term human health effects of chemicals based on animal studies have an exceptionally difficult job. Their analyses can only be as good as the data with which they are provided to make their judgment; often laboratory studies contain weaknesses that hinder the process. In any case, every effort is made to detect potential adverse health effects of chemicals

Table 4.1. Extrapolation issues

Projected risk	Example
Species to species	Laboratory animals to humans
High dose exposure to low dose exposure	Laboratory animals exposed to high daily doses of a chemical versus intermittant low dose exposure of humans
Single compound exposure to mixture exposure	Chemicals are usually tested individually, but humans are generally exposed to contaminants as part of complex mixtures
Short-term to long-term	2-year laboratory studies versus lifetime human exposures
Route to route	Laboratory feeding studies versus human dermal application of a given chemical

(hence laboratory animals receive large daily doses of chemicals throughout their lifetime) and to identify an exposure level at which no adverse effects occur.

From human exposure data or laboratory studies, regulators attempt to determine exposure levels that will pose negligible risk over a lifetime of repeated daily exposure for each chemical. For chemicals that are not carcinogens, a safety factor is commonly applied and exposure limits are set 10- to 100-fold below levels that have been proven to have no adverse effects in humans or laboratory animals. For chemical carcinogens, exposure limits are set such that tumors might develop in a very small number of exposed individuals (typically one in a million).

There is a significant degree of uncertainty associated with projecting risks due to chemical exposure. Part of this uncertainty stems from the existence of different risk assessment models. The models used by the U.S. Environmental Protection Agency to establish water standards for carcinogenic chemicals are conservative, intending to provide a "worst case" risk projection. However, different experts can interpret the same data in different ways, resulting in controversy that can be confusing to the public. The controversy over the safety of Alar reflects this point (Rosen, 1990). New findings by scientists can modify projected risks and regulators may change standards to reflect new information. This process, even though it refines risk estimates and thus further protects human health, can cause additional public confusion.

Environmental Risks

The enactment of the National Environmental Policy Act of 1969 (NEPA) established a legal framework for evaluating the environmental impacts or risks associated with governmental policies. Environmental impact research is designed to establish the dynamics of environmental systems, diagnosing the extent of harm to air, land, water, and biological resources (Anderson, 1973). The risk to the ecosystem can be real or projected and, like health-risk data, can be subject to controversy, scientific dispute, and may cause public uncertainty.

A substantial number of agricultural practices cause adverse, sometimes irreversible, environmental changes. The draining and conversion of wetlands for crop production eliminates natural habitat and reduces fish and wildlife populations. Chlorinated hydrocarbons, such as DDT, persist in soil and water for long periods of time, pass through the food chain, and may concentrate in toxic amounts for many species, particularly birds. Documentation of the adverse effects of these chemicals by Rachel Carson in 1962 in her landmark book, *Silent Spring*, contributed to the ban of DDT, a product viewed with such favor that its discoverer, Paul Muller, won the Nobel Prize (Carson, 1962). Updated research is important for determining environmental risk as well as for health risks.

Research and monitoring continues to determine the extent of contamination of surface or ground waters by agriculture. The EPA's recently released *National Survey of Pesticides in Drinking Water Wells* documents that nitrates and pesticides are found in both public and private ground water supplies of drinking water (U.S. Environmental Protection Agency, 1990d). Recent water quality surveys reviewed in Appendix D indicate that nitrates and pesticides, when found, were generally below drinking water standards for those compounds.

The adverse effects of agricultural nonpoint source pollutants, primarily soil sediment and nutrients, have been well documented. Soil sediment, eroded from cropland, can impair the habitat and reproduction of aquatic life in rivers and lakes (Water Quality 2000 Report, 1991). Loss of submerged aquatic vegetation in the Chesapeake Bay appears to be closely linked to increasing nutrient enrichment. Enhanced phytoplankton growth has reduced the amount of light reaching the submerged aquatic vegetation to below critical levels. Excess nutrients can increase blooms of undesirable algae, reduce dissolved oxygen, and decrease water clarity. Submerged aquatic vegetation is used by waterfowl and provides necessary habitat for fish. Toxicants, such as herbicides, have been identified as a problem in local areas of the Chesapeake Bay (U.S. Environmental Protection Agency, 1983). Water pollution may be the most damaging and widespread adverse environmental effect of agricultural production. Agriculture is reported to be the nation's largest source of nonpoint water pollution (National Research Council, 1989).

Projecting environmental risks can be as difficult as projecting health risks. Experts disagree about the value of mathematical models to predict the future of dynamic, biologically sensitive ecosystems. Projecting risks to surface waters is complicated by natural events like flooding and droughts. Projecting risks of ground water contamination requires extensive hydrogeological research.

Economic Risks

Economic analysis, particularly the effect of financial incentives or disincentives, continues to be a vital part of considerations of risks and benefits. Issues of who pays and who benefits may be greatly influenced by institutional policies and practices established many years ago. Determination of economic efficiency, the balancing of costs and benefits, including social and environmental costs, are complicated by existing laws, court interpretations, and governmental institutional responsibility. Changes in the rights and obligations of users, or in the economic and social cost of water-use options may be needed to reduce water pollution (Libby, 1990).

Perception of Risk

The way different segments of the public perceive risk may depend more on the credibility and trust of the information provider than on its scientific validity. Perception of risk may be based on emotion or may reflect personal, moral, or even religious values. Public perception can change over time, and the degree of change can be influenced by the political climate, news events, scientific uncertainty, personal economic factors, fear, public trust and confidence, and other factors.

Scientists and regulators charged with protecting human health have an exceptionally difficult job. Photograph courtesy of F. J. Humenik, North Carolina State University, Raleigh.

For the most part, the public does not differentiate between industrial or agricultural contamination. The origin, benefits, relative toxicity, and pervasiveness of different contaminants in the environment are not separated in the minds of much of the public (Holden, 1986).

Public confusion may result from the scientific uncertainties associated with assigning risks. The scientific community's ability to detect chemicals is much more advanced than the understanding of the toxicology associated with such discoveries. Scientists do not fully understand all the health or environmental risks of low levels of chemicals such as pesticides. Public understanding of pesticides is based more on perception than knowledge. But the public understands that pesticides are not a natural component of drinking water. They also understand that pesticides were created to kill living things. They are generally unaware of the scientific basis of the debate over "safer levels of exposure" that surrounds establishment of pesticide tolerances for exposure in food or water.

How the media report and explain risk has been the subject of research. One study of media reporting of environmental contamination events concluded that risk is not a dominant theme of news reporting. News is determined by traditional journalistic determinants (timeliness, human interest, prominence, proximity). Risk perception frequently is based on opinion rather than scientific evidence. Reporting of immediate threats to public health generally is the only risk information presented during news coverage of an environmental accident or emergency. Little relationship is found between the amount of coverage of an environmental news event and the risk to public health. When journalists present risk information they seek out officials, including governmental sources (Sachsman et al., 1988), but they also shop for counter positions to increase the "newsworthiness."

Public perception can be a political catalyst that stimulates legislative and executive action. Public policies are a reflection of prevailing public values, attitudes, and perceptions of societal problems, which are significantly shaped by the media.

Political leaders use opinion polls to help gauge the public mood. Opinion polls are like a snapshot; they capture a particular public mood at a particular time. Trend information, such as similar questions asked of comparable groups at different times, is a more accurate indicator of public opinion. As trends are identified, response patterns emerge, and it becomes possible to more meaningfully interpret public attitudes. Public opinion trend information indicates that public support for environmental protection not only remains strong, but has continued to increase (The Conservation Foundation, 1982).

Recent public opinion polls relating to agricultural contamination of ground water reinforce trend data. Polls even suggest that the general public would favor changing to a less chemically-dependent agriculture. In several polls, the majority of respondents thought that contaminated drinking water is a serious national problem and standards for its protection are not strict enough (Harris, 1986). This is especially true in the corn belt states, where one poll found the majority surveyed favored restrictions on the use of agricultural chemicals to protect ground water, even if such restrictions reduced yields or increased farmer costs (Pins, 1986). A 1986 survey of Big Spring Basin farmers in Iowa found that ground water was of equal importance to farmers as was profitability. This result may have been because the farmers worried about the purity of their own drinking water (Padgitt, 1986). Telephone interviews with a random sample of North Carolinians between November 1988 and January 1989, found that almost three-fourths of all respondents believed that agricultural chemicals, such as fertilizers and pesticides, were harmful to the environment. There was no significant difference of opinion between farmers and nonfarmers (Hoban, 1990). Responses to all opinion polls depend on the wording of the question, sampling techniques, professionalism of pollsters, and maybe even current events.

A recent report by the OTA (U.S. Congress, 1990) contains the following summary on how perception of risks associated with agrichemical use has the potential to influence public policy without regard for undisputed scientific information or with uncertain facts:

"Public concern over agrichemical contamination of groundwater illustrates the extent to which perceptions of risk are changing. While the presence of agrichemicals in drinking water have been shown to have some association with disease and mortality, public surveys have shown that contaminated groundwater commonly is believed more risky than other conditions that some scientists believe to be more hazardous to personal health (e.g., indoor air pollution). Individual and, thus, societal decisions about risk may depend more on the conditions of exposure than on knowledge about the probabilities of adverse outcomes. For example, people tend to accept risks if they are self-imposed or if they are familiar. However, agrichemically contaminated drinking water involves an involuntary risk, one associated with a resource for which there are no substitutes (i.e., water), with unfamiliar multisyllabic chemical names, and with uncertain and far distant consequences.

"Claims are often made that the public is ignoring risks much more hazardous than those appearing in the press and on television and, thus, their attention should be redirected towards the 'real' risks, presumably allowing the 'perceived' risks to sink low on lists of concerns. However, because such questions involve consideration of values, and differing values are held by different groups in society (e.g., consumers, producers, urban environmentalists), risk-management and communication decisions must be negotiated between those concerned and thus who govern the process that acts on the risk. Moreover, when organizations are perceived to be ignoring the values voiced in the debate, the public has a tendency to lose faith in the ability or willingness of the organization charged with minimizing risk, and may undertake risk management on its own, for example, by changing consumption patterns. Such unanticipated changes in consumption could have far more adverse impacts than a gradual shift in production practices in response to public concerns.

"Clearly, the public is unwilling to wait until scientific inquiry provides all the facts necessary to determine an uncontroversial, measurable level of risk. Instead, it is calling on Congress to meet a challenge 'posed by policy-related science issues, characterized by uncertain facts, disputed values, high stakes, and a need for urgent decisions.' (Bradbury, 1989)."

Historical Perception of Agriculture

Historically, agricultural interests have been valued by society and have benefitted from government support. In the past, the agrarian dominance provided free land to farmers, developed water resources in arid lands, established a network of research and technology transfer programs, and over the years created an assortment of government programs from crop subsidies to land retirement.

Today only a small percentage of the general population has first hand agricultural experience. The number of farmers has declined while the total population has increased in the United States.

A former USDA chief economist stated that sometime in the 1960s or 1970s agriculture and its supporters lost the initiative of public policy formation. This initiative reverted to nonfarmers, consumers, and environmentalists. Agricultural interests were forced into a defensive posture, dealing with the policies of other interest groups (Paarlberg, 1980).

Although agricultural interests have been valued by society, the number of farmers has declined. Photograph courtesy of Soil Conservation Service, U.S. Department of Agriculture.

Risk/benefit considerations of health, environment, and economics are an important aspect of agricultural production. Public perception of the 1990s reflects concern about environmental protection and wise management of the entire ecosystem. Agriculture is just one part of that ecosystem.

5 Current Approaches to Protecting Water Quality from Agricultural Contaminants

Introduction

Numerous approaches to protecting water from agricultural contaminants have been developed and are being used in and out of government. Some, such as best management practices (BMPs) for minimizing sediment contamination of surface water, are well established while others have only recently been applied. Extent or effectiveness of implementation varies from program to program, state to state, county to county, farm to farm, or even from field to field.

The existence of numerous efforts at all levels of government to protect water from agricultural contaminants necessitates development of an effective coordination strategy to avoid conflicts and duplication of efforts. Failure to recognize this need can lead to squandering of limited resources and may result in such deleterious cross media effects as increased contamination of ground water from the application of approaches designed to reduce contamination of surface water (or vice versa).

Some states have ground water protection coordination committees. These may be valuable for coordinating the many and varied ground water protection activities conducted under various local, state, and federal programs such as state pesticide management plans, nutrient management plans, septic tank management initiatives, wellhead protection programs, comprehensive state ground water protection programs, nonpoint source programs, and the USDA's Water Quality Initiative. They may also assist in coordinating activities that affect hydrologically connected ground water and surface water systems.

This section characterizes approaches to protect water from agricultural contamination by general types of approaches, categorized as nonregulatory/voluntary, regulatory, liability, or comprehensive protection. Most of these approaches emphasize pollution prevention. Exceptions are those approaches that help assure safe water at the tap (i.e., drinking water programs) or provide for cleanup of contamination. Appendix F presents an overview of major programs or activities to protect water quality from agricultural contaminants.

Types of Approaches

Several types of general approaches to protect water quality from agricultural contaminants currently exist both in and out of government. Although these are discussed individually below, they often represent complementary parts of a more comprehensive effort. For example, the USDA is carrying out research, education, technical assistance, and financial assistance efforts as part of the Water Quality Initiative. The discussion that follows is not an attempt to evaluate the effectiveness of the approaches (which may not yet be known in many instances), but simply presents and describes them in general terms. Specific examples of the approaches are provided in the discussion of current government programs/activities in Appendix F.

Nonregulatory/Voluntary

Producer Initiative

Choices that individual farmers make can affect the quality of our water resources. Whether influenced by economic factors, such as cost-share assistance or the cost of pesticides, concern for their families' health, or by a strong environmental ethic, many farmers have voluntarily adopted BMPs and other measures that will help protect water from contamination by sediment and agricultural chemicals.

Surveys have demonstrated farmer concern over water quality (Abdalla, 1989; Hallberg, 1988; Moore, 1989). The surveys also found, however, some ambivalence toward environmental concerns, attributed in part to the large investments that many farmers have in the current agricultural system. Survey results suggest that initiative in adopting practices to protect water quality may be limited for these farmers. In any event, increased producer initiative will demonstrate that more producers are willing to accept responsibility for the water quality impacts of their production practices.

Research

Research is an approach that is universally necessary to understand the nature of environmental processes and how to respond appropriately to agriculturally-related water quality problems. Basic and applied research supports all other approaches and is conducted (or sponsored) by universities, pesticide manufacturers, mineral fertilizer producers, and agencies at all levels of government.

Examples of current efforts include research on

1. Fate and transport of agricultural chemicals/nutrients.
2. Health effects of drinking water contaminants, including pesticides and nitrate/nitrites.
3. Integrated pest management and alternative production practices.
4. Alternative pesticide and fertilizer products.
5. Alternative nutrient sources.
6. Effectiveness of BMPs on water quality.
7. Effects of irrigation drainage on water quality.
8. Sediment transport and siltation.
9. Insect-, disease-, and weed-resistant crop varieties.

Education

Education and information on the impact of agriculture on water quality is provided to farmers, policymakers, and the general public by a wide variety of public and private entities. These include local, state, and federal government agencies, universities, chemical manufacturers, business and trade associations, environmental organizations, and public interest groups. Education is an approach that can be based on the notion that an informed individual will voluntarily behave appropriately or it can be used simply to transmit information on requirements under pending or existing legislation/regulations.

Education is conducted in a variety of ways depending on the intended audience, the purpose of the education, and the available resources. For example, the USDA Soil Conservation Service or Extension Service may inform or educate farmers about the water quality impacts of sediment, nutrients, or pesticides through the use of training films, field manuals and other literature, or field demonstrations. A local official will necessarily use a different approach to inform the general public about impending controls on septic tanks, perhaps through a newspaper interview and a public hearing.

Technical Assistance

Assistance on how to develop or implement the technical aspects of programs or regulations is an approach commonly used by government agencies to support efforts to protect water from agricultural contaminants. Chemical manufacturers and dealers provide assistance on how to use their products. Forms of technical assistance include preparation and distribution of printed materials, maps, training films, training courses, computer software, field demonstration projects, and workshops/seminars. Technical assistance often accompanies educational activities.

Education on the impact of agriculture on water quality is provided to many audiences in many different ways. Photographs courtesy of F. J. Humenik, North Carolina State University, Raleigh.

Technical assistance is a major focus of the USDA programs to protect water quality. The USDA and state agriculture agencies demonstrate technologies for preventing and minimizing contamination and train farmers in the proper and safe application, storage, and disposal of agricultural chemicals and nutrients. Technical assistance to support water protection programs is also a major activity of other federal agencies such as the EPA and U.S. Geological Survey (USGS).

Economic Incentives

Economic incentives for inducing actions to protect water quality from agricultural contaminants or to discourage overuse of agricultural chemicals include federal or state cost-share assistance, grants, loans, taxes, and fees. Federal agencies make grants to states, localities, and private individuals to support the development and implementation of programs, plans, or practices for protection of water quality. A few states make no- or low-interest loans to farmers for BMP installation. States charge pesticide registration fees and at least one state, Iowa, levies a fixed-per-ton tax on nitrogen fertilizers in addition to a sales tax (Mosher, 1987).

Economic incentives can be targeted to specific chemicals or used to promote the adoption of BMPs through cost-share programs. Under cost-sharing, federal or state agencies pay landowners up to 80% of the costs of installing such BMPs as manure storage facilities, conservation tillage, and alternative agricultural practices.

Product Stewardship

Taking responsibility for overseeing all phases of the development and use of a potentially harmful product, or product stewardship, is another approach to water quality protection. Product stewardship can be applied to the manufacture, testing, registration, sale, handling, use, storage, and disposal of such potential agricultural contaminants as pesticides and fertilizers as well as to the use, storage, and disposal of manure and sludge. It can be exercised by the manufacturers, regulators, dealers, and users of the product.

An instance of product stewardship exercised by the regulator would occur when the EPA ensures that the manufacturer of a pesticide submits adequate data on the pesticide and carefully reviews the data before deciding whether to register the product. Fertilizer registration laws applying to labeling, permiting, fees, penalties, etc., exist in 49 states. The user of that same product would exercise a form of stewardship by carefully following the label directions on proper use of the pesticide.

Regulatory

Product Controls

Controls on manufactured products used in agriculture are also used to protect water quality. These products include pesticides, processed fertilizers, and sludge (since it is treated and often composted). The difference between product stewardship and product control can be illustrated by using the example cited above. While carefully reviewing data needed to make a considered decision on registering a pesticide product is an instance of product stewardship, the requirement to register is a form of product control.

Among agricultural contaminants, product controls on pesticides are most prevalent. Such controls include requirements for the manufacturer to (1) register, test, and monitor the product; (2) ban and restrict use (including limiting use to certified applicators); and (3) produce legally enforceable labeling directions that provide users with explicit instructions on how to safeguard water. In addition to controls on pesticides, at least one state (Nebraska) has placed use restrictions on fertilizers in highly vulnerable ground water areas.

Other Regulations

Regulation of potential agricultural contaminants of water is an approach applied primarily to pesticides and quasi-point or point sources of nitrate such as feedlots and fertilizer manufacturers and dealers. Under the Safe Drinking Water Act (SDWA), the EPA establishes standards for microbial contaminants, metals, radionuclides, pesticides, nitrate, and other chemicals for public drinking water supplies. The EPA is also promulgating standards for heavy metals, PCBs, and pathogens for sludge applied to land (U.S. Environmental Protection Agency, 1989a). A few states have either qualitative or quantitative water quality standards for nutrients or nitrate that are apart from the largely health-based drinking water standards.

Localities often regulate the density and placement of septic systems; at least one state, Delaware, has placed a moratorium on installation of septic tanks due to threats to water quality. Finally, states and localities have enacted sediment control laws, although agricultural sources of sediment are generally exempt from these laws. The 1985 farm bill, however, requires farmers with highly erodible cropland to implement Soil Conservation Service-approved soil conservation plans or lose farm program benefits.

The Federal Insecticide, Fungicide and Rodenticide Act is the major federal authority for regulating the use of pesticides, while the Clean Water Act also provides authority for addressing both point and nonpoint sources of pesticides as well as nutrients under National Pollution Discharge Elimination System (NPDES) permits and under the Nonpoint Source Program. Under the Toxic Substances Control Act (TSCA), the EPA has broad authority to control manufacturing, processing, distribution in commerce, and use or disposal of a chemical substance or mixture if it "presents or will present an unreasonable risk of injury to health or the environment."

All these federal authorities are augmented by state pesticide control laws, chemigation regulations, water quality protection laws, general environmental protection statutes, state and local regulations for restricting pesticide and nutrient use in wellhead protection areas, and local ordinances and land use controls. Additional discussion of federal, state, and local authorities that address agricultural contaminants of water is provided later in Appendix F.

Most, if not all of these laws or regulations, carry penalties for noncompliance. States use penalties and threats of civil suits to enforce compliance with water quality standards. For instance, both California and Arizona may levy fines of $2,500 per day per incident of illegal contamination of drinking water (Batie and Diebel, 1989). Fines can also be levied for failure to use pesticides according to label directions.

Liability

In recent years, liability for the adverse environmental consequences of agricultural production has emerged as an issue. The debate is often over who should bear the responsibility for pollution and to what degree. Should the polluter bear the entire responsibility (e.g., strict "polluter pays" approach) or should the burden be borne by the consumer (in prices) or the taxpayer (e.g., all those who benefit from agricultural production)? Although evolution to a strict "polluter pays" approach is unlikely, trends indicate that farmers will not be exempt from environmental responsibility.

Liability for knowing, willful, or negligent acts that lead to water contamination currently exists under federal environmental statutes. States have also addressed the liability issue. Connecticut, for example, applied strict liability to polluters of ground water, irrespective of the degree of care exercised. Farmers who applied chemicals according to directions on the label could be held liable for damages. The Connecticut law was revised to reduce liability if the farmer applied the chemicals properly, implemented plans to minimize the potential for contamination, and kept complete records of chemical applications, but farmers and chemical companies still remain liable to some extent (U.S. Congress, 1990).

Comprehensive Protection

Resource-Based Protection

Resource-based protection is an approach that focuses on maintaining the environmental integrity of the resource itself, rather than on individual sources of contamination or individual source controls. It is a comprehensive approach when it employs all of the previously mentioned approaches to protect an important resource from all the major sources and activities that threaten it. Examples of resource-based protection include watershed management and comprehensive state ground water protection programs, both of which define critical areas for priority management.

Another important feature of resource-based protection is that the resource's vulnerability to contamination, site-specific characteristics, and value are part of the design of the controls. This is in contrast with chemical-by-chemical approaches, which often have not taken such factors into account in the development and implementation of source controls.

All other approaches discussed in this section, from producer initiative to regulation, may be applied in resource-based protection. Often, numerous public and private parties participate in the development and implementation of specific actions. Since such land-use instruments as zoning, easements, land acquisition, and comprehensive planning typically contribute significantly to resource-based protection, local and state governments often play major roles under this approach. Regional cooperative efforts are also common to protect large water resources, such as the Chesapeake Bay.

6 Future Water Quality Programming

Introduction

The reaffirmation of the importance to control pollution from nonpoint sources after a period of intensive activity on point source control and ground water quality provides a current focus for addressing future water quality programming in relationship to agriculture's role in water quality.

GAO Recommendations

Concern about the impacts of nonpoint source pollution and the prospect that federal programs may be inadvertently contributing to the problem led to the publication, *Water Pollution: Greater EPA leadership Needed to Reduce Nonpoint Source Pollution* (U.S. General Accounting Office, 1990). The GAO was asked to determine the following:

1. What barriers may be inhibiting state and local efforts to control nonpoint source pollution, noting in particular federal programs that may be contributing to the problem.
2. What actions the EPA can take to improve the focus of federal efforts on reducing nonpoint source pollution problems.

The background section of the 1990 GAO report noted that given the diversity of nonpoint source pollution and its relationship to local land uses, Congress historically has been reluctant to allow the EPA to deal directly with the problem. While the Water Quality Act of 1987 left primary responsibility for nonpoint source pollution control with the states, it expanded the EPA's role by requiring the agency to review and approve

1. State assessments of the extent to which nonpoint sources cause water quality problems.
2. State programs designed to address these problems.

Among the problems the 1990 GAO report identified as significantly affecting state and local efforts to control nonpoint source pollution are the inherent conflicts between some federal agencies' policies and states' water quality goals. A prime example of the problem is the USDA Farm Commodity Programs, which indirectly contribute to nonpoint source water pollution through policies that encourage maximum crop production goals without regard for natural resource protection. Among the other problems confronting state and local efforts to control nonpoint source pollution are

1. Insufficient monitoring data on both the scope and impacts of the problem and on the effectiveness of potential solutions.
2. Political sensitivities in controlling local land uses that indirectly cause water pollution.

In the EPA report, *Nonpoint Sources: Agenda for the Future* (U.S. Environmental Protection Agency, 1989c), an ambitious five-year agenda to focus the EPA's efforts to deal with nonpoint source control problems was outlined. Nevertheless, the GAO report (U.S. General Accounting Office, 1990) concluded that the EPA's agenda will remain largely unfulfilled if the agency stays on its present course. A key contributing factor associated with resource constraints has been that available funds are overwhelmingly oriented toward point source control activities rather than nonpoint source. However, the agency's own analysis of comparative risks posed by alternative pollution problems suggests that nonpoint source water pollution poses a level of health risks comparable with that presented by point sources and substantially more serious ecological risks. The EPA administration explains that the agency's budgetary priorities reflect statutory mandates that place greater emphasis on programs to control point source pollution rather than nonpoint source pollution.

The 1990 GAO report recommended that the EPA establish funding priorities among its water quality programs that will allow the agency to pursue key objectives of an effective nonpoint source agenda that have had little progress under existing funding constraints. Additional recommendations to further the EPA's chances of success in implementing its nonpoint source pollution agenda presented by the GAO were to

- Resolve problems arising out of conflicts between the policies of federal agencies and water quality goals.
- Develop nonpoint source pollution criteria so that states can develop and implement nonpoint source water quality standards.
- Develop monitoring techniques to help states determine the extent of nonpoint source pollution problems and the effectiveness of corrective actions.
- Educate the public about the health and environmental impacts of nonpoint source pollution.

In highlighting a matter for consideration by the Congress, the 1990 GAO report states, ". . . in light of (1) the importance of nonpoint source pollution as a primary cause of the nation's remaining water quality problems, and (2) the overwhelming emphasis of EPA resources devoted to point source problems, the Congress may wish to consider allocating EPA's water quality funding during the fiscal year 1992 budget process to provide greater emphasis on controlling nonpoint source pollution."

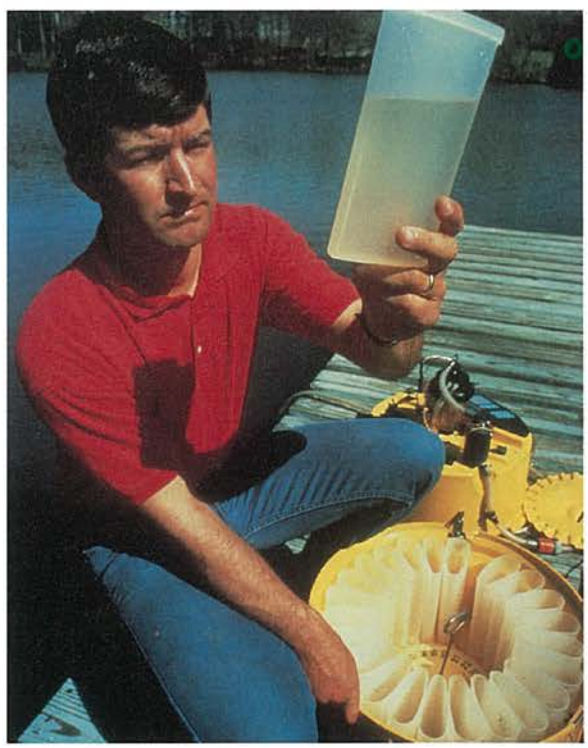
EPA Options to Improve Nonpoint Source Program

The authors of the January 25, 1991 *Environmental Reporter* article noted that the EPA Office of Water is considering broader water quality standards for more pollutants as an option to help deal with nonpoint source pollution problems. The agency is also considering ways to improve nonpoint source pollution control by using market forces. Point/nonpoint trading could be encouraged whereby polluters could lessen their permit requirements for point source discharges by decreasing nonpoint source discharges of similar pollutants—either their own or another discharger's.

The authors of the *Environmental Reporter* article (1991) state that the EPA could also encourage "marketable discharge rights" for large nonpoint source polluters. Under this theory, discharge limits could be set for a pool of large volume polluters, and those dischargers could then buy and sell discharge rights within the pool. Similar to the provisions of the new Clean Air Act Amendments, dischargers could alter their permit requirements as long as the total pool of discharges does not exceed an established level. Marketable discharge rights would be opposed by those claiming it ignores the zero discharge goal of the Clean Water Act.

The *Environmental Reporter* authors suggested that initiatives for improving the nonpoint source pollution program could focus also on creating financial incentives, such as targeting federal/state cost-share programs to priority nonpoint source areas, promoting use of set-asides and easements in sensitive areas, or making nutrient management and water quality compliance a condition of agriculture and timber subsidies. The EPA could also require states to implement best management practices and on-farm nutrient management programs in targeted watersheds. In fact, the EPA may need to redraw the lines that separate point sources, which require permits, from nonpoint sources, which generally do not. Permits may be needed for larger problems such as irrigation return flows and agricultural feedlots.

The EPA Office of Water is to focus on improving its nonpoint source pollution program and on controlling combined sewer overflows. The Office's newly organized Management Advisory Group is to focus on the Clean Water Act Reauthorization. The reauthorization of the Clean Water Act will gain national attention, especially from those who feel better control of agricultural nonpoint sources is necessary to



The control and monitoring of nonpoint source pollution represents difficult technical and agency challenges. Photograph courtesy of F. J. Humenik, North Carolina State University, Raleigh.

achieve water quality goals. Designation of 1992 as the "Year of Clean Water" in commemoration of the 20th Anniversary of the Clean Water Act serves to direct even further attention to technology, public policy, and regulations necessary to achieve national water quality goals. Defining a balanced and technically sound role for agriculture in maintaining water quality will be a very important cooperative and multidisciplinary challenge.

7 Toward a New Agricultural Ethic

Introduction

The traditional responsibility of agriculture to produce food and fiber is being expanded to include protection of environmental quality. New perspectives, new policies, new programs, new regulations, and, in some cases, new ways of farming are being established. Already some positive actions have been taken toward a new agricultural ethic that places increased emphasis on environmental quality.

A New Beginning

The convergence of many concerns over the present agricultural system are facilitating an integration of agricultural and environmental policies. This presents opportunities to reshape these policies to mutually enforce objectives that environmentalists and agriculturalists are now pursuing largely in isolation. The general public will need to become more financially supportive of implementing environmental policies that have desired off-farm benefits.

Clearly, the environment, the farm sector, and the tax-paying public would benefit from policies that simultaneously address the economic and environmental consequences of U.S. agricultural techniques and capacity. In the immediate future, three specific areas of federal agricultural policy afford opportunities for the EPA and the USDA to work together toward integrating agricultural and environmental policies. The first is the conservation provisions contained within the 1985 and 1990 farm bills, the second relates to the USDA's commodity programs, and the third is the President's Water Quality Initiative. Also, the Clean Water Act, the Coastal Zone Management Act, the Federal Insecticide, Fungicide and Rodenticide Act, the Safe Drinking Water Act, and state programs contribute considerably to resource and environmental protection.

The 1985 farm bill established a set of conservation programs designed to reduce erosion, reduce surplus production, stabilize farm income, enhance water quality, and protect wetlands. One of these programs, the Conservation Reserve Program (CRP), compensates farmers for taking cropland that is highly erodible out of production. Under this program, nearly 34 million acres were enrolled through the reserve signup closing April 15, 1991.

Ideas are being discussed for the expansion of CRP to deal with nonpoint-source surface and ground water pollution. Targeting critical environmental lands for CRP practices could yield significant water quality and habitat protection benefits while reducing overall federal farm program costs. Further, the reduction in crop acreage would reduce chemical use while holding farm incomes constant. The EPA is currently working together with the USDA on ways to implement such programs.

A coordinated targeting approach would complement the EPA/state approach to implementing the 1987 Water Quality Act. Just idling relatively small areas of land in CRP is unlikely to solve ground water and surface water problems. Broader and more effective changes in the management of agricultural contaminants will still be necessary in many areas. It is important to integrate the implementation of these programs with the nonpoint-source control programs that states are developing in response to the 1987 Water Quality Control Act and with the ground water protection programs that many states have begun to adopt.

USDA Commodity Programs

In their present form, certain provisions of the USDA commodity programs tend to foster continuous, single crop (monocultural) production practices. Such practices typically require higher levels of pesticide and nutrient input than is necessary when crops are rotated.

These USDA programs are intended to counterbalance the fluctuations in the farm economy. For this reason, the program payments, farmer participation, amount of land idled, and overall program costs tend to increase in hard times. When the farm sector enters a recovery phase and prices begin to strengthen, there is less need for USDA commodity programs and their influences are reduced.

1990 Farm Bill

The design of the conservation title of the 1985 farm bill was directed primarily at soil conservation. While keeping that goal intact, the challenge of implementing the 1990 farm bill will be to address other critical problems, particularly ground water and surface water quality.

One of the best opportunities for doing so may be in expanding the goals and scope of CRP by targeting CRP enrollment on environmentally sensitive in addition to highly erodible lands. Increased state participation in CRP cost sharing also has been suggested, particularly as a tool for states to use in fulfillment of nonpoint-source programs. The conservation title demonstrated that addressing pervasive environmental problems through agricultural policy is possible. In developing future agriculture policies, the challenge will be to expand on the integration of environmental goals into agricultural programs in a way that continues the environmental and economic success of the 1985 Food Security Act.

New or better methods need to be developed to continue CRP over the long term for meaningful protection of land and water resources and not have CRP limited by short-term legislation. Better techniques also must be developed for enforcement of CRP and water quality legislation so intended benefits will be realized. The excellent educational and technical assistance programs already in place can result in greater benefits when complemented by balanced enforcement of appropriate regulations.

Alternative Agriculture

A small but growing number of U.S. farmers are trying to avoid the potentially negative environmental impacts resulting from the chemical-based farm systems that have dominated since the 1950s. These farmers are not simply discarding farm technology as it has developed over the past four decades nor are they giving up agrichemicals completely. However, they are turning to an "alternative" agriculture which is variously defined as "conservation," "sustainable," or "regenerative" farming. While some are attempting to use no synthetic chemicals, most are trying to reduce their use of chemicals for both environmental and economic reasons resulting in a low input farming approach.

The USDA defines alternative farming as a production system, which avoids or largely excludes the use of synthetically compounded fertilizers, pesticides, growth regulations and livestock feed additives. To the maximum extent feasible, organic farming systems rely upon crop rotation, crop residues, animal manures, legumes, grain manures, off-farm organic waste, mechanical cultivation, mineral-bearing rocks, and aspects of biological pest control to maintain soil productivity and tilth, to supply plant nutrients and to control insects, weeds and other pests (U.S. Department of Agriculture, 1991). However, proper management is still required to protect water quality.

Many of the practices considered to be alternative farming methods are certainly not new. For years, many of these methods have been standard recommendations from the Soil Conservation Service to reduce soil erosion and runoff. Technologies such as residue management, contour tillage, integrated pest management, and the fortification of animal manures to provide crop needs based upon waste and soil testing are being refined continuously to make them more attractive to producers. New practices such as using productive agricultural and forested lands for the recycling of sludge add opportunities for urban/rural partnering. As a result, restoration of some old farming practices augmented with newly developed technologies provide additional opportunities to reduce the environmental impacts of food and fiber production. These also provide opportunities to recycle waste in a manner that emphasizes resource recovery and overall environmental quality protection.

Future Opportunities

During the past five years, a number of factors have come together to encourage the integration of agricultural and environmental policies for the mutual achievement of agricultural and environmental quality goals.

As a practical matter, the successful integration of agricultural and environmental policies will be highly cost effective. Compensating farmers for retiring environmentally sensitive land can enhance water quality and wildlife habitat, while at the same time reduce farm program costs. The challenge is in bringing together such highly diverse groups as farmers, conservationists, and regulators to achieve an understanding and respect for each other's goals and then build a broadly based commitment to attaining mutually compatible objectives.

The development of strong government regulatory programs alone will not solve the environmental problems that are linked to agricultural practices. Because those problems are so diverse and because agricultural practices vary so widely, the creative, voluntary participation of farmers from across the country will be necessary to achieve environmental goals. Fortunately, farmers can easily be enlisted in the process for a more effective agricultural system and protection of environmental quality.

Farmers are dependent upon high environmental quality for both production and their own well being. Farmers are the first to be affected by poor surface water and well water. Farmers will make productive partners in national and local pollution control programs because they are affected first by the problems and are the key for effective solutions. Therefore, it is most important to provide farmers with adequate education, technical assistance, and incentives so that they can implement practices to protect environmental quality.

Clearly the environment, the farm sector, and the tax-paying public benefit from policies that simultaneously address the economic and environmental needs associated with U.S. agriculture. Farmers adopt new practices when buying equipment or facing deadlines for compliance. Development and implementation of soil and water conservation techniques or farm conservation plans take longer than anyone desires because of the time and coordination requirements from initial planning to final installation.

Environmentalists need to recognize that there are limits on the speed and degree to which agricultural programs can be altered to serve environmental goals. It is equally important for the agricultural community to recognize the need to integrate agriculture and environmental policies in establishing a new ethic that places equal emphasis on production and environmental protection. The time is right for everyone to work toward a new agricultural ethic that will achieve agricultural goals of a safe, abundant, and affordable food supply and a prosperous farm sector while protecting the nation's water resources.

In future agricultural policies the challenge will be to expand integration of environmental goals into agricultural programs. Photograph courtesy of F. J. Humenik, North Carolina State University, Raleigh.

Appendix A Development of National Drinking Water Standards and Guidelines

Introduction/Summary

Risk assessment is an integral part of the regulatory decision process, particularly in the qualitative determination of the strength of evidence relating to carcinogenicity and the classification within the EPA ranking system. That leads to an "aspirational" nonregulatory Maximum Contaminant Level Goal (MCLG) of zero for "probable" carcinogens and nonzero values based upon classical toxicology for "noncarcinogens" and a related system for "equivocal" evidence substances involving either additional safety factors or a nonthreshold risk model calculated target.

Legally enforceable drinking water standards, Maximum Contaminant Levels (MCLs), are required to be set as near as technically and economically feasible to the MCLGs. For "noncarcinogen" and "equivocal" evidence substances, the MCL is usually the same as the MCLG. For "probable carcinogens," the MCL is set based on a variety of technological performance/cost factors, but also a "reference risk" rank is targeted between 10^{-4} and 10^{-6} (incremental lifetime risk using a conservative model unlikely to have underestimated the risk). Standards falling in that range are concluded to be safe and protective of public health.

Background

The Safe Drinking Water Act (SDWA) requires the EPA to establish primary drinking water regulations which: (1) apply to public water systems; (2) specify contaminants which, in the judgment of the administrator, may have any adverse effect on the health of persons; and (3) specify for each contaminant (a) MCLGs and (b) either (i) MCLs or (ii) treatment techniques. A treatment technique requirement would only be set if "it is not economically or technologically feasible" to ascertain the level of a contaminant in drinking water.

MCLGs are nonenforceable health goals and are to be set at a level at which, in the administrator's judgement, "no known or anticipated adverse effects on health of persons occur and which allow an adequate margin of safety." The nonbinding House Report on the Safe Drinking Water Act states that for carcinogens, the MCLGs should be set at zero.

MCLs must be set as close to the MCLGs as feasible. Feasible means "with the use of the best technology, treatment techniques and other means which the Administrator finds, after examination for efficacy under field conditions and not solely under laboratory conditions, are available (taking costs into consideration)."

Primary drinking water regulations are also to include monitoring requirements. Specifically, regulations are to contain criteria and procedures to assure a supply of drinking water that dependably complies with MCLs including quality control and testing procedures.

Selection of Contaminants for Regulation

The most relevant criteria for selection of contaminants are: (1) the potential human health risk and (2) the occurrence or potential for occurrence in drinking water.

A set of selection criteria has been developed that essentially expands the two primary factors listed above. Use of a specific formula to apply selection criteria is not believed to be appropriate because of the many variables associated with contaminants in drinking water. For each contaminant, the essential factors in the analysis are as follows:

1. Are there sufficient health effects data upon which to make a judgment on the potential health effects of human exposure?
2. Are there potential adverse human health effects from exposure to the contaminant via ingestion?
3. Does the contaminant occur in drinking water?
4. Has the contaminant been detected in significant frequencies and in a widespread manner?
5. If data are limited on the frequency and nature of the contaminant, is there a significant poten-

tial of drinking water contamination?

Factors considered in the analysis of potential occurrence include the following:

1. Occurrence in drinking water other than community water supplies.
2. Present in direct or indirect additives.
3. Present in ambient surface water or ground water.
4. Present in liquid or solid waste.
5. Mobile to surface water (runoff) or ground water (leaching).
6. Widespread dispersive use patterns.
7. Production rates.

Determination of MCLGs

MCLGs are to be set at a level at which "no known or anticipated adverse effects on the health of persons occur and which allows an adequate margin of safety."

Noncarcinogens

For toxic agents not considered to have carcinogenic potential, "no-effect" levels for chronic/lifetime periods of exposure, including a margin of safety, are referred to commonly as Acceptable Daily Intakes (ADI) or Reference Doses (RfD). These ADI are levels estimated to be without significant risk to humans when received daily over a lifetime.

The intent of a toxicological analysis is to identify the highest no-observed-adverse-effect-level (NOAEL) based upon assessment of available human or animal data (usually from animal experiments). To determine the ADI for regulatory purposes, the NOAEL is divided by (an) appropriate "uncertainty" or "safety" factor(s). This process accommodates for the extrapolation of animal data to the human, for the existence of weak or insufficient data, and for individual differences in human sensitivity to toxic agents, among other factors.

ADIs traditionally are reported in mg/kg/day but for MCLG purposes, the "no effect" level needs to be measurable in terms of drinking water quality, i.e., mg/l. Conversion of the ADI to mg/l is accomplished by factoring in an assumed weight of the consumer and the assumed amount of drinking water consumed per day. The "no effect level" in mg/l has been termed the Drinking Water Equivalent Level (DWEL) and is calculated as follows:

$$\text{DWEL} = \frac{\text{NOAEL (in mg/kg/day)(70 kg)}}{\text{(UF) (2 l/day)}}$$

where:

NOAEL is No-Observed-Adverse-Effect-Level,
Seventy kg is the reference weight of an adult,
Two liters/day is the assumed amount of water consumed by an adult per day, and
UF is the uncertainty factor (usually 10, 100, or 1,000).

The National Academy of Sciences (NAS) recommended an approach for use of uncertainty factors when estimating ADI for contaminants in drinking water (National Research Council, 1977). The NAS outlines are as follows:

1. An uncertainty factor of 10 used when good acute or chronic human exposure data are available and supported by acute or chronic data in other species.
2. An uncertainty factor of 100 used when good acute or chronic data are available for one species, but human data are not.
3. An uncertainty factor of 1,000 used when acute or chronic data in all species are limited or incomplete.
4. Other uncertainty factors can be used to account for other variations in the available data.

To determine the MCLG, the contribution from other sources of exposure, including air and food, are taken into account. When sufficient data are available on the relative contribution of other sources, the MCLG is determined as follows:

MCLG = (DWEL) – (contribution from food) – (contribution from air).

This calculation assures that the total exposure from drinking water, food, and air does not exceed the ADI. However, comprehensive data are usually not available on exposures from air and food. In these cases, the MCLG is determined as follows:

MCLG = (DWEL) (percentage of drinking water contribution).

The percentage of drinking water contribution often used is 20% of the total as a default value for organic chemicals.

Table A-1. U.S. Environmental Protection Agency classification system for chemicals using the degree of evidence of carcinogenicity (U.S. Environmental Protection Agency, 1986a)

Group	Degree of evidence
A	Human carcinogen (sufficient evidence from epidemiological studies).
B	Probable human carcinogen.
B1	At least limited evidence of carcinogenicity to humans.
B2	Usually a combination of sufficient evidence in animals and inadequate data in humans.
C	Possible human carcinogen (limited evidence of carcinogenicity in animals in the absence of human data).
D	Not classified (inadequate animal evidence of carcinogenicity).
E	No evidence of carcinogenicity for humans (no evidence of carcinogenicity in at least two adequate animal tests in different species or in both epidemiological and animal studies).

The EPA has published guidelines for carcinogen risk assessment which contain a classification system for chemicals using the degree of evidence of carcinogenicity (U.S. Environmental Protection Agency, 1986a). The categorization scheme places chemicals into five groups (Table A–1).

The EPA uses a three-category approach based upon strength of evidence of carcinogenicity to set the MCLGs. Category I includes those chemicals that have sufficient human or animal evidence of carcinogenicity to warrant their regulation as probable human carcinogens. The MCLGs for Category I chemicals are proposed at zero. Category II includes those substances for which some limited inconclusive evidence of carcinogenicity exists from animal data. These will not be regulated as human carcinogens. However, MCLGs will reflect the fact that some possible evidence of carcinogenicity in animals exists. Thus, they will be treated more conservatively than Category III substances. Category III includes substances with inadequate or no evidence of carcinogenicity. MCLGs will be calculated based upon ADIs. These categories are summarized in Table A–2.

The method for determining the MCLGs for Category II chemicals is more complex than for other categories. To be placed in Category II, chemicals are not considered to be probable carcinogens via ingestion, although some data may be available that cause concern. Thus, these substances should be treated more conservatively than Category III "noncarcinogens," yet less conservatively than Category I chemicals. Two options are available for setting the MCLGs for Category II chemicals; the first option involves basing the MCLG upon the ADI. To account for the possible evidence of carcinogenicity, an additional factor would be applied (e.g., ADI divided by a factor of 10 or some other value). The second option involves basing the MCLGs on a lifetime risk calculation in the range of 10^{-5} to 10^{-6} using a conservative method. This risk range is commonly considered to be protective and in the future, if additional data led to reconsideration of a chemical's carcinogenicity, the MCLG would have been conservative and not likely to have resulted in a significant underestimate of toxicological concern.

Table A-2. Summary of categories of carcinogenicity evidence used by the U.S. Environmental Protection Agency to set the Maximum Contaminant Level Goals (MCLGs)

Category	Evidence	EPA group
I	Strong evidence of carcinogenicity	Group A Group B
II	Equivocal evidence of carcinogenicity	Group C
III	Inadequate or no evidence of carcinogenicity in animals	Group D Group E

Determination of MCLs

MCLs are to be set "as close to" the MCLGs "as is feasible." The term "feasible" means "feasible with the use of the best technology, treatment techniques, and other means which the Administrator finds to be available after examination for efficacy under field conditions and not solely under laboratory conditions and availability (taking costs into consideration)," i.e., Best Available Technology (BAT).

The general approach to setting MCLs is to determine feasibility of controlling contaminants. This requires an evaluation of

1. The availability and cost of analytical methods.
2. The availability and performance of technologies and other factors relative to feasibility and identifying those that are "best."
3. An assessment of the costs of the application of technologies to achieve various concentrations.

Key factors in the analyses include the following:

1. Technical and economic availability of analytical

methods: precision/accuracy of analytical methods that would be acceptable for accurate determination of compliance limits of analytical detection, laboratory capabilities, and costs of analytical techniques.
2. Concentrations attainable in public drinking water supplies by application of best technology generally available.
3. Levels of contamination (i.e., concentrations) in drinking water supplies.
4. Feasibility-reliability of removing contaminants to specific concentrations.
5. Costs of treatment to achieve contaminant removal.

Other feasibility factors relating to the BAT determination include air pollution and waste disposal, and indirect effects of the technology on other drinking water quality parameters.

Following are two agricultural chemical examples (nitrate/nitrite and alachlor) illustrating toxicological analyses performed by the EPA in the course of developing a national drinking water standard or a nonregulatory health advisory. These evaluations usually produce recommendations for drinking water concentration levels considered unlikely to pose any noncarcinogenic adverse effect in the general population under a variety of exposure conditions (e.g., 1 day, 10 days, longer term/7 years, and lifetime). For a carcinogen, one or more mathematical extrapolations employing typical risk models are applied and concentration values hypothetically attributable to an incremental upperbound lifetime risk of one in ten thousand (10^{-4}) to one in a million (10^{-6}) are generated.

For a noncarcinogen, both the MCL and the MCLG would be the same as the Lifetime Health Advisory Level. For a probable human carcinogen, the MCLG would be zero, and the MCL would be a value determined from the Best Available Technology Analysis. That MCL would almost always fall within the hypothetical incremental upperbound risk range of one in ten thousand (10^{-4}) to one in one million (10^{-6}) and it is considered to be a "safe" value.

Appendix B Health Effects Information for Nitrate/Nitrite and Alachlor Drinking Water Standards and Guidelines

Introduction

Nitrate/nitrite and alachlor were selected as examples of commonly used agricultural chemicals that can be found on occasion in ground water or drinking water. Nitrate/nitrite is inorganic and representative of an input from natural sources, animal and human waste, and nutrients used for crop production. Alachlor is organic and representative of an agricultural chemical that is used primarily for crop protection. These two chemicals were used to provide specific examples for the development of drinking water standards and guidelines. See Appendix D for updated survey information on the prevalence of these substances in community and rural wells.

Nitrate and Nitrite[1]

General Information

Surveys of naturally occurring levels of nitrate and nitrite in ground and surface water reveal that contaminant levels generally do not exceed 1 to 2 mg/l for nitrate and 0.1 mg/l for nitrite. Nitrate and nitrite concentrations are expressed as N for which the drinking water standard is 10 mg/l rather than as nitrate for which the drinking water standard is 45 mg/l. Surface waters usually contain lower levels of nitrate and nitrite than ground water. Nitrate has been included in a number of drinking water surveys, which indicate its occurrence at levels of less than 1 mg/l in most surface and ground water supplies. Nitrate has been detected at levels exceeding 5 mg/l in about 3% of surface waters and 6% of ground waters surveyed. In 1987, about 40 surface water supplies and 568 ground water supplies were known to exceed the nitrate Maximum Contaminant Level (MCL) of 10 mg/l. Systems that exceed the MCL are usually contaminated by nitrate as a result of the use of fertilizers or from animal wastes or septic systems. Nitrite levels have not been surveyed in drinking water supplies but are expected to be typically much lower than 1 mg/l in the absence of waste contamination (U.S. Environmental Protection Agency, 1987a).

Nitrate occurs naturally in a number of foods, particularly vegetables. They are also added to meat products as preservatives. For adults, the major source of nitrate is dietary. For infants, contaminated water can be the major source of nitrate (U.S. Environmental Protection Agency, 1987a).

Pharmacokinetics

Both nitrate and nitrite are readily and completely absorbed after oral administration. Both nitrate and nitrite readily distribute throughout the tissues but do not bioaccumulate. Nitrate is not directly metabolized to other compounds in humans. However, bacterial metabolism of nitrate to nitrite in humans, particularly infants, can markedly decrease the ability of blood to carry oxygen to tissues. Nitrate is readily excreted by the kidneys.

Health Effects

The Lethal Dose (LD) of potassium nitrate for an adult ranges from 54 to 462 mg/kg; the LD of sodium nitrate ranges from 32 to 154 mg/kg.

The toxicity of nitrate in humans is due to reduction of nitrate to nitrite. By reacting with hemoglobin, nitrite forms methemoglobin, does not transport oxygen to the tissues, and thus leads to possible asphyxia.

Normal methemoglobin levels in humans range from 1 to 2% (Shuval and Gruener, 1977). A level greater than 3% is defined as methemoglobinemia. However, there is a consistent elevation of the methemoglobin concentration in pregnant women from the 14th gestational week through delivery (Skrivan, 1971).

[1]Based on U.S. Environmental Protection Agency health advisories and drinking water standards supporting documents.

Quantification of Toxicological Effects

The available data suggested that calculation of the Health Advisory (HA) values for nitrate/nitrite should include the following considerations: (1) recognition of the newborn infant as the population group at greatest risk, (2) recognition of the conversion of orally ingested nitrate to nitrite, and (3) use of human data whenever possible because of the extreme quantitative and qualitative variations in nitrate and nitrate toxicity observed among species.

The HA values are presented for a 4-kg infant (assumed to consume 0.64 liters of formula/d) and a 70-kg adult. The HAs are usually determined for a 10-kg child and a 70-kg adult. However, infants assumed to weigh 4 kg or less are the population subgroup at greatest risk, and thus HAs are provided for a 4-kg infant.

Although no separate HAs for a 10-kg child are provided, the HAs for a 70-kg adult are protective for all age groups other than a 4-kg infant, since they are based on data obtained in children (Craun et al., 1981).

Nitrate is toxic because it is converted to nitrite, and therefore the toxicity of nitrate and nitrite must be additive. Thus, nitrate and nitrite cannot be considered independently. Each HA is expressed as both mg nitrate-nitrogen/l drinking water and mg nitrite-nitrogen/l drinking water. Appropriate use of these values requires information on both the nitrate and nitrite content of drinking water so that a total "effective" nitrate concentration can be calculated and used as follows:

1. The "effective" nitrate-nitrogen concentration (mg/l) for all age groups is equal to nitrate-nitrogen + 10 x nitrite-nitrogen.
2. The "effective" nitrate-nitrogen concentration (mg/l) should not exceed the appropriate nitrate standard for the appropriate group (4-kg infant or 70-kg adult) or exposure period.

One Day Health Advisory

The available data are insufficient to develop One-Day HAs for nitrate and nitrite. The Ten-Day HA should be protective of 1-day exposures.

Ten-Day Health Advisory

For Populations Other than 4-kg Infant

Craun et al. (1981) conducted an epidemiologic study of 102 children aged 1 to 8 yr in Washington County, Illinois. Of the study subjects, 64 consumed water with high nitrate levels (22 to 111 mg/l nitrate-nitrogen) and 38 consumed water with low nitrate levels (< 10 mg/l nitrate-nitrogen). Ingestion of water containing 22 to 111 mg/l nitrate-nitrogen did not result in abnormal mean methemoglobin levels and was not related to increased methemoglobin levels in comparison to controls. In the total study group of 102 children, only five had methemoglobin levels > 2% (maximum of 3.1% in a child from the low-exposure group).

For a 70-kg adult and all age groups other than a 4-kg infant, the Ten-Day nitrate HA value is 111 mg/l nitrate-nitrogen, the No-Observed-Adverse-Effect Levels (NOAEL) observed by Craun et al. (1981). Because the study was based on observations in humans and the most sensitive subgroup (i.e., infants) was considered separately, no uncertainty factor has been used in deriving the Ten-Day nitrate HA from the NOAEL.

No available studies provide a direct measure of the NOAEL for nitrite in children. The Ten-Day nitrite HA for a 70-kg adult and all other age groups other than a 4-kg infant can be calculated from the NOAEL for nitrate, assuming 10% conversion of nitrate to nitrite, as follows:

(111 mg/l nitrate-nitrogen)(0.10) = 11 mg/l nitrite-nitrogen

where:

111 mg/l = NOAEL for nitrate based on the absence of methemoglobinemia in children, and
0.10 = assumed 10% conversion of nitrate to nitrite by a 10-kg child.

For a 4-kg Infant

A survey by the American Public Health Association (Walton, 1951) found more than 278 cases of cyanosis in infants that were definitely associated with consumption of nitrate-contaminated water by the infant or nursing mother. No cases associated with water containing 10 mg/l or less of nitrate-nitrogen were found. Hegesh and Siloah (1982) demonstrated that nitrites were synthesized in infants with acute diarrhea. Nitrite is responsible for methemoglobinemia, and thus it is possible that infants with diarrhea may be the population most sensitive to the toxic effects of both nitrate and nitrite. Because diarrhea is relatively common in infants, at least some of the infants were believed to have had diarrhea. Thus, it was concluded that a Ten-Day HA derived from the study by Walton could protect all infants, including those with diarrhea.

Based on the previous discussion, the Ten-Day nitrate HA for 4-kg infants is 10 mg/l nitrate-nitrogen, which is also the NOAEL for methemoglobinemia observed by Walton (1951). Studies by Winton et al. (1971) and Toussaint and Wurkert (1982) support this HA.

No study provides a direct measure of the NOAEL for nitrite in infants. However, the Ten-Day nitrite HA for a 4-kg infant can be calculated from the NOAEL for nitrate as follows:

$$\frac{(10\ \text{mg/l nitrate-nitrogen})(100\%)}{(10)} =$$

$$1\ \text{mg/l nitrite-nitrogen}\ (1{,}000\ \mu\text{g/l})$$

where:

10 mg/l = NOAEL for nitrate-nitrogen based on the absence of methemoglobinemia in infants,
100% = the assumed conversion of nitrate to nitrite by a 4-kg infant, and
10 = uncertainty factor.

Longer-Term Health Advisory

The available data are insufficient to develop Longer-Term HAs for nitrate and nitrite. However, for both nitrate and nitrite, the Ten-Day HA for a 4-kg infant is judged to offer protection against the formation of methemoglobin induced by the ingestion of either nitrate or nitrite in all age groups.

Lifetime Health Advisory

No suitable studies for calculation of a Lifetime HA were located. However, for both nitrate and nitrite, the Ten-Day HA for the 4-kg infant (10 mg/l nitrate-nitrogen and 1 mg/l nitrite-nitrogen) is judged to offer protection against the formation of methemoglobin induced by the ingestion of either nitrate or nitrite in all age groups. As previously discussed, a 4-kg infant is the most sensitive member of the population with respect to the formation of methemoglobin induced either by nitrite directly or by in vivo reduction of nitrate to nitrite. In addition, as a 4-kg infant ages (e.g., becomes a 10-kg child) both sensitivity to the effects of methemoglobin and the amount of nitrate reduced to nitrite decrease, thus rendering the older child and the adult less sensitive to the effects of both nitrate and nitrite. Thus, the Ten-Day HA for a 4-kg infant for both nitrate and nitrite (10 mg/l nitrate-nitrogen and 1 mg/l nitrite-nitrogen) was concluded to offer adequate protection against methemoglobin formation in all other age groups as well.

Evaluation of Carcinogenic Potential

Animal studies provided inconclusive evidence regarding the carcinogenicity of nitrate and nitrite administered in the absence of nitrosatable compounds (U.S. Environmental Protection Agency, 1985a).

Applying the criteria described in U.S. Environmental Protection Agency guidelines for assessment of carcinogenic risk (U.S. Environmental Protection Agency, 1986a), both nitrate and nitrite may be classified in Group D: not classified. This category is for agents with inadequate or no animal evidence of carcinogenicity.

Other Criteria, Guidance, and Standards

The Maximum Contaminant Level (MCL) for nitrate-nitrogen is 10 mg/l and 1 mg/l for nitrite-nitrogen. Total nitrate/nitrite should not exceed 10 mg/l as N. The U.S. Environmental Protection Agency Quality Criteria for Water suggested the maximum concentrations of nitrate-nitrogen and nitrite-nitrogen in domestic water supplies not exceed 10 mg/l and 1 mg/l, respectively.

Alachlor[2]

General Information

Alachlor, also known as Lasso, is an herbicide whose major use (99%) is in preemergence application to field corn, soybeans, and peanuts. Alachlor is applied to soil either before or just after the crop has emerged, and is degraded in the environment by a number of mechanisms. It is metabolized rapidly by crops after application. Once in the soil, alachlor is degraded by bacteria under both aerobic and anerobic conditions. It is not photodegraded and does not hydrolyze under environmental conditions. It has moderate mobility in sandy and silty soils, has been demonstrated to migrate to ground water, but does not bioaccumulate.

The occurrence of alachlor in water, food, and air has been documented by the U.S. Environmental Protection Agency. Alachlor was estimated to be detected in less than 0.1% of drinking water wells sampled in the EPA's National Pesticide Survey.

Food does not appear to be a major route of expo-

[2]Based on U.S. Environmental Protection Agency health advisory and drinking water standards supporting documents.

sure for the general population. Residues of alachlor in food are usually nondetectable. Current U.S. Environmental Protection Agency standards for alachlor food residues are limited to levels which, when combined, would result in a maximum daily dose of 0.6 μg/kg. In areas where alachlor levels in drinking water exceed 0.3 μg/l, daily water intake would be 0.01 μg/kg/d.

Pharmacokinetics

A gavage metabolism study by the Monsanto Company (1983) showed that alachlor was absorbed by the gut of male and female rats (four of each sex).

Health Effects

There are no adequate data on the carcinogenicity of alachlor in humans. One limited epidemiology study investigated the ocular status of workers in a plant where alachlor was manufactured, but found no effects (Coleman and Gaffey, 1980).

Quantification of Toxicological Effects

One-Day Health Advisory

No duration-specific data are available to derive a One-Day Health Advisory (HA) for alachlor. Therefore, it is recommended that the Ten-Day HA of 0.1 mg/l, calculated below, be applied for the One-Day HA.

Ten-Day Health Advisory

Data from a 6-month dog feeding study (Ahmed et al., 1981) using 5, 25, 50, and 75 mg/kg/d dose levels of alachlor were also considered for the Ten-Day HA calculations. These results reflected 17, 58, and 92% mortality at 25, 50, and 75 mg/kg/d, respectively. The lowest dose tested (LDT) in this study, 5 mg/kg/d, reflected mild hepatotoxic responses (i.e., increase in liver weight) that were intensified at higher doses. However, a more recent 1-yr dog feeding study (Naylor et al., 1984) at 1, 3, and 10 mg/kg/d, reflected a NOAEL of 1 mg/kg/d, based on the absence of hemosiderosis in the liver and spleen. Therefore, the Naylor et al. (1984) study was used to calculate the Ten-Day HA.

The Ten-Day HA for a 10-kg child is calculated as follows:

$$\frac{(1\ \text{mg/kg/d})(10\text{kg})}{(100)(1\ \text{l/d})} = 0.1\ \text{mg/l}\ (100\ \mu\text{g/l})$$

Longer-Term Health Advisory

A Longer-Term HA was not determined for alachlor because alachlor has been shown to be carcinogenic in less than 5.5 months in rats.

Lifetime Health Advisory

The 1-yr feeding study in dogs (Naylor et al., 1984) was selected as the basis for the Drinking Water Equivalent Level (DWEL). This study reported a NOAEL of 1 mg/kg/d based on hemosiderosis in the liver and spleen of animals exposed to higher doses of alachlor in feed.

The Reference Dose (RfD) and DWEL were determined as follows:

Step 1: Determination of the Reference Dose (RfD)

$$\text{RfD} = \frac{(1\ \mu\text{g/kg/d})}{(100)} = 0.01\ \text{mg/kg/d}$$

Step 2: Determination of the Drinking Water Equivalent Level (DWEL)

$$\text{DWEL} = \frac{(0.01\ \mu\text{g/kg/d})(70\ \text{kg})}{(2\ \text{l/d})} = 0.35\ \text{mg/l}\ (350\ \mu\text{g/l})$$

Step 3: Determination of the Lifetime Health Advisory

Alachlor is classified in Group B2: probable human carcinogen. A Lifetime HA is not recommended. The estimated upper bound risk to a 70-kg adult consuming 2 l/d of 350 μg/l alachlor over a lifetime would be 10^{-3} to 10^{-4}. These data are based on the multistage model and the combined incidence of nasal turbinate tumors in male and female rats (Stout et al., 1984).

Evaluation of Carcinogenic Potential

The U.S. Environmental Protection Agency evaluated alachlor for carcinogenic risk assessment based on the Office of Pesticide Programs' (OPP) risk characterization of the nasal tumors from alachlor. The chronic feeding study by Stout et al. (1984) was used for these calculations. Using the multistage model and the combined incidence of these tumors in both male and female rats, the oncogenic potency q_1^*, based on a 70-kg adult, was 8.3×10^{-2} $(\mu g/kg/day)^{-1}$. This would translate to a hypothetical upper bound lifetime risk of about 8 in 100 for each microgram of alachlor ingested per kilogram of body weight if the exposure occurs every day (on average) for 70 years. That would mean 70 micrograms per day for a 70 kilogram person for 70 years, or drinking two liters of water each day containing 35 micrograms per liter. For two liters of water with one microgram per liter, the hypothetical upper bound lifetime risk would be on the order of 2 in 1,000 over the background cancer risk of about 1 in 4 (i.e., 0.002 more than 0.250 equals 0.252). The lower bound risk would be zero (i.e., if alachlor were not carcinogenic to humans at low doses). If there were a risk, it would be small in comparison to the background cancer risk.

The EPA's Office of Water used several mathematical models for comparison of the potential oncogenic risk for a 70-kg adult. The cancer risk estimates (95% upper limit) from several different models are projections that one excess cancer per 1,000,000 (10^{-6}) population may be associated with exposure to alachlor levels in drinking water of 0.4 μg/l (multistage), 0.4 μg/l (one hit), 10 μg/l (Weibull), 0.1 μg/l (logit), and 53 μg/l (probit).

Applying the criteria described in the EPA guidelines for assessment of carcinogenic risk, alachlor is classified in Group B2: probable human carcinogen. This category applies to agents for which there is inadequate evidence from human studies and sufficient evidence from animal studies.

The maximum contaminant level (MCL) for alachlor in drinking water is 2 μg/l based upon cancer risk concern and the technological feasibility of measurement and control in public water supplies. According to the EPA, drinking water that meets this standard is associated with little to none of this concern and is considered safe with respect to alachlor.

Even with advanced techniques, it is difficult to obtain data for health advisories. Photograph courtesy of F. J. Humenik, North Carolina State University, Raleigh.

Appendix C Water Quality Standards

Introduction

The water quality standards program is authorized under Section 303 of the Clean Water Act as one mechanism to "restore and maintain the chemical, physical, and biological integrity of the nation's waters" (Clean Water Act, 101(a) United States Code, Vol. 33 1251(a)). Water quality standards provide the regulatory and legal basis for requiring point source and nonpoint source water quality-based treatment technology beyond "best available technology."

A water quality standard defines the water quality goals of a body of water, or portion thereof, by (1) designating the use or uses to be made of the water and (2) setting criteria necessary to protect those uses. States adopt water quality standards to protect public health or welfare, enhance the quality of water, and serve the purpose of the Clean Water Act.

States must follow the requirements of 40 Code of Federal Regulation (CFR) Part 131 in order to receive EPA approval for their water quality standards. If the EPA does not approve the state's water quality standard, it may promulgate federal water quality standards necessary to meet requirements of the Clean Water Act.

To receive EPA approval, states must do the following:

1. **Identification**. Identify all surface waters within the state. (Ground waters are not included in this process.)
2. **Designated Uses.** Determine the uses of each water body. At a minimum, designated uses must provide for the protection and propagation of fish, shellfish, wildlife, and recreation in and on the water ("fishable/swimmable"), unless states can demonstrate that this goal is not obtainable. States can also designate a water body as a public drinking water supply, water supply for agriculture, industry, commerce, and/or navigation. Waste transport or waste assimilation are not acceptable designated uses.
3. **Water Quality Criteria.** Adopt water quality criteria that are sufficient to protect the designated use(s), using water quality criteria developed by the EPA under §304(a) as a basis. (The EPA criteria documents are based on the latest scientific research on human health and environmental effects of a contaminant. However, they are not enforceable.) Criteria may be expressed as concentrations, levels, or narrative standards. The criteria must be numeric for the 126 toxic pollutants listed pursuant to §307(a) for which the EPA has published a criteria.
4. **Antidegradation Policy**. Develop and implement an antidegradation policy to maintain and protect existing uses, higher quality waters, and outstanding national resource waters.
5. **Public Participation**. At a minimum, hold a public hearing to review proposed water quality standards.

States can develop standards more stringent than those required by the Clean Water Act. States can also adopt additional policies on the application and implementation of the standards, such as, variances, mixing zones, and low-flow exemptions.

Water quality standards are implemented through limits placed on the amount of pollutants discharged by point sources and through controls developed for nonpoint sources of pollution. Each point source discharger is required to obtain a National Pollutant Discharge Elimination System (NPDES) permit that limits the discharged pollutants and specifies monitoring and reporting requirements.

If technology-based limits are insufficient to obtain or maintain quality standards, the state or the EPA must determine the total maximum daily load (TMDL: the amount of a pollutant that may be discharged into a water body and still maintain water quality standards). The TMDL is the sum of the waste load allocation (from point sources) and the load allocation (from nonpoint and background sources), plus a margin of safety. The state must then allocate load reductions among the sources. Point source discharges are controlled through NPDES permits. Nonpoint sources are controlled through state or local laws.

Existing water quality standards must be reviewed and revised, if necessary, through a public process at least once every three years.

Appendix D Recent Water Quality Surveys

Ground Water

EPA Survey

During the 1980s, ground water protection became one of the EPA's top priorities. As more became known about the importance of ground water and the threats posed to the resource, Congress reauthorized several of the agency's statutes with a greater focus on ground water. The EPA also initiated several new activities to address the resource such as a *National Survey of Pesticides in Drinking Water Wells* (U.S. Environmental Protection Agency, 1990d). *Agriculture and Groundwater Quality* (Council for Agricultural Science and Technology, 1985) was published in response to concerns about the effects of modern agriculture on ground water quality. At that time, very little factual information existed about ground water quality and the levels of nitrate and pesticides that were present in ground water on a national basis.

The initial report (U.S. Environmental Protection Agency, 1990c) for the EPA National Survey of Drinking Water Wells conducted during 1988 and 1989 estimated that 10% of the nation's community drinking water wells and about 4% of the rural domestic wells have detectable residues of at least one pesticide. However, less than 1% of the wells had pesticide residues above the levels considered protective of human health. The survey results also estimated that more than one-half of the nation's wells contained nitrate, with about 1.2% of the community wells and 2.4% of the rural wells showing detections above the 10 mg/l nitrate as N maximum contaminant level established to protect human health. Undoubtedly, much of this nitrate originated from nutrients applied in agriculture; however, state surveys in the early and mid-1900s showed ambient levels of nitrate from 40 to more than 1,000 mg/l as N. Conclusions from several of these early surveys were that in at least some instances high nitrate levels have resulted from natural causes (Zillinger, pers. com., 1992).

The EPA Deputy Administrator, in making public the preliminary results of the survey, stated, "The findings of the survey indicate that the vast majority of drinking water wells in this country do not have levels of pesticides or nitrate that would pose a risk to public health. Where pesticides were detected, they were usually found at low levels—below levels of health concern. At the same time, the findings underscore the need to be ever vigilant in order to avoid more serious problems in the future. Consequently the agency is more determined than ever to push ahead aggressively to prevent further contamination of drinking water—one of this country's most valuable resources." (U.S. Environmental Protection Agency, 1990c)

In the national survey (U.S. Environmental Protection Agency, 1990d), the EPA tested for nitrate, 126 pesticides, and pesticide breakdown products in 564 community and 783 rural domestic drinking water wells. Testing began in every state in early 1988. The survey was designed to yield results that are statistically representative of more than 10.5 million rural domestic wells and more than 94,600 wells in approximately 38,300 community water systems. Wells were selected from a random statistical sample that took into account different patterns of pesticide use and ground water vulnerability. Because the survey was designed to provide current national estimates, the individual well results do not provide an assessment of ground water quality or pesticide contamination of drinking water wells at the local, county, or state level, or, of possible trends in water quality changes. The well water survey provides, for the first time, national estimates of the frequency and concentration of pesticides and nitrate in community and rural domestic drinking water wells.

The most frequently detected pesticide, a breakdown product of DCPA or Dacthal, was, when found, nearly always at only about 0.1% of the level of health concern. Dacthal is a broad leaf weed killer used primarily on lawns and is also approved for use on a variety of fruit and vegetable crops. Atrazine, a weed control product used primarily on corn and sorghum, was second in frequency of detections among pesticides found. In addition to atrazine, alachlor, dibromochloropropane, ethylene, thiourea, ethylene dibromide, and gamma lindane were sometimes found at levels above those considered protective of human health. Pesticide detections above levels established to protect human health with a margin of safety account for less than 0.8% of the wells.

Alachlor Survey

In 1990, the results of the National Alachlor Well Water Survey, which was designed by Monsanto Agricultural Company and Research Triangle Institute with active participation by the EPA, were released (Monsanto Agricultural Company, 1990). Among the 6 million wells that serve approximately 20 million people in the survey area, each well had a chance of being randomly selected. Nearly 1,430 wells in 26 states were sampled. Water samples were tested for alachlor, atrazine, metolachlor, cyanazine, simazine, and nitrate.

Based on survey data, less than 0.1% of all wells were projected to have herbicide occurrence in excess of the EPA's proposed maximum contaminant level (MCL) or health advisory level for that product. These health-based levels reflect lifetime consumption and thus provide a significant margin of safety. The survey results showed that more than 99% of rural wells were projected to be completely free of detectable levels of alachlor and only an estimated 0.02% of wells were projected to be above the proposed MCL.

Detectable levels of nitrate were projected in 52% of the wells in the survey area. A majority of these, however, had levels less than 3 ppm, which is generally regarded as a naturally occurring nitrate level present in some water supplies. About 5% of wells in the survey were projected to exceed the MCL of 10 ppm.

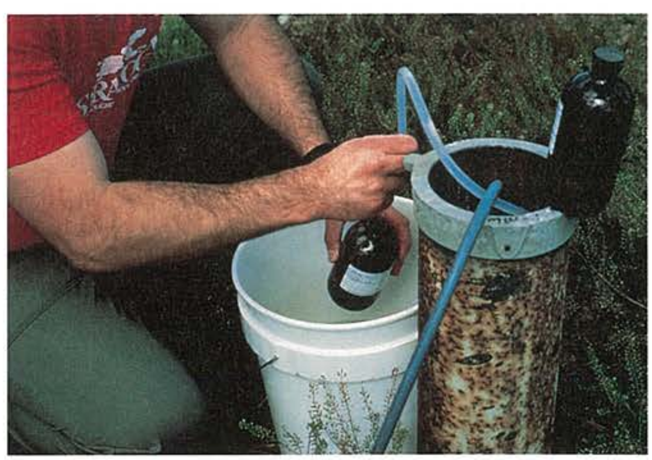
The report summary noted, "Approximately 87 percent of the estimated 6 million wells in the survey area are expected to be completely free of any detectable levels of the five herbicides studied. Where herbicides are detected, the typical trace levels are found well below the health-based standard set by the EPA. More than 99 percent of all wells are projected to show no herbicide levels exceeding the EPA Standard for Drinking Water Quality. The survey results are particularly encouraging with regard to drinking water quality. It found, for example, that the frequency and level of occurrence in rural, domestic wells of all herbicides studied are extremely low." (Monsanto Agricultural Company, 1990)

State Studies

In Ohio, 16,166 wells have been voluntarily sampled by owners starting in 1987 (Baker, 1990). Of these wells, 13% exceeded a nitrate concentration of 3 mg/l and 2.9% exceeded 10 mg/l. The percent of wells with nitrate concentrations greater than 10 mg/l for wells less than 50 feet deep was 7.2%; for wells between 50 and 100 feet deep, 1.7%; and for wells over 100 feet deep, 0.9%. Alachlor exceeded the health advisory level in four wells, atrazine in three wells, and cyanazine in none of the 610 wells of the private water systems tested.

In North Carolina, a total of 9,026 rural wells were sampled by trained volunteers or county extension agents in 29 of the 100 counties during 1989 and 1990 (Jennings et al., 1991; Sneed et al., 1991). On a statewide basis, 10.8% of the wells had nitrate as N between 3 and 6 mg/l, 5.1% between 6 and 10 mg/l, and 3.2% over 10 mg/l. On a regional basis, wells exceeding a nitrate concentration of 10 mg/l as N were 5.1% in the coastal plains and 1.6% in the Piedmont/Blue Ridge. These regional differences are further emphasized by subregion differences for exceeding the 10 mg/l nitrate as N concentration of 0.2% in the southeastern coastal area and 7% in the middle coastal plain. On a statewide basis for wells deeper than 100 feet, 1% exceeded the 10 mg/l nitrate concentration, whereas for wells less than 50 feet, 9% exceeded 10 mg/l nitrate as N concentration.

Some states have shown much higher nitrate concentrations, such as a 1985 nonrandom study in Kansas where 103 wells were sampled (Steichen et al., 1988). Pesticides were detected in 8 wells and nitrate in 29 wells. Twenty-eight percent of the wells exceeded the nitrate as N concentration of 10 mg/l and 14% of the wells exceeded a nitrate as N concentration of 20 mg/l.



Ground water quality has recently been surveyed in several national and state studies. Photograph courtesy of F. J. Humenik, North Carolina State University, Raleigh.

In Iowa, 686 wells were nonrandomly sampled in 1990 (Iowa Department of Natural Resources, 1990). The mean nitrate as N concentration was 6.2 mg/l with 18.3% of the wells exceeding the 10 mg/l nitrate as N concentration. For wells of less than 50 feet, 35.1% exceeded the 10 mg/l nitrate as N concentration, whereas for wells deeper than 50 feet, 12.8% exceeded that concentration. Pesticides were found in 13.6% of the wells overall, 17.9% of the wells less than 50 feet deep, and 11.9% of the wells deeper than 50 feet.

Appendix E Management of Agricultural Nutrients

Nutrients

Nitrogen

Nitrogen is no more essential for crop production than any of the other 15 essential elements. If any essential element is present in insufficient amounts in plant-available forms, crop yields are limited. The amounts of nitrogen required, however, are much larger than any of the other essential mineral elements except potassium, for which the amounts required are essentially the same as for nitrogen. Amounts of nitrogen removed in harvested grain crops in the United States range from 100 to 200 lb/acre, depending on the crop and the total grain yield. High yields of forage crops remove from 200 to 500 lb/acre/yr. Nearly an equal amount of nitrogen is required for the production of roots, stems, and leaves of grain crops. The same order of magnitude of nitrogen must be available for the production of vegetable and fruit crops. These amounts of available nitrogen must be present in the soils of the United States to produce the food, feed, and fiber that are required to feed and clothe our population and for international trade. This available nitrogen can be supplied from various sources. It must be provided if we are to produce adequate yields of crops.

Inputs and outputs of nitrogen from the soil-plant system and nitrogen transformations within the soil are listed in Figure E–1. Minor contributions consist of inputs from rainfall, nonsymbiotic fixation, and irrigation waters. Rainfall adds about 10 lb/acre/yr or less depending on the total rainfall and the number of electrical storms. Nonsymbiotic biological conversion of nitrogen in the air to fixed forms is considered to be about the same as that from rainfall, and has been estimated to range from 5 to 20 lb/acre/yr. Irrigation waters contribute 2.7 lb of nitrate nitrogen for each 1 mg of nitrogen per acre-foot of water. If we assume that 3 acre-feet of water are used per acre per year, the amount of nitrogen contributed will be 8.1, 40, and 81 lb/acre/yr, respectively, for concentrations of 1, 5, and 10 mg of nitrogen per liter. Thus, contributions in irrigation waters can range from insignificant to substantial amounts.

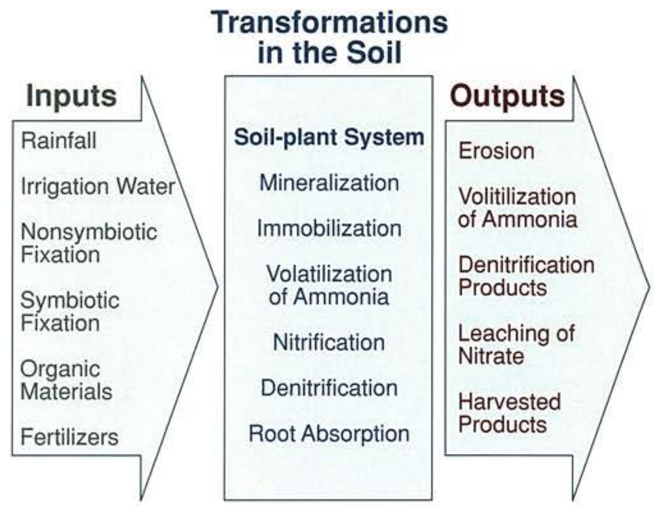


Figure E–1. Inputs and outputs (losses of nitrogen from the soil-plant system and the transformations that take place in the soil.

The main inputs of nitrogen into the soil-plant system in most cropped lands are

1. Symbiotic conversion of atmospheric nitrogen into fixed forms by the association of rhizobium bacteria living in nodules on the roots of leguminous crop plants.
2. The application of organic residues (animal manures and sewage sludges) and fertilizers.

Symbiotic fixation by leguminous crops ranges from 50 to several hundred pounds per acre per year, depending on the crop and the yield (Brady, 1984). Alfalfa tops the list for symbiotic nitrogen fixation with quantities fixed depending on the length of season and other cultural practices that affect yields. The nitrogen input into the soil-plant system, however, is largely removed in the harvested forage or in harvested crops such as soybeans. The only way to significantly increase the total nitrogen in the soil by growing these leguminous crops is to return the total crop to the soil as a green manure. On the other hand, no other nitrogen inputs are required, most legumes are effective in removing nitrate nitrogen from the soil profile, and roots and other residues of these crops are rapidly decomposed to release available nitrogen to following crops.

Organic materials contribute substantial amounts of nitrogen. Typical rates of application are 10 to 20 t/acre/yr. If 10 tons (20,000 lb) of manure containing 2% nitrogen are added per acre, the total nitrogen added would be 400 lb/acre. Nearly all of this nitrogen is in organic form and must be mineralized to become available to plants. Assuming that 35% is mineralized during the cropping season, a total of 140 lb would become available to the crops. The amount of nitrogen that becomes available from an application of organic materials depends not only on the amount of material added and the percent nitrogen, but also on how resistant the organic nitrogen compounds are to microbial mineralization, which depends on the nature of the material and the weathering that has occurred. For example, fresh dairy manure will mineralize rapidly to give 60 to 70% conversion to mineral forms in a crop season, whereas very old composted manure might convert at a rate of 10 to 20% during a cropping season.

The main output of nitrogen from the soil-plant system for most croplands are the denitrification products, nitrous oxide and dinitrogen, which escape into the atmosphere, removal in harvested products, and leaching of nitrate. Erosion can remove considerable amounts of nitrogen, but if erosion is properly controlled the amount of nitrogen lost becomes relatively small. Volatilization of ammonia can be controlled by proper management techniques such as proper selection of fertilizers and placement of ammonium fertilizer sufficiently deep in the soil.

Removal in harvested products can be changed by changing the crop or the total yield of a given crop, but the economic objective of growing a crop is to obtain a substantial harvest, and the agronomic objective should be to put as much as possible of the available nitrogen into the harvested material. Leaching and denitrification are both largely controlled by the nature of the soil and the water that enters the soil-plant system from rainfall or irrigation or a combination of both.

Within the soil, a number of reactions occur that influence the availability of nitrogen for the crop. Organic nitrogen contained in the residual soil organic matter is mineralized at rates of about 1 to 4% per year. Crop residues, roots, stems, and leaves from previous crops are also subject to microbial decay. If these materials have nitrogen contents of greater than about 1.25%, nitrogen will be released in mineral or inorganic form and become available to plants. On the other hand, if the nitrogen content is less than 1.25%, the organisms that attack the crop residues will take inorganic nitrogen from the soil to provide the basic needs of their metabolism and thus reduce the available supply for crops. This process is called immobilization. The same process will take place when any organic residues of low nitrogen content are added.

Volatilization of ammonia nitrogen occurs when ammonium sources are added to the surface of alkaline soils. Prevention or reduction in volatilization can be attained by placement of ammonium fertilizers at least 4 in. below the surface. If the fertilizer cannot be placed in the soil, the use of nitrate sources can eliminate the problem of ammonia losses to the atmosphere. The placement of animal manures on the surface of the land can also contribute to losses of ammonia. Manures have alkaline pH values so that as the manure is decomposed, the nitrogen released into the ammonium form is subject to conversion to ammonia and is lost by volatilization. To prevent this loss, the manure should be incorporated into the soil so that the ammonium released can react with the soil and subsequently converted to nitrate.

The mineralization process consists of (1) conversion of organically bound nitrogen to ammonium, (2) conversion of ammonium to nitrite, and (3) conversion of nitrite to nitrate. The process of conversion of nitrite to nitrate is faster than that for conversion of ammonium to nitrite, so that nitrite does not accumulate under most soil conditions. Thus, the nitrate ion represents the final product of the mineralization process and, because the nitrate does not react with soil particles, it readily moves with soil water and is subject to leaching to depths below the root zone. Ammonium reacts with negatively charged soil particles and is therefore not subject to leaching. Both nitrate and ammonium can be absorbed by roots and utilized by plants.

Denitrification is the process of conversion of nitrate to gaseous forms that escape back to the atmosphere. The main products are nitrous oxide and dinitrogen. The process is one of reduction, which occurs in anaerobic soils and anaerobic microsites in otherwise aerobic soils. When soils are saturated with water or are near saturation, the oxygen in the water is rapidly consumed by soil microorganisms, which then obtain oxygen by taking oxygen from the nitrate (NO_3^-) and converting it to nitrous oxide (N_2O) and dinitrogen (N_2). This process is favored by warm conditions and by a good supply of readily decomposable source of organic material, which supplies energy to the microorganisms that reduce to nitrate to obtain oxygen.

The roots of plants then compete with leaching of nitrate, denitrification, ammonia volatilization, and, in some cases, immobilization for the available nitrogen in the soil system. Preventing the conversion of ammonium to nitrate (nitrification) would eliminate both leaching and denitrification losses and keep more available nitrogen in the soil.

Nutrient Management Practices

The reductions of the direct transport of nitrogen and other elements to surface water is attained by control of soil erosion. Runoff water containing no soil has very little nitrogen. Erosion control practices that lessen or prevent phosphorus transport to surface water will also control the transport of nitrogen. Because erosion control is the critical practice for reducing phosphorus effects on water quality, it will be discussed briefly in the section dealing with that element. And because the main problem with nitrogen is leaching of nitrate to ground water, the management concepts and practices discussed in this section deal with reduction of leaching losses.

The reduction in nitrate leaching to ground water is a consequence of managing nitrogen wisely to maximize the fraction of the available nitrogen in the soil that is used by the crop and that goes into harvested useful products. The best way to minimize leaching of nitrate is to focus on practices that favor its most efficient use (Aldrich, 1984).

Optimum Crop Management

Agronomic management for high yields will promote efficient utilization of the available nitrogen in the soil-plant system. Selection of crop varieties with high yield potential that are well adapted to the local conditions, proper timing of planting, harvesting and other cultural practices, control of weeds and diseases, proper fertilizer use, and proper water practices in irrigated areas are all essential to the production of high yields and to high nitrogen use efficiency.

Yield-Input Relationships

The relationships among yield of an annual crop such as corn, excess nitrate at the end of the cropping season, and total nitrogen inputs are illustrated in Figure E–2. These relationships assume fairly ideal conditions of no other limitations to production except nitrogen supplies and little or no leaching or denitrification losses. In this hypothetical case, the

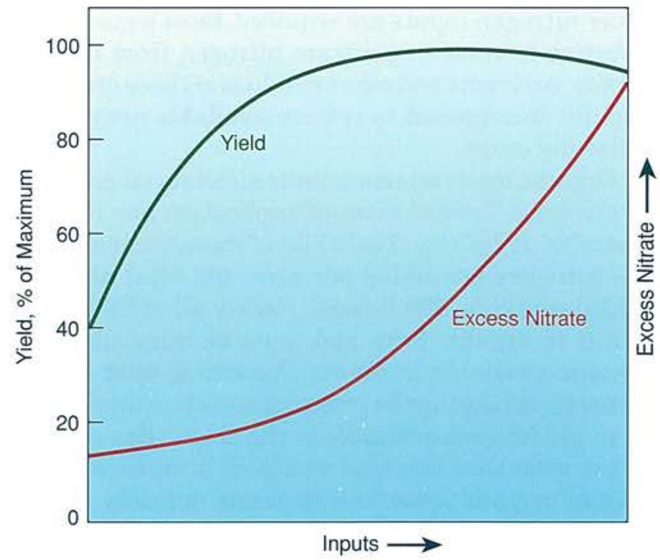
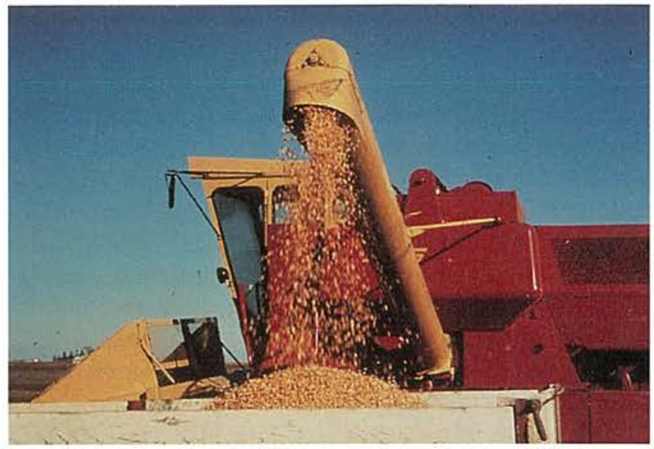


Figure E–2. Relationships among crop yield, excess nitrate in the soil at the end of a cropping season, and nitrogen inputs into the soil-crop system. These relationships assume little or no losses by leaching or by denitrification during the cropping season.

soil supplied sufficient nitrogen to produce 40% of maximum yield and all other inputs that were required to obtain maximum yield. The nitrogen from the soil is the sum of available nitrogen residual from a previous crop, mineralization from the organic matter including residues from the previous crop, and small inputs from rain and irrigation water if any was used. The inputs are from application of various rates of fertilizer nitrogen. The excess nitrate in the soil profile at the end of the cropping period increased very little until the maximum yield was approached, because as more nitrogen was added more was absorbed by roots and transformed into plant materials including the harvested product. But as maximum yield was exceeded, the excess nitrate increased rapidly with increase in nitrogen inputs.

Broadbent and Carlton (1978) found that the ideal relationships in Figure E–2 were duplicated in two field experiments with irrigated corn. Both soils were deficient in nitrogen. In each experiment, the excess nitrate was nearly constant until maximum yield was attained after which it increased dramatically with increase in nitrogen fertilizer.

The relationships in Figure E–2 suggest that to minimize the amount of excess nitrate in the soil at the end of a growing season and subject to leaching to ground water, we need to know how much available nitrogen the soil can provide and how much additional nitrogen is needed to approach a maximum



Agronomic management for high yields will promote efficient utilization of available plant nutrients. Photographs courtesy of F. J. Humenik, North Carolina State University, Raleigh.

ditional nitrogen is needed to approach a maximum yield.

Assessment of Available Nitrogen

Integration or assessment of available nitrogen from the soil, from irrigation water if the land is irrigated, and from applied organic materials before fertilizer needs are estimated can avoid amounts that exceed those required for maximum yields. Soil supplies consist of mineral nitrogen (ammonium plus nitrate) residual from the previous crop and the nitrogen that will be mineralized from the soil organic matter and from residues from the previous crop. The residue from a grain crop such as wheat will contribute little available nitrogen and in fact may cause immobilization and thus be a nitrogen demanding residue. The residues from alfalfa or other legumes, however, will contribute substantial amounts of available nitrogen because of their high nitrogen contents.

The integrated nitrogen management concept requires an estimate of the amount of available nitrogen required to meet the yield goal of the farmer or the yield potential of the crop. After this estimate of nitrogen need is obtained, the nitrogen supplies from the soil, added organic materials, and from irrigation water can be subtracted from it to obtain an estimate for fertilizer nitrogen needs (Meisinger, 1984). In the case of legumes or legume-grass pastures or hay crops, the nitrogen supplied by symbiotic fixation should also be considered before nitrogen fertilizer needs are estimated. In the case of most legume crops, this formula indicates that no nitrogen fertilizer is needed.

The application of this integration concept requires diagnostic techniques to assess the available mineral nitrogen in the soil at the beginning of the cropping season and an estimate of the mineralization of nitrogen during the growing season. It requires a determination of the nitrogen concentrations in irrigation waters and the amount of water to be added. It also requires an estimate of the nitrogen to become available from manures and sludges. These diagnostic techniques are largely crop system specific and best developed, tested, and applied to specific crop rotations or cropping sequences in local areas or at least on a regional basis.

Fertilizer Practices

After fertilizer nitrogen needs are established, proper practices can ensure that the fertilizer nitrogen is efficiently used by the crop. These practices include selection of the fertilizer, timing of the application relative to crop needs, and method of application. Because these practices differ with the crop, the soil type, the climate, and other local factors, only the general concepts involved can be mentioned here.

The nitrogen source must be selected to minimize the potential volatilization of ammonia. Surface application of ammonia or ammonium sulfate should be avoided particularly on alkaline soils. Injection of fertilizers into the soil is considered a safe practice to avoid losses of ammonia in all situations (Randall, 1984). Special problems are present in no-till systems (Wells, 1984).

Proper timing of applications to meet the needs of the crop throughout its growth cycle can increase the effectiveness of the fertilizer and also reduce the potential for losses by denitrification and by leaching to ground water. Proper timing will avoid large applications followed by unusually rainy periods that

Annual crops, such as small grains, corn, cotton, and many vegetables, follow the growth curve illustrated in Figure E–3. Some available nitrogen is required during the seedling stage, but most of the demand comes during the grand period of growth. Thus, a starter fertilizer application at the time of planting followed by an application at the beginning of the grand period of growth or two or more applications during the grand period represent optimum timing. Broadbent (1984) presented data from various researchers showing that the uptake of nitrogen with time by annual crops was essentially the same as the growth curve of Figure E–3.

Placement of nitrogen fertilizer is critical if there is potential for volatilization of ammonia. It can also have a significant effect on nitrogen use efficiency. Substantial losses by volatilization have been recorded with surface applications of anhydrous ammonia, ammonium sulfate, and urea. Thus, these materials need to be incorporated into the soil (Randall, 1984).

With special methods of application such as application with irrigation water and spray application to foliage of the crop, one must consider timing of application and the source of the nitrogen. Also, special methods of application and proper selection of the nitrogen source must be used in no-till cropping systems to ensure no volatilization losses, high use efficiency, and maintenance of a surface organic mulch for erosion control.

Nitrification Inhibitors

Nitrification inhibitors are organic compounds that suppress or inhibit the activity of nitrosomonas bacteria that convert ammonium to nitrite. This blockage maintains a greater fraction of the applied nitrogen in the ammonium form and, since this form is a cation that reacts with the cation-exchange properties of soil clays and organic matter, it is not subject to leaching. Also, because there is no conversion to nitrate, denitrification losses are minimized. Both leaching and denitrification losses are prevented or reduced and, since the ammonium form is available to plants, the use of an effective inhibitor would increase nitrogen use by the crop.

Hoeft (1984) concluded that nitrification inhibitors should be considered as a nitrogen management tool and that the benefit to be obtained depends on the soil type, time and rate of application, and the weather conditions, i.e., temperature and moisture conditions, between time of application and use by the crop.

An effective inhibitor can greatly extend the time between fertilizer application and the planting of the crop so that fall applications to provide available nitrogen following spring planted crops can be effective in cold climates having wet springs. However, there is no consistent economic return from their use. Results of field trials with various crops on the soil types and weather conditions of local areas must be used to develop recommendations for the use of these compounds.

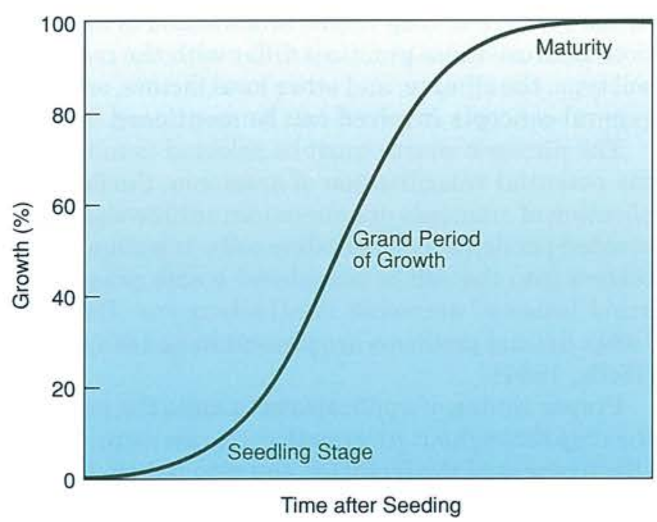


Figure E–3. Relationship between growth and time for an annual crop.

Water-Nitrogen Relationships

While a crop is growing and using available nitrogen, several processes are competing for the available nitrogen in the soil. These processes are (1) volatilization of ammonia, (2) microbial immobilization, (3) denitrification, and (4) leaching of nitrate. Assuming that a system is well managed, the main losses of nitrogen from the soil-plant system will be denitrification and leaching.

The amount of nitrate that leaches from a soil depends on the amount of water that moves through the soil and the amount of nitrate in the soil when water drains through and out of the soil profile. Thus, the drainage volume and the leachable nitrate are the primary factors, but these are related to many other factors (Figure E–4). Soil, climate, and economics determine to a large extent the selection of the crop to be grown. When the crop cultivar has been selected, management of the crop, irrigation, and nitrogen fertilizer must ensure that the crop has a competitive advantage over competing processes.

A number of studies reported by Pratt (1984) have shown that the nitrate leached from the root zone, in both freely-drained fields and in fields requiring tile drains, is related to nitrogen input and to the

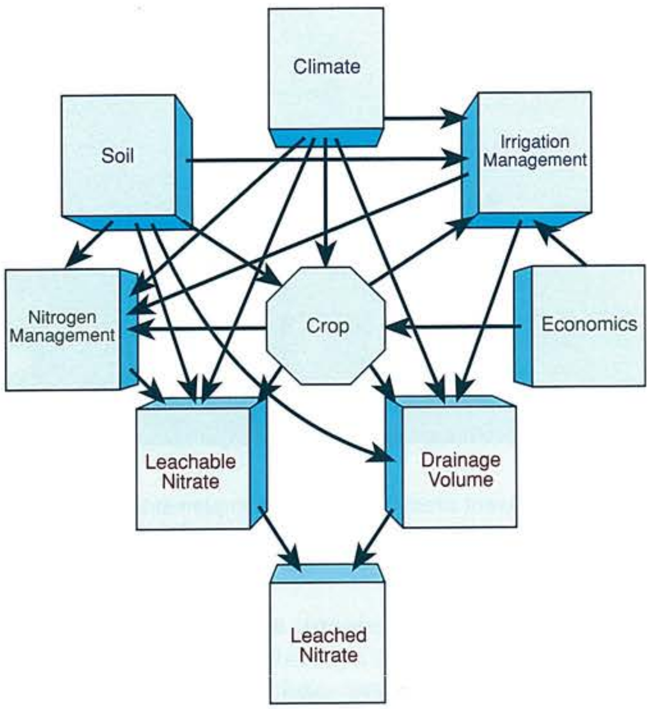


Figure E–4. Relationships among various factors that control drainage volume and leachable nitrate (NO_3^-) in irrigated agriculture. The arrows indicate dominate effects.

drainage volume for any given cropping system.

Legume Rotations

Crop rotations or sequence of crops involving deep-rooted legumes can have a large effect on the leaching of nitrate. Legumes can use available soil nitrogen as well as the nitrogen fixed from the air by the rhizobium bacteria living in nodules of the root system. In fact, the legumes use soil nitrogen in preference to symbiotically fixed nitrogen and rely on the microbiotically fixed source when the soil nitrogen is exhausted. Thus, the deep-rooted legumes serve as scavengers for nitrate in the soil profile. Letey et al. (1977) reported very low leaching losses of nitrate in the drains from fields in which alfalfa was the crop, but that the leaching increased substantially when the alfalfa crop was plowed under and an annual cotton, grain, or vegetable crop was grown. Mathers et al. (1975) reported that alfalfa was effective in removing nitrate to depths of 5.9 and 11.8 ft (1.8 and 3.6 m), respectively, in the first and second years of the crop, whereas annual crops were not effective. The available data suggest that the leaching of nitrate to ground water could be reduced by increasing the fractional time that the land is in deep-rooted legume crops. This recommendation, however, can only be implemented if such a system is economically productive for the climate and soil. The relationships in Figure E–4 must be considered. No cropping sequence will survive unless the crops are productive and there is a market for the products that gives a suitable return for the farmers.

Phosphorus

Transport of phosphorus into waters is of concern primarily when erosion moves soil materials into lakes, streams, and oceanic coastal areas and estuaries. Except for very small areas of sands and organic soils that are almost completely devoid of clays, oxides, and carbonates that retain (adsorb) phosphates, the phosphorus added in organic materials or commercial fertilizers is retained in the soil. However, these small areas may have a high level of agricultural activities and be in sensitive ecological settings. An example is the concern over phosphorus enrichment of Lake Okeechobee in Florida from agricultural runoff. At usual recommended rates of application for agronomic purposes on the vast majority of soils, only minute amounts of phosphorus move with percolating water.

The increased plant cover that results from the application of fertilizers containing phosphorus can reduce soil erosion from cultivated areas. Also, the proper use of fertilizers can reduce the total area needed for crop production having more land for grass, forests, parks, and uncropped watersheds. However, the environmental side effects of increased phosphorus use must also be considered. Increased phosphorus availability in surface soils can increase the phosphorus in surface runoff. This increased transport of phosphorus to the aquatic environment can cause deterioration of water quality from accelerated eutrophication (increased biologic production) resulting in problems in water use for fisheries, recreation industries, and drinking because of increased algal and weed growth. Because of problems in the limiting of other growth factors, phosphorus is the element of prime importance in reducing accelerated eutrophication.

Phosphorus is transported from cropland by surface runoff in soluble and particulate forms. The soluble form is immediately available to aquatic organisms, but the particulate form must be desorbed or undergo dissolution. The soluble phosphorus comes from eroded soil. A productive soil adequately supplied with available phosphorus to meet the needs of crop plants will have about 200 µg of soluble phoscrop plants will have about 200 µg of soluble phosphorus per liter of soil solution. If this solution were to move into a lake, it would need to be diluted by more than 20 times to reduce the phosphorus concentration to less than the critical concentration of 10 µg/l to ensure no adverse biological growth in the lake. Techniques to control transport of bioavailable phosphorus in agricultural runoff are very important (Chapter 3) because of the low levels of phosphorus that can stimulate algal growth.

Phosphorus adsorbed on surfaces of soil particles that are transported by erosion can desorb as the soluble phosphorus is diluted and thus contribute to the accelerated eutrophication problem. Although small amounts of soluble phosphorus are transported in surface runoff of clean water containing no soil particles, the control of soil erosion is effective in reducing the phosphorus transport. If no soil materials are transported, the phosphorus stays where it can be used by crops, and fertilized croplands, do not contribute to accelerated eutrophication of surface waters.

Erosion is a common geological process. It is the process that is responsible for the leveling of mountains and the formation during geologic time of plateaus, plains, valleys, river flats, and deltas. Normal erosion is a slow process that amounts to fractions of a ton of soil per acre per year. When the transportation by water greatly exceeds this amount by an order of magnitude or more, it is called accelerated erosion and is of concern because of loss of soil productivity and because of water quality in streams, lakes, and oceans.

The mechanisms of erosion by water are the detachment of soil particles and the movement of these particles over the land by running water. Detachment is produced by the impact of raindrops and by the abrasive action of running water. Thus, control measures consist of reducing the impact of raindrops through ground cover by a crop or by an organic mulch, reducing the velocity of the runoff water and increasing the stability of the soil aggregates.

The factors involved in estimating accelerated soil erosion are (1) rainfall and runoff, (2) soil erodibility, (3) slope length, (4) slope steepness, (5) ground cover and crop management, and (6) erosion control practices. Factors such as rainfall intensity, distribution throughout the year, and total amount and the topography of the land are not controllable for any given location, but other factors are amenable to modification by the farmer. Soil erodibility, slope length, ground cover, and control practices can be manipulated to reduce soil erosion. Incorporating organic matter into the surface soil can maintain or improve the soil stability and reduce detachment of soil particles. Slope length can be reduced by terracing the land. Ground cover can be improved by changing the cropping sequence to include more grasses and legumes and by low-tillage or no-tillage practices to keep an organic mulch on the land surface. Control practices consisting of terraces and strip cropping can be used to decelerate the runoff processes.

Best management practices are being implemented to protect agricultural land and water quality. Photograph courtesy of Ron Nichols, Soil Conservation Service, U.S. Department of Agriculture.

Best management practices to reduce soil erosion are highly dependent on local conditions. Climatic conditions, soil types, and topographic situations within the United States demand that soil erosion control measure be established on a local basis. Economic factors and climate influence the type of cropping sequences that are viable for any region, also require that effective control measures be determined for each region or location.

Appendix F Major Programs/Activities to Protect Water Quality from Agricultural Contaminants

Numerous efforts are underway to protect ground and surface water from agricultural contaminants. Among these are programs and legislation at all levels of government. This appendix will outline some of the numerous federal, state, regional, and local government efforts underway.

Federal Water Quality Legislation

The Clean Water Act

The Federal Water Pollution Control Act Amendments of 1972 (PL 92-500) with subsequent changes in 1977, 1982, and 1987 have been the framework for water pollution control in the United States. A national celebration is planned to commemorate the 20th anniversary of that legislation (now referred to as The Clean Water Act) throughout 1992, "The Year of Clean Water."

In a series of enactments between 1948 and 1965, Congress moved cautiously towards establishing a national strategy for water pollution control. The early strategy involved support for studies and encouragement of interstate cooperation. The 1965 Act provided for the creation of water quality standards for interstate streams.

By 1972, Congress was ready to establish a comprehensive national program for water pollution control. It chose to pursue the goal of clean water primarily through technological controls on all discharges of pollutants from discrete sources such as pipes. However, under Section 208, a planning process was created by which states were to identify various nonpoint pollution problems and then were to devise means to control these problems to the extent feasible.

In 1977, Congress recognized "Best Management Practices," as the standard for controlling nonpoint pollution sources. In 1987, Section 319 was added to the Clean Water Act. This Section requires states to submit an assessment report to the EPA that

1. Identifies state waters not meeting water quality standards because of nonpoint source pollution.
2. Identifies the general and specific nonpoint sources causing problems.
3. Describes processes for identifying Best Management Practices that can address the identified problems.
4. Identifies programs for controlling nonpoint source pollution.

Then states are to develop a management plan for these nonpoint sources.

Clean water continues to be an important national priority. There is increasing public support for developing regulations to address agricultural nonpoint sources just as has been done for point sources as the next step necessary to achieve water quality goals.

The Coastal Zone Management Act

The original Coastal Zone Management Act legislation was passed in 1972, amended in 1980, and reauthorized in 1990. The lead agencies for implementation of the latest Coastal Zone Management Act are the Environmental Protection Agency and the National Oceanic and Atmospheric Administration (NOAA).

One of the important parts of this legislation is Section 6217, which requires each state with a federally approved Coastal Zone Management Program to develop a "coastal nonpoint pollution control protection program" to implement coastal land use management measures for controlling nonpoint source pollution. This provision reinforces existing requirements for effective land use control and affirms that state programs under the Coastal Zone Management Act and Section 319 of the Clean Water Act should be more effectively organized and coordinated in developing and implementing coastal land use management measures that will control nonpoint pollution of coastal waters. The states are to be provided maximum flexibility in establishing the state and local institutional arrangements to accomplish this task. However, state programs under this section must be developed and implemented in conformity with national guidelines.

The USDA and other federal and state agencies have been invited to participate in writing portions of the guidance for implementation of Section 6217. The EPA published "proposed" management measure guidelines in May 1991 and was to publish "final" guidance by May 1992. As of December 1992, the Office of Management and Budget (OMB) was reviewing the final guidance and publication is expected early in 1993. Each of the 35 states and territories with coastal waters will be required to develop a coastal nonpoint pollution control program in conformity with this guidance. These state programs must be approved jointly by the EPA and NOAA.

The EPA intends that the coastal nonpoint pollution control programs to be developed by states apply only to sources that are not regulated as point sources and that the management systems be implemented in critical or priority areas. However, for overlaps between nonpoint and point sources EPA has chosen to err on the side of inclusiveness in the proposed guidance and to include management measures to address those sources. Indications are that some of the approaches taken in the coastal Zone Management Act Reauthorization for nonpoint source control may be used in the reauthorization of the Clean Water Act.

Federal Programs

There are numerous federal programs that address some aspect of protecting water resources from agricultural contaminants. Since it is beyond the scope of this report to discuss all of these programs, this appendix will limit itself to outlining some of the major programs of the three federal agencies with extensive agriculture-related water quality responsibilities–the U.S. Environmental Protection Agency (EPA), the U.S. Department of Agriculture (USDA), and the U.S. Geological Survey (USGS).

U.S. Environmental Protection Agency

The EPA, as the primary federal agency responsible for protecting the nation's water resources from pollution, implements several major regulatory and nonregulatory programs that address agricultural sources. These programs are outlined below.

Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) Programs

Under FIFRA, the EPA collects environmental fate data that are used, among other things, to indicate whether a pesticide poses a threat to ground water or surface water. Based on such data, the agency may require label directions and precautions to inform the applicator that the pesticide must be used in a manner that prevents water supply contamination.

Also under FIFRA, the EPA may restrict, cancel, or temporarily suspend all or some pesticide uses that pose unreasonable risks to human health or the environment through contamination of water supplies. The agency has proposed a Ground Water Restricted-Use Rule that describes criteria (i.e., a pesticide's tendency to leach, detections of the pesticide in ground water) for identifying pesticides for possible restricted-use classification because of ground water concern. After the final rule is promulgated, the EPA will initiate reviews to classify up to 30 pesticides as restricted-use chemicals because of their tendencies to leach to ground water. Restrictions may include limiting use to certified applicators.

As already mentioned in the discussion of pesticide management plans (under "State-Implemented EPA Programs"), a key component of the EPA's Pesticides and Ground Water Strategy is the development and implementation of SMPs under the authority of FIFRA.

Drinking Water Programs

Under the Safe Drinking Water Act's Public Water Systems Program (PWSP), the EPA originally regulated six pesticides and nitrate/nitrite in addition to other chemicals and biological contaminants. Under EPA drinking water regulations announced in January 1991, states must adopt new drinking water standards for 33 potential drinking water contaminants including 18 pesticides. The regulations became effective in July 1992. The EPA also has developed Health Advisories for about 70 pesticides that are actual or potential ground water contaminants. In addition, the EPA promulgated new standards of 1 ppm for nitrite and 10 ppm for nitrate/nitrite as N combined, and they also became effective in July 1992.

The EPA has established requirements for regular monitoring, public notification of contamination, and specific timeframes for removal of the contamination. Incidently, monitoring for the 18 pesticides covered under the new drinking water standards was phased in after July 1992. Such an approach gives states the opportunity to institute watershed and ground water protection measures to keep pesticides out of drinking water.

The EPA also conducts and enforces drinking water programs in states that do not have primacy or are not enforcing their programs adequately. See the part of this appendix on state-implemented EPA programs for a discussion of the state role in EPA's PWS program. Also, see Appendix D for discussion of EPA's National Survey of Pesticides in Drinking Water Wells, which provides a statistically accurate one-time assessment (e.g., "snapshot") of the frequency and concentration of pesticides, pesticide degradates, and nitrate in the nation's drinking water wells.

National Pollution Discharge Elimination System (NPDES)

Under the authority of the Clean Water Act, NPDES deals with runoff from manure and wastewater accumulated in the feeding areas of livestock operations of a certain category. The categories of livestock operations requiring NPDES permits include operations with (1) more than 1,000 animal units that discharge indirectly to U.S. waters, (2) more than 300 animal units that discharge directly through a conveyance to U.S. waters, and (3) fewer than 1,000 animal units that cause significant water quality impairment.

The NPDES requires participating farmers to build animal waste and wastewater storage structures. The number of operations that should be issued NPDES permits may be as large as 10,000, but as of 1989, permits had been issued to only 759 operations (U.S. Environmental Protection Agency, 1990a). In any event, great care must be taken to ensure that the animal waste storage structures required under the NPDES permits do not encourage ground water contamination.

Superfund

Superfund, or the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), is an important tool in the EPA's response to the nation's hazardous waste problem. Superfund was created in 1980. Since then, approximately 31,000 hazardous waste sites have been identified. Some of these sites are in rural areas, and sometimes involve contamination of ground and surface water due to improper disposal of septic tank wastes and sludge containing hazardous substances such as PCBs, benzene, and toluene, or wastes from pesticide and fertilizer manufacturers.

Estimated costs for cleaning up some of these Superfund sites are very high, running in the millions of dollars. Proposed remedial actions include excavating contaminated soil and disposing of it in a landfill that meets federal safety standards, treatment of the contaminated water, providing alternative water supplies, and long-term, frequent monitoring of the site.

Toxic Substances Control Act (TSCA)

The EPA has broad authority under Section 6 of the TSCA to control manufacturing, processing, distribution in commerce, use or disposal of a chemical substance or mixture if it "presents or will present an unreasonable risk of injury to health or the environment."

Under Section 4 of the TSCA, the EPA may require industry to test a chemical substance or mixture if the agency finds it "may present an unreasonable risk of injury to health or the environment." If the EPA decides that it lacks important information about toxicity or exposure, it can specify what information the industry must provide, through additional testing if necessary.

The EPA has been working with chemical companies, trade associations, and other interested constituencies to encourage safer handling of chemical substances and mixtures throughout their life cycle. The agency could consider both regulatory and nonregulatory means to promote greater care of such substances in their manufacture, use, and disposal and is emphasizing pollution prevention means to reduce exposures and risks of toxic chemicals.

Research Programs

The EPA is involved in several research programs or initiatives that support its efforts to protect water quality from agricultural contaminants, primarily agricultural chemicals. Some of these programs are outlined below.

Transport and Transformation of Contaminants

In order to predict the movement of contaminants in the subsurface, and thereby predict potential human and ecological exposure, the EPA's Office of Research and Development (ORD) maintains a research program in transport and transformation of contaminants. Predicting contaminant behavior in the subsurface requires understanding the mechanisms and rates of transport, and chemical, physical, and biological transformations of contaminants. The ORD studies transformation and transport processes for various contaminants in different settings, and develops models for predicting time of travel and exposure concentrations.

Some of this research is done to predict the leaching behavior of agricultural chemicals. This includes advances in integrating process level information into predictive tools such as the pesticide soils leaching model PRZM, the pesticide ground water leaching model RUSTIC, and the development and application of the comprehensive environmental management model CEEPES to agricultural chemicals. Also, a new effort is underway to support the Office of Water in determining the sorptive properties of soils as a factor in protecting wellheads from contaminant migration.

Finally, the EPA has joined with the USDA and USGS in the Midwest Initiative. Under a coordinated plan of study drafted in 1989, the three agencies selected the midcontinent soybean and corn-growing region to determine the regional factors affecting the distribution of atrazine, an herbicide of long-standing use, through the environment. An interagency workgroup has discussed several proposed research areas for the EPA, called collectively the Midwest Agrichemical Subsurface/Surface Transport and Effects Research (MASTER). Possible research components for MASTER include studying subsurface degradation processes of agricultural chemicals, behavior of nitrate in surface and ground waters, macropore flow in the subsurface, testing and improving EPA-developed pesticide leaching models, real time monitoring methods, interaction of pesticide runoff with wetlands and potential recharge to ground water, and ecosystem effects.

Information Systems for Preventing Ground Water Contamination from Pesticides

Tools exist to locate pesticide problem areas, and develop strategies for regulation and use of pesticides on a local level. These tools include models that have been developed to predict the leaching of pesticides to ground water, data that have been collected on soil properties and other relevant environmental factors, and geographic information systems for displaying and analyzing spatial information. These types of tools, however, have not been systematically integrated into a workstation framework of state and local risk management.

The EPA's ORD has initiated research to provide such a framework for states upon which they can develop locally meaningful pesticide management plans. The work will also include field evaluation of monitoring and modeling schemes. The project will be coordinated with related research on the effects of agricultural chemicals on water quality at USGS and USDA, in order to ensure integration of information and dissemination of results.

Methods for Assessing Aquifer Sensitivity to Pesticides

To assist states in assessing ground water vulnerability to pesticides as part of their efforts to develop pesticide management plans, the EPA's Office of Ground Water and Drinking Water is preparing a technical assistance document on methods for assessing the natural sensitivity of aquifers to pesticide contamination.

U.S. Department of Agriculture (USDA)

USDA has recently added water quality protection to its traditional responsibilities. USDA's new Policy for Water Quality Protection (1990a) states that the Department will "foster agricultural and forestry practices that protect and enhance the nation's ground and surface water resources" through research, education, technical assistance and technology transfer, cost-share assistance, and farm management guidance. The USDA has several agencies that have been assigned responsibilities for water quality protection, including the Soil Conservation Service (SCS), the Extension Service (ES), the Agricultural Research Service (ARS), Cooperative State Research Service (CSRS), and the Economic Research Service (ERS). Some of its major water quality protection activities and programs are outlined below.

President's Water Quality Initiative (WQI)

The President's Water Quality Initiative called for a vigorous effort to protect ground and surface water from contamination by agricultural chemicals, commercial fertilizers, and wastes, especially pesticides and nutrients. The WQI is using the combined expertise of USDA, USGS, EPA, and the National Oceanic and Atmospheric Administration (NOAA), to promote the use of environmentally and economically sound farm production practices, and to develop improved chemical and biological pest controls.

In meeting its responsibilities under the WQI, USDA has established the USDA Water Quality Program to (1) determine the precise nature of the relationship between agricultural activities and ground water quality; and (2) develop and induce the adoption of agrichemical management and agricultural production strategies that protect ground and surface water quality. The program will be implemented over a five-year period that began in 1990.

For Fiscal Year (FY) 1991, the USDA implemented the WQI through three types of projects that focus on education and technical assistance activities. These were

1. Demonstration projects to accelerate the transfer and adoption of innovative technologies to protect water quality, with emphasis on agrichemicals and ground water.
2. The Nonpoint Source Hydrologic Unit Area Initi-

atives to provide technical, financial, and educational assistance to implement programs within hydrologic units or aquifer recharge areas to address nonpoint source water quality problems identified in state nonpoint source assessment or management reports or in state ground water protection strategies.

3. The ACP (Agricultural Conservation Program) Water Quality Special Projects to accelerate cost-sharing in hydrologic units and aquifer recharge areas to address nonpoint source water quality problems that adversely affect surface or ground water, as identified by local or state agencies.

Farm Bill Programs

These programs are discussed in more detail in Appendix G. The 1985 farm bill (i.e., Food Security Act) has four major provisions that may contribute toward meeting water quality protection objectives. The Conservation Reserve Program (CRP) authorized the USDA to make annual rental payments to landowners who voluntarily retire highly erodible cropland and other environmentally critical lands from production for 10 years. It also pays up to 50% of the costs of establishing a soil-conserving cover on the retired lands. The Conservation Compliance provision requires that farmers who produce crops on highly erodible lands finish implementing approved conservation plans by January 1, 1995, or become ineligible for USDA program benefits. Sodbuster provisions require farmers who convert highly erodible land to crop production do so under an approved conservation plan, or lose USDA program benefits. Swampbuster provisions prevent farmers who convert wetlands to crop production from collecting farm program benefits, unless USDA determines that conversion would minimally affect wetland hydrology or biology (U.S. Congress, 1990).

The 1990 Farm Bill, or the Food, Agriculture, Conservation, and Trade Act of 1990 (FACT) adds four programs that may contribute to protecting water quality. The CRP directs an enrollment of six million new acres of environmentally sensitive lands. The Wetlands Reserve Program will enroll up to one million acres of wetlands into 30-year or permanent easements out of the total CRP acreage. The SCS, under the Water Quality Incentives Program (WQIP), will provide incentive payments (up to $3,500 per year, per farm for up to five years) to farmers for adoption of BMPs to protect water quality. The Environmental Easement Program provides for permanent easements on lands that pose a significant environmental threat. The exact eligibility for these lands has not yet been determined, nor is any funding available.

The bill establishes Water Quality Incentive projects. For FY 1992, the WQIPs were funded at $6.75 million and were implemented in existing Water Quality Initiative Project areas. For FY 1993, $10 million was provided for funding WQIPs. Eligible areas for WQIP implementation have expanded to include areas identified in state nonpoint source management plans (Section 319), areas with shallow karst topography, and others.

The purpose of WQIP proposals are to achieve a source reduction of nonpoint source agricultural pollutants in an environmentally and economically sound manner. The USDA will provide agricultural producers with the necessary financial, educational, and technical assistance required to make changes in mangement systems to

- Restore or enhance the empaired water resources where agricultural nonpoint source pollution has a detrimental effect, and
- Prevent future impairments.

Some of the potential regulations for controlling agricultural nonpoint sources that were not included in the FACT are being proposed for the Clean Water Act Reauthorization.

Technical and Financial Assistance Programs

A federal Office of Technology Assessment (OTA) report provides brief summaries of USDA technical and financial assistance programs related to water quality (U.S. Congress, 1990). Summaries for many of these programs are excerpted from the OTA report and presented below.

Agricultural Conservation Program (ACP)

The ACP, initiated in 1936, provides financial assistance to farmers for implementing approved soil and water conservation and pollution abatement practices. Cost-share payments may not exceed $3,500 per year for 1-year agreements, or an average of $3,500 for multi-year agreements. Except for Water Quality Special Projects, conservation priorities are set by states and counties based on local soil and water quality problems.

Conservation Technical Assistance (CTA)

The CTA program, also initiated in 1936, provides SCS technical assistance through Conservation Districts to farmers for planning and implementing soil and water conservation and water quality improvement practices.

Rural Clean Water Program

This program, initiated in 1980 and ending in 1995, is an experimental program implemented in 21 selected projects. It provides cost-sharing and technical assistance to farmers voluntarily implementing BMPs to improve water quality. Cost-sharing is limited to $50,000 per farm.

Extension Service (ES)

The ES provides information and recommendations on soil and water quality practices to landowners and operators, in cooperation with SCS and Conservation Districts.

Farmers Home Administration (FHA)

FHA provides loans to farmers and associations of farmers for soil and water conservation, pollution abatement, and building or improving water systems that serve several farms. It may require 50-year conservation easements to help farmers reduce loan payments.

Resource Conservation and Development Program

This program, initiated in 1962, assists multicounty areas to enhance conservation, water quality, wildlife habitat and recreation, and rural development.

Great Plains Conservation Program (GPCP)

The GPCP, initiated in 1957, provides technical and financial assistance in Great Plains States to farmers and ranchers who implement total conservation treatment of their entire operation. Cost-sharing assistance is limited to $35,000 per contract.

Small Watershed Program

This program, initiated in 1954, provides technical and financial assistance to local organizations for flood prevention, watershed protection, and water management.

Water Bank Program

This program, initiated in 1970, provides annual payments for preserving wetlands in important migratory waterfowl nesting, breeding, or feeding areas.

National Agriculture Library (NAL)

The NAL collects and distributes information on all aspects of U.S. agriculture, and has received special funding to develop a new information program on agriculture and water quality.

Technical and financial assistance programs have helped farmers implement practices that protect ground and surface water. Photograph courtesy of Tim McCabe, Soil Conservation Service, U.S. Department of Agriculture.

Research Programs

The USDA's Agricultural Research Service (ARS), Cooperative State Research Service (CSRS), and Economic Research Service (ERS) conduct research on agriculture and water quality. The ARS conducts research on new and alternative crops and agricultural technology to reduce the impacts of agricultural production on soil and water. The CSRS coordinates soil conservation and water quality research conducted by State Agricultural Experiment Stations and land-grant universities. The CSRS allocates funds appropriated for special and competitive grants for water quality research. The ERS estimates the economic impacts of existing and alternative policies, programs, and technology for preserving and improving soil and water quality (Schmidt, 1990). Along with the National Agricultural Statistics Service, the ERS collects data on agrichemical use, agricultural practices, and costs and returns.

One of the objectives of the USDA's Research Plan for Water Quality is to improve existing and develop new cost-effective agricultural systems to address water quality problems. This system's research objective will focus initially (fiscal year 1990) on the USDA's Midwest Initiative (MI) on Water Quality, planned cooperatively with the USGS' Mid-Continent Herbicide Initiative (MCHI). The MI/MCHI will establish Management Systems Evaluation Areas (MSEA) to evaluate midwest crop production systems designed to be economically feasible and minimize contamination by nutrients and pesticides. The MSEA will be selected within predominantly corn and soybean production areas (U.S. Geological Survey, 1990).

U.S. Geological Survey (USGS)

The USGS is a scientific and technical agency without regulatory responsibilities. It monitors ground and surface water, conducts water quality assessments, investigates trends in water quality as well as the relation of land uses to water quality. It also provides assistance to agencies at all levels of government and the public in support of water quality protection efforts. This assistance includes basic and applied research, mapping and transfer of mapping technology, information collection and management, and outreach.

In carrying out these responsibilities, USGS supports efforts to protect water quality from agricultural sources by helping to determine the location and extent of contamination, and then mapping and disseminating its findings. Discussion of specific programs follows.

National Water Quality Assessment (NAWQA) Program

The NAWQA is a major national assessment designed to describe the status and trends of U.S. waters and identify the factors that affect water quality. In the pilot phase of this program, the USGS is investigating the extent and location of ground water pollution by agrichemicals in several regions of the United States. Beginning in fiscal year 1991, with a budget of $18 million, the USGS began to study the first 20 hydrologic units. The first cycle of investigations of all 60 units is scheduled for completion in 2002. Costs will increase to about $60 million annually. The national and regional synthesis of this information emphasizes nutrients beginning in fiscal year 1992.

Mid-Continent Herbicide Initiative

In cooperation with USDA's Midwest Initiative (MI), USGS is conducting the Mid-Continent Herbicide Initiative (MCHI), a five- to ten-year research program on the impact of the agricultural herbicide atrazine on ground and surface water. More information on MI/MCHI is provided above in the discussion of USDA research programs.

Federal-State Cooperative Program

This program is a partnership for water-resources investigations involving 50–50 cost sharing between the USGS and more than 1,000 cooperating state or local government agencies. The USGS performs most of the work on behalf of the cooperators. A variety of hydrologic data collection activities and water-resources investigations are included in the program. Examples include providing support for mapping aquifers, for monitoring pesticide contamination, and assisting in developing wellhead protection programs.

State Water Resources Research Institutes Program

Under this program, the USGS provides grants to 54 state and U.S. territory Water Research Institutes at land-grant colleges or universities. The grants support research, information dissemination, and training for students in water resources fields. Examples of past funded projects include Removal of Nonpoint Source Pollution by Buffer Areas, Ground-Water Contamination from Agricultural Pesticides, and Evaluation of Evaporation Ponds for Saline Drainage Waters.

Information Dissemination Programs

Through its annual National Water Summary report, the USGS provides water quantity and quality information on a state-by-state and national basis to aid policymakers in the analysis and development of water policies, legislation, and management actions. The report also includes case studies of nonpoint source contamination and summaries of studies on managing and coordinating federal and state water protection efforts.

The USGS' Hydrologic Data Collection Program provides information on the quantity, quality, location, and use of the nation's surface and ground water. Data collection stations are maintained at selected locations to provide records on streamflow, reservoir and lake storage, ground water levels, and the quality of surface and ground water. These data form an information base that supports national and regional water-resource assessments. The USGS also maintains a computerized National Water Storage and Retrieval System (WATSTORE) as well as a computer-based National Water Data Exchange (NAWDEX).

State/Regional/Local Programs

These programs consist of two general types: (1) efforts initiated wholly at the state, regional, or local levels; and (2) efforts initiated at the federal level with responsibility for implementation delegated to qualifying states.

State/Regional/Local Government-Initiated Efforts

Regulations

Pesticide Control Regulations

Many states have developed their own regulations to control the use of pesticides. The regulations of three states, Maine, Iowa, and California, are summarized below. Only those regulations related to water quality protection are described.

Maine's Pesticide Control Regulations. The Maine Pesticide Control Act of 1975 is the primary legislative authority to regulate the labeling, distribution, storage, transportation, use, and disposal of pesticides. Under this Act the state may cancel the registration of a pesticide, restrict its use, or suspend its use if it poses an imminent hazard. Part of the state's pesticide registration fee is deposited into a fund to cover the costs of Maine's IPM program. The state is adding training in ground water protection to its restricted-use pesticide certification program.

The state's Pesticide Control Board has the authority to designate critical areas where pesticide use would present an unreasonable threat to water quality. Maine also has pesticide drift regulations that require identification of sensitive areas (which include public and private drinking water sources) before spraying can commence.

Iowa's Restrictions on Atrazine. Prior to the EPA classification of atrazine as a restricted-use pesticide in 1991, Iowa classified atrazine as a restricted-use pesticide (RUP), limiting its use to certified applicators. The state also reduced the statewide maximum allowable application from 4 to 3 lb/acre/yr, and restricted maximum application to 1.5 lb/acre/yr in contaminated or vulnerable ground water areas in all or parts of 23 counties. In addition, Iowa now prohibits the application of atrazine within 50 ft of a sinkhole, well, cistern, lake, or surface water impoundment, and mixing, loading, and repackaging within 100 ft of the same.

California's Pesticide Control Measures. Public concerns over exposure to toxic chemicals in the environment led to the passage of two pieces of legislation in California that impact ground water: Proposition 65 and The Pesticide Contamination Prevention Act (Assembly Bill 2021 or AB2021). Proposition 65 requires that the governor publish (and update yearly) a list of chemicals known to the state to cause cancer or reproductive toxicity. One of the provisions prohibits a person in a business with 10 or more employees from knowingly discharging a chemical on the list into water or onto or into land where the chemical may pass into a source or potential source of drinking water. Thus, any pesticides that are known to cause cancer or reproductive toxicity will be subject to the provisions of Proposition 65. Civil and criminal sanctions may be imposed on persons who violate the prohibition.

The Pesticide Contamination Prevention Act (AB2021) was passed specifically to try to prevent or minimize future ground water contamination by pesticides. This act states that a review of the use of a pesticide will be conducted if it is detected in the ground water or found in the soil at or below the deepest of the following three depths: 8 ft below the soil surface, below the root zone of the crop, or below the soil microbial zone. The only pesticides that are subject to restricted use under AB2021 are those that the California Department of Pesticide Regulation is satisfied are in ground water as a result of normal, legal, agricultural use. Civil and criminal sanctions may be imposed on persons who violate the prohibition.

The act also provides for the establishment of Pesticide Management Zones (PMZs). The PMZs are 1 mi^2 areas around a well where a pesticide has been detected in ground water due to agricultural use, and thus the ground water is considered to be vulnerable to contamination. In 1987, as its first decision under the Act, California banned the use of atrazine over 114 square miles in 16 counties. To date, seven pesticides have been placed on the list of detected leachers and some or all of their uses have been restricted in their respective PMZs (Table F–1).

In addition to the pesticides that have been detected in ground water, AB2021 requires that the California Department of Food and Agriculture (CDFA) establish a list of suspected leachers. These are pesticides that, by virtue of their chemical and/or physical properties, may contaminate ground water even when used according to label directions. To identify suspected leachers, the CDFA has established Specific Numerical Values (Table F–2). In order for a pesticide to be placed on the list, it must meet criteria for both mobility and persistence. In other words, it must meet either the water solubility or the soil adsorption coefficient and the hydrolysis half-life, aerobic soil metabolism half-life, or anaerobic soil metabolism half-life criteria. To date, 49 pesticides have been placed on the suspected leachers list (Table F–3).

An important fact to note about AB2021 is that it applies to all pesticides, regardless of whether or not they have any effects on health. In addition, the act does not prescribe a minimum concentration where action must be taken. This means that any pesticide found in ground water, or in the soil at the depth de-

Table F-1. Restricted uses of detected leachers in California

Pesticide	Restriction
Atrazine	All outdoor agricultural, outdoor industrial, and outdoor institutional uses prohibited in atrazine PMZs[a]
Bromacil (Hyvar)	All noncrop uses prohibited in the respective PMZs
Diuron (Karmex)	All noncrop uses prohibited in the respective PMZs
Simazine (Princep)	All noncrop uses prohibited in the respective PMZs
Prometon (Pramitol)	All agricultural, outdoor industrial, and outdoor institutional uses prohibited in prometon PMZs
Aldicarb	Fall applications will be prohibited and maximum rates allowed per acre reduced by 50%
Bentazon	Shall not be applied in Del Norte or Humboldt counties, shall not be used in the production of rice, shall not be applied prior to April 1 or after July 31 of each year, and irrigation water applied to sites shall only be applied by sprinkler through December 31

[a]PMZ = Pesticide management zone.

scribed above, at any concentration, will be subject to restricted use under AB2021 provided its presence is determined to be due to agricultural use. The severity of the use restrictions imposed by the CDFA will, however, take into consideration health effects, site conditions, and the availability of alternative materials.

Regulating Other Agricultural Contaminants

Pesticides are not the only agricultural contaminant regulated at the state and local levels. Agricultural sources of nutrients such as feedlots and manure storage facilities, land application of manure, agricultural drainage wells, septic systems, and, in at least one state (Nebraska), fertilizer use in sensitive ground water areas are also regulated. In addition, application of sludge is regulated as a potential source of heavy metals, nitrate, PCBs, and pathogens, while a few counties regulate agricultural sources of sediment. Examples of some of these state and local regulations are provided below.

State Animal Waste Controls in the Midwest. In addition to the National Pollution Discharge Elimination System (NPDES) permits for large feedlots required under the Clean Water Act, most midwestern states have manure storage facility and feedlot standards to protect surface and ground waters. Indiana, for example, requires feedlots that exceed a certain size to submit waste management plans to the Indiana Department of Environmental Management for review and approval. Illinois, Iowa, Minnesota, Ohio, and Wisconsin have similar siting, design, and waste management controls (DiNova and Jaffe, 1984).

Restrictions on Fertilizer Use in Nebraska. The Central Platte Natural Resource District (a multi-county regional political subdivision) has established restrictions on nitrogen fertilizer use in a designated Ground-water Management Area. The program has three phases depending on the concentration of nitrate found in wells. All phases include requirements

Table F-2. Specific numerical values

Property	Value
Water solubility	> 3 ppm
Soil adsorption coefficient	> 1,900 $cm^3\ g^{-1}$
Hydrolysis half-life	> 14 days
Aerobic soil metabolism half-life	> 610 days
Anaerobic soil metabolism half-life	> 9 days

Feedlots and concentrated animal production units have developed management systems to protect water quality. Photograph courtesy of F. J. Humenik, North Carolina State University, Raleigh.

Table F-3. Suspected leachers as defined by the California Department of Pesticide Regulation (August 1991)

Acephate (Orthene)	Disulfoton (Disyston, Dithiosystox, Frumin AL, Solvirex)	Molinate (Ordram)
Alachlor (Lasso)	EPTC (Eptam, Eradicane)	Napropamide (Devrinol)
Aldicarb (Temik)	Ethofumesate (Nortran, Tramat)	Naptalam, sodium salt (Alanap)
Azinphos methyl (Guthion, Gusthion M)	Ethoprop (Mocap, Prophos)	Norflurazon (Evital, Solicam, Zorial)
Bensulide (Betasan, Prefar)	Fenamiphos (Nemacur)	Oryzalin (Dirimal, Ryzelan, Surflan)
Butylate (Sutan)	Fluometuron (Cotoran)	Oxadiazon (Ronstar)
Chloropicrin	Fonofos (Dyfonate)	Oxydemeton methyl (Metasystox R)
Chlorsulfuron (Glean, Telar)	Fosetyl-Al (Aliette, Mikal)	Parathion (Bladan, Folidol, Fosferno, Niran)
Cyanizine (Bladex, Fortrol)	Hexazinone (Velpar)	Pebulate (Tillam)
Cycloate (Ro-Neet)	Linuron (Lorox, Afalon)	Prometryn (Caparol, Gesagard)
2,4-D, dimethylamine salt	Metalaxyl (Apron, Fubol, Ridomil)	Propyzamide (Kerb)
Diazinon	Metaldehyde	Sulfometuron (Oust)
Dichlobenil (Casoron, Decabane, Prefix D)	Methiocarb (Mesurol, Draza)	Tebuthiuron (Perflan, Spike)
Dicloron (Allisan, Botran)	Methomyl (Lannate, Nudrin)	Triallate (Avadex BE, Fargo)
Diethalyl ethyl (Antor)	Methyl isothiocyanate (Trapex)	Vernolate (Vernam)
Dimethoate (Cygon, Fostion MM, Perfekthion, Rogor, Roxion)	Metolachlor (Dual)	
Diquat dibromide (Aquicide, Cleansweep, Pathclear, Reglone, Weedol)	Metribuzin (Lexone, Sencor)	

for education, collection of soil and water samples, and efficient fertilizer use. The most severe phase totally bans applications.

Erosion Control Ordinance of Fillmore County, Minnesota. Fillmore County is located in a karst area (limestone region with sink holes, caveins, and underground streams) of Minnesota and has identified agricultural runoff and erosion as sources of both surface and ground water contamination. The County's Erosion Control Ordinance considers any occupiers of farmland to be in compliance if (1) they are using soil conservation practices approved by the County Soil and Water Conservation District Board; (2) they do not have rills, gullies, or sediment deposits in their fields; and (3) their farming methods do not create sediment problems on adjoining properties.

Violators of the ordinance have 30 days to work with the County Soil and Water Conservation District Board to develop a plan that must include (1) specific practices to stop the sedimentation and (2) a timetable for completing the practices. The county zoning administrator indicates that the ordinance has resulted in an improvement in local conservation practices (DiNova and Jaffe, 1984).

Regulation of Private Wells

The EPA has no authority to regulate water quality in private drinking water wells. Generally, states do not regulate water quality in private wells either, with a few exceptions. Washington requires any well with two or more connections to meet bacteria and inorganic chemical standards. Idaho requires any well with at least 10 connections to meet all primary drinking water standards. New Jersey mandates that all new private wells must be tested for nitrate and bacteria, and must meet all the primary drinking water standards, except for pesticides. States variously recommend that private wells be located a minimum of 50 to 100 ft upgradient from a potential source of contamination such as a septic system.

Many states try to influence the water quality of private wells by regulating the construction of new wells or the upgrade of existing wells. States require placement of new wells outside a zone of contamination and at some minimum depth (usually 10 to 30 ft). Construction with certain casing material and grouting mix specifications are also common requirements. Some states regulate well drillers through licensing or registration procedures. Many officials believe enforcement of these regulations is spotty or just beginning.

Local health officials are often more involved than their state counterparts with private well owners, but many programs are limited by lack of funds. States do not often mandate specific programs for private well testing to the counties.

Resource-Based Protection

Critical Area Designation

A common approach to protecting a valuable water resource from contamination is to designate an area around the resource as an area that should receive a high level of protection. Such "critical" areas often include areas adjoining important waterways, aquifer recharge areas, areas of influence around public wells (e.g., wellhead protection areas), watersheds of reservoirs used for drinking water, and watersheds in karst environments. If the critical areas are large, they may be divided into zones that vary in the stringency of protection required.

Critical area protection varies in the comprehensiveness of protection afforded the resource. Wellhead protection areas, for example, are to be managed to protect public wells from all sources of contamination, including agricultural sources. Other critical area protection programs, such as Nebraska's Groundwater Management Area program in the Central Platte Natural Resource District, focus on protecting the resource from a priority pollutant or pollutants (e.g., nitrate). An example of a critical area protection programs is outlined below.

Maryland Critical Area Program. The goal of the program is to improve the water quality of the Chesapeake Bay. Critical areas are defined as lands within 1,000 ft of mean high tide in the Maryland portion of the Bay, land that is likely to play a critical role in the Bay's ecological health. The Maryland Conservation Reserve Program (MCRP) will pay farmers $20/acre annually to enroll cropland within critical areas and along stream borders in the federal CRP. Under the CRP, land is kept out of production and under vegetative cover or trees for ten years or longer, thereby reducing soil erosion and the use of agricultural chemicals. Vegetative cover along streams further protects water quality by trapping sediment and agricultural chemicals in runoff.

Cooperative Regional Programs

In addition to critical area designation programs, there are numerous multicounty and multistate regional cooperative programs that form in order to protect important water resources, such as aquifers that serve as primary sources of drinking water, river basins, major lakes, and estuaries. Some of these resource-based programs, such as EPA's Chesapeake Bay Program, attempt to provide protection from many sources of contamination. These overarching programs may contain components or programs that focus on agricultural contaminants. Examples of these latter types of programs are outlined below.

Chesapeake Bay Nutrient Reduction Program. The Chesapeake Bay Agreement of 1987 calls for a 40% reduction of nitrogen and phosphorus entering the mainstem of the bay by the year 2000. Three mid-Atlantic states—Maryland, Pennsylvania, and Virginia—have initiated nutrient management programs to assist in reducing agricultural nonpoint source pollution to the bay.

Maryland's Nutrient Management Program

Maryland's Cooperative Extension Service (CES) assists farmers in the development of nutrient management plans. Since 1989, farmers have prepared 748 plans, covering 49,966 acres of cropland. Nutrient management plans include manure tests for nutrient content, soil tests, documentation of crop histories and manure management, documentation for a statewide nutrient management data base, and personalized service from consultants. First priority for preparing the plans will be given to farmers applying for state cost-share funds for all animal waste storage BMPs.

Pennsylvania's Nutrient Management Program

Pennsylvania's cost share program is funded in part by the Chesapeake Bay Program. Cost sharing for installation of BMPs is available within priority watersheds in 28 counties responsible for the most nutrient inputs to the bay. Farmers within these watersheds must adopt nutrient management plans to receive cost share payments. Such plans include manure tests, soil tests, summaries of recommended nutrient applications, and provisions for verifying nutrient and pollution reductions. Conservation districts provide technical assistance in developing the plans.

A major outreach and education effort in Pennsylvania is the mobile nutrient laboratory, which provides rapid analyses of soils, water, and manure.

Virginia's Nutrient and Pest Management Program

The recently enacted Chesapeake Bay Preservation Act requires farmers in the 13 coastal plain counties to develop pest management as well as nutrient management plans. Nutrient management plans are implemented through three mechanisms:

1. Since 1989, the state has required farmers statewide to develop nutrient management plans to re-

ceive state cost share funds for animal waste BMPs.
2. A new law allows tax credits for purchases of manure and pesticide spreaders for farmers with nutrient management plans approved by their local conservation district.
3. The Chesapeake Bay Preservation Act requires farmers in the coastal plain counties to develop water quality management plans that include integrated pest management plans, soil conservation plans, and nutrient management plans.

Economic Incentives

State Cost-Share Programs

Twenty-six states have established cost-share programs to address agricultural and other sources of contaminants (U.S. Congress, 1990). Most of these programs support the implementation of BMPs or the construction of animal waste storage facilities. Examples of cost-share programs in Kansas and North Carolina are discussed below.

Kansas Cost-Share Efforts under the State Water Plan. In 1989, Kansas established the State Water Plan Fund to serve as a dedicated source of funding for State water planning activities. The fund's appropriations for FY 1991 for the State Conservation Commission included over $3 million for land treatment cost-share activities. These appropriations cover both practices to treat highly erodible land and practices to protect water quality by limiting run-off of agricultural contaminants.

Cost-Sharing to Reduce Nutrients in North Carolina. The voluntary North Carolina Agricultural Cost-Share Program was established to protect surface water from contamination by sediment, nutrients, animal wastes, and pesticides. The program pays farmers 75% of the average cost to implement appropriate BMPs.

Nutrient reduction is a recent emphasis of cost-share efforts in the Tar-Pamlico River Basin in eastern North Carolina. Under a new concept called nutrient trading, expanding waste water treatment plants in the basin have the option to meet state-proposed nutrient load reduction goals by funding the implementation of BMPs for agricultural nonpoint source runoff.

Grants/Loans

Some states provide incentives for water quality protection activities in the form of grants or loans. Kansas, for example, appropriated almost $1.8 million for FY 1991 from its State Water Plan Fund for grants to local governments (e.g., county health departments) for the development of Local Environmental Protection Plans. Local Nonpoint Source (NPS) Management Plans initiated by conservation districts form a part of these Local Environmental Protection Plans.

States and localities also contribute a specified share of federal matching grant money. For instance, under the U.S. Geological Survey's Water Research Institute Program, grants were allocated in FY 1990 for research on priority water problems on the basis of one federal share to not less than two nonfederal shares.

Five states provide no- or low-interest loans as incentives for installing BMPs (U.S. Congress, 1990). Jefferson County, Washington is the first program in the nation to use state revolving loan funds to finance nonpoint source management. This program is described in more detail below.

The Jefferson County Water Quality Improvement Fund. Washington State will provide $200,000 to Jefferson County for it to loan to county residents in a low-interest loan program—the Jefferson County Water Quality Improvement Fund—which will finance major nonpoint source pollution control projects. The funds for the state loan are from the state's Revolving Loan Fund, capitalized by an EPA grant and a 20% state matching grant.

Malfunctioning septic systems and some agricultural practices have been identified as nonpoint sources of pollution in Puget Sound. The Water Quality Improvement Fund is designed to encourage and assist county residents to repair or upgrade existing septic systems under the direction of the County Health Department and to design and implement farm plans and agricultural BMPs under the direction of the County Conservation District. Low-income households will receive highest priority for the greatest amount of financial assistance and will receive lower interest rates.

Taxes and Fees

States levy taxes and fees as disincentives for activities that may result in contamination of water resources (see fee proposal for Puget Sound below), to help ensure that those who cause contamination bear the costs of controlling it, and to finance programs to protect water quality. In addition, a few states allow income or property tax credits or deductions for the installation of BMPs.

All states have pesticide registration fees: Iowa, California, Wisconsin, Minnesota, and North Carolina have fees over $100 per product, which many chemical companies consider restrictively high (Batie and Diebel, 1989). Iowa levies fees on both pesticide dealers (an annual dealer's license, based on annual Iowa sales) and pesticide manufacturers (a registration fee of $250 to $3,000 per product, also based on annual Iowa sales), as well as a tax of $0.75/t on nitrogen fertilizer. The revenue from these charges passes into the Iowa Groundwater Protection Fund and is used to finance programs to protect ground water from agricultural chemicals.

A relatively comprehensive fee system has been proposed by Washington's State Department of Ecology to finance nonpoint source pollution control efforts in the 12-county Puget Sound region.

Nonpoint Source Pollution Control Fee Proposal for Puget Sound. At the direction of the Puget Sound Water Quality Authority, Washington's State Department of Ecology has developed a nonpoint source pollution control fee proposal, which is under review by a broad range of interest groups, local governments, and state agencies in the Puget Sound region. The main sources of nonpoint source pollution in the region are failing individual septic tanks and runoff from agriculture, forest and urban lands. Basic to the fee proposal is a fee structure based on charges to those land uses that cause or have the potential to cause nonpoint source pollution.

This fee structure would consist of a basic fee plus two avoidable "disincentive" fees. The basic fee would amount to an annual assessment of at least $12 per parcel on lands draining into the sound, with designated open space and lands in communities with stormwater fees exempt. Localities could set higher fees if necessary to control nonpoint source pollution. The disincentive fee that addresses nonpoint source agricultural sources would amount to an annual $75 avoidable surcharge assessed to landowners with onsite septic tanks or livestock. The surcharge could be avoided when septic tanks are inspected and in good working order, or when BMPs to control animal wastes and runoff from farms are installed and working.

Over 90% of the revenue from these fees (excluding the septic tank/livestock avoidable surcharge) would go to local governments for nonpoint source pollution control and fee administration costs. The remainder would go to state agencies for oversight, nonpoint source pollution control administration, and technical assistance in repairing or maintaining septic systems and in implementing BMPs/farm management plans. The Department of Ecology also suggests that a local fund could be established to provide low interest loans for fixing septic tanks or installing farm management plans.

Education and Technical Assistance

States, localities, and regional entities have developed programs to provide education and technical assistance for water quality protection from sediment, pesticides, animal wastes, fertilizers, septic system effluent, and toxic materials in sewage sludge. For instance, in addition to USDA agencies in the states, state agriculture agencies conduct training and demonstration projects on sediment control practices, animal waste management, soil testing for nutrients, and the proper handling and use of pesticides to avoid water contamination.

These education and technical assistance programs vary in degree of comprehensiveness and in their intended audience (e.g., farmers, general public, etc.). They may also vary in the level of expertise and resources they command. Cooperative Extension Service personnel, for example, may in some cases lack the knowledge and experience to adequately address the technical and behavioral aspects of ground water protection (Batie and Diebel, 1989).

Iowa has one of the more comprehensive education and technical assistance programs for water quality protection; efforts underway in Iowa related to protection from agricultural contaminants are described below, followed by brief examples of efforts underway in other states.

State Assistance Programs

Iowa's Education and Technical Assistance Efforts. Iowa's 1987 Groundwater Protection Act establishes a program for research, education, and demonstration projects to address ground water problems caused by agricultural contaminants and other sources. The law requires the state Department of Agriculture and Land Stewardship (DALS) to promote the adoption of BMPs for soil conservation and for reducing ground water contamination from agricultural chemicals. As part of this effort, DALS is helping finance the Private Pesticide Applicator Training Program conducted by the Iowa State University Cooperative Extension Service, which is educating over 60,000 farmers on environmental and personal safety when applying fertilizers and restricted-use pesticides. The program also covers nonchemical methods to control weed and insect pests. Farmers must pass an examination on the material to become certified to apply restricted-use chemicals for a period of three years.

The new law also established the Leopold Center for Sustainable Agriculture at Iowa State University. The center's charge is to conduct research and educational programs on sustainable agriculture.

Projects include improving educational programs to inform the agricultural community and the general public about sustainable agriculture.

In 1986, DALS initiated the Integrated Farm Management Program. The program demonstrates and promotes the adoption of integrated farm management practices that are designed, among other things, to reduce the nonpoint source pollution of surface and ground waters and to bolster the efficiency and profitability of agricultural production. More than 300 demonstrations have been conducted statewide; these show how economic and environmental gains are possible by reducing the excessive use of chemicals and nutrients. In addition, the demonstrations promote the integration of nutrient and chemical management with conservation tillage, land treatment, and cropping sequences. Finally, the University of Northern Iowa is participating in the program by developing teacher education materials that teachers will use to describe the energy and environmental effects of farm management practices to students.

Wisconsin and Minnesota: Farmstead Assessment Worksheets. Wisconsin and Minnesota have prepared pilot versions of worksheets to assist farmers in assessing the effectiveness of farmstead practices in protecting drinking water. The Farmstead Assessment System is a series of 12 worksheets, each covering distinct farmstead structures and/or practices. When completed, the worksheets can provide farmers with an accurate, firsthand assessment of how their own practices might be affecting their drinking water. Practices/structures for assessment include well condition, pesticide storage and handling, fertilizer storage and handling, household wastewater treatment, and livestock waste storage. Accompanying each worksheet is a separate publication with recommendations on modifying practices to minimize farmstead pollution risks, and suggested sources for additional information.

Maine's BMP Manual. Maine collaborated with the USDA's Soil Conservation Service, the Extension Service, and farmers to produce a BMP manual that educates farmers on the characteristics of agricultural chemicals and offers practical tips on protecting water from contamination.

Virginia's Outreach Efforts. The Virginia Water Resources Center has developed instructional materials, exhibits, and publications on water quality protection. Center staff make presentations to community groups on water quality issues and conduct training sessions for extension and state agency personnel. The Center also has prepared a workshop and handbook to educate local officials on ground water protection issues. In addition, the Virginia Extension Service conducts water quality related outreach activities for the agricultural community as well as local citizens, local government staff, and students. Moreover, county health departments and utilities in Virginia conduct limited educational activities.

Research and Data Management

Basic and applied research that supports water quality protection efforts is being carried out by the states, mostly at state Agricultural Experiment Stations, land-grant universities, and Water Resources Research Institutes. Much of this research is at least partially funded by federal grants. States are also developing data management systems to store and maintain the information they need to implement their water quality protection efforts. Examples of the types of research conducted by state facilities and the data management systems under development are outlined below.

Connecticut. The College of Natural Resources of the University of Connecticut conducts research on pesticide usage issues and on IPM, while the state Agricultural Experiment Stations study the fate of pesticides in the environment.

Connecticut has an extensive data base on the hydrogeological conditions of the state. In cooperation with USGS, the state Department of Environmental Protection has collected information on all watersheds, the properties and distribution of aquifers, depth to water tables, water quality in vulnerable or sensitive areas, locations of public water supply wells, locations of pollution sources, etc.

New York. The state Water Resources Research Institute at Cornell University conducts research on the water quality effects of agricultural chemicals. Researchers are evaluating the relationship between pesticide application practices, crop production, and ground water quality for potato crops. In addition, the Institute is interested in studying the effects of soil organisms on chemical transport, microbial degradation of chemicals, transport of microbes within the soil, and the toxic effects of ground water contaminants on ecological systems.

Faculty at Cornell, Oregon State, Michigan State, and the University of California at Davis have been developing a toxicological information system call EXTOXNET. The system will be used by Extension agents to answer questions about current or potential contamination by agricultural contaminants.

Pennsylvania. The Pennsylvania State University is involved in several research efforts. First, Penn

State and three other U.S. universities are studying the environmental fate of pesticides under minimum and conventional tillage, respectively. Second, Penn State is involved in a cooperative venture to reduce nonpoint source pollution in the Chesapeake Bay watershed. Third, the university participates in a well-funded program to develop expert systems for pest management on all crops. The system will use artificial intelligence computers to provide decision-making assistance. Fourth, the university is interested in developing insect and disease forecasting and monitoring techniques; these include counting insects and the use of weather-based data to predict the occurrence of plant pathogens in food crops. Finally, Penn State is studying pest resistance in apples in a cooperative project with the University of Vermont and four or five other states; the study focuses on how to increase resistance in host or crop plants through selective plant breeding.

Florida. Florida has studied the hydrogeological, soil, and environmental conditions of ten major agricultural counties. It is also developing an overlay mapping system and is working to refine its computer modeling and graphics capabilities.

State-Implemented EPA Programs

The U.S. Environmental Protection Agency has the authority under some federal statutes to delegate the development and/or implementation of several major water protection programs to states that have demonstrated the capacity to carry them out. Under such an approach, the EPA generally provides technical and financial support to states to assist them in building their capacity to develop and implement the programs, and exercises its authority to review, approve, and oversee them.

Five state-implemented EPA programs with major relevance to protection of water resources from agricultural contaminants are discussed below.

Comprehensive State Ground Water Protection Programs (CSGWPPs)

Since 1984, the EPA has encouraged states to develop state ground water protection strategies and programs, and supported the states' efforts with technical and financial assistance. The EPA's policy to give states and local governments the key role in ground water protection is based on the following factors:

1. Contamination of ground water comes primarily from many diverse smaller sources, as well as a relatively few large sources; therefore, focusing protection on the few large sources alone may not yield adequate protection.
2. Ground water vulnerability to contamination differs from site to site due to site-specific hydrogeologic conditions, climatic variables, characteristics of the potential pollutant, land use practices, etc.
3. Measures to minimize or prevent contamination may require land-use controls, historically a prerogative of local government.
4. Site-specific problems require site-specific solutions.

In 1989, the EPA established a high-level Ground-Water Task Force to "develop a strategy for the direction EPA will take in ground-water protection." The task force has recently released a final report that sets forth a new strategy to ensure comprehensive protection of the nation's ground water resources (U.S. Environmental Protection Agency, 1991b). A key component of this strategy is to actively involve state officials in developing and implementing Comprehensive State Ground Water Protection Programs (CSGWPPs). The EPA will promote the development of CSGWPPs through technical and financial (e.g., grants) assistance to the states, and will review CSGWPPs for adequacy. To the extent authorized by federal statute and consistent with federal program objectives, the EPA will defer to state policies, priorities, and standards once the agency recognizes that a state has developed a comprehensive protection program.

The CSGWPPs will provide the overarching framework within which state and local activities to protect ground water from all sources of contamination will occur. Efforts under programs to protect ground water from agricultural contaminants (state pesticide control programs, state pesticide management plans, wellhead protection programs, drinking water programs, nonpoint source programs, etc.) should be integrated within this framework; EPA will work with other federal agencies to ensure that their ground water protection efforts are consistent with activities implemented under CSGWPPs.

States have prepared ground water protection strategies and many have begun to implement at least parts of these strategies. A few states have relatively advanced (but not "comprehensive") programs in place. Most of these programs use a mix of regulatory and nonregulatory measures to protect ground water.

Minnesota's ground water protection program, for example, is a preventive approach that calls for first, encouraging, then requiring if necessary, BMPs that keep contaminants out of ground water. Areas that are susceptible to contamination will be identified and targeted for BMPs through education and demonstration projects. Some of these sensitive areas may be taken out of agricultural production through Minnesota's Conservation Reserve Program. The Minnesota Ground Water Protection Act of 1989 also directs the state Department of Health to develop health-based risk limits for contaminants for which there is no federal drinking water standard.

Wellhead Protection Programs

The Safe Drinking Water Act requires each state to prepare a Wellhead Protection (WHP) Program to protect public water supply wells from all potential sources of contamination. As of September 30, 1992, the EPA has approved 25 state (and U.S. territorial) WHP programs. In many instances, regional agencies and local governments have taken the initiative in pursuing WHP.

The WHP programs must include a number of specific elements. These include delineation of WHP areas, source identification, description of management approaches, contingency plans, and site controls for new wells. Many states that have not submitted WHP programs have incorporated similar efforts, such as recharge area protection and special area protection for public water supplies, in their ground water protection programs.

Some states are developing measures to deal with agricultural sources within WHP areas. In Florida, for instance, regulation of pesticide use within WHP areas is awaiting modeling of pesticide behavior in soil and water for selected restricted-use pesticides. Also, efforts to develop policy or regulations for governing nutrient discharges to ground water have begun.

Local governments are applying land use controls to agricultural sources in WHP areas. Spokane County, Washington and the Panhandle Health District in Idaho, for example, are conducting a joint program to incorporate local land use controls in the protection of WHP areas that overlay the Spokane-Rathdrum Aquifer. The program is addressing nonpoint source pollution, nitrate from septic systems, and industrial contaminants.

Finally, the 1990 farm bill includes a provision to make cropland within WHP areas eligible for inclusion in a new Water Quality Initiative program. Congress also expanded the Conservation Reserve Program (CRP) to explicitly enroll lands where onsite or offsite threats to water quality exist. Since CRP land is taken out of production, the use of nutrients and pesticides is greatly reduced or eliminated, thus reducing the potential for contamination of water.

Wellhead protection programs are necessary to protect water supply wells. Photograph courtesy of F. J. Humenik, North Carolina State University, Raleigh.

Nonpoint Source Programs

Under Section 319 of the 1987 Water Quality Act, states are required to prepare assessments of their nonpoint source impaired and threatened water bodies and develop nonpoint source management programs to address their highest priority problems. The EPA has approved the nonpoint source assessments and management programs for all the 57 eligible states, territories, and the District of Columbia. For FY 1991, Congress appropriated $51 million to help states implement the nonpoint source program, an increase of about one-third over grants made available for FY 1990. In 1990, the EPA also selected 12 states for bonus awards of $250,000 ("outstanding") or $105,000 ("honorable mention") for long-term commitment to quality nonpoint source programs.

State nonpoint source assessment reports show agriculture to be the greatest nonpoint source pollution problem in the United States. Similarly, the largest share of state nonpoint source management reports focus on agriculture. More specifically, livestock and nutrient management have been identified as the major nonpoint source problems of the immediate and short-term future. Louisiana's nonpoint source management program, identified as "commendable" by the EPA, integrates agricultural nonpoint source considerations in its water quality programs that include

1. Exploring the establishment of water quality standards to help control the overuse of agricultural chemicals.
2. Implementing a cooperative ground water effort

between the USDA and the state Department of Environmental Quality in Tangibahoa Parish to prevent ground water contamination from manure–lined waste lagoons.
3. Revamping long-term water quality trend monitoring stations both to sense changes in water quality due to nonpoint source/best management plan installation in target areas, and to cover new state-suspected nonpoint source problem areas based on evaluation, but for which monitoring data are lacking.
4. Initiating an agricultural demonstration project for new rice farming BMPs in the Mermentau Basin.

In addition, the USDA has indicated it will work closely with state and local agencies to solve identified and prioritized water quality problems on all projects under the President's 1990 Water Quality Initiative. These projects will involve considerable financial and technical assistance to farmers for implementation of technologies and BMPs to protect both ground and surface waters from agricultural contaminants. As such, it is important that state water quality staff assist, USDA in the selection and implementation of water quality projects that address priority ground and surface water quality problems as these are identified in state nonpoint source assessment reports.

Drinking Water Program Implementation

The Safe Drinking Water Act (SDWA) directs the EPA to establish minimum national drinking water standards (i.e., maximum contaminant levels, or MCLs), which set legally enforceable limits on the amounts of potentially harmful substances, including some pesticides and nitrate, in drinking water. The standards apply to public water supplies only, although they are also being used as guidelines to assess contamination of private wells. The EPA also sets nonregulatory health advisory levels (HALs) on contaminants for which it has not yet established MCLs. Further description of the federal role in drinking water protection appears later in the appendix in the discussion of federal programs.

Congress intended the states to have the primary responsibility for protecting public drinking water supplies. Since 1974, the EPA has granted primary enforcement authority to 54 states and territories. Indian tribes are also eligible for primacy. To be granted primacy, a state or Indian tribe must adopt drinking water standards at least as stringent as the national ones. Each state or tribe must also be able to carry out adequate monitoring and enforcement; otherwise, the EPA will conduct and enforce the program. Maximum penalties for violations are $25,000 per day.

How a state chooses to implement its drinking water program may have a great impact on agricultural sources. States that have adopted more stringent standards than the EPA's, for example, may apply stricter source controls at lower levels of contamination. In addition, states can be expected to apply progressively more stringent controls as contamination approaches the MCL or HAL. Early action to apply preventive, nonregulatory measures at low levels of contamination may preclude the need for stringent regulation later. In any event, BMPs and other measures taken under nonpoint source programs, pesticide management plans, nutrient management plans, wellhead protection programs, and CSGWPPs will help the states in meeting their responsibilities under their drinking water programs.

Pesticide Management Plans

Because of site-specific differences in ground water sensitivity and pesticide usage, the EPA believes that states are in the best position to tailor preventive pesticide management measures to local conditions. Under the Agency's Pesticides and Ground Water Strategy released in 1991, states would implement State Pesticide Management Plans (SMPs). In line with this approach, the EPA is providing funding and guidance to states to assist them in developing generic SMPs, and in building their capacity to evaluate such factors as ground water vulnerability, monitoring data, and how and where the pesticide of concern may be used.

Further, the pesticides and ground water strategy explains that under the authority of the Federal Insecticide, Fungicide and Rodenticide Act, the EPA may require states to develop chemical-specific SMPs for a particular pesticide of concern as a condition of continued use of that pesticide. The SMPs may vary widely from state to state, depending on a state's ground water sensitivity assessments, the level of pesticide usage in the state, and the state's ground water protection philosophy. The SMPs must include several components, including discussion of roles and responsibilities, legal authorities, prevention actions, available resources, monitoring, enforcement, and response to detections.

The EPA will encourage the development of SMPs that support the further development of, and which can be subsequently integrated with, Comprehensive State Ground-Water Protection Programs. States will also need to coordinate the development and implementation of their SMPs with other relevant programs, such as nonpoint source programs, wellhead protection programs, farm bill programs, the Water Quality Initiative projects, and others.

Underground Injection Control (UIC) Program

A provision of the Safe Drinking Water Act mandates the development of an EPA-approved underground injection control (UIC) program for each state, U.S. possession, or territory. The purpose of the program is to prevent contamination of underground sources of drinking water by injection wells, classified into five categories by the EPA. Class V wells include agricultural drainage wells, which may pose a high potential for ground water contamination.

Agricultural drainage wells may receive field drainage from precipitation and floodwaters, irrigation return flow, and animal yard, feedlot, or dairy runoff. Potential contaminants include suspended solids, pesticides, nutrients (nitrogen and phosphorous compounds), salts, organics, metals, and microbes including pathogens. Although there have been estimates (probably gross underestimates), the number of agricultural drainage wells that exist is unknown. States with the greatest number of wells identified include Idaho, Iowa, New York, Texas, and Indiana.

Some states have recommended guidelines for addressing ground water contamination by agricultural drainage wells. These include

1. Plugging abandoned wells in the immediate area of agricultural drainage wells (Iowa).
2. Requiring that fluids meet drinking water standards at the point of injection (Nebraska, Oregon).
3. Requiring irrigation tailwater recovery and pumpback (Oregon).
4. Reducing the volume of irrigation return flow (where appropriate) by applying only the quantity of water necessary (California).
5. Closing surface inlets in order to allow infiltration through soil to decrease the transport of bacteria, some pesticides, and sediment to the aquifer (Missouri).
6. Raising the inlets above the maximum ponding levels (Iowa).
7. Discouraging use and encouraging elimination of agricultural drainage wells by developing alternative drainage methods (Iowa).

Current EPA regulations authorize Class V wells to operate by rule if (1) their existence was reported to the states or the EPA within the specified time and (2) they do not contaminate an underground source of drinking water to the extent that it would violate an MCL or otherwise endanger public health. An EPA workgroup has been formed to develop more specific regulations and guidance for Class V wells.

The EPA also has the authority to regulate septic systems under the UIC program; however, septic systems that serve single-family homes and those that are used only for sanitary waste and have the capacity to serve fewer than 20 people a day are exempt from regulation.

Appendix G Environmental and Conservation Programs Affecting U.S. Farmers

Conservation Programs Linked to Program Benefits Eligibility

Conservation Compliance Plan (1985 Farm Bill)

- Applies to producers who plant commodity (annually tilled) crops on highly erodible land (HEL). To remain eligible for certain USDA program benefits, producers must have developed and be actively applying an approved conservation compliance plan for the highly erodible land. The plan must be fully implemented by January 1, 1995.
- Affects 40% of U.S. farmers, 135 million acres of highly erodible land, and involves 1.3 million plans. Less than 2% of highly erodible land is not covered by a Conservation Compliance Plan.
- Research has shown that conservation tillage on the average reduces soil loss by 81%, surface runoff by 31%, and soil sediment concentration by 66%.
- During the first year (1990), 39% of plans and 37% of acres were fully implemented.
- Failure to actively implement a compliance plan on schedule may result in penalties: (a) one-time graduated sanctions for an inadvertent violation, (b) complete sanctions.

Sodbuster Provision (1985 Farm Bill)

- Discourages the conversion of highly erodible land for agricultural production.
- When farmers apply for USDA farm programs they must certify that they have not broken out highly erodible land since December 23, 1985, in order to produce crops—unless they have done so under a locally approved conservation plan. To do so without the SCS approval could render them ineligible for many USDA program benefits. Graduated sanctions exist for inadvertent violations.

Swampbuster Provision (1985 Farm Bill)

- Discourages the conversion of wetland for agricultural purposes after December 23, 1985.
- For farmers to remain eligible for certain USDA farm programs they must not plant annually tilled crops on wetland converted after December 23, 1985.
- The 1990 farm bill modified Swampbuster such that after November 28, 1990, farmers who convert wetlands to make cropping possible may lose eligibility for USDA programs, even if no crop is planted. Several exemptions apply. Graduated sanctions exist for inadvertent violations.

Cost Sharing Programs

Agricultural Conservation Program

- Offers farmers cost-sharing money for environmental and conservation programs they would not undertake without financial help. The federal share of the cost depends on the public benefits resulting from the conservation or pollution abatement practice.
- Designed to help prevent soil erosion and water contamination, preserve and develop wildlife habitat, etc.

Environmental Conservation Acreage Reserve Program—ECARP (1990 Farm Bill)

- ECARP separates wetlands from highly erodible croplands eligible for the Conservation Reserve Program (CRP) of the 1985 farm bill, protecting them in the new Wetlands Reserve Program (WRP).
- Easements of 15 to 30 years are obtained for land placed in ECARP. Farmers can receive some continued benefits beyond CRP 10 years if land coming out is put under an approved Conservation Compliance Plan.

Conservation Reserve Program (1985, 1990 Farm Bills)

- Offered farmers help in retiring highly erodible land from cropping. Under 10-year contracts, ASCS makes annual rental payments of up to $50,000 to these farmers as long as the terms of the contract are met. The ASCS will share up to 50% of the cost of establishing permanent grasses, legumes, trees, windbreaks, or wildlife. The goal for CRP is 40 to 45 million acres removed from production for a decade or more (36 million to date).
- Extended by the 1990 farm bill. However, CRP qualifying acres now include cropland that contributes to water quality protection, such as grassed water ways, filter strips, windbreaks, shelterbelts, and other plantings on highly erodible land. CRP is part of ECARP.

Wetlands Reserve Program (1990 Farm Bill)

The Wetlands Reserve Program (WRP) is a voluntary program offering landowners a chance to receive payments for restoring and protecting wetlands on their property. Authorized by the Food, Agriculture, Conservation, and Trade Act of 1990 (FACT or 1990 Farm Bill), the WRP provides a unique opportunity for farmers to retire marginal cropland and reap the many benefits of having wetlands on their property.

WRP obtains conservation easements from participating landowners and provides cost share payments for wetland restoration. Through this program, the Department of Agriculture plans to restore and protect one million acres in the years 1991 to 1995. Similar to the Conservation Reserve Program (CRP), WRP pays farmers for safeguarding certain defined land—in this case, the restoring and protecting of wetlands. However, WRP requires longer term easements, rather than 10 year agreements as in CRP.

The Wetlands Reserve Program is part of ECARP.

Water Quality Incentive Program (1990 Farm Bill)

The Water Quality Incentive Program (WQIP) has not received the full funding authorized by Congress but had a small appropriation ($6.75 million) within the Agricultural Conservation Program (ACP) in the form of a "Management Practices Initiative." The goal of WQIP is to achieve source reduction of agricultural pollutants by implementing management practices in an environmentally and economically sound manner on 10 million acres of farmland by the end of 1995.

For FY 1992, WQIP can be implemented in the 74 existing Hydrologic Unit Areas, 16 Water Quality Demonstration Projects, and the 32 1991 Water Quality Special Projects. Producers must submit applica-

Environmental and conservation programs are helping farmers protect water quality. Photographs courtesy Soil Conservation Service, U.S. Department of Agriculture.

tions for enrollment into WQIP. The first sign-up period was from February 3 to February 21, 1992. A Water Quality Resource Management Plan is to be developed for the highest priority applications that cover the individual producer's entire tract or tracts which are located within the specified project area.

A Long-Term Agreement (LTA) will then be developed, generally for three years. The WQIP incentive payment limitation is $3,500 per person per year. Any WQIP payment will be limited by any other payments made under ACP during the same year because WQIP is a part of the ACP, and thus overall cost sharing may not exceed $3,500 per year per producer.

WQIP Incentive Payments will be for Integrated Crop Management (ICM) and other management (cultural) practices such as waste utilization, contour farming, conservation tillage, nutrient management, and similar components. Although they may be part of the Water Quality Resource Management Plan, structural practices such as terraces, waterways, animal waste storage facilities, irrigation systems, ponds, and other similar components will not be eligible for WQIP Incentive payments. However, they could be cost shared with regular ACP funds or other cost-share programs.

In FY 1993, $15 million was appropriated under the ACP and WQIP was expanded for nationwide implementation. A total of 106 projects in 42 states were approved using an interagency selection process. Due to the apparent competition of this program with more traditional ACP projects, the policies of appropriation will continue to dictate the future of the Water Quality Incentive Program.

Conservation Environmental Easement Program (CEEP) (1990 Farm Bill)

- Presently unfunded, will provide long-term protection of environmentally sensitive land or reduction in the degradation of water quality on farms through permanent easements. Payments can total up to $250,000.
- There is no acreage limit. Qualifying land includes cropland already in the conservation reserve, protected under the Water Bank Act or cropland containing environmentally sensitive areas such as riparian areas or critical habitat for wildlife (especially threatened or endangered). Some exclusions apply.
- The owners must develop and abide by a natural resource conservation management plan. Cost-sharing of up to 100% is available for installation of conservation measures.

Integrated Farm Management Program Option (1990 Farm Bill)

- Adds planting flexibility and encourages farmers to adopt resource conserving crop rotations to help prevent soil erosion and protect water quality. The goal is 5 million acres.
- Beginning in 1991, farmers who contracted to develop and carry out an approved farm management plan to promote the use of soil conserving crops and rotations on at least 20% of their crop base qualified for deficiency payments and it did not reduce crop acreage bases or farm program payment yields as a result. Acreage devoted to this program may also qualify for other programs.

Rural Clean Water Program

- Offers financial and technical assistance to farmers in 21 selected U.S. areas where protection Best Management Practices are needed that specifically target significant agricultural-related water pollution and water quality problems.

Water Bank Program

- Provides farmers annual payments in 10-year contracts to preserve and improve wetlands to conserve surface waters, reduce runoff and soil erosion, improve water quality, and provide habitat for wildlife and waterfowl.
- Primarily in the Central and Mississippi River flyways.

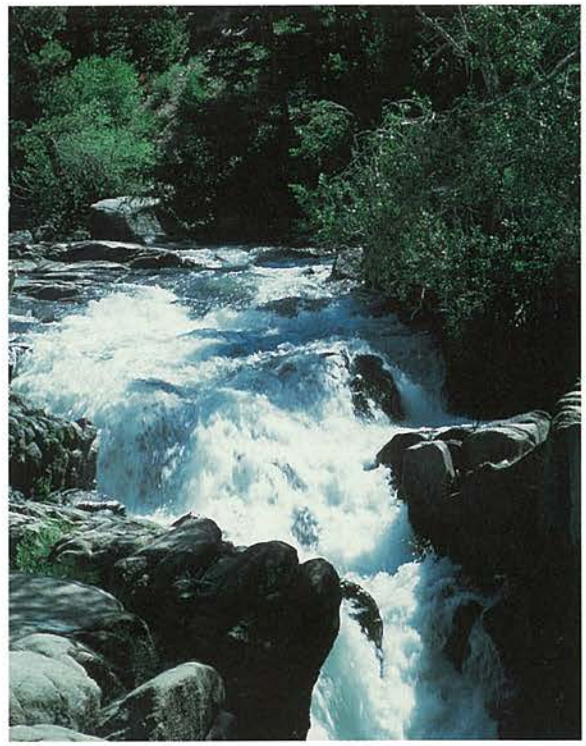
USDA Programs Affected by Noncompliance

- Price and income supports
- Crop insurance
- Farmers Home Administration loans
- Commodity Credit Corporation storage payments
- Other programs under which USDA makes commodity-related and disaster assistance payments.
- Farm storage facility loan and payments.
- Conservation Reserve Program.

Options for Farmers

- Develop and apply a conservation plan for their highly erodible fields, in cooperation with SCS and the local conservation district. The plan will help them reduce soil loss to levels that are technically and economically achievable. They will retain eligibility for USDA farm program benefits as they grow crops on highly erodible land.

- Plant permanent cover on land where annually tilled crops should not be grown because of excessive erosion. If they choose this option, they may voluntarily offer to enter the land into the Conservation Reserve and plant permanent grasses, legumes, trees, windbreaks, or wildlife cover. They still would have other USDA programs open to them.
- Produce crops on highly erodible land without using a locally approved conservation system, but they would lose eligibility for USDA program benefits.
- Produce crops on newly converted wetlands, but they would lose eligibility for USDA program benefits.



Photograph courtesy of Charlton Photos, Inc., Mequon, Wisconsin.

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