Chapter 1

Current Water Quality Conditions and Government Programs To Protect Water Quality

The quality of the Nation's water is an important environmental issue. While water quality laws passed since 1972 have resulted in some improvements, many water quality problems remain. The latest EPA Water Quality Inventory reports that, of the water resources assessed by the States, more than one-third of the river miles, lake acres, and estuary square miles are impaired to some degree. Nonpoint-source pollution has been identified as a major reason for these problems, with agriculture a major contributor. Agricultural pollutants include sediment, nutrients, pesticides, salinity, and pathogens. Comprehensive estimates of the damages from agricultural pollution are lacking, but soil erosion alone is estimated to cost water users $2 billion to $8 billion annually. Federal and State programs rely heavily on economic and educational tools to deal with water quality problems. Inadequate water quality monitoring hinders use of a full range of policy instruments to deal with nonpoint-source water pollution.

Water Quality in the United States

The Nation's surface-water quality has improved since 1972's Clean Water Act, primarily through reductions in pollution from industrial and municipal sources. No longer are there news stories of the Cuyohoga River catching fire, or Lake Erie being biologically dead. Indeed, we read stories about increasing recreational use of major rivers such as the Potomac, Delaware, and Hudson, even close to major urban areas. However, water quality problems remain, especially those associated with nonindustrial sources. We now read of microbe-related fish kills in nutrient-enriched waters, the presence of pesticides in drinking water, and the degradation by nutrients of important national resources such as the Gulf of Mexico, Chesapeake Bay, and the Everglades. In 1998, the White House called for a shift in national water quality policy to address more effectively the problems caused by nonpoint-source pollution (EPA, USDA, 1998).

Water pollution may be categorized by two types of sources. Point sources discharge effluent directly into water resources through an identifiable pipe, ditch, or other conveyance. Industrial and municipal discharges fall into this category. Nonpoint-source pollution (NPS) enters water diffusely in the runoff or leachate from rain or melting snow, and is often a function of land use. Agriculture is generally recognized as the largest contributor to NPS water pollution in the United States (EPA, 1998a). Animal waste and certain farm practices (soil tillage, use of chemicals, use of irrigation) are the major sources of pollutants such as sediment, nutrients, pesticides, salts, and pathogens.

The first part of this chapter presents what is known about the current condition of the Nation's water resources. The second section summarizes agriculture's contribution to specific water quality problems. The costs of water pollution are then presented, along with Federal and State programs to address water pollution. The chapter concludes with a discussion of how deficiencies in current water quality data affect water quality policies.

Surface Water

Since the passage of the Clean Water Act (33 U.S.C. §§ 1288, 1329) in 1972, water quality has improved largely through reductions in toxic and organic chemical loadings from point sources. Discharges of toxic pollutants have been reduced by an estimated billion pounds per year (Adler, 1994). Rivers affected by sewage treatment plants show a consistent reduction in

Table 1-1—Status of the Nation's surface-water quality, 1990-96

Item	Rivers				Lakes[1]				Estuaries			
	1990	1992	1994	1996	1990	1992	1994	1996	1990	1992	1994	1996
	*Percent of total water**											
Water systems assessed	36	18	17	19	47	46	42	40	75	74	78	72
	Percent of assessed waters											
Meeting designated uses[2]:												
Supporting	69	62	64	64	60	56	63	61	67	68	63	62
Partially supporting[3]	21	25	22	36	19	35	28	39	25	23	27	38
Not supporting	10	13	14		21	9	9		8	9	9	
Clean Water Act goals: Fishable												
Meeting	80	66	69	68	70	69	69	69	77	78	70	69
Not meeting	19	34	31	31	30	31	31	31	23	22	30	30
Not attainable	1	-	-	-	0	-	-	-	-	0	0	0
Clean Water Act goals: Swimmable												
Meeting	75	71	77	79	82	77	81	75	88	83	85	84
Not meeting	15	20	23	20	18	22	19	25	12	17	15	16
Not attainable	10	9	-	-	-	-	-	-	-	0	-	-

- = less than 1 percent of assessed waters.
[1] Excluding Great Lakes.
[2] Supporting - water quality meets designated use criteria; partially supporting - water quality fails to meet designated use criteria at times; not supporting - water quality frequently fails to meet designated use criteria.
[3] In 1996, the categories "Partially supporting" and "Not supporting" were combined.
* Miles of rivers, acres of lakes, square miles of estuaries.

Source: Environmental Protection Agency, National Water Quality Inventories (1992b, 1994b, 1995, 1998a).

ammonia between 1970 and 1992 (Mueller and Helsel, 1996). The percentage of the U.S. population served by wastewater treatment plants increased from 42 percent in 1970 to 74 percent in 1985 (Adler, 1994). A widely scattered surface-water monitoring network has shown national reductions in fecal bacterial and phosphorus concentrations (Knopman and Smith, 1993; Smith, Alexander, and Lanfear, 1993; Lettenmaier, Hooper, Wagoner, and Faris, 1991; Mueller and Helsel, 1996). Case studies, opinion surveys, and anecdotal information suggest that these reductions in pollutants have improved the health of aquatic ecosystems in many basins, particularly near urban areas (Knopman and Smith, 1993). However, challenges to water quality remain, including continuing discharges of pollutants from a growing population and economy, inadequate discharge permit requirements in some States, violations of permits issued, and pollution from nonpoint sources.

The most recent EPA Water Quality Inventory reports indicate the nature of water quality impairments (table 1-1) (EPA, 1998a). The Water Quality Inventory is prepared with information contained in biennial reports from the States, required by the Clean Water Act, on the status of their surface-water resources (known as Section 305(b) reports). In 1996, 36 percent of river miles, 39 percent of lake acres (excluding the Great Lakes), and 38 percent of estuary square miles were found to not fully support the uses for which they were designated by States under the Clean Water Act (see box 1.1). States reported that agriculture is the leading source of impairment in the Nation's rivers and lakes, and a major source of impairment in estuaries.

While many agencies and organizations assess water quality, only the 305(b) reports provide a snapshot of how well waters across the Nation meet designated uses (see box 1.2). However, 305(b) data are not gath-

Box 1.1—How Is Water Quality Defined?

The Clean Water Act (passed in 1972 as the Federal Water Pollution Control Act) defines water quality in terms of designated beneficial uses with numeric and narrative criteria that support each use. Designated beneficial uses are the desirable uses that water quality supports. Examples are drinking water supply, primary-contact recreations, and aquatic life support. Numeric water quality criteria establish the minimum physical, chemical, and biological parameters required for water to support a beneficial use. Physical and chemical criteria may set maximum concentrations of pollutants, acceptable ranges of physical parameters, and minimum concentrations of desirable parameters, such as dissolved oxygen. Biological criteria describe the expected attainable community attributes and establish values based on measures such as species richness, presence or absence of indicator species, and distribution of classes of organisms (EPA, 1994b). Narrative water quality criteria define conditions and attainable goals that must be maintained to support a designated use. Narrative biological criteria describe aquatic community characteristics expected to occur within a water body.

The Clean Water Act allows jurisdictions to set their own standards but requires that all beneficial uses and their criteria comply with the goals of the Act. At a minimum, beneficial uses must provide for the "protection and propagation of fish, shellfish, and wildlife" and provide for "recreation in and on the water" (fishable and swimmable) (U.S. Congress, PL 92-500, 1972, p. 31). The Act prohibits waste assimilation as a beneficial use.

Source: U.S. Congress, PL 92-500, 1972.

ered in a consistent manner from one State to another, and often are not based on actual monitoring. Only a portion of water bodies are actually monitored in any given year (ranging from 19 percent of rivers and streams to 94 percent of Great Lakes shoreline in 1996), so variations in estimates between years could be due to changes in actual water quality, changes in the water bodies sampled, or changes in assessment protocols. These data cannot therefore be used to identify trends.

Nationwide, about one-third of surface waters are deemed impaired, but large, regional problems exist. These include:

- The Great Lakes show only 3 percent of the assessed shoreline miles (with 94 percent assessed) fully supporting designated uses (EPA, 1998a). Fish consumption is the designated use most frequently impaired. Most of the shoreline is polluted with toxic chemicals, primarily polychlorinated biphenyls (PCB's), mercury, pesticides, and dioxins that are often found in fish samples. Atmospheric deposition of toxics (delivery by wind or rain), point sources, and contaminated sediment are the leading sources of impairment.

- The Chesapeake Bay, the largest estuary in the world, has seen water quality degrade due primarily to elevated levels of nitrogen and phosphorus (EPA, 1998a). An aggressive pollution control program has reduced phosphorus, but nitrogen concentrations have largely remained unchanged, leaving the bay overenriched. Excess nitrogen and phosphorus promote algae growth that clouds the water and reduces oxygen levels. Excessive nutrient levels in tributaries of the Bay are believed responsible for the outbreak of the micro-organism *Pfiesteria*, which led to large fish kills in 1997 (Mlot, 1997). Shellfish harvests have declined dramatically in recent years, and poor water quality is believed to be an important contributing factor (State of Maryland, 1984).

- The Gulf of Mexico has seen since 1993 a doubling in the size of an oxygen-deficient "dead" zone to 7,000 square miles (Rabalais, Turner, and Wiseman, 1997). The primary cause is believed to be increased levels of nitrates carried to the gulf by the Mississippi and Atchafalaya Rivers. The amount of nitrate discharged into the gulf has increased threefold since 1954 (Goolsby and Battaglin, 1997). A major source of nitrates is fertilizers from the Upper Mississippi Basin (Antweiler, Goolsby, and Taylor, 1995).

Ground Water

Groundwater quality in the United States is not well known. Unlike surface water, no comprehensive groundwater monitoring system exists. However, many States report on the general quality of their groundwater resources in their section 305(b) reports.

Box 1.2—Assessing Water Quality

Many Federal, State, and local agencies and private groups monitor water quality (EPA, 1997c). The U.S. Geological Survey (USGS) monitors surface and ground water extensively. For example, under its National Stream Quality Accounting Network, 618 watersheds of major U.S. rivers and streams are monitored for physical characteristics (e.g., stream flow, temperature) and quality characteristics (e.g., nutrient levels). The USGS National Water Quality Assessment Program uses a regional focus to study status and trends in water, sediment, and biota in selected major watersheds. The Environmental Protection Agency (EPA) provides grants for water quality monitoring, or, in some cases, conducts monitoring itself. Under its National Monitoring Program, EPA attempts to obtain long-term data on the effectiveness of nonpoint-source pollution control measures. The Environmental Monitoring and Assessment Program is designed to provide information on status and trends of selected waters for a variety of ecosystems. Other Federal agencies involved in water quality monitoring include the U.S. Fish and Wildlife Service, the National Oceanic and Atmospheric Administration, and the U.S. Army Corps of Engineers. In some cases, other agencies and groups may receive Federal support for monitoring, or they may conduct such activities for their own uses.

However, using monitoring data to assess water quality at a national level is not a simple exercise. Water quality varies by time, location, and depth (e.g., shallow or deep portion of an aquifer or reservoir). Further, water quality is composed of a variety of characteristics, the importance of which will vary with the desired use of the water (e.g., dissolved oxygen concentration to support aquatic life; nitrate or pesticide concentrations that may violate drinking water standards; the presence of pathogens that would inhibit recreational uses). In many cases, monitoring is often done to study only one or a few components of water quality, or a specific problem, and might not address other quality questions. USGS reports status and trends of specific characteristics of water in which one may be interested, but does not weight the characteristics to develop an aggregate measure. EPA, in its biennial report to Congress on the Nation's water quality, draws from the States' assessments of how well waters meet their designated uses to report an aggregate measure of water quality in different water sources (e.g., rivers, lakes, estuaries), though there is no standardization across the States.

Of 38 States that reported overall groundwater quality in 1992, 29 judged their groundwater quality to be good or excellent (EPA, 1994b). Generally, States report that contamination of ground water is localized. In 1994, over 45 States reported that pesticide and fertilizer applications were sources of groundwater contamination (EPA, 1995). Other indications of groundwater quality come from the EPA's National Survey of Pesticides in Drinking Water Wells, conducted in 1988-90. The survey provided the first national estimates of the frequency and concentration of nitrates and pesticides in community water system wells and rural domestic drinking water wells.

Agricultural Pollutants

Both natural and human-caused sources of pollutants affect the Nation's water resources. Anthropogenic sources include point sources, such as industrial and municipal discharges, and nonpoint sources such as agriculture, forestry, construction, and urban runoff.

Agricultural pollutants include sediment, nutrients (nitrogen and phosphorus), pesticides, salts, and pathogens. While farmers do not intend for these materials to move from the field or enterprise, they often do. For example, as much as 15 percent of the nitrogen fertilizer and up to 3 percent of pesticides applied to cropland in the Mississippi River Basin make their way to the Gulf of Mexico (Goolsby and Battaglin, 1993). A U.S. Geological Survey (USGS) study of agricultural land in watersheds with poor water quality estimated that 71 percent of U.S. cropland (nearly 300 million acres) is located in watersheds where the concentration of at least one of four common surface-water contaminants (dissolved nitrate, total phosphorus, fecal coliform bacteria, and suspended sediment) exceeds criteria for supporting water-based recreation (Smith, Schwarz, and Alexander, 1994).

Sediment

Disturbing the soil through tillage and cultivation and leaving it without vegetative cover increases the rate of soil erosion. Dislocated soil particles can be carried in runoff water and eventually reach surface-water resources, including streams, rivers, lakes, reservoirs, and wetlands.

Sediment causes various damage to water resources and to water users. Accelerated reservoir siltation reduces the useful life of reservoirs. Sediment can clog roadside ditches and irrigation canals, block navigation channels, and increase dredging costs. By raising stream beds and burying streamside wetlands, sediment increases the probability and severity of floods. Suspended sediment can increase the cost of water treatment for municipal and industrial water uses. Sediment can also destroy or degrade aquatic wildlife habitat, reducing diversity and damaging commercial and recreational fisheries. Siltation is the leading pollution problem in U.S. rivers and streams (EPA, 1998a). Sediment damages from agricultural erosion have been estimated to be between $2 billion and $8 billion per year (Ribaudo, 1989). These estimates include damages or costs to navigation, reservoirs, recreational fishing, water treatment, water conveyance systems, and industrial and municipal water use.

Trends in erosion losses and instream sediment concentration seem to show improvements in recent years. The National Resources Inventory reports that the average rate of sheet and rill erosion on cropland declined by about one-third between 1982 and 1992. In most regions, the USGS found that suspended sediment concentrations trended slightly downward over the 1980's, particularly in the Ohio-Tennessee, and Upper and Lower Mississippi regions (table 1-2) (Smith, Alexander, and Lanfear, 1993). Areas characterized by corn and soybean production and mixed crops had the greatest downward trends. Soil conservation efforts over the past 10 years, particularly the Conservation Reserve Program and Conservation Compliance, likely played a role (USDA, ERS, 1997). Table 1-3 shows estimated benefits of soil conservation programs to be on the order of several hundred million dollars to billions of dollars over the life of the conservation practices adopted.

Table 1-2—Trends in concentrations of agricultural water pollutants in U.S. surface waters, 1980-90

Water resources region	Nitrate	Total phosphorus	Suspended sediment
	Average percentage change per year		
North Atlantic	*	-1.4	-0.4
South Atlantic-Gulf	*	0.1	0.2
Great Lakes	*	-3.3	0.5
Ohio-Tennessee	*	-1.0	-1.3
Upper Mississippi	-0.4	-1.2	-1.3
Lower Mississippi	-1.6	-3.8	-1.2
Souris-Red-Rainy	*	-0.8	1.2
Missouri	*	-1.7	-0.2
Arkansas-White-Red	*	-3.1	-0.7
Texas-Gulf-Rio Grande	*	-0.9	-0.6
Colorado	*	-2.4	-0.8
Great Basin	*	-2.7	-0.2
Pacific Northwest	*	-1.7	-0.1
California	*	-1.4	-0.6

* Between -0.1 and 0.1.
Source: Smith, Alexander, and Lanfear, 1993.

Nutrients

Nutrients, chiefly nitrogen, potassium, and phosphorus, promote plant growth. About 11 million tons of nitrogen, 5 million tons of potash (the primary chemical form of potassium fertilizer), and 4 million tons of phosphate (the primary chemical form of phosphorus fertilizer) are applied each year to U.S. cropland (USDA, ERS, 1997). Nutrients can enter water resources three ways. *Runoff* transports pollutants over the soil surface by rainwater, melting snow, or irrigation water that does not soak into the soil. Nutrients move from fields to surface water while dissolved in runoff water or adsorbed to eroded soil particles. *Run-in* transports chemicals directly to ground water through sinkholes, porous or fractured bedrock, or poorly constructed wells. *Leaching* is the movement of pollutants through the soil by percolating rain, melting snow, or irrigation water.

Of the three nutrients, nitrogen and phosphorus can cause quality problems when they enter water systems. Nitrogen, primarily found in the soil as nitrate, is easily soluble and is transported in runoff, in tile drainage, and with leachate. Phosphate is only moderately soluble, and relative to nitrate, is not very mobile in soils. However, erosion can transport considerable amounts of sediment-adsorbed phosphate to surface waters. If soils have been overfertilized, rates of dissolved phosphorus losses in runoff will increase due to the buildup of phosphates in the soil.

Nitrogen and phosphorus from agriculture accelerate algal production in receiving surface water, resulting in a variety of problems, including clogged pipelines, fish kills, and reduced recreational opportunities (EPA, 1998a). Nitrogen is primarily a problem in brackish or salt water, where it is the limiting nutrient, while phosphorus is primarily a problem in freshwater. EPA reports that nutrient pollution is the leading cause of water quality impairment in lakes and estuaries, and is the second leading cause in rivers (EPA, 1998a). Increases in the occurrence of harmful algal blooms in coastal waters have been attributed to nutrients from human-caused sources, including fertilizers (Boesch and others, 1997).

Besides harming aquatic ecosystems, nitrate is also a potential human health threat. The EPA has established a maximum contaminant level (MCL, a legal maximum long-term exposure) in drinking water of 10 mg/liter. Nitrate can be converted to nitrite in the gastrointestinal tract. In infants, nitrite may cause methemoglobinemia, otherwise known as "blue-baby syndrome," which prevents the transport of sufficient oxygen in the bloodstream. Public water systems that violate the MCL must use additional treatment to bring the water they provide into compliance, though exemptions are specified (42 U.S.C. §300g).

Data (from USGS monitoring stations) on nutrients in surface waters over the 1980's show different trends for nitrate and phosphorus (table 1-2) (Smith, Alexander, and Lanfear, 1993). Nitrate, in general, showed no statistically significant trend, which differs from the rise noted during 1974-81 (Smith, Alexander, and Wolman, 1987). This follows the pattern of agricultural nitrogen use, which rose sharply during the 1970's, peaked in 1981, and then stabilized. Phosphorus in water during the 1980's continued a decline noted in the 1970's, likely due to improved wastewater treatment, decreased phosphorus content of detergents, reduced phosphorus fertilizer use, and reduced soil erosion. Indeed, the rate of phosphorus decline in water in cropland areas was more than twice that in urban areas (Smith, Alexander, and Lanfear, 1993).

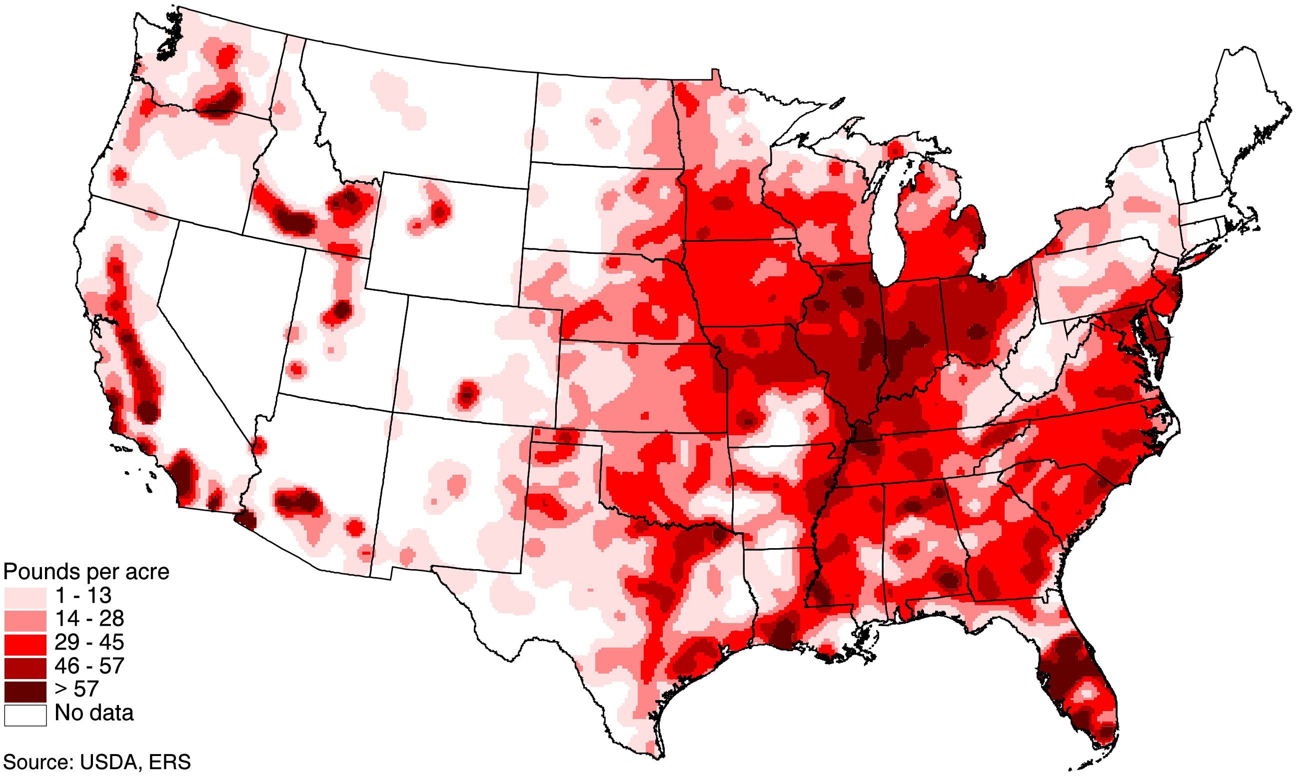
Exposure to nitrate in drinking water is chiefly a concern to those whose source water is ground water, which generally has higher nitrate concentrations than surface water (Mueller and others, 1995). From its 1988-90 national survey of drinking water wells, the EPA found nitrate in more than half of the 94,600 community water system wells (CWS) and almost 60 percent of the 10.5 million rural domestic drinking water wells, making nitrate the most frequently detected chemical in well water (EPA, 1992a). However, only 1.2 percent of the CWS's and 2.4 percent of the rural domestic wells were estimated to contain levels above the MCL. About 3 million people (including 43,500 infants) using water from CWS's and about 1.5 million people (including 22,500 infants) using rural wells are exposed to nitrate at levels above the MCL (EPA, 1992a).

A 1991 USGS study of nitrate in near-surface aquifers in the midcontinental United States detected nitrate in 59 percent of the samples taken (Kolpin, Burkart, and Thurman, 1994). Concentrations greater than the MCL were found in 6 percent of the samples. Statistical analyses indicated that the frequency of samples having concentrations greater than 3 mg/l (believed to be the maximum level from natural sources) was positively related to the proximity of agricultural land, to the use of irrigation, and to fertilizer application rates.

More recently, in a study of well water samples in 18 USGS National Water Quality Assessment Program study units, USGS found that the MCL was exceeded in about 1 percent of CWS's and 9 percent of rural domestic wells (Mueller and others, 1995). About 16 percent of domestic wells under agricultural land exceeded the MCL in selected watersheds, with particularly high proportions exceeding the MCL in the Northern Plains (35 percent) and the Pacific (27 percent) regions.

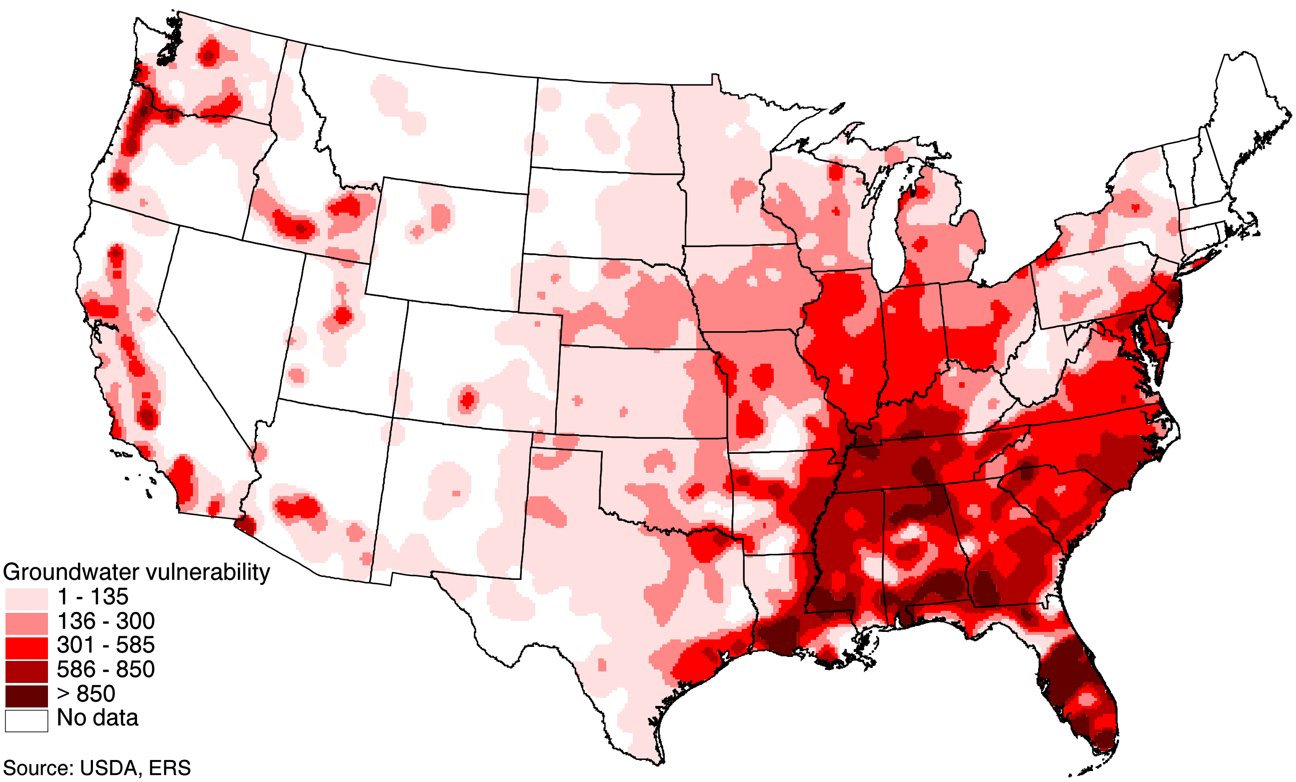
Data developed by the Economic Research Service of the USDA were used to identify regions most vulnerable to nitrate problems (see box 1.3). (Data are not yet available to conduct a similar analysis for phosphorus). Residual nitrogen on cropland (nitrogen from commercial fertilizer, manure, and natural sources in excess of plant needs) is an indicator of potential nitrate availability for runoff to surface water or leaching to ground water. Regions with relatively high residual nitrogen include the Corn Belt, parts of the Southeast, and the intensively irrigated areas of the West (fig. 1.1). Whether residual nitrogen actually contaminates water depends on the leaching characteristics of the soil and on precipitation. For example, regions with the greatest potential for nitrate contamination of groundwater mainly include parts of the Lower Mississippi River and the Southeast, based on an index of groundwater vulnerability that considers factors such as soil type and depth to ground water (Kellogg, Maizell, and Goss, 1992) (fig. 1.2). A simi-

Figure 1.1
Residual nitrogen, including manure



Source: USDA, ERS

Figure 1.2
Groundwater vulnerability index for nitrogen, including manure



Source: USDA, ERS

Box 1.3—Using GIS To Create the Maps

Residual Nitrogen Including Manure (fig. 1.1). Residual nitrogen is that portion of nitrogen available from natural and manmade sources that is not taken up by crops. Residual nitrogen on cropland (nitrogen from both commercial and manure sources in excess of plant needs) is an indicator of potential nitrate availability for runoff to surface water or leaching to ground water. Data for this figure include commercial fertilizer applications and manure use by farmers recorded in ERS/NASS Cropping Practices, Area Studies, Fruit, and Vegetable Surveys during 1990-1993 (USDA-ERS/NASS). Manure application rates were calculated from 1992 Census of Agriculture data on livestock numbers and average livestock densities by animal type. Nitrogen fixation by legumes in the rotation and nitrogen uptake by crops were estimated using standard agronomic coefficients (Meisinger, 1984; Meisinger and Randall, 1991).

Groundwater Vulnerability Index for Nitrogen, Including Manure (fig. 1.2). Nitrate leaching depends on the quantity of residual nitrogen above crop needs and the leachability of the soils to which it is applied. Residual nitrogen, calculated as above, is combined with the leaching characteristics of the soil and the rainfall characteristics in an index of vulnerability to leaching (Kellogg and others, 1992).

Manure Nitrogen per Acre of Onsite Cropland, 1992 (fig. 1.3). The amount of nitrogen from manure per acre of land available to the operation for land disposal is an indicator of potential problems with excessive manure nitrogen. Economically recoverable nitrogen in manure from confined cattle, swine, and poultry per acre of cropland and managed pasture on the operation is a more sensitive measure than the ratio of nitrogen from manure to total cropland because livestock operators may not have access to much of the land in a county. This measure was developed by Letson and Gollehon from census farm micro data at the U.S. Bureau of the Census, accounting for disclosure restrictions (Letson and Gollehon, 1996).

Nitrogen From Point Sources (fig. 1.4). National Pollution Discharge Elimination System (NPDES) permit data on nitrogen discharged by point sources is reported by EPA in the Permit Compliance System (PCS). Both municipal sewage treatment plants and industrial point sources are required to have NPDES permits (Moreau, 1994). However, because ambient pollutant levels may not be nitrogen-limited, or because nitrogen reductions may not otherwise be called for, many point sources that could be expected to have nitrogen discharges report none.

Groundwater Vulnerability Index for Pesticides, Weighted by Persistence and Toxicity (fig. 1.5). The amount of active pesticide ingredient applied is an inadequate measure of ground water vulnerability because it does not account for the time the pesticide remains in contact with the environment, the relative seriousness of exposure, and the likelihood that the pesticide will be leached. Data for this figure include pounds of active ingredients in pesticide applications by farmers recorded in ERS/NASS Cropping Practices, Area Studies, Fruit and Vegetable Surveys during 1990-1993 (USDA-ERS/NASS). Persistence of the material in the environment is proportional to the half-life of the material (Kellogg, Maizel, and Goss, 1992). The seriousness of exposure is inversely proportional to the toxicity of the material, measured by the lethal dose (LD50) in rats. Pesticide leaching depends on the characteristics of the active ingredient with regard to solubility and transport, and the leachability of the soils to which it is applied. Pesticide characteristics are combined with the leaching characteristics of the soil and the rainfall characteristics in an index of vulnerability to leaching (Kellogg and others, 1992).

lar index is not yet available for surface water. However, areas with high residual nitrogen and low soil permeability would tend to have a high surface-water vulnerability.

Nitrogen from animal waste is an important source of total nitrogen loads in some parts of the country. A USGS study of nitrogen loadings in 16 watersheds found that manure was the largest source in 6, primarily in the Southeast and Mid-Atlantic States (Puckett, 1994).

Nitrogen (and other contaminants) from manure is an increasing concern given the recent trend toward larger, more specialized beef, swine, and poultry operations. Approximately 450,000 operations nationwide confine or concentrate animals (EPA, 1998a). Of these, about 6,600 have more than 1,000 animal units,

Box 1.4—Animal Waste Storage Failures

The growing concerns over concentrated animal operations were highlighted in June 1996 when a dike surrounding a large hog-waste lagoon in North Carolina failed, releasing an estimated 25 million gallons of hog waste (twice the volume of the oil spilled by the Exxon Valdez) into nearby fields, streams, and the New River (Satchell, 1996). The 8-acre earthen lagoon was built to allow microbes to digest the waste, and is a common form of management for confined operations. The spill killed virtually all aquatic life in the 17-mile stretch between Richlands and Jacksonville, NC (Satchell, 1996).

There are approximately 6,000 confined animal operations with at least 1,000 animal units in the United States (Letson and Gollehon,1996). (One animal unit equals 1 beef head, 0.7 dairy head, 2.5 hogs, 18 turkeys, or 100 chickens.) Under the Clean Water Act, these facilities cannot discharge to waters except in the event of a 25-year/24-hour storm. This requirement necessitates the construction of onsite storage facilities for holding manure and runoff. In addition to these large operations, facilities with more than 300 animal units that discharge directly to waters are required to take the same measures. Regions with large numbers of animal operations containing more than 1,000 animal units include the Northern Plains (for beef), Pacific (dairy), Corn Belt (swine), Appalachian (swine), and Southeast (broilers) (Letson and Gollehon, 1996).

Most States are responsible for carrying out Clean Water Act regulations. A survey of livestock waste control programs in 10 Midwest and Western States indicated that few States actively inspect facilities for problems, including the integrity of storage structures (Iowa Dept. Nat. Res., 1990). National estimates of broken or leaking storage facilities do not exist. However, a North Carolina State University study estimated that wastes were leaking from half of North Carolina's lagoons built before 1993 (Satchell, 1996), so the problem may be widespread.

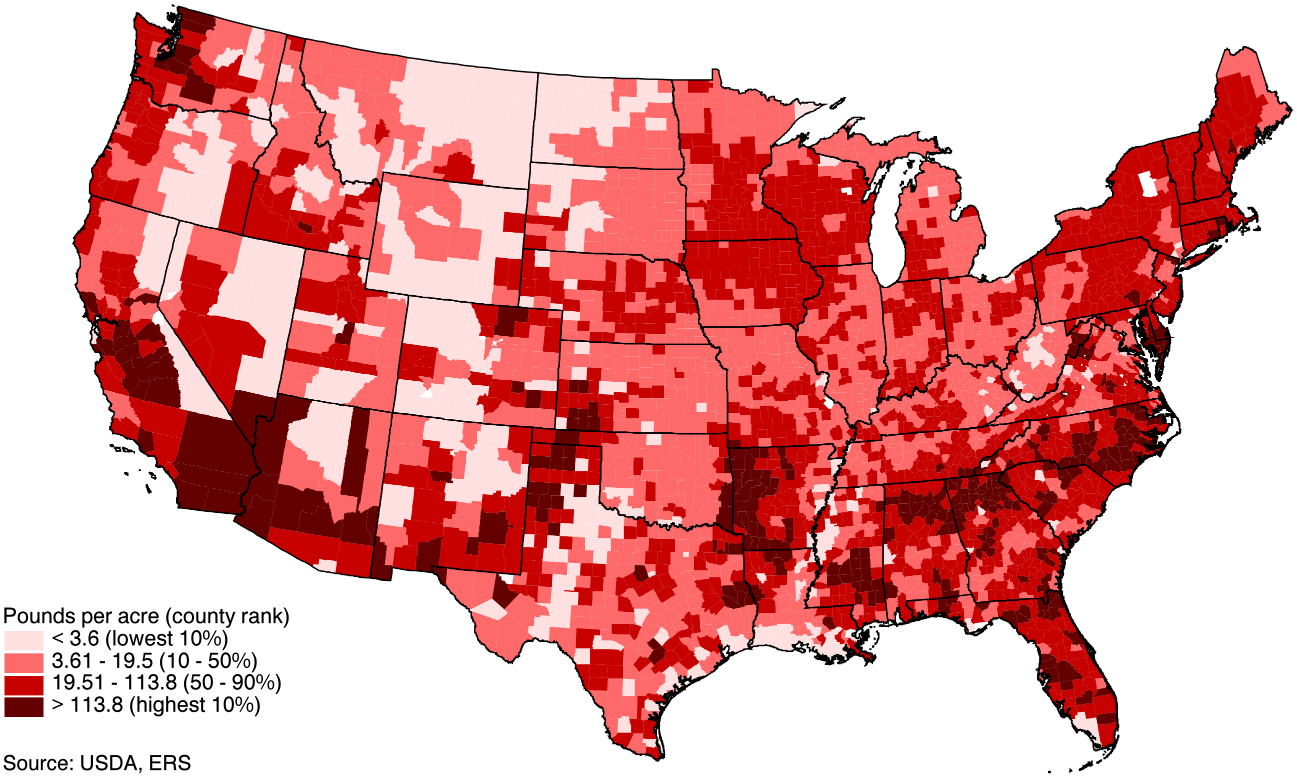
and are defined under the Clean Water Act as Concentrated Animal Feeding Operations, or CAFO's. Such operations must handle large amounts of animal waste, and can cause two sources of water quality problems. First, CAFO's require large and sophisticated manure handling and storage systems, which have at times failed with serious local consequences (see box 1.4, "Animal Waste Storage Failures"). Second, CAFO's tend to lack sufficient cropland on which manure can be spread without exceeding the plants' nutrient needs (Letson and Gollehon, 1996). The highest ratios of manure nitrogen to land are mostly found in parts of the Southeast, Delta, and Southwest (fig. 1.3).

Agricultural activities are not the only source of nutrient pollution. Other loadings stem from point sources such as wastewater treatment plants, industrial plants, and septic tanks. Atmospheric deposition of pollutants is another nonpoint source of nitrogen. Indeed, more than half the nitrogen emitted into the atmosphere from fossil fuel-burning plants, vehicles, and other sources is deposited on U.S. watersheds (Puckett, 1994). The shares of total nitrogen load to selected eastern U.S. estuaries from atmospheric deposition have been estimated to range between 4 and 80 percent (Valigura, Luke, Artz, and Hicks, 1996).

The shares of point and nonpoint sources vary by region, with commercial agricultural fertilizers the dominant source in some areas of the West, and in the central and southeastern United States (Puckett, 1994). Nitrogen discharges from point sources such as sewage treatment plants and fertilizer plants, based on National Pollution Discharge Elimination System permits, are concentrated in the Northeast and Lake States, often areas with major population centers and large concentrations of industry (fig. 1.4). By comparing figures 1.1 and 1.4, one can identify regions where water resources are likely stressed by both point and nonpoint sources of nitrogen. These include the eastern Corn Belt, Florida, Mid-Atlantic, and the agricultural valleys of California.

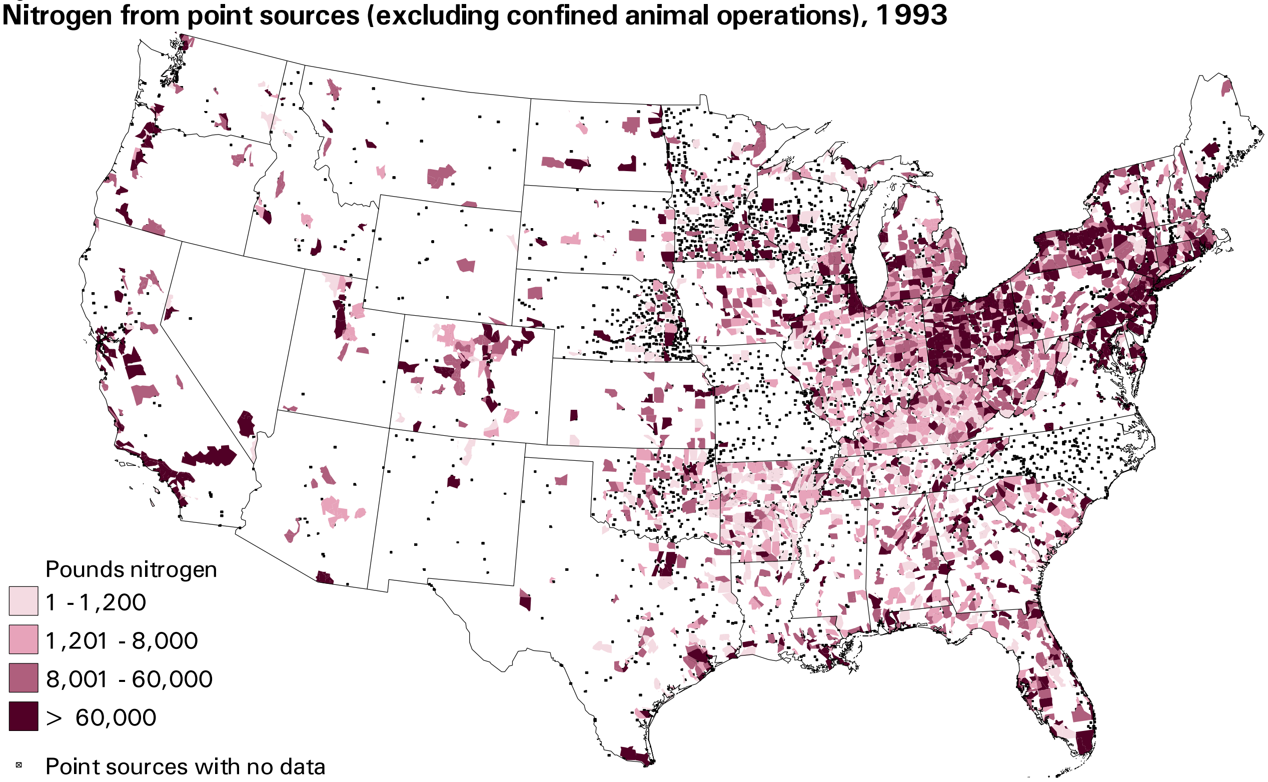
The cost of nutrients in water resources has not been fully estimated. EPA (1997a) estimated costs of $200 million for additional drinking water treatment facilities to meet Federal nitrate standards. Also, consumers are estimated to be willing to pay significant sums to reduce nitrate in the water. Crutchfield, Feather, and Hellerstein (1995) estimated total consumer willingness to pay for reduced nitrate in drinking water in four areas of the United States to be about $350 million per year.

Figure 1.3
Manure nitrogen per acre of onsite cropland, 1992



Source: USDA, ERS

Figure 1.4
Nitrogen from point sources (excluding confined animal operations), 1993



Source: USDA, ERS, based on EPA permit compliance system data.

Pesticides

A wide variety of pesticides are applied to agricultural crops to control insect pests, fungus, and disease. Well over 500 million pounds (active ingredient) of pesticides are applied annually on farmland, and certain chemicals can travel far from where they are applied (Smith, Alexander, and Lanfear, 1993; Goolsby and others, 1993). Pesticides move to water resources much as nutrients do, in runoff, run-in, and leachate. In addition, pesticides can be carried into the air attached to soil particles or as an aerosol, and deposited into water bodies with rainfall. Which route a pesticide takes depends on its physical properties and the properties of the soil.

Pesticide residues reaching surface-water systems may harm freshwater and marine organisms, damaging recreational and commercial fisheries (Pait, DeSouza, and Farrow, 1992). Pimentel and others (1991) estimate that direct annual losses from fish kills due to pesticides are less than $1 million, though the authors considered their result an underestimate.

Pesticides in drinking water supplies may also pose risks to human health. Some commonly used pesticides are probable or possible human carcinogens (Engler, 1993). Regulation requires additional treatment by public water systems when certain pesticides exceed health-safety levels in drinking water supplies, though exemptions are specified (42 U.S.C. §300). Enforceable drinking water standards have been established for 15 currently used pesticides, and more are pending (see box 1.5, "Maximum Contaminant Levels"). EPA (1997a) estimates that costs for additional treatment facilities needed to meet current regulations for pesticides and other specific chemicals would be about $400 million, with about another $100 million required over the next 20 years.

Pesticides are commonly detected in water quality studies, though usually at low levels. USGS (1997) detected at least one pesticide in every sampled stream and in about half of sampled ground water in 20 major U.S. watersheds. Pesticides in water supplies have been scrutinized in the Midwest, where large amounts of pesticides are used. Goolsby and others (1993) found that herbicides are detected throughout the year in the rivers of the Midwest, including the Mississippi River. Concentrations are highest during the spring when most pesticides are applied and when spring rains occur. The amounts transported by streams and rivers in the Midwest are generally less than 3 percent of the amount applied, but can still result in concentrations above the MCL (Goolsby and others, 1993). Atrazine (and its metabolites), alachlor, cyanazine, and metolachlor, used principally for weed control in corn and soybeans, were the principal contaminants detected, and are also the most widely used pesticides in the region. Such chemicals, once in drinking water supplies, are not controlled by conventional treatment technologies (Miltner and others, 1989).

Pesticides may pose a special problem for reservoirs. Results from a study of herbicides in 76 midwestern reservoirs showed that some herbicides are detected more frequently throughout the year in reservoirs than in streams, and except for the spring, at higher concentrations (Goolsby and others, 1993). Many of these reservoirs receive much of their storage during the spring and early summer rains, when runoff from cropland contains high concentrations of herbicides.

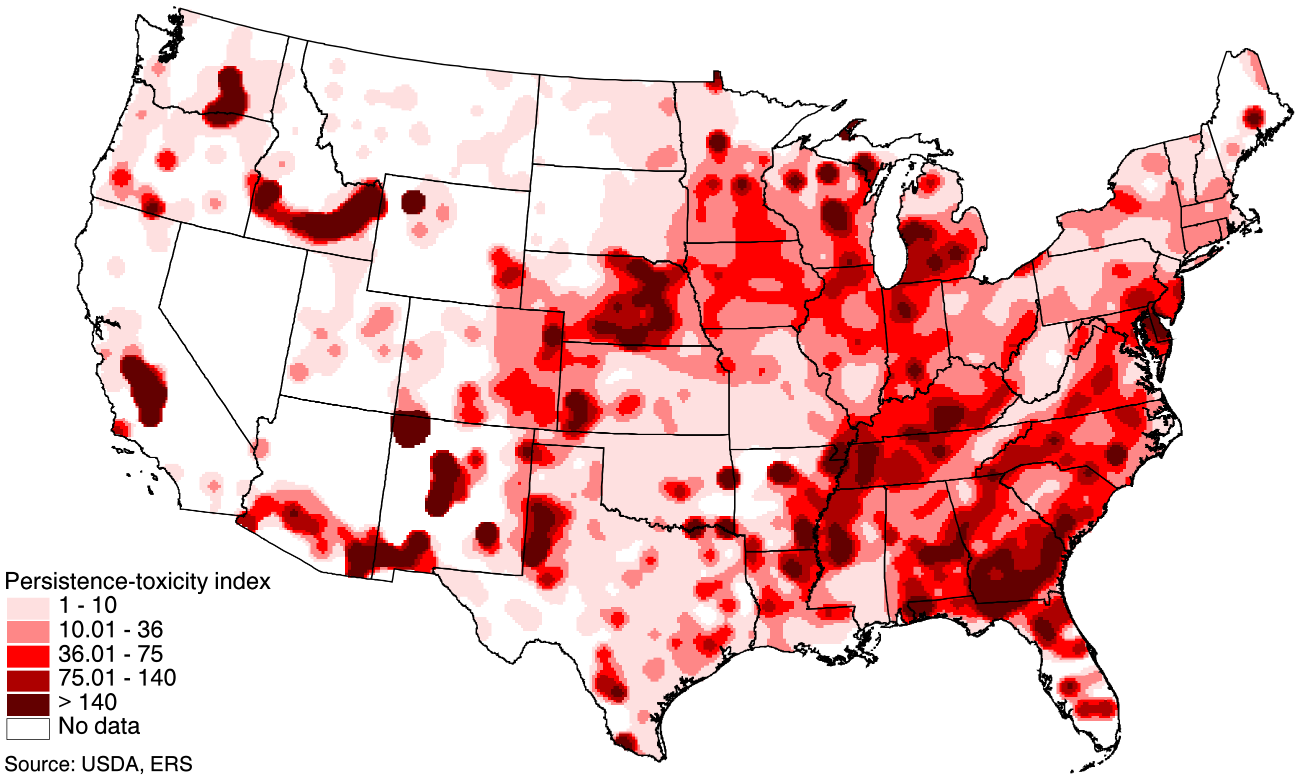
Box 1.5—Maximum Contaminant Levels

Public water systems are required to ensure that chemicals in the water are below specified thresholds, the maximum contaminant level (MCL) for each chemical. These are enforceable standards, set by EPA, that are considered feasible and safe. MCL's have been set for 15 agricultural chemicals.

Chemical	MCL (mg/l)	Type chemical
Nitrate	10.0	fertilizer
Alachlor	.002	herbicide
Atrazine	.003	herbicide
Carbofuran	.04	insecticide
2,4-D	.07	herbicide
Dalapon	.2	herbicide
Dinoseb	.007	herbicide
Diquat	.02	herbicide
Endothall	.1	growth regulator
Glyphosate	.7	herbicide
Lindane	.0002	insecticide
Methoxychlor	.04	insecticide
Oxamyl	.2	insecticide
Picloram	.5	herbicide
Simazine	.004	herbicide

Source: EPA, 1994a.

Figure 1.5
Groundwater vulnerability index for pesticides weighted by persistence and toxicity



Source: USDA, ERS

Because the half-lives of many herbicides are longer in the water than in the soil, relatively high concentrations can persist in reservoirs long after the materials have been applied.

Some pesticides leach into underlying aquifers. Pesticides or their transformation products have been detected in the ground water of 43 States (Barbash and Resek, 1995). EPA's survey of drinking water wells found that 10 percent of the CWS's and 4 percent of rural domestic wells contained at least one pesticide (1992a). However, the EPA estimated that less than 1 percent of the CWS's and rural domestic wells had concentrations above MCL's or Lifetime Health Advisory Levels (the maximum concentration of a water contaminant that may be consumed safely over an average lifetime). In a 1991 study of herbicides and some of their metabolites in near-surface aquifers in the midcontinental United States, USGS detected at least one herbicide in 28.7 percent of the wells sampled (Kolpin, Burkart, and Thurman, 1994). However, no herbicides were found at concentrations greater than the MCL or Lifetime Health Advisory Level. Atrazine and its metabolite desethylatrazine were the most frequently detected compounds.

Groundwater vulnerability to pesticides varies geographically, depending on soil characteristics, pesticide application rates, and the persistence and toxicity of the pesticides used (fig. 1.5) (see box 1.3 for a description of how the map was created). Areas with sandy, highly leachable soils and high application rates of toxic or persistent pesticides, such as central Nebraska, generally have high vulnerability ratings. Irrigated areas in Idaho, California, Texas, Washington, and the Southeast also have high vulnerability ratings. Despite widespread use of pesticides, the Corn Belt ranks lower than some of the above-mentioned areas because the predominant soils are not prone to leaching, are not irrigated, or because the chemicals used (mostly herbicides) are less persistent or toxic.

Salts

When irrigation water is applied to cropland, a portion of it runs off the field into ditches and flows back to a receiving body of water. These irrigation return flows may carry dissolved salts, as well as nutrients and pesticides, into surface or ground water. Increased concentrations of naturally occurring toxic minerals, such as selenium and boron, can harm aquatic wildlife and degrade recreational opportunities. Increased levels of dissolved solids in public drinking water can increase water treatment costs, force the development of alternative water supplies, and reduce the lifespans of water-using household appliances. Increased salinity levels in irrigation water can reduce crop yields or damage soils so that some crops can no longer be grown.

Dissolved salts and other minerals are an important cause of pollution in the Southern Plains, arid Southwest, and southern California. Total damages from salinity in the Colorado River range from $310 million to $831 million annually, based on the 1976-85 average levels of river salinity. These include damages to agriculture ($113-$122 million), households ($156-$638 million), utilities ($32 million), and industry ($6-$15 million) (Lohman, Milliken, and Dorn, 1988).

The USGS reports mixed trends of salinity in surface water over the 1980's (Smith, Alexander, and Lanfear, 1993). Measures of dissolved solids (mostly ions of calcium, magnesium, sodium, potassium, bicarbonate, sulfate, and chloride) indicate that water quality improved at more stations than it worsened. Salinity trends in water for domestic and industrial purposes generally improved during the 1980's, though salinity worsened for irrigation purposes. Among USGS cataloguing units (watersheds) with significant irrigation surface-water withdrawals, the share with annual average dissolved solids concentrations greater than 500 mg/L increased from 30 percent in 1980 to 33 percent in 1989 (Smith, Alexander, and Lanfear, 1993).

Pathogens

The possibility of pathogen-contaminated water supplies is attracting increased attention (NRAES, 1996; Olson, 1995). Bacteria are the third leading source of impairment of rivers and the second leading cause in estuaries (EPA, 1998a). Potential sources include inadequately treated human waste, wildlife, and animal operations. Animal waste contains pathogens that pose threats to human health (CAST, 1996). Microorganisms in livestock waste can cause several diseases through direct contact with contaminated water, consumption of contaminated drinking water, or consumption of contaminated shellfish. Bacterial, rickettsial, viral, fungal, and parasitic diseases are potentially transmissible from livestock to humans (CAST, 1996). Fortunately, proper animal management practices and water treatment minimize the risk to human health posed by most of these pathogens. However, protozoan parasites, especially *Cryptosporidium* and *Giardia*, are important etiologic agents of water-borne disease outbreaks (CDC, 1996). *Cryptosporidium* and *Giardia* may cause gastrointestinal illness, and *Cryptosporidium* may lead to death in immunocompromised persons. These parasites have been commonly found in beef herds, and *Cryptosporidium* is estimated to be prevalent on dairy operations (USDA, APHIS, 1994; Juranek, 1995).

Outbreaks of waterborne diseases are a growing concern. EPA (1997a) estimates the cost of facilities for improved microbial treatment to be about $20 billion over the next 20 years, with about half of that needed immediately. The health cost of *Giardia* alone is estimated to be $1.2-$1.5 billion per year (EPA, 1997b). Cryptosporidia is a more recently identified threat, with oocysts present in 65-97 percent of surface water sampled in the United States (CDC, 1995). The organism has been implicated in gastroenteritis outbreaks in Milwaukee, Wisconsin (400,000 cases and 100 deaths in 1993) and in Carrollton, Georgia (13,000 cases in 1987). The cost of the Milwaukee outbreak is estimated to exceed $54 million (*Health and Environment Digest*, 1994). While the source of the organism in these outbreaks was never determined, its occurrence in livestock herds has brought some attention to this sector, especially given the proximity of cattle and slaughterhouses to Milwaukee (MacKenzie and others, 1994).

Costs of Pollution

The total costs of water pollution from point and nonpoint sources are largely unknown. Research has examined the costs of some specific pollutants (e.g., sediment) or the costs of poor water on some desired uses (e.g., recreation). Other indicators of damages include the estimated benefits from pollution control efforts, which give a lower bound to damages (table 1-3). Water quality damages due to sediment from soil erosion are substantial, and appear greater than estimated damages from other pollutants (nutrients, pesticides, and pathogens).

Table 1-3—National estimates of the damages from water pollution or benefits of water pollution control

Estimate of—	Study/year	Description
	Selected estimates of annual damages	
Water quality damages from soil erosion	Clark and others (1985)	Damages to all uses: $3.2-$13 billion, "best guess" of $6.1 billion (1980 dollars). Cropland's share of damages: $2.2 billion.
Water quality damages from soil erosion	Ribaudo (1989)	Damages to all uses: $5.1-$17.6 billion, "best guess" of $8.8 billion. Agriculture's share of damages: $2-$8 billion.
Adjustments to net farm income considering effects of soil erosion	Hrubovcak, LeBlanc, and Eakin (1995)	Reduction in net farm income account of about $4 billion due to soil erosion effects.
Environmental costs of pesticides	Pimentel and others (1991)	Direct costs from fish kills: less than $1 million.
Infrastructure needs to protect drinking water from poor source-water quality	EPA (1997a)	$20 billion in current and future (20-year) need under Safe Drinking Water Act requirements for microbial treatment; $0.2 billion for nitrates; and $0.5 billion for other synthetic chemicals, including pesticides.
Health costs from waterborne disease outbreaks	EPA (1997b)	Damages from *Giardia* outbreaks: $1.2-$1.5 billion in health costs.
Recreational damages of water pollution	Freeman (1982)	Total recreational damages from all forms of water pollution: $1.8-$8.7 billion; "best guess" of $4.6 billion (1978 dollars/year).
	Selected estimates of annual benefits from water pollution control	
Water quality benefits of reduced soil erosion from conservation practices	Ribaudo (1986)	Erosion reduction from practices adopted under the 1983 soil conservation programs were estimated to produce $340 million in offsite benefits over the lives of the practices.
Water quality benefits of reduced soil erosion from Conservation Reserve Prog.	Ribaudo (1989)	Reducing erosion via retirement of 40-45 million acres of highly erodible cropland would generate $3.5-$4.5 billion in surface-water quality benefits over the life of the program.
Recreational fishing benefits from controlling water pollution	Russell and Vaughan (1982)	Total benefits of $300-$966 million, depending on the quality of fishery achieved.
Recreational benefits of surface-water pollution control	Carson and Mitchell (1993)	Annual household willingness to pay for improved recreational uses of $205-$279 per household per year, or about $29 billion.
Recreational benefits of soil erosion reductions	Feather and Hellerstein (1997)	Total of $611 million in benefits from erosion reductions on agricultural lands since 1982, based on recreation survey data.

Programs for Controlling Agricultural Pollution

Agricultural nonpoint-source pollution (NPS) is addressed at both Federal and State levels. A host of programs using several types of policy instruments have been implemented.

Federal Programs

At the Federal level, EPA is chiefly responsible for policies and programs that deal with water quality, mainly under provisions of the Federal Water Pollution Control Act of 1972 (the Clean Water Act). The Act deals with point-source pollution through technology-based controls (uniform, EPA-established standards of treatment that apply to certain industries and municipal sewage treatment facilities), and water quality-based controls that invoke State water quality standards (Moreau, 1994). The National Pollutant Discharge Elimination System (NPDES) sets limits on individual point-source effluents. Large, confined animal operations (over 1,000 animal units) fall under the NPDES, though enforcement has been a problem, and many facilities lack permits (Westenbarger and Letson, 1995).

When technology-based controls are inadequate for waters to meet State water quality standards, Section 303(d) of the Clean Water Act requires States to identify those waters and to develop total maximum daily loads (TMDL) (EPA, 1993). A TMDL is the sum of individual wasteload allocations for point sources, load allocations for nonpoint sources and natural background, and a margin of safety (Graham, 1997). A TMDL approach forces the accounting of all sources of pollution. This helps identify how additional basin reductions, if needed, might be obtained. EPA has responsibility for developing TMDL's if a State fails to act (EPA, 1993). Over 500 TMDL plans have been initiated since 1992, and 225 have been completed and approved by EPA (EPA, 1997).

NPS pollution is dealt with directly in several programs authorized by the Clean Water Act. Section 319 established EPA's Nonpoint Source Program, which grants States funds to develop and promote nonpoint-source management plans and other programs. EPA also provides program guidance and technical support under the program. States had a deadline of 1995 for developing and implementing nonpoint-source management plans. Under the Clean Lakes Program (sec. 314), EPA provides grants to States for various activities, including projects to restore and protect lakes. The National Estuary Program (sec. 320) helps States develop and implement basinwide comprehensive programs to conserve and manage their estuary resources.

The Coastal Zone Management Act Reauthorization Amendments (CZARA) is the first federally mandated program requiring specific measures to deal with agricultural nonpoint sources (16 U.S.C. §§ 1455(d)(16), 1455b). CZARA requires each State with an approved coastal zone management program to submit a program to "implement management measures for NPS pollution to restore and protect coastal waters" (cited in USDA, ERS, 1997). States can first try voluntary incentive mechanisms, but must be able to enforce management measures if voluntary approaches fail. Implementation of plans is not required to begin until 2004.

The Safe Drinking Water Act (SDWA) requires the EPA to set standards for drinking water quality and requirements for water treatment by public water systems (Morandi, 1989). The SDWA authorized the Wellhead Protection Program in 1986 to protect supplies of ground water used as public drinking water from contamination by chemicals and other hazards, including pesticides, nutrients, and other agricultural chemicals (EPA, 1993). The program is based on the concept that land-use controls and other preventive measures can protect ground water. As of December 1998, 45 States had an EPA-approved wellhead protection program (EPA, Office of Ground Water and Drinking Water, 1998). The 1996 amendments to the SDWA require EPA to establish a list of contaminants for consideration in future regulation (EPA, 1998b). The Drinking Water Contaminant Candidate List, released in March 1998, lists chemicals by priority for (a) regulatory determination, (b) research, and (c) occurrence determination. Several agricultural chemicals, including metolachlor, metribuzin, and the triazines, are among those to be considered for potential regulatory action (EPA, 1998b). EPA will select five contaminants from the "regulatory determination priorities" list and determine by August 2001 whether to regulate them to protect drinking water supplies.

Also under the 1996 amendments, water suppliers are required to inform their customers about the level of certain contaminants and associated EPA standards, and the likely source(s) of the contaminants, among other items (EPA, 1997e). If the supplier lacks specific

Table 1-4—USDA programs associated with water quality and the incentives they employ

Program	Economic	Educational	Research & Development
Environmental Quality Incentives	X	X	
Water Quality	X	X	X
Conservation Technical Assistance		X	
Conservation Compliance	X	X	
Conservation Reserve	X		
Wetlands Reserve	X		

See USDA, ERS (1997) for a description of these programs.

information on the likely source(s), set language must be used for the contaminants, such as “runoff from herbicide used on row crops” (e.g. for atrazine). “The information contained in the consumer confidence reports can raise consumers’ awareness of where their water comes from,...and educate them about the importance of preventative measures, such as source water protection...” (*Federal Register*, August 19. 1998, p. 44512). Increased consumer awareness concerning water supplies could lead to public pressure on farmers to reduce pesticide use (Smith and Ribaudo, 1998).

USDA administers a variety of water quality programs that directly involve agricultural producers (table 1-4). These programs use financial, educational, and research and development tools to help improve water quality and achieve other environmental objectives. The Environmental Quality Incentives Program (EQIP), authorized by the Federal Agriculture Improvement and Reform Act of 1996, provides technical, educational, and financial assistance to eligible farmers and ranchers to address soil, water, and related natural resource concerns on their lands in an environmentally beneficial and cost-effective manner (USDA, NRCS, 1998). This program consolidated the functions of a number of USDA programs, including the Agricultural Conservation Program, Water Quality Incentives Program, Great Plains Conservation Program, and Colorado River Basin Salinity Program. EQIP assistance is targeted to priority conservation areas and identified problems outside of those areas. Five- to 10-year contracts may include incentive payments as well as cost-sharing of up to 75 percent of the costs of installing approved practices. Fifty percent of the program funding is to be targeted at natural resource concerns related to livestock production (USDA, NRCS, 1998). Owners of large, concentrated livestock operations are not eligible for cost-share assistance for installing animal waste storage or treatment facilities. However, technical, educational, and financial assistance may be provided for other conservation practices on these large operations. EQIP is designed to maximize environmental benefits per dollar expended (USDA, NRCS, 1998).

The Water Quality Program (WQP), established in 1990 and essentially completed, has attempted to determine the precise nature of the relationship between agricultural activities and water quality. It has also attempted to develop and induce adoption of technically and economically effective agrichemical management and production strategies that protect surface- and groundwater quality (USDA, 1993). WQP includes three main components: (1) research and development; (2) education, technical, and financial assistance; and (3) database development and evaluation. The first two components were carried out in targeted project areas. Seven projects were devoted to research and development (Management System Evaluation Areas) and 242 to assisting farmers implement practices to enhance water quality (Hydrologic Unit Area projects, Water Quality Incentive projects, Water Quality Special projects, and Demonstration Projects). The database development activity consists of annual surveys of chemical use on major field, vegetable, and fruit crops.

Since 1936, USDA has provided technical assistance to farmers for planning and implementing soil and water conservation and water quality practices through Conservation Technical Assistance (CTA) (USDA, ERS, 1997). Farmers adopting practices under USDA conservation programs and other producers who request aid in adopting approved USDA practices are eligible for technical assistance. Some programs have required technical assistance as a condition for receiving financial assistance.

Conservation Compliance provisions were enacted in the Food Security Act of 1985 to reduce soil erosion (USDA, ERS, 1997). Producers who farm highly erodible land (HEL) were required to implement a soil conservation plan to remain eligible for other specified USDA programs that provide financial payments to producers.

Water quality would also be expected to improve from two USDA land retirement programs. The Conservation Reserve Program (CRP) was established in 1985 as a voluntary long-term cropland retirement program (USDA, ERS, 1997). USDA provides CRP participants with an annual per-acre rent and half the cost of establishing a permanent land cover in exchange for retiring highly erodible or other environmentally sensitive cropland for 10-15 years. U.S. cropland erosion has been reduced by about 20 percent under the program (USDA, ERS, 1994). The Wetlands Reserve Program, authorized as part of the Food, Agriculture, Conservation, and Trade Act of 1990, is primarily a habitat protection program, but retiring cropland and converting back to wetlands also has water quality benefits (USDA, ERS, 1997). These benefits include not only reduced chemical use and erosion on former cropland, but also the ability of the wetland to filter sediment and agricultural chemicals from runoff and to stabilize stream banks.

In addition to the above programs that provide direct assistance to producers, USDA also provides assistance to State agencies and local governments through the Small Watershed Program (otherwise known as Public Law 566) (USDA, ERS, 1994). To help prevent floods, protect watersheds, and manage water resources, this program includes establishment of measures to reduce erosion, sedimentation, and runoff.

State Programs

Most, if not all, States provide incentives to farmers to adopt management practices that reduce agricultural NPS pollution. Common strategies include watershed and land-use planning, development of voluntary best management practices, technical assistance programs, and cost-sharing for prevention and control measures.

Recently, more States have been moving beyond a voluntary approach to address NPS pollution. Mechanisms to enforce certain behavior include regulation and liability provisions (ELI, 1997). State laws using such provisions for NPS pollution vary widely in definitions, enforcement mechanisms, scope, and procedures, largely because of the absence of Federal direction (ELI, 1997). Catalysts moving States toward stronger measures include immediate and urgent problems (such as nitrate contamination of ground water in Nebraska, animal waste problems in North Carolina, and pesticide contamination of ground water in California and Wisconsin), the use of total maximum daily load provisions for identifying sources of water contaminants, the requirements of the Coastal Zone Act Reauthorization Amendments, and the improving technical ability of States to assess their waters (ELI, 1997).

States are using five different mechanisms to make adoption of best management practices (BMP's) more enforceable (ELI, 1997). These include making BMP's directly enforceable in connection with required plans and permits; making BMP's enforceable if the producer is designated a "bad actor"; making compliance with BMP's a defense to a regulatory violation; making BMP's the basis for an exemption from a regulatory program; and making compliance with BMP's a defense to nuisance or liability actions.

While many States have provisions that deal with water quality as it relates to agricultural NPS pollution, they often target only a subset of water quality problems. Few States deal with agricultural NPS pollution in a comprehensive manner (table 1-5). Most target individual pollutants (sediment), resources (ground water), regions (coastal zone), or type of operations (swine). Most of these laws have been enacted within the past 5 years, so the impacts of these policies on producers have yet to be seen.

Summary and Policy Implications

Nonpoint sources of pollution are the largest remaining sources of water quality impairment in the United States. While most of the sampled waters are reported to be supporting designated uses, runoff from agriculture, forests, urban areas, and other land uses are causing impairments in some important water resources. Nutrients, bacteria, and siltation are reported to be the largest causes of impairment to surface waters; agriculture is the primary source of impairments in rivers and lakes, and a major source in estuaries (EPA, 1998a). Both Federal and State governments have responded with primarily voluntary programs for addressing nonpoint-source pollution, though some States are moving toward stronger policy measures.

Deficiencies in water quality data hinder the development of a full range of water quality policies at Federal and State levels, and complicate measuring the progress of initiatives already undertaken. Data are often unable to identify the relative contributions of pollutant loadings from different sources (Knopman and Smith, 1993). In many cases, current monitoring efforts of nonpoint-source pollution are incapable of attributing changes in water quality to the actions of a specific polluter. How these deficiencies affect policy development is addressed more fully in the next chapter.

Table 1-5—Summary of State water quality mechanisms for controlling agricultural pollution[1]

State	Nutrient plan requirement	Pesticide restriction	Sediment restriction	Animal waste disposal plan	Comprehensive
Alabama					
Alaska					
Arizona	X	X		X	
Arkansas				X	
California		X		X	
Colorado	X			X	
Connecticut				X	
Delaware					
Florida	X			X	
Georgia					
Hawaii					
Idaho					
Illinois				X	
Indiana					
Iowa	X	X		X	
Kansas		X		X	
Kentucky				X	X
Louisiana					
Maine				X	X
Maryland	X		X	X	X
Massachusetts					
Michigan					
Minnesota				X	
Mississippi				X	
Missouri				X	
Montana	X	X		X	
Nebraska	X		X	X	
Nevada					
New Hampshire					
New Jersey					
New Mexico					
New York					
North Carolina				X	
North Dakota					
Ohio			X	X	
Oklahoma				X	
Oregon				X	X
Pennsylvania			X	X	
Rhode Island					
South Carolina				X	
South Dakota				X	
Tennessee				X	
Texas					
Utah					
Vermont				X	X
Virginia				X	X
Washington				X	X
West Virginia	X			X	
Wisconsin	X	X		X	X
Wyoming				X	

[1] Mechanisms may apply only under certain conditions or in certain localities.
Sources: ELI, 1998; NRDC,1998; Animal Confinement Policy National Task Force, 1998.