The Impact of Agriculture on Water Quality: A Survey of Five States' Data Bases and Information Systems

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ABSTRACT

Growing concern over water contamination from agricultural activities has prompted an expanded effort by states to design policies and programs to monitor and mitigate the contamination problem. Data limitations have forced states to focus first-round policy initiatives on data collection and monitoring efforts, as well as on funding research centers and research projects.

Data bases and information systems pertaining to agriculture and water quality were surveyed for five states--Iowa, Kansas, North Dakota, Oregon, and Wisconsin. For these five states, a total of over fifty state agencies, state offices of federal agencies, and research centers were visited. The states are compared in terms of their agricultural activities, hydrogeologic environments, water use, evidence of water contamination, legislation, state agencies, water quality monitoring systems, data bases, and research projects. The comparison provides a framework for discussion of issues related to collection, analysis, and archiving of environmental data.

Each of the five states surveyed routinely collects an extensive amount of data pertinent to the impact of agriculture on water quality, as well as data about the physical environment. These efforts are conducted by a variety of state agencies, often in collaboration with federal agencies, but the data bases are generally separate and narrow in scope. Generally, it is only for specific regions or research projects that comprehensive data collection occurs. Considered as a whole, these data collection efforts cover much of the multifaceted relationship between agricultural activity and water quality. Only recently have states begun to address issues of sharing, coordinating access to, and integrating the variety of data that exists.

The sums of states' current data constitute large and "informal" data bases. Even if the variety of data that states routinely collect could be brought together, differences between data collection procedures, purposes of data collection, and such generally prevent the integration of different individual data bases. If cause and effect relationships between agricultural activities and water contamination are to be revealed and understood in a manner supportive of policy responses, continued data base development and integration is needed.

INTRODUCTION

The effects of water contamination brought about by agricultural land use have caused growing concern by a broad segment of the population. States have begun to seek policy designed to better monitor and mitigate water contamination problems in their regions of the country.

Limitations in available state-level data suggest that the first step in designing effective water quality policies is to strengthen data collection. Policymakers want to know what kinds of data and analyses are currently available, whether these data are usable for the kinds of research that will support policy, and how data collection can be improved to provide for more well-grounded policy initiatives.

CARD and the Center for Policy Research at the National Governors' Association (NGA) conducted a study on the scope, availability, and use of currently available data bases related to agriculture and water quality issues. Five states were surveyed: Iowa, Kansas, North Dakota, Oregon, and Wisconsin. Comparisons were made of the states' agricultural activities, hydrogeologic environments, water use, evidence of water contamination, legislation, state regulatory agencies, water quality monitoring systems, data bases, and research projects.

The comparison of data collection in the five states provides a framework for discussion and further study of various issues related to water quality.

Agricultural and Natural Environment, and Evidence of Water Contamination

Agricultural Environment

The agricultural environment of Iowa, Kansas, North Dakota, Oregon, and Wisconsin as revealed in agricultural statistics for 1986-87 included crop and livestock production. Pesticide and fertilizer use, which are major agricultural contaminants, were examined in these two areas.

Crop Production. The greater the area being cropped, the greater the chance of water quality problems. In Iowa, corn and soybeans occupy 87 percent of the total cropland. Hay and oats raise the amount to 99.7 percent leaving little area for other crops. In North Dakota and Oregon, the top five crops account for 83 and 88 percent of total cropped acres. A relatively long list of other crops with greater than 1 percent of the total area contributes to a more diverse crop mix. Crop production figures for these states plus Kansas and Wisconsin are presented in Table 1.

Table 1 also shows the total acres of cropland harvested and the amount being irrigated. Irrigation creates special water quality problems for states like Kansas with over 11 percent of cropland irrigated.

Pesticide Use for Five States. Of the five states, Iowa is clearly the largest user of agricultural pesticides. An accurate ranking of North Dakota is not possible because pesticide usage in pounds of active ingredient was not collected. Figures are given in Table 2. In

Table 1. 1986 crop production statistics for five states

	Iowa	Kansas	North Dakota (millions)	Oregon	Wisconsin
Total of all crop acres[a]	23.796	20.964	20.693[b]	2.934[c]	9.315
Percentage of acres irrigated	<1.0%	11.5%	<1.0%	<1.0%	3.0%
Rank					
1 Crop •	Corn	Wheat	Wheat	Wheat	Corn
Acres harvested •	12.250	10.200	9.380	1.025	3.860
Percentage of total •	51.5%	48.6%	45.3%	34.9%	41.4%
2 Crop •	Soybeans	Sorghum	Barley	All other hay[d]	Alfalfa
Acres harvested •	8.450	4.280	3.450	0.650	3.150
Percentage of total •	35.5%	20.4%	16.7%	22.1%	33.8%
3 Crop •	Alfalfa	Soybeans	Alfalfa	Alfalfa	Oats
Acres harvested •	1.600	1.760	1.550	0.460	0.850
Percentage of total •	6.7%	8.4%	7.5%	15.7%	9.1%
4 Crop •	All other hay[d]	All other hay[d]	All other hay[d]	Barley	All other hay[d]
Acres harvested •	0.800	1.600	1.550	0.365	0.530
Percentage of total •	3.4%	7.6%	7.5%	12.4%	5.7%
5 Crop •	Oats	Corn	Sunflower	Oats	Soybeans
Acres harvested •	0.630	1.430	1.407	0.080	0.320
Percentage of total •	2.6%	6.8%	6.8%	2.7%	3.4%
Other crops with > 1% share of total acres	None	Alfalfa Barley	Corn Oats Flaxseed Soybeans Beans, dry edible	Corn Potatoes Peppermint Sweet corn Green peas	Wheat Sweet corn

SOURCE: Iowa Agricultural Statistics, 1987; Kansas Agricultural Statistics, 1986; North Dakota Agricultural Statistics, 1987; Oregon Agricultural Statistics, 1986-87; Wisconsin Agricultural Statistics, 1987.

[a]Excluding tree crops.
[b]Total of principal crops.
[c]Includes trees.
[d]All hay except alfalfa.

Table 2. A summary of chemical use for five states

	Iowa[a]	Kansas	North Dakota	Oregon	Wisconsin
Pounds of chemical applied to surveyed crops (millions)					
Herbicides	58.439	23.854	NA	4.650	15.084[b,c]
Insecticides	6.237	4.300	NA	2.220	3.096[b,c]
Fungicides	NA	NA	NA	2.470	0.634[b,c]
Other	NA	NA	NA	5.710	NA
Number of acres treated (millions)					
Herbicides	21.572	9.908	17.539	3.478[b,d]	5.133[b]
Insecticides	5.949	4.029	2.558	1.550[b,d]	2.904[b]
Fungicides	NA	NA	0.472	0.828[b,d]	0.158[b]
Other	NA	NA	0.071	0.145[b,d]	NA
Fertilizer used (thousand tons)					
Nitrogen	934	545	323	134	258
Phosphate	313	140	145	38	136
Potash	451	33	24	24	339

SOURCE: Iowa State Cooperative Extension Service, 1987; Kansas Crop and Livestock Reporting Service, 1979; North Dakota State University Cooperative Extension, 1985; Oregon State University Extension Service, 1989; Wisconsin Agricultural Statistics Service and Economics Research Service, 1986.

[a]Values are for corn and soybeans only.
[b]Not reported specifically in summary tables included in the published document(s): Calculated by authors from information in tables provided.
[c]Pounds of chemical applied was not reported for some crops because of insufficient information.
[d]The area treated reflects multiple applications (i.e., if one acre receives four applications it is recorded as four treated acres in the Oregon survey.
NA = Not available.

all the states pesticide usage and acreage treated as well as major chemicals used (Table 3) typically reflect the total number of acres of crop and pasture land as well as the mix of crops grown in the state. In Iowa and Wisconsin where corn is the largest crop, atrazine and alachlor are the major herbicides. Atrazine is used primarily on corn while alachlor is used on corn and soybeans. The major insecticides in these states are terbufos, chlorpyrifos, and fonofos all of which are used primarily for control of corn rootworm and other corn insects.

In Kansas, North Dakota, and Oregon wheat is the major crop, and 2,4-D is used more than any other herbicide in all three states for weed control. In Kansas the major insecticides carbofuran and toxaphene are used primarily on wheat, sorghum, and corn. In Oregon chlorpyrifos and azinphos-methyl are used on a variety of fruit, nut, and vegetable crops, which means they are used on more acres than any other insecticides in this state. In North Dakota, fenvalerate and parathion are the most commonly used insecticides, with the largest share of their use being in sunflower production.

In Iowa there were over 23 million acres in crops in 1986 of which corn and soybeans accounted for 87 percent, or about 20 million acres (Table 1). Of this amount, 97 percent, or close to 19.5 million acres, received at least one application of herbicides. Of the corn acres, 42 percent received at least one insecticide treatment (Iowa State University Cooperative Extension Service 1987).

In Wisconsin 3.8 million of a total 9.3 million acres of harvested cropland was in corn production (Table 1). Ninety-eight percent of them (3.7 million) received at least one herbicide treatment, and 57 percent

Table 3. Major chemicals used in five states

	Iowa[a]	Kansas	North Dakota	Oregon	Wisconsin
Major Chemicals used and acres treated (millions)					
Herbicide 1	Atrazine	2,4-D	2,4-D amine	2,4-D	Atrazine
Acres treated	5.796	4.002	5.138	0.630[b,e]	3.362
Herbicide 2	Alachlor	Atrazine	Trifluralin	Dicamba	Alachlor
Acres treated	5.609	3.472	4.541	0.479[b,e]	1.944[b,c]
Insecticide 1	Terbufos	Carbofuran	Fenvalerate	Chlorpyrifos	Terbufos
Acres treated	1.642	0.575	1.414	0.115[b,e]	0.890
Insecticide 2	Chlorpyrifos	Toxaphene	Parathion	Azinphos-m[d]	Fonofos
Acres treated	1.282	0.235	0.504	0.076[b,e]	0.583[c]
Fungicide 1	NA	NA	Mancozeb	Tilt	NA
Acres treated			0.186	0.151[b,e]	
Fungicide 2	NA	NA	Maneb and Zn	Chlorothalonil	NA
Acres treated			0.118	0.126[b,e]	

SOURCE: Iowa State Cooperative Extension Service, 1987; Kansas Crop and Livestock Reporting Service, 1979; North Dakota State University Cooperative Extension, 1985; Oregon State University Extension Service, 1989; Wisconsin Agricultural Statistics Service, 1986.

[a]Values are for corn and soybeans only.
[b]Not reported specifically in summary tables included in the published document(s): Calculated by authors from information in tables provided.
[c]Pounds of chemical applied was not reported for some crops because of insufficient information.
[d]The full name is azinphos-methyl.
[e]The area treated reflects multiple applications (i.e., if one acre receives four applications it is recorded as four treated acres in the Oregon survey).
NA = Not applicable.

(2.1 million) were treated with insecticides. Surprisingly, even though soybeans compose only 6 percent of the total crop acres--about half a million--herbicide usage on them was the second largest in the state. A relatively large mix of hay and oats received relatively fewer and/or smaller treatments of pesticides. Wisconsin also produces significant quantities of fruits (primarily apples) and vegetables, which contributed, often weightily, to the use of pesticides, especially insecticides and fungicides (WASS 1987).

For Kansas, North Dakota, and Oregon, wheat constitutes the single largest share of harvested cropland (Table 1). Insecticide treatments on wheat are relatively small in all three states, but herbicide treatments differ immensely.

In North Dakota over 90 percent of the wheat acres receive herbicide treatments (North Dakota State University 1985). Though it is impossible to determine the percentage of acres treated in Oregon, nearly all of them received at least one application (Oregon State University Extension Service 1989).

The reverse is the case in Kansas where only 10 percent of the wheat acres received herbicide treatments. Production of corn and sorghum, however, contributed heavily to the use of herbicides, with sorghum being the single largest user in the state. Large amounts of herbicides (over 2 million pounds) were also used on pasture and rangeland. Corn, sorghum, and alfalfa were major consumers of insecticides in Kansas (Kansas Crop and Livestock Reporting Service 1979; Perry et al. 1988).

In North Dakota, sunflower and barley production received large applications of herbicides. Sunflower producers were also the heaviest users of insecticides with sugarbeet and potato production contributing significantly. Potatoes and sugarbeets accounted for most of the use of fungicides, as well. North Dakota's large pasture and rangeland areas have seen few pesticides, according to the 1984 survey (North Dakota State University Cooperative Extension 1985). But the recent spread of leafy spurge on pasture and rangeland has likely contributed to an increase in the use of herbicides on this land.

In Oregon, the diversity of crops makes it difficult to pinpoint the ones that are primary users of pesticides. In general, it can be said that the small grains (wheat, barley, and oats) and feed grains, such as corn, were primarily accountable for the use of herbicides, while the production of fruits, nuts, and vegetables used insecticides and fungicides heavily. The sizable applications of other chemicals in Oregon are mainly attributed to metam-sodium. This chemical is described as a soil fungicide, nematocide, and herbicide with fumigant action. It is typically applied at rates from 140 to 190 pounds of active ingredient/acre to potatoes via sprinkler irrigation systems (Oregon State University Extension Service 1989).

Fertilizer Use for Five States. Just as Iowa is the largest user of pesticides of the five states studied, so is it the largest consumer of fertilizers (Table 2). Nitrogen, which has been linked previously to water quality problems, is used more often than phosphate and potash in all five states. Corn, especially in a continuous rotation, is a major consumer of nitrogen in Iowa and Wisconsin, where it is applied to 97 percent of planted corn acres. In Kansas, North Dakota, and Wisconsin, wheat frequently receives nitrogen applications also (79, 81, and 96 percent of wheat acres respectively) (Economic Research Service 1987).

Livestock Production. Because of the nature of modern livestock production, especially production of large numbers of slaughter animals in concentrated areas, water quality problems often result. An indicator of the potential water quality problems related to livestock production is seen in 1986 figures (Table 4). Iowa, Kansas, and Wisconsin all have large inventories of cattle but Kansas clearly slaughtered the most, which is evidence of a large number of cattle kept in concentrated feedlots. In states with large cattle inventories relative to slaughter, feeder calf production is more predominant than slaughter cattle production. Feeder calf production, which should be a far lesser risk to water quality, seems to occur relatively more often in Iowa and Wisconsin.

Sheep, hogs, chickens, and turkeys were included in the data. Sheep production is relatively unimportant in all of the states with Iowa leading the way in numbers and slaughter levels. Hog inventories and slaughter is clearly dominated by Iowa. Iowa also has an edge on chicken numbers but Oregon and Wisconsin produce more broilers for meat. Turkey production is predominant in Iowa and Wisconsin. Finally, dairy production as indicated by milk cow numbers, which also has potential to cause water quality problems, is clearly most prevalent in Wisconsin.

In general, livestock production is very important to Iowa (hogs), Kansas (cattle), and Wisconsin (dairy). In North Dakota and Wisconsin, livestock production is less prevalent, although North Dakota is a significant producer of cattle, especially feeder cattle, and Oregon produces a large number of broilers.

Table 4. 1986 livestock numbers for five states

	Iowa	Kansas	North Dakota	Oregon	Wisconsin
			(thousand head)		
Number on Jan.1					
Cattle	4,950	5,800	2,000	1,575	4,280
Hogs	13,500	1,410	275[a]	125[a]	1,250
Sheep	350	210	180	430	83
Chickens	8,100	2,370[a]	290	3,280	4,453[a,e]
Milk cows (average number)	335	111	97	99	1,862
Slaughtered					
Cattle	1,969	6,494	147	532[b]	1,820
Hogs	18,711	1,417	81	218[c]	2,062
Sheep	520	337	149	215[d]	7
Raised					
Broilers	2,700	1,675	NA	15,800	11,600
Turkeys	7,000	104	1,030	1,510	6,128

SOURCE: Iowa Agricultural Statistics, 1987; Kansas Agricultural Statistics, 1986; North Dakota Agricultural Statistics, 1987; Oregon Agricultural Statistics, 1986-87; Wisconsin Agricultural Statistics, 1987.

[a]Dec. 1 inventory.
[b]Number of cattle marketed.
[c]Number of hogs marketed.
[d]Number of lambs marketed.
[e]Excludes commercial broilers.
NA = Not applicable.

The preceding summary of agricultural practices is a basis for discussion of agriculture-related water quality problems. Each state is unique in its problems and solutions. In Iowa with over 23 million acres of cropland, mostly planted to corn and soybeans with heavy pesticide and fertilizer use, and over 27 million head of livestock, the problems and approaches are necessarily different from those in Oregon with less than 3 million acres in cropland, a diverse crop mix, and livestock numbering just over 9 million head. Other agricultural practices will factor in each state's water quality issue, such as the extensive use of irrigation in Kansas.

Let us now turn to a second major aspect of the water quality discussion, hydrogeology and the use of water.

Hydrogeology and Water Use

Differences in geology and human-made features can account for different rates and levels of chemical contamination of water. Such features as karst zones (limestone regions with sinks, underground streams, and caverns), agricultural drainage wells from the 1940s and 1950s, and old wells with worn-out well casings are potential pathways for introducing agricultural chemicals to groundwater. In addition, groundwater flows supply surface waters and visa versa.

Overall, states depend heavily on groundwater resources for drinking water supplies, especially in rural areas. For states with irrigated agriculture, irrigation is generally the major user of groundwater. It often is the case that agricultural areas coincide with shallow aquifers and/or plentiful supplies of groundwater--as in Kansas, Oregon, Wisconsin--either because of the agricultural quality and land topography or because water can be utilized easily. This coincidence of agriculture and groundwater resources also has implications for groundwater contamination.

Iowa. Iowans use groundwater for 80 percent of their drinking water. In western Iowa, alluvial aquifers offer large quantities of good quality water, which is tapped for urban and rural residents. However, these aquifers occur beneath low relief-floodplains and thus beneath intensive row crop production. Kelly et al. note that alluvial aquifers are greatly at risk for contamination. "The relatively thin nature of the fine-textured soil mantle and unsaturated zones above these alluvial deposits offers little protection from surficial contaminants to the groundwater they contain" (Kelley et al. 1988, 8). Karst regions in northeastern Iowa also increase the potential for introduction of agricultural chemicals to groundwater.

Kansas. Kansans utilize groundwater resources for public, rural, industrial, and irrigation purposes. Groundwater supplies approximately 85 percent of all water used, is the sole water source for more than a quarter of the state's population, and provides 85 percent of the drinking water in rural areas. It is relied on more heavily in western Kansas where surface water is less available than in the eastern portion of the state. Irrigation is the largest user of groundwater in Kansas.

Oregon. Oregon's largest supply of fresh water is groundwater, and about 60 percent of Oregonians depend on it for all or part of their daily needs. The breakdown of usage as of 1980 was 75 percent for irrigation, 12 percent for rural domestic and livestock, 7 percent for industry, and 6 percent for public water supplies (Oregon Department of Environmental Quality 1988, 1). The main stems and important tributaries of Oregon's 19 river basins add up to 27,000 miles, although it is estimated that the total mileage of rivers, streams, and creeks is 110,000 miles. Oregon's shallow aquifers cover an area of 9,500 square miles underground (Oregon Department of Environmental Quality 1988b, 5).

North Dakota. In North Dakota, groundwater provides a little over half of the water to public and private drinking water systems and 47 percent to irrigation and other agricultural purposes (NDSDH 1988). Significant development of groundwater is possible only in glacial drift aquifers in the east-central part of the state, but the natural quality of water from these aquifers varies. Water from shallow aquifers, though most susceptible to human-made contaminants, is usually suitable for most uses. Water from the deeper aquifers is often unsuitable for irrigation, although it may occasionally be used for domestic or stock purposes.

The Missouri River is the most significant source of surface water in the state, with more than 80 percent of the state's total measured streamflow, as recorded at Bismarck. Lake Sakajawea, formed by Garrison Dam on the Missouri River mainstem, stores slightly less than 19 million usable acre feet. All other streams in the state generally do not provide dependable supplies of surface water unless storage is provided. The quality of water in Lake Sakajawea and the mainstem is suitable for irrigation and domestic use, while the water in the principal Missouri River tributaries is marginally suitable for domestic use but is often unsuitable for irrigation (Winter et al. 1984).

Wisconsin. In Wisconsin, 67 percent of the residents receive water for domestic purposes from groundwater. The state has nearly 43,000 miles of streams and rivers and nearly 15,000 inland lakes (Schreiber 1986). In addition, Wisconsin is favored with four principal aquifers: the sand and gravel aquifer, the eastern dolomite aquifer, the sandstone and dolomite aquifer, and the crystalline bedrock aquifer (WDNR 1984). The natural quality of the groundwater varies greatly, depending upon the rocks and minerals with which the water is in contact, but is described as good in general (Schreiber 1986).

Wisconsin is relatively susceptible to groundwater contamination, and several areas are especially vulnerable. Areas of shallow fractured bedrock in the western and northeastern parts of the state provide a direct path for contaminants to aquifers. Sandy glacial deposits in the northwest and Central Sands regions are highly permeable and thus susceptible to contamination. Sandy river valleys, such as the Wisconsin River Valley in the southwest and the Rock River Valley in the southeast, are also vulnerable areas (Schmidt 1987). Approximately 3 percent of Wisconsin's surface area is covered by surface water. The natural quality of these waters is considered good but point and nonpoint pollution have led to significant degradation (Schreiber 1986).

Evidence of Agricultural Chemical Contamination

Nitrates and pesticides are commonly found in the water of four states--Iowa, Kansas, Oregon, and Wisconsin--but North Dakota has been relatively contamination free.

Iowa. Surveys of water sources in Iowa have consistently detected varying levels of contamination from agricultural chemicals, mainly fertilizer, nitrates, and pesticides. Early 1980s surveys to assess pesticide contamination in Iowa groundwater found that, of the sources examined, 50 percent of public wells and 70 to 80 percent of private sources (in susceptible hydrogeologic areas) exhibited pesticide residues. Furthermore, based on surface water data from 1968, a trend of increasing persistence of pesticide residues is developing (Kelley et al. 1988, 1, 2). Nutrients (at least in part from agricultural fertilizers) and pesticides had a moderate-to-minor impact on 99 percent and 93 percent, respectively, of the stream miles in Iowa (Iowa Department of Natural Resources, 1988, 2-15).

The problem seems to be pervasive. Researchers found that pesticides in groundwater occur statewide; shallow aquifers suffer most. "There is a relationship between depth of the water-supply and the occurrence of pesticides...'shallow,' productive aquifers, the most relied upon source of drinking water in the state, are susceptible to contamination" (Kelley et al. 1988, 2).

Some studies have shown evidence of contamination even in deep bedrock aquifers and hypothesize that these too are susceptible to contamination (Hallberg and Libra 1989). In ten instances, private or public supply wells have been closed. These wells were close to agricultural chemical supply dealerships (IDNR 1988, 3-16).

Kansas. In Kansas, both pesticides and nitrates are present in groundwater. Of 311 surface drinking water supply samples collected between 1977 and 1987, 38 percent exceeded the EPA health advisory levels for atrazine, a pesticide (Kansas Department of Health and Environment 1989a). For 130 statewide stream monitoring stations of the same time period, 98, or 75 percent, had pesticide detections, an occurrence that is "increasing over time" says the Kansas Department of Health and Environment (1988, 5). For 1987, pesticides were detected in only 12 of 123 public water supply wells (judged to be at risk for contamination because of location, construction, and other factors) that were sampled, a rate of detection of less than 10 percent.

Nitrates have also been found. In a Farmstead Well Water Survey conducted in 1986, of 103 wells distributed across 50 counties, 28 percent had nitrate levels exceeding the EPA maximum contamination limits for drinking water. In a second phase of the survey, of 84 wells of representative depths and construction, 32 percent had nitrates exceeding the EPA maximum contamination limits (Kansas Department of Health and Environment 1989a). In general for Kansas, nitrates are the greatest concern as contaminants. "Currently, the most significant violation in terms of public effort and expenditure of tax dollars is the violation of the nitrate level," states the Kansas Department of Health and Environment (1989a, 27). Pesticide contamination is generally more localized, and occurs primarily in eastern Kansas (Kansas Department of Health and Environment 1989b).

Oregon. In Oregon, the limited number of studies have found nitrate and pesticide contamination in specific areas. The Department of Environmental Quality found nitrates and pesticides occurring in varying percentages of the wells tested in five regions. In some areas over 50 percent of the wells were tainted and in some cases at levels exceeding

EPA maximum contaminant levels or health advisory levels. The wells selected for sampling were chosen for the highest likelihood of contamination (Pettit 1988).

North Dakota. Contamination in North Dakota has been relatively infrequent, has been linked more often to nitrates than pesticides, and has occurred in local areas throughout the state. In the Oakes Test area, where there are more observation wells than anywhere else in the state, 5 percent of the samples had levels between 1 mg/liter and 10 mg/liter, while 2 percent had levels greater than 10 mg/liter (NDSDH 1989, 26). Nitrates were found to be stratified in the groundwater with higher concentrations occurring closer to the surface. To date, out of eleven hundred samples taken as part of eight studies, only 34 have tested positive for pesticides, although none at levels considered high enough to pose a threat to human health (NDSDH 1989, 22).

Wisconsin. Detection of nitrate and pesticide contamination in Wisconsin, on the other hand, is relatively common. Nitrogen is most often tested for and most often found. The Wisconsin State Laboratory of Hygiene did 1,235 tests between June 1984 and July 1985 and found concentrations above 10 mg/liter in 26 percent of the samples. The Wisconsin Department of Natural Resources in 1985 sampled nearly 5,500 noncommunity public water wells (those serving schools, service stations, churches, parks, etc.) and found that 314 of the samples had concentrations greater than 10 mg/liter (Wisconsin Department of Natural Resources 1986, 25).

Pesticides have been detected in the Central Sands region, where 228 of 1,000 wells had detectable levels of aldicarb (Schreiber 1986). Twenty-five different pesticides have been detected in groundwater, including atrazine, alachlor, and aldicarb in 20, 9, and 24 percent of the samples, respectively (WGCC 1988). These results reflect investigations of point source cases or sampling in vulnerable areas and are not representative of the frequency of detection in randomly selected wells. A 1988-89 survey of Grade A dairy farm wells selected at random found pesticides in approximately 13 percent of 534 wells. Approximately 1 percent of the wells had a pesticide level above the enforcement standard, and 10 percent had nitrate concentrations above the state drinking water standard.

State Legislation and Administrative Structure

Formulation of state legislation to protect water quality is made difficult by the complexity of water contamination issues. Water quality problems associated with agricultural activities involve a broad range of potential contaminants and pathways by which they reach water systems. Uncertainty about effects of water contamination on human health and the environment also increases the difficulty states face in formulating legislation. Differences in soils, topography, hydrology, geology, and agricultural activity between states means different problems and different legislative responses.

States have enacted legislation to set and enforce standards, to expand and coordinate regulatory and research activities, and to provide funds for these activities (Batie et al. 1989; Wise and Johnson 1989). In addition, states are bound by federal regulations, namely in the Safe

Drinking Water Act (SDWA), the Clean Water Act (CWA), the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA or Superfund), the Resource Conservation and Recovery Act (RCRA), and the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA).

The following sections compare the five states in terms of protection philosophies, water quality legislation, and coordination of state agencies.

Protection Philosophy

The protection philosophies that states apply to their surface water and groundwater resources have been divided into the following three categories (Batie et al. 1989, 14-18):

- Nondegradation is defined as protecting or maintaining the existing quality of the water.
- Limited degradation is defined as the allowance or tolerance of contamination of the water resource to a health (or environmental) standard.
- Differential protection is defined as providing different standards of protection (limited degradation and/or nondegradation) based upon the use of the water resource (lake, river, aquifer) or possibly on the use of adjacent or overlying land.

Table 5 indicates the type of protection status that each of the five states gives to surface water and groundwater.

Kansas. Kansas provides one example of the application of the differential protection standard. Kansas surface waters are "classified" by use and different standards apply for different contaminants according to the use of the water: agriculture (irrigation, livestock), aquatic life support, and domestic water supply. Standards include criteria established by the EPA and the Kansas Department of Health and Environment (KDHE). Similarly for groundwater, Kansas's policy is that of nondegradation for potential sources of drinking water:

> The basic policy is to protect all fresh and useable water at its natural quality. If groundwater which is fresh or usable is contaminated it is to be restored to the criteria required by the most demanding beneficial use (Kansas Department of Health and Environment 1989b, 20).

In part, this differential protection approach is based on differences in groundwater quality across the state:

> Since natural groundwater quality varies widely throughout the state, a set of specific water quality criteria is inappropriate to assess pollution impacts. The criteria to identify groundwater pollution is a significant deterioration of quality from the expected natural range for the local area (Kansas Department of Health and Environment 1989b, 23).

Iowa. In contrast, the Iowa Groundwater Protection Act has a goal of nondegradation of the water resource: "to prevent contamination of groundwater to the maximum extent practical, and if necessary to restore

Table 5. Comparison of surface water and groundwater protection status for five states

State	Protection status: Nondegradation	Limited degradation	Differential protection
Iowa	groundwater		surface water
Kansas			surface water groundwater
North Dakota	surface water groundwater		
Oregon	surface water	groundwater	
Wisconsin		groundwater	surface water

the groundwater to a potable state, regardless of present condition, use, or characteristics" (Iowa Groundwater Protection Act of 1987, Section 104). Iowa surface waters are classified by use and, as in Kansas, different standards apply according to designated uses (IDNR 1986, 16-18).

North Dakota. North Dakota has a nondegradation protection philosophy for both surface and groundwater.

> It is the policy of the state to protect, maintain, and improve the quality of waters in the state for continued use as public and private water supplies; promulgation of wildlife, fish and aquatic life; and for domestic, agricultural, industrial, recreational, and other legitimate beneficial uses (NDSDH 1988).

Wisconsin. Wisconsin's limited degradation protection status utilizes a two-tiered set of contamination limits based on a health risk standard. These standards apply to all of the state's water resources. Other states have chosen to imitate Wisconsin's two-tiered protection strategy (Wisconsin Statutes 1984). Provisions of this legislation are discussed in the next section.

Oregon. In recent legislation, H.B. 3515, Oregon groundwater is given a limited degradation status based on trigger levels of contamination:

> It is the goal of the people of the State of Oregon to prevent the contamination of Oregon's groundwater resource while striving to conserve and restore this resource for present and future

uses...groundwater contamination levels shall be used to trigger specific governmental actions designed to prevent those levels from being exceeded or to restore groundwater quality to those levels.

As Batie and Diebel point out, there are costs and benefits to each approach to water quality protection. Because of the perceived impossibility of eliminating any impacts of human activities on the quality of local water resources, a nondegradation approach to water quality policy is considered unworkable by some. On the other hand, setting effective water quality standards is difficult because of uncertainty about the human health impacts of small amounts of waterborne contaminants and the diversity of agricultural chemicals and their properties.

Provisions of Water Quality Legislation: Standards, Cleanup, Prevention

Standards. While all states have water quality standards they employ, some have developed more extensive legislation than others.

Wisconsin. Of the five states, Wisconsin has the most comprehensive and specific standards. Wisconsin's 1984 groundwater legislation enacted a two-tiered system of standards: the first tier is a preventative action limit (PAL) that serves as a trigger for remedial action; the second tier is an enforcement standard that serves as the maximum allowable concentration of the substance in groundwater. The PAL is set as a percentage of the enforcement standard. The main criteria for the enforcement standard is human health impact.

Each Wisconsin regulatory agency is required to make a list of substances related to facilities, activities, and practices within its domain, which are detected in or could enter the groundwater of the state. Using these lists the Wisconsin Department of Natural Resources (WDNR) must rank the substances according to perceived risk to health or welfare of the citizens of the state (Wisconsin Department of Health and Social Services 1985). The health risk determined by the Wisconsin Department of Health and Social Services (WDHSS), is based on information from previous health risk-related studies (available through the Environmental Protection Agency's IRIS--a bibliography of such studies). The WDHSS then makes a recommendation to the WDNR, which reviews the recommendation, holds public hearings, and establishes the enforcement standard.

In general, it is expected that Wisconsin enforcement standards will be amended to be consistent with the federal standard for specific substances as they are determined by the Environmental Protection Agency (WDNR 1988).

Oregon. With passage of H.B. 3515 in 1989, Oregon initiated a comprehensive standard-setting policy similar to Wisconsin's in which pollution levels prompt official action. H.B. 3515 says that "groundwater contamination levels shall be used to trigger specific governmental actions designed to prevent those levels from being exceeded or to restore groundwater quality to those levels" (H.B. 3515 1989, Section 19, 9).

The Oregon Environmental Quality Commission establishes maximum measurable contaminant levels in groundwater. The criteria and methods it uses are determined by a technical advisory group appointed by the Strategic Water Management Group (representatives of nine state agencies involved in natural resources and water management). The commission must consider but is not bound by any federal standards that may exist, and it can determine a stricter standard. The Department of Environmental Quality oversees and supports the standard-setting process.

Kansas. Kansas Water Quality Standards include maximum contamination levels for surface water for a variety of potential contaminants according to the beneficial use of the water. In considering water use Kansas differs from Wisconsin and Oregon, who do not take into account the use of the water resource. At present no standards exist for Kansas groundwater, but drinking water and surface water standards are assumed to apply (conversation with Ron Fox, Director, Bureau of Environmental Quality, Kansas Department of Health and Environment).

North Dakota. In North Dakota, water quality standards for nitrogen are enumerated in the State Administrative Code. State standards for agricultural pesticides have not been developed. Initially intended for the protection of surface waters, the state standards have been extended to groundwater as well.

Iowa. Iowa follows federal standards for surface water quality. For groundwater, the Iowa Groundwater Protection Act of 1987 specified a policy of almost zero tolerance for contamination. Despite its current stance, Iowa legislation indicates that standards are to be considered in the future. It remains an open question whether Iowa will join other states in establishing its own set of standards and rules for enforcement.

National Perspective. On one hand, standards tailored to each state's goals, problems, and institutional structures create an uneven pattern of protection with implications for interstate coordination, interstate businesses, and environmental quality. On the other hand, allowing states to determine approaches that best meet their needs and can be administered through existing administrative structure may allow more efficient and flexible implementation of environmental policy than a single federal policy.

The tendency among these five states is to rely on standards to provide a signal of excessive contamination and need for action, and to define tolerable limits of contamination. Philosophically, these approaches are in keeping with concepts of limited degradation and differential protection. Federal maximum contamination levels (MCLs) and state enforcement standards seek a balance between economic activity that may contaminate water resources and the maintenance of a certain level of water quality.

Cleanup and Prevention. Regardless of its development or implementation of water quality standards, each of the five states has extensive and varied programs for cleanup and/or prevention of contamination. Similarities among programs include registration of toxic substances including pesticides, provision of funds for local cleanup or preventative efforts, areawide education and management programs, and regulatory authority to limit contaminant use in affected areas. Specific examples are discussed below.

Oregon. Oregon Senate Bill 23 (1987) established the Watershed Enhancement Program to provide support and funding for projects that "improve or enhance riparian areas and associated uplands" (Watershed Enhancement Program brochure). The program was given $500,000 in 1987 for watershed projects relying on local volunteers and local matching funds. Between August 1987 and April 1989, 19 projects were approved at a cost of $434,000. An additional $27,000 was allocated for education and public awareness programs, and $34,000 was granted to Soil and Water Conservation Districts. The program is coordinated by the Governor's Watershed Enhancement Board, consisting of five voting members of state natural resource boards and commissions and five nonvoting members from state and federal agencies.

In terms of regulatory policy, the Oregon Department of Environmental Quality and the Health Division have the power to declare an "area of groundwater concern" if they detect presence of contaminants from nonpoint sources. If the contamination levels are high enough (above 50 percent of the state maximum contamination levels for pesticides and above 70 percent of the state maximum contamination levels for nitrates), the area is declared a "groundwater management area." In each case, the Oregon Strategic Water Management Group (an interagency group that coordinates water contamination regulation and policy development) appoints a local groundwater management committee, and helps draft local action plans. In the less severe contamination case, local action plans rely on voluntary participation. Where contamination has passed "trigger" limits and a groundwater management area is designated, the Strategic Water Management Group appoints a state agency to take the lead in developing an action plan that may include regulatory action such as restriction of pesticide use. Other cleanup and prevention programs include wellhead protection, anti-back-siphoning devices for irrigation equipment, and permanent abandonment of wells.

North Dakota. In North Dakota, the Pesticide Control Board was created for the purpose of regulating all aspects of pesticide use. The board is composed of the state agricultural commissioner, the directors of the North Dakota Agricultural Experiment Station, and the North Dakota Cooperative Extension Service, and has the power to restrict use of pesticides in designated areas for specified periods of time. The North Dakota Agriculture Department is authorized to make rules concerning chemigation, the applications of the pesticides and fertilizers through the irrigation system. The State Water Commission has authority to reduce or discontinue an irrigation project if it is determined it may cause groundwater contamination, and also to require certain standards in well construction before permitting use of a well for irrigation purposes.

Wisconsin. Wisconsin's Nonpoint Source Pollution Abatement Program was established in 1978 to provide grants and technical assistance to individual landowners and communities to offset installation costs of pollution control practices and devices. At present there are 39 priority watershed projects in various stages of development or implementation (WDNR 1988).

The Wisconsin Soil and Water Resources Management Program was created in 1987-89 to provide financial and technical assistance to local management agencies, such as soil conservation departments, who implement plans to limit soil erosion and animal waste pollution, for example. The Wisconsin Department of Agriculture, Trade and Consumer

Protection (WDATCP) administers the program and has various options for responding to water contamination above Wisconsin enforcement standards when pesticides or fertilizers are involved (WDNR 1988).

Iowa. In Iowa, pesticide usage in accordance with product label is not considered to constitute a hazardous condition. However, the states' Environmental Protection Commission has authority to determine when an agricultural chemical is a threat to humans or the environment. After making such a determination, the commission alerts the secretary of the Iowa Department of Agriculture and Land Stewardship and recommends action. The secretary reviews the pesticide's impact and implements recommended actions. The secretary may impose statewide or local bans or restrictions, and designate management practice areas. In addition, the Iowa Groundwater Protection Act places emphasis on educational programs and voluntary compliance in establishment of environmentally sound agricultural practices. This is accomplished through the support of programs, such as the Integrated Farm Management Demonstration Program, and research centers, such as the Aldo Leopold Center for Sustainable Agriculture and the Center for Health Effects of Environmental Contaminants.

Administration

A variety of agencies in each of the five states has responsibility in water quality and agricultural contamination issues (see Tables 6-10). For example, water use and water quality regulation is usually divided between agencies responsible for water use (i.e., issuing water permits for irrigation) and agencies responsible for water quality with an

Table 6. Iowa state agencies and institutions involved in agriculture and water quality data collection, research, and regulation

Agency	Responsibility/Activities concerning agriculture and water quality
Iowa Department of Natural Resources	Lead environmental regulatory agency responsible for reporting to federal agencies on water quality in Iowa; various research projects--Big Spring Basin, Statewide Rural Well Water Survey, others.
Iowa Department of Agriculture and Land Stewardship	Lead state agricultural agency. Cooperator in county soil surveys, collection and reporting of state agricultural statistics. Participates in various agricultural projects, such as the Integrated Farm Management Demonstration Program.
Iowa Agricultural Statistics (IAS)	Reports on Iowa agricultural statistics--yields, production, acreages, livestock numbers, prices, and costs--on annual basis; gathers specific agricultural data on a project basis pending approval of the Iowa secretary of agriculture; provides state data to U.S. Department of Agriculture by request.
University Hygienics Laboratory (UHL)	Handles the majority of surface and groundwater laboratory analyses undertaken as monitoring programs and research projects.
Center for Health Effects of Environmental Contaminants (CHEEC)	Maintains computerized data base on water sample analyses, water supply sources, and water supply treatment characteristics for municipal and private drinking water in Iowa. Participates in research projects on water quality and human health. Created by the 1987 Groundwater Protection Act.
Institute of Agricultural Medicine and Occupational Health	Participates with CHEEC in the validation of health information collected in water quality surveys, and with other agencies in data collection and analysis (i.e., Statewide Rural Well Water Survey).

Table 6. Continued

Agency	Responsibility/Activities concerning agriculture and water quality
Agriculture and Home Economics Experiment Station	Agricultural research--chemical input use efficiency, tillage and conservation measures, low-input sustainable agriculture; maintains system of Outlying Research Centers representing different environmental and agronomic characteristics of Iowa.
Aldo Leopold Center for Sustainable Agriculture	Funds research in alternative resource conserving and low-input agricultural practices; collaborates with Cooperative Extension Service in dissemination and education about alternative, sustainable practices. Created by the 1987 Groundwater Protection Act.
Center for Agricultural and Rural Development (CARD)	Employs hydrological and geophysical and economic models to study (CARD) environmental and agricultural economic consequences of alternative agricultural policies.
University of Iowa	Various departments--environmental engineering, preventative medicine--are involved in agriculture and water quality research. Emphasis on engineering (chemical fate and transport models) and health effects.

Table 7. Kansas state agencies and institutions involved in agriculture and water quality data collection, research, and regulation

Agency	Responsibility/Activities concerning agriculture and water quality
Kansas Department of Health and Environment (KDHE)	Lead regulatory agency for the state in water quality issues, monitoring, and enforcement. Collaborates with the U.S. Geological Survey in surface and groundwater fixed site monitoring networks. Establishes minimum well construction standards and programs for abandoned wells, well development for drinking water, and underground storage tanks.
Kansas Water Office	Created in 1981 to provide organizational coordination through formulation of State Water Plan--a continuous policy planning process that prioritizes goals and approves water programs and projects of all state agencies. Prepares annual report detailing current and ongoing water-related research.
State Board of Agriculture	Composed of 12 members of various agricultural organizations. Elects the secretary of agriculture. Various divisions of the board regulate water and agricultural chemical use including: water rights permits, pesticide applicator certification, chemigation procedures, pesticide and fertilizer bulk storage and handling.
Kansas Water Authority	Representatives of agencies with water-related activities. Advises the governor, the legislature, and the director of the Kansas Water Office on water policy issues.
Kansas Geological Survey (KSG)	Research and data collection activities, including pesticide fate and transport, and mapping activities--digitized stream, geology, and depth to water.
Kansas Biological Survey (KBS)	Research and data collection concerning nonpoint source pollution problems in streams and riparian zones and impacts on biological organisms. Development of rapid assessment techniques and biotic indices of water quality.

Table 7. Continued

Agency	Responsibility/Activities concerning agriculture and water quality
Kansas Department of Wildlife and Parks	Stream sampling involving fish surveys and tissue sampling. Provides cost share with USDA/SCS on watershed protection projects, collaborates with the KDHE on reported fish kills. Inventories wetlands of the state.
Kansas State Conservation Commission	Operates nonpoint source pollution control program, provides state matching funds on water resource projects, and provides state aid to conservation districts.
Kansas Water Data Committee	Formed in 1983 as an interagency committee involving local, state, and federal agencies for the purpose of sharing water-related data across agencies and avoiding duplication of effort in data base development. Compiles Kansas Water Resources Database, a listing of state and federal water-related data bases. Recent initiatives include coordinating development of a geographic information system for water-related agencies and the standardizing of well identification.

Table 8. North Dakota state agencies and institutions involved in agriculture and water quality data collection, research, and regulation

Agency	Responsibility/Activities concerning agriculture and water quality
North Dakota State Department of Health (NDSDH)	Lead agency for the protection of water quality in the state. Collects and stores water quality data, funds projects to restore or protect water quality.
North Dakota Water Commission (NDWC)	Issues water use permits, inventories water resources, carries out projects related to agriculture and water quality, such as Garrison Diversion Project.
North Dakota Geological Survey (NDGS)	Funds and carries out projects.
North Dakota Department of Agriculture (NDDA)	Enforces state laws regulating the use of pesticides. Collects information on pesticide use and application methods.
North Dakota State University Cooperative Extension Service	Research, demonstration, and education in efficient and resource conserving agricultural practices, specifically the Oakes Test area project.
North Dakota Water Quality Task Force and Working Group	Representatives from major state and federal government agencies within the state, farm organizations, special interest groups. Identification and prioritization of groundwater issues.

Table 9. Oregon state agencies and institutions involved in agriculture and water quality data collection, research, and regulation

Agency	Responsibility/Activities concerning agriculture and water quality
Department of Environmental Quality (DEQ)	Administers all or part of federal programs, such as Clean Water Act, Safe Drinking Water Act, and Superfund. Conducts groundwater sample testing, provides public information, coordinates state and federal agencies on all matters affecting the state's water resources.
Water Resources Department (WRD)	Statutory provisions require development of integrated state policy and programs; preservation of stream flows by the establishment of in-stream water rights; characterization of groundwater resources; enforcement of water rights; and identification of critical groundwater areas. Groundwater Act of 1955 identifies WRD responsibility for development of well construction and abandonment requirements. Licenses well constructors. A newly created water availability program provides for systematic identification of surface water availability at gauged locations and estimations for ungauged locations.
Department of Human Resources, Health Division (HD)	In accordance with the provisions of the Safe Drinking Water Act, establishes drinking water standards. Identifies health hazards. Involved in developing rules for standards for eight volatile organic compounds (VOCs), and is responsible for implementing EPA VOC standards as they are developed.
Department of Agriculture (ODA)	Administers FIFRA rules concerning registration of pesticides used, sold, and formulated in the state. Licenses pesticide applicators. Oversees records on all pesticides and fertilizers formulated and sold in the state. Groundwater sampling and testing for some agricultural chemicals.
Department of Land Conservation and Development (DLCD)	Reviews local land use plans and resource inventories for compliance with statewide planning goals.

Table 9. Continued

Agency	Responsibility/Activities concerning agriculture and water quality
Department of Forestry (DOF)	Coordinates with HD, DEQ, and WRD on forest operations impact on water quality, state and federal regulations, and water resource development.
Department of Fish and Wildlife (DFW)	Responsible for maintaining the fish and wildlife resources of the state. Coordinates with WRD on water rights and minimum stream flows, and with DEQ on water quality.
Oregon State University	Various departments participate in agricultural and water quality research. Location of Oregon Water Resources Research Institute.

Table 10. Wisconsin state agencies and institutions involved in agriculture and water quality data collection, research, and regulation

Agency	Responsibility/Activities concerning agriculture and water quality
Department of Natural Resources (DNR)	Lead responsibility for water resources management, surface and groundwater quality standards, monitoring programs, water quality data management, regulation of private and public domestic water supplies, well drilling, well abandonment, and drinking water standards.
Department of Health and Social Services (DHSS)	Serves in an advisory role, recommending levels for groundwater standards and drinking water standards to the DNR based on health risk assessment.
Department of Agriculture, Trade and Consumer Protection (DATCP)	Regulates the storage of pesticides and fertilizers, enforces FIFRA, regulates the manufacture, sale, and use of pesticides in the state. Administers the Wisconsin Farmers Fund, which provides grants to eligible applicants for construction of animal waste management facilities. Develops agricultural best management practices (MBPs).
Geological and Natural History Survey (WGNHS)	Inventories and maps geologic and hydrogeologic resources of the state. Groundwater-related research, and county-level groundwater resource reports. Prepares and disseminates informational materials.
Central Wisconsin Groundwater Center	Initiated in 1985 to provide groundwater information and education to the citizens of Central Wisconsin. Manages informal program for sampling finished water in Central Sands District. Develops pilot geographical information system for Central Sands and agricultural best management practices.
University of Wisconsin	Conducts research, develops MBPs, disseminates information through agricultural extension offices, prepares and presents education materials.

emphasis on public drinking water supplies (i.e., state departments of health, environment, or natural resources). While most water quality monitoring is carried out by departments of environment or natural resources, departments of agriculture are often responsible for handling contamination incidents from agricultural chemicals.

Data collection and research are handled by a broad group of state agencies and institutions, including state universities, research centers, and research-oriented state agencies. The Iowa Groundwater Protection Act of 1987 provided for creation of two such research and educational centers--the Aldo Leopold Center for Sustainable Agriculture and the Center for Health Effects of Environmental Contaminants. The Central Wisconsin Groundwater Center conducts research and educational activities in the Central Sands region of the state. (The center is an outreach function of the University of Wisconsin-Stevens Point, Department of Natural Resources and is funded through the University of Wisconsin-Cooperative Extension Service.)

The research and data collection efforts are aided and complemented by regional or state-level offices of federal agencies or federally supported institutions, such as the U.S. Geological Survey, U.S. Environmental Protection Agency, several agencies within the U.S. Department of Agriculture including the Soil Conservation Service, National Agricultural Statistical Service and the Cooperative Extension Service, and the Water Resource Research Institutes (see Table 11).

To cope with this diverse group, states have developed a variety of mechanisms for interagency coordination. Most commonly, state agencies establish bilateral memorandums of understanding between agencies to

Table 11. Federal and state-level institutions involved in agriculture and water quality research common to all states

Agency	Responsibility/Activities concerning agriculture and water quality
U.S. Geological Survey	Organizes the collection of water quality, discharge, and site inventory data; updates national data base (WATSTORE); transfers WATSTORE to EPA. Operates office in each state.
U.S. Environmental Protection Agency	Supports and maintains the STORET data base containing information on quality of surface waters on a state by state basis; funds numerous research projects covering water contamination, pesticide use, health impacts. Supports a bibliographic data base of health-related studies (IRIS). Operates regional offices covering 3-4 states.
U.S. Department of Agriculture, Soil Conservation Service	Participates in and funds projects involving soil conservation. Lead agency for and publisher of county-level soil maps.
U.S. Department of Agriculture, Economic Research Service	Conducts and supports research projects related to agriculture and water quality. Maintains data bases on agricultural practices.
U.S. Department of Agriculture, National Agricultural Statistics Service (NASS)	Collects data regarding agricultural practices and agricultural resource inventories at the state and substate level. Publishes national and state agricultural statistics annually. Cooperates with state departments of agriculture and agricultural statistics.
U.S. Department of Agriculture, Cooperative Extension Service	Research, demonstration, and education in efficient and environment conserving agricultural practices; participation in various statewide projects.
(State) Water Resources Research Institute	Funds research projects concerning the fate and transport of agricultural chemicals, best management practices, etc. Provides training for scientists in various disciplines through research activities.

handle exchanges of information, data collection, and coordination of regulatory activities. For example, the development of water quality standards in Wisconsin begins with a recommendation by the Department of Health and Social Services to the Department of Natural Resources for consideration in its rule-making process. In addition, state laboratories typically disseminate results of water quality analyses to appropriate regulatory agencies, such as the state departments of agriculture in pesticide cases.

Some states have created specific offices or working groups to provide coordination in state strategies, priority setting, policy making, and research.

- Oregon's Strategic Water Management Group, chaired by the governor, consists of 12 agencies, including the Department of Environmental Quality, the Water Resources Department, the Department of Health, and the Department of Agriculture among them. The group is charged with developing and maintaining a centralized repository for groundwater information including hydrogeology, monitoring program results, and residential, industrial, and agricultural best management practices for the protection of groundwater.

- The North Dakota Groundwater Task Force includes representatives from state agencies, federal government agencies within the state, farm organizations, and special interest groups. It performs several functions including identification and prioritization of groundwater issues.

- The Kansas State Water Office and the Kansas Water Authority are in charge of continuous planning and review to prioritize goals and coordinate activities of various state agencies in keeping with the state water plan. Each year the Kansas Water Authority reviews program plans and budgets pertaining to the state's water resources. Kansas state statutes require coordination of financial assistance and research: "review and coordination of financial assistance for research that may be provided by federal or state agencies to public corporations concerned with management, conservation, and development of water resources to prevent duplication of effort" (K.S.A. 82a-928(14)). The Kansas Water Data Committee develops methods for sharing water-related data between agencies, and coordinates data collection and storage. To enhance sharing of data among agencies, the committee publishes a manual, Kansas Water Resources Database, which compiles descriptions of 68 data files maintained by various member agencies of the committee. The monthly meetings of the water data committee provide a forum for development of standardized data collection and record keeping, such as a well identification numbering system, locational indicators for identifying sampling sites, and such. The Kansas Water Office collects and compiles information pertaining to climate, water, and soil as these are affected by water usage for agricultural, industrial, and municipal purposes.

- The Wisconsin Groundwater Coordinating Council coordinates the nonregulatory activities of various state agencies and the exchange of information relating to groundwater (WDNR 1984, 4).

The council has eight members representing the governor and state agencies involved in groundwater issues (the departments of natural resources, industry, transportation, health and social services, agriculture, and trade and consumer protection, and the University of Wisconsin, and the State Geologist). The Department of Natural Resources is developing a groundwater information network to serve as a repository for groundwater data, including groundwater quality test results, well inventory, and such.

- The Iowa Department of Natural Resources has begun development of a statewide geographic information system intended to provide a common data repository with analytical capabilities for planning natural resource use and development activities.

State Data Bases and Research Projects

In this section we will first take a general look at available data, then discuss water quality monitoring systems and pesticide use surveys.

Overview of Available Data

The total data set available to states for policy formulation and investigation of agriculture and water quality issues consists of federal and state data bases and research projects. Because of the interdisciplinary nature of the agriculture and water quality issue, data are dispersed among a wide variety of state and federal agencies and are aggregated and stored in different forms. Research projects represent an informal set of data, with some data kept in idiosyncratic forms by individual researchers and some data added to state or federal data bases.

Tables 12 through 16 provide descriptions of data bases and selected research projects for each of the five states.

Several types of data bases are found, including the following:

1. Common to all states is the registration of all agricultural pesticides prior to their use in the state. States typically license or certify applicators of agricultural chemicals and register merchants of restricted-use or toxic chemicals. Usually, such data consist of a current record kept in manual or paper files.

2. States also keep records of wells drilled by licensed well drillers--often numbering in the hundreds of thousands. These data bases are often manual files (Iowa, Oregon), although Kansas and North Dakota have computerized their water well record and Iowa is developing one. It is uncertain how complete these well records are, since some wells may predate data collection efforts or were never reported, and some wells have been abandoned. The Iowa record of rural wells is based on responses to a survey of property owners and tenants.

3. States have a variety of natural resource information/data bases, many of which represent collaboration between federal and state agencies. For example:

(a) Soil surveys done on a county basis for all states are published by the U.S. Department of Agriculture/Soil Conservation Service. Counties are resurveyed periodically, but certain county surveys may be 10 to 20 years old. For very few of the counties in any of the five states have the soil surveys been digitized (stored electronically according to mapping coordinates).

Table 12. Iowa data bases and research projects supporting environmental policy for agriculture and water quality

Data Base/Source of Data (Principal Institution)	Purpose	Description	Data Characteristics	Collaborating Agencies
<u>Data Base</u>				
Statewide Rural Well Water Survey (Department of Natural Resources)	Monitor rural groundwater/ drinking water contamination levels.	700 rural wells in 99 Iowa counties were surveyed in 1988-89 as part of the 1987 Groundwater Protection Act. Wells were selected based on a stratified systematic sample weighted by rural population density.	Nitrate, coliform bacteria, 27 pesticides, selected environmental metabolites of pesticides, organic and toxicity screening, and major ions. Ten percent of the wells were sampled twice, and 63 wells in representative soil-landscape-hydrogeologic regions were sampled quarterly.	9, 15, 16, 17, 18
Municipal Water Supply Inventory (MWSI) (Department of Natural Resources)	Consolidate information on municipal wells.	Active municipal wells number about 2,000 in Iowa (inactive wells are equally numerous). Initiated in 1981, the MWSI consists of a computerized data base of municipal wells.	Parameters include well depth and construction, metal and mineral analyses. Water quality information available is included either for individual wells or for associated aquifers.	17
Stream Monitoring Network (Iowa Department of Natural Resources)	Ambient and point source waste discharge monitoring.	Routine monitoring of streams at 38 fixed stations initiated in the early 1970s; 37 other locations monitored by other agencies (Army Corps of Engineers, power companies, etc.).	Sampling done quarterly for conventional parameters including nitrates, phosphorus, but not including pesticides. Data entered into EPA STORET.	
Fish Tissue Monitoring (Iowa Department of Natural Resources)	Identify location, type and trends of toxic contamination.	Since 1980, IDNR monitors fish tissue for pesticides and heavy metals in addition to the 17 sites of the EPA's Regional Ambient Fish Tissue Monitoring Program.	IDNR samples six fixed locations on a monthly basis for two pesticides and heavy metals.	

Table 12. Continued

Data Base/Source of Data (Principal Institution)	Purpose	Description	Data Characteristics	Collaborating Agencies
Rural Wells Estimate (Iowa Department of Natural Resources)	Inventory private wells.	In 1982, at the direction of the Legislature, the Iowa Geological Survey cooperated with the Iowa State Association of Assessors and the Iowa Department of Revenue in mailed survey of property owners and tenants.	A total of 158,320 wells were reported, including 21,775 abandoned wells. Wells were identified by type—irrigation, drainage, household, abandoned, other—and location (address).	
<u>Research Projects</u>				
Prairie Rose Lake (USDA/SCS and ASCS)	Develop non-regulatory approach to sedimentation problem.	Sedimentation and agricultural chemical reduction in Prairie Rose Lake through culvert and control basin construction and subsidies for adoption of Best Management Practices among area farmers.		
Big Spring Basin Demonstration Project (Department of Natural Resources)	Develop and demonstrate alternative agricultural practices.	Demonstrations of alternative tillage, fertilizer and weed management techniques; development of a non-regulatory approach to reduce environmental impacts of agriculture in 103 square mile Big Spring Basin.		
Floyd and Mitchell Counties Rural Well Water Survey (Department of Natural Resources)	Assess relationship between geology and groundwater contamination	Survey of the presence of nitrates and pesticides in groundwater in two Iowa counties for 184 rural wells at different depths, in association with different area agricultural practices, etc.		

Table 12. Continued

Data Base/Source of Data (Principal Institution)	Purpose	Description	Data Characteristics	Collaborating Agencies
Integrated Farm Management Demonstration Program (Iowa Cooperative Extension Service, Iowa Ag. Experiment Station)	Demonstrate alternative farming practices.	Research and education program aimed at enhancing efficient use of agricultural chemical inputs and reducing environmental impacts.		
Geographic Information System (GIS) (Department of Natural Resources)	Resource use planning, development, and regulation.	Development of comprehensive natural resource GIS for improved management of Iowa's natural resources. Includes landscape, land use, hydrogeology, mineral resource, etc., data.		

Key to collaborating agencies:

1. U.S. Geological Survey
2. U.S. Environmental Protection Agency
3. USDA/Soil Conservation Service
4. USDA/Agricultural Stabilization and Conservation Service
5. U.S. Army Corps of Engineers
6. Iowa Department of Natural Resources
7. Iowa Department of Agriculture and Land Stewardship
8. Iowa Agricultural Statistics
9. Iowa State Cooperative Extension Service
10. Iowa State University, Dept. of Agricultural Engineering
11. Iowa State University, Dept. of Agronomy
12. Aldo Leopold Center for Sustainable Agriculture
13. Center for Agricultural and Rural Development
14. Iowa State Water Resources Research Institute
15. University of Iowa, Dept. of Civil and Environmental Engineering
16. Institute of Agricultural Medicine and Occupational Health
17. Center for Health Effects of Environmental Contaminants
18. University Hygienics Laboratory
19. National Oceanic and Atmospheric Administration
20. Iowa State University Statistical Laboratory

Table 13. Kansas data bases and research projects supporting environmental policy for agriculture and water quality

Data Base/Source of Data (Principal Institution)	Purpose	Description	Data Characteristics	Collaborating Agencies
Data Base				
Stream Monitoring Network (Kansas Department of Health and Environment)	Analysis of stream water quality for compliance with state and federal regulations.	Begun in 1967, the network currently consists of 115 fixed monitoring sites across the state (55-60 of which are U.S. Geological Survey gauging stations). Stations reflect water run-off flows, generally located upstream and downstream of major cities.	Historical and current data on EPA STORET system. From 1985, data also on Kansas computer system. 85 sites monitored monthly, 10 quarterly 20 annually. Pesticides, VOCs, heavy metals only tested for annually. All sites identified by longitude/latitude and township/range/section.	
Lake Monitoring Network (Kansas Department of Health and Environment)	Analysis of lake water quality for compliance with state and federal regulations	The network includes 120 lakes statewide of which roughly 30 are tested per year. Samples are taken in summer months.	All data identified by longitude/ latitude and township/range/ section. Historical data is on EPA's STORET system. From 1985, data also entered on Kansas computer system.	
Kansas Stream Survey (Kansas Department of Wildlife and Parks)	Inventory and evaluate fish communities and physical and chemical characteristics of stream waters.	Initiated in 1976, the stream survey provides variable coverage statewide. Future plans include establishment of fixed station monitoring system.	Data are identified by longitude/ latitude and township/range/section. Sampling is done once annually. Data is maintained in SAS file at the department.	

Table 13. Continued

Data Base/Source of Data (Principal Institution)	Purpose	Description	Data Characteristics	Collaborating Agencies
Groundwater Quality Monitoring Network (Kansas Department of Health and Environment)	Determine background conditions of groundwater and identify water quality changes over time.	Established in 1976, the network now consists of approximately 240 wells located with an emphasis on public water supplies and irrigation wells, which are deep and of good construction. These wells are representative of aquifers, not susceptible areas.	Groundwater samples from the well network are tested for inorganic compounds each year. 50 wells on a rotational basis are tested each year for VOCs, pesticides, and heavy metals. Well collection sites are identified by longitude/latitude and township/range/section. Historical and current data is on USGS' WATSTORE. From 1985, data also on Kansas computer system.	
Chemigation Well Monitoring (Kansas State Board of Agriculture)	Test for pesticide detections/ concentrations in chemigation wells.	Initiated in 1987, based on Kansas 1985 regulations on chemigation practices.	29 pesticides and fertilizer tests are done for each sample. Sample sites are identified by longitude/ latitude and township/range/ section.	
Pesticides in Treated Drinking Water (Kansas Department of Health and Environment)	Test for pesticide detections/ concentrations in treated drinking water from surface water sources.	Testing is done every three years, including between 60 and 100 wells.	Sampling occurs during March through October.	
Water Well Records (Kansas Department (of Health and Environment)	Record of construction and location of wells.	Record of well driller log information required by state at time of well drilling and construction. Water Well Record form includes: location, depth to water, casing, pump test, local potential contamination sites.	Computerized records from 1974 to the present on the Kansas computer system. On-line query and batch capabilities. Locational identifier is township/range/section/quarter/ quarter.	

Table 13. Continued

Data Base/Source of Data (Principal Institution)	Purpose	Description	Data Characteristics	Collaborating Agencies
Groundwater Quality Data (Kansas Geological Survey)	Chemical properties of groundwater as needed for water use.	Chemical properties and concentrations of trace constituents of groundwater are evaluated on a request basis.	Data are stored on Kansas Geological Survey computer system. Data from 1974. Sampling done on an ad hoc basis.	
Research Projects				
Farmstead Well Contamination Study (Kansas Department of Health and Environment)	Estimate farmstead well contamination and sources of contamination, develop educational program.	Phase I: statewide sampling of 103 farmstead wells between 1986-87 for VOCs, inorganics, and pesticides, based on well density per county for 50 counties. Phase II: 84 various wells representing different characteristics, such as soil type, depth to water, well construction, and proximity to potential contamination sources.	Prevalence of contaminants evaluated by farm type and local land use.	
Public Water Supply Well Pesticide Screening (Kansas Department of Health and Environment)	Test for pesticide detections/ concentrations in public water supply source wells.	Initiated in 1987 for PWS source wells deemed susceptible to contamination due to construction, depth and local land use.	A total of 123 wells of 2,100 wells were sampled of which 12 contained pesticides. Two were removed from service.	

Table 14. North Dakota data bases and research projects supporting environmental policy for agriculture and water quality

Data Base/Source of Data (Principal Institution)	Purpose	Description	Data Characteristics	Collaborating Agencies
Data base				
North Dakota State Department of Health Groundwater Quality Base (North Dakota State Department of Health)	Document groundwater quality and record detections of contamination in the state.	The data base is a collection of results from the monitoring of community and noncommunity wells in compliance with the Safe Drinking Water Act (SDWA) of 1977, compliance monitoring required when contamination incidents are suspected and from special studies initiated to evaluate the effectiveness of existing programs, facility performance, etc.	Records in the NDSDH groundwater data base date back to the 1960s. Data are collected from the routine sampling of 333 community (serve more than 25 individuals) wells once every 3 years for primary inorganic contaminants and 373 noncommunity wells are sampled quarterly for nitrates and other contaminants in compliance with the SWDA. 275 compliance monitoring wells at a myriad of facilities all across the state are actively sampled. Data are locationally identified by township/range/section.	
Water Quality/Levels Monitoring Network (North Dakota State Water Commission)	To evaluate groundwater resources, and to determine the effects of seasonal variation in climate and water withdrawal in areas of significant groundwater development.	Data are collected in areas of groundwater development, selected monitoring and production wells are sampled for water quality. These wells are part of a major network of wells most of which are monitored for water levels.	Wells are sampled on a monthly or annual basis. Approximately 500 to 700 wells are sampled each year, and another 200 to 300 wells are monitored as part of site specific studies. The records are identified locationally by township/range/section.	

Table 14. Continued

Data Base/Source of Data (Principal Institution)	Purpose	Description	Data Characteristics	Collaborating Agencies
Computerized Water Permit File (North Dakota State Water Commission)	To track annual water use and to efficiently store information related to the issuance of water permits.	Information from water permit documentation is stored in the Water Permit File. It includes information on intended use, points of diversion, identification of land irrigated, pumping rates, and annual water use.	Most of the data related to the water permits are recorded only once, such as intended use. Area irrigated, pumping rates and water use however are collected annually. Locations are identified by township/range/section. It includes data from over 300 water permits.	
County Groundwater Program (U.S. Geological Survey)	To determine the location, condition, and extent of major aquifers and groundwater movements.	Contains information from a project begun in 1950. Every county in the state was inventoried to determine the quantity and quality of groundwater available for all uses in North Dakota.	Water quality measurements for nitrates and other contaminants from 353 water samples was collected. Geologic and hydrologic data from 1,209 wells, test holes, and springs, water level measurements from 148 observation wells and other data were collected. County updates were made as technology and resources permitted. The data are stored in 3 volumes of reports created for each county.	2, 3, 5

Table 14. Continued

Data Base/Source of Data (Principal Institution)	Purpose	Description	Data Characteristics	Collaborating Agencies
Research Projects				
Groundwater Mapping Program (Bottineau County Weed Board)	To identify areas with a high risk of groundwater contamination from agricultural chemicals.	Given aquifer type and depth to water table, areas were ranked low, moderate, and highly susceptible to contamination according to weighting of soil type, hydrology, and underlying geology. Ranking was limited to areas where the water table was within 60 inches of the surface. The rankings identify geographical cross sections of soil series and aquifers in the form of maps. A separate map was completed for each county in the state.		1, 6
Major Management Studies (North Dakota State Water Commission)	Further define geometry of aquifer system and water movement.	Viewed as second generation studies of several aquifer systems after the County Groundwater Program. Two of 15 studies investigate agricultural chemical contamination problems. In part, studies motivated by requests for water permits.		

Table 14. Continued

Data Base/Source of Data (Principal Institution)	Purpose	Description	Data Characteristics	Collaborating Agencies
Various Studies—Garrison Diversion Unit/Oakes Test Area (U.S. Bureau of Reclamation)	To evaluate various aspects of irrigated agriculture.	All of the studies were carried out at the Oakes Test area near Oakes, North Dakota. A multitude of studies provide evaluations of best management practices, irrigation system designs, composition of return flow waters, water levels and quality. Data include inventories of agricultural practices, pesticide use, soils inventory, pesticide concentrations in surface and groundwater. N, P, and K water sampling data collected monthly from 62 wells.		7, 8, 9
Priority Watersheds Program (North Dakota Department of Health)	Technical and financial assistance for nonpoint source pollution control.	High priority watersheds were identified on the basis of value of water bodies, risk of nonpoint source contamination, potential cost-effectiveness of programs, cooperation and interest of various agencies, and public concern. Participating agencies will also implement: demonstration, education, and monitoring projects as well as regulatory programs.		1,2,5,6 10, 11

Key to collaborating agencies:

1. North Dakota State Department of Health (NDSDH)
2. North Dakota State Water Commission (NDSWC)
3. North Dakota Geological Survey (NDGS)
4. North Dakota Agricultural Department (NDAD)
5. County/Water Management Districts
6. USDA/Soil Conservation Service (SCS)
7. North Dakota State University (NDSU)
8. Agricultural Experiment Station—NDSU
9. U.S. Geological Survey (USGS)
10. North Dakota Game and Fish Department
11. County Soil Conservation Districts

Table 15. Oregon data bases and research projects supporting environmental policy for agriculture and water quality

Data Base/Source of Data (Principal Institution)	Purpose	Description	Data Characteristics	Collaborating Agencies
<u>Data Base</u>				
Surface Water Gauging Stations (Water Resources Department)	Monitor flow levels.	Statewide system of stream gauging stations with an emphasis on the bottom of river basins and major tributary sites. Data collection began in 1900. The current system includes 270 gauging stations, of which 120 are operated cooperatively with the U.S. Geological Survey.	Data collected monthly and quarterly. Data collected to 1984 are manual; post-1983 data are on computer. The stations provide a continuous record of water flow (cubic feet per second); a few stations are monitored for temperature. Locational identifiers include longitude/latitude, station number and name, hydrologic unit, stream name, river mile.	
Well Net (Water Resources Department)	Groundwater water level monitoring.	The network consists of approximately 400 wells across the state. Chosen wells provide an early warning of groundwater supply instability and help to monitor groundwater reservoir behavior.	The network is currently under review for representativeness. Sampling is done on a quarterly basis and records are kept at the WRD. Well locations are identified by township/range/section/quarter.	
Oregon Pesticide Use Estimates (Oregon State University Extension Service)	Assess pesticide usage on a statewide basis.	Pesticide usage survey conducted every five years beginning in 1981. Source of information is survey of county agents, pesticide dealers, agricultural consultants, extension agents. (Therefore not objective measurement).	Includes active ingredients of pesticides used by pesticide and by crop, percentage of acres treated by crop, treatment type, and rate. No locational identifiers; information is estimated for county and crop.	

Table 15. Continued

Data Base/Source of Data (Principal Institution)	Purpose	Description	Data Characteristics	Collaborating Agencies
Pesticide Investigation (Oregon Department of Agriculture)	Record pesticide contamination investigations and agency responses.	Data collection began in 1985. Agency responds on a complaint basis to human or environmental contamination incidents. Each record represents one investigation.	All files are manual (paper) and include information about the product, samples taken, company name, applicator name, and laboratory analysis.	
Case Classification (Pesticide Analytical and Response Center)	Standardize information about pesticide contamination incidents and trends.	Data collection began in 1978 with the formation of the Pesticide Analytical and Response Center (PARC).	Data collected include type of exposure, pesticide, medical symptoms, laboratory analyses, applicator, application method. Files are confidential, but case summary information is available in annual reports.	
Well Log (Water Resources Department)	Record all wells drilled for monitoring appropriation and use of groundwater resources.	Data collection began in 1955, and data base includes over 200,000 wells. Information collected from well drillers includes: well depth, depth to first water, static water depth, materials drilled through construction, diameter, use, location, owner's name and address.	Manual (paper) files. Locational identifiers include township/range/section/quarter/quarter or street address.	

Table 15. Continued

Data Base/Source of Data (Principal Institution)	Purpose	Description	Data Characteristics	Collaborating Agencies
Chemical Product Registration (Oregon Department of Agriculture)	Record of all chemical products available for legal use in the state.	The file contains the label information of chemical products currently registered in the state.	Manual (paper) files at the ODA. A computer data base for Oregon, Washington, and Idaho is maintained in Washington (Cooperative Extension Service, Washington State University) called Northwest Pesticide Label Information Retrieval System (PAIRS).	
Merchants of Restricted Use Pesticides (Oregon Department of Agriculture)	Identification of sales of restricted-use pesticides.	The Oregon Department of Agriculture maintains a current file of all merchants of restricted-use pesticides based on pesticide dealers licensing requirements. There are approximately 290 at present.	Files updated each December. Data include name, address, and names of products sold. Query by name and license number only.	
Certified Applicators (Oregon Department of Agriculture)	Identify and categorize applicators of agricultural chemicals.	The Oregon Department of Agriculture maintains a current file of all certified commercial (4,186) and private (9,616) applicators of agricultural chemicals.	Records are based on certification and are updated annually. Data are stored on the state mainframe computer.	
Water Rights Information System (Water Resources Department)	Regulate water rights, and appropriation.	Water rights are based on the right of prior appropriation. The data base represents 149 years of water rights information. Data are collected on the basis of water rights issued.	Data include: name, location, use by type (i.e., agricultural or industrial), water source, amount used. Data are referenced by township/range/section/quarter/quarter.	

Table 15. Continued

Data Base/Source of Data (Principal Institution)	Purpose	Description	Data Characteristics	Collaborating Agencies
<u>Research Projects</u>				
Assessment of Oregon's Groundwater for Agricultural Chemicals (Oregon Department of Environmental Quality)	Assess selected groundwaters for agricultural chemical contamination.	Project started in 1985 to address questions of pesticide use, area vulnerability to contamination, and the level and nature of contamination by agricultural chemicals in groundwater. Five sites were selected on the basis of overlaying maps of characteristics of land use, depth to groundwater, etc.		
Watershed Enhancement Program (Watershed Enhancement Program Board/Oregon Water Resources Department)	Provide technical assistance and funds on a grant basis for watershed enhancement.	Enable public and private agencies or individuals to develop projects to improve riparian and upland areas of watersheds.		

Table 16. Wisconsin data bases and research projects supporting environmental policy for agriculture and water quality

Data Base/Source of Data (Principal Institution)	Purpose	Description	Data Characteristics	Collaborating Agencies
Data Base				
Computer Assisted Management and Planning System (CAMPS) (Department of Agriculture, Trade, and Consumer Protection)	To provide a comprehensive inventory of participation in the state's Farmland Preservation Program, fields livestock facilities, agricultural practices, soil loss, and needs for pollution control.	The system was built on the USDA Soil Conservation Service's CAMPS system using state and local options. It contains sections including field inventories, sediment delivery inventory and management, stream bank erosion control needs and barnyard runoff control needs, and manure storage facilities. It is designed to be used by county land conservation departments.	Coverage is limited to the lower 53 counties for data on erosion rates and the 39 priority watersheds for most other data. All records are identified by an operating unit (farm) number. This number is the link between the national data base and the Wisconsin data. Township/range/section is used as a location identifier.	2, 7, 14
Groundwater Information Network (GIN) (Wisconsin Department of Natural Resources)	To provide a comprehensive data base system for state groundwater data in the state of Wisconsin.	The data base is the central receptacle for groundwater quality monitoring results in Wisconsin. It links sample results from a multitude of sources. It is designed to characterize the site conditions where specific contaminants have been detected. In conjunction with the data base, the Wisconsin Department of Natural Resources has developed a well numbering system, called the unique well number system, as a systematic way of identifying wells and well histories.	Coverage is statewide. Locational identifiers include longitude/latitude and township/range/section. A Wisconsin unique well number is given to new wells and old wells upon inspection or testing.	

Table 16. Continued

Data Base/Source of Data (Principal Institution)	Purpose	Description	Data Characteristics	Collaborating Agencies
Central Sands Geographic Information Project (Central Sands Groundwater Center)	To develop a prototype geographic information system.	The GIS for the initial pilot study was created for a small area of Portage County. Information from the Portage County Planning and Zoning, USDA Soil Conservation Service, U.S. Geologic Survey, Wisconsin Department of Transportation, and other sources was collected. Much of the information was in the form of maps and needed to be digitized.	Data describing the areas' hydrology, geology, soils, land uses/cover, wells, monitoring results, regulated contaminant sources, political boundaries and roads were included in the system	2, 4, 5, 6, 7
<u>Research Projects</u>				
Groundwater Best Management Practices Demonstration Project	To demonstrate impact on groundwater quality of alternative fertilizer application rates and other corn production practices.	Two demonstration sites in two counties for experimenting with and demonstrating corn production using various fertilizer sources—legume, livestock manure, chemical fertilizer were established. Groundwater in the area is monitored. Data collected include soil types, pesticide treatments, soil test results, tillage practices, fertilizer rates and the results of groundwater monitoring for nitrates.		5, 6, 7, 8 9, 10, 11

Table 16. Continued

Data Base/Source of Data (Principal Institution)	Purpose	Description	Data Characteristics	Collaborating Agencies
Nutrient and Pesticide Best Management Practices for Wisconsin Farmers (Department of Agriculture, Trade and Consumer Protection)	To prepare a technical bulletin containing recommended nutrient and pesticide best management practices primarily for the production of corn in Wisconsin.	A technical advisory committee was formed with personnel from the cooperating agencies to develop a technical bulletin. Pesticide and nutrient management working groups were responsible for collection of most of the information.		5, 6, 7, 9 10, 11, 12, 13
Nonpoint Source Priority Watershed Program (Department of Natural Resources)	To provide the framework and financial and technical assistance for the abatement of nonpoint source pollution in Wisconsin.	Area-wide water quality management plans, which involve systematic monitoring of water quality, help identify priority watersheds. The Department of Natural Resources provides funding, education, and technical assistance to willing local units of government to identify water quality problems and pollutant reductions necessary and to initiate solutions. Abatement plans include water quality monitoring before and after implementation. Water use, polluting practices, circumstances are evaluated for each area. Currently there are 39 priority watersheds in various stages of the program.		1, 14

Table 16. Continued

Data Base/Source of Data (Principal Institution)	Purpose	Description	Data Characteristics	Collaborating Agencies
Groundwater monitoring for pesticides	To determine the extent of groundwater contamination resulting from pesticide use in highly and moderately susceptible areas of the state.	Monitoring wells were drilled in highly to moderately susceptible areas of the state (depending on soil type, depth to groundwater, and irrigation practices). Nests of 3 monitoring wells are placed at intervals down the gradient ends of fields. The occurrence of 14 pesticides determined to have a high potential for leaching is monitored. Sampling occurs at either monthly or semiannual intervals. In addition to information on sampling results, pesticide application dates and amounts as well as depth to groundwater are collected.		1, 2
Grade A Dairy Farm Well Water Quality Survey (Department of Agriculture, Trade and Consumer Protection)	Assess statewide contamination of well water by alachlor, atrazine, and other chemicals.	Data from 534 randomly selected wells (meeting state well code) on Grade A dairy farms were used to make statewide and district estimates of proportion of wells contaminated. Department of Agriculture's inspectors have authority to routinely inspect these wells. Coverage of the survey was statewide.		2, 3

Key to collaborating agencies:

1. Wisconsin Department of Agriculture, Trade and Consumer Protection (WDATCP)
2. Wisconsin Department of Natural Resources (WDNR)
3. Wisconsin Agricultural Statistics Service (WASS)
4. Wisconsin Geological and Natural History Survey (WGNHS)
5. University of Wisconsin-Stevens Point
6. Golden Sands Resource, Conservation and Development Area
7. USDA/Soil Conservation Service (SCS)
8. Marathon County Land Conservation Department
9. Marathon County University of Extension
10. Portage County University of Extension
11. Univeristy of Wisconsin-Madison
12. Marathon County Land Conservation Department
13. Portage County Land Conservation Committee
14. All County Land Conservation Departments

(b) In conjunction with the National Agricultural Statistics Service (NASS), states keep annual records of cropping patterns, yields, prices, production, and so on. Agricultural data typically are aggregated or estimated on a county basis, and none of the data is spatially referenced.

In general, natural resource data is site or area specific, and emphasis is given to digitizing such information. In contrast, agricultural data are aggregated or estimated for large areas. Making associations between these different types and categories of data has been the focus of research projects that attempt to identify causal relationships in agricultural activity and water quality, and nonregulatory, educational programs aimed at promoting alternative practices in identified problem areas.

To provide a more in-depth description of state data bases the following two sections discuss water quality monitoring systems and pesticide usage surveys.

Water Quality Monitoring Systems

All five states operate water quality monitoring systems. While they all conduct sampling as part of investigations in response to accidents and other localized incidents, more systematic sampling and/or development of statewide monitoring networks vary by state. All states have surface water monitoring networks consisting of varying numbers of fixed stations. Three states have similar groundwater fixed monitoring networks. Fixed station monitoring networks can be used to monitor the ambient quality of the water or to serve as an early warning system for contamination of areas adjacent to possible sources of pollution, or a combination of both these purposes.

Iowa. Iowa has an ambient surface water monitoring system of 75 fixed stations on streams and reservoirs. Thirty-eight of the stations are operated by the Iowa Department of Natural Resources and the remaining 37 by other agencies, such as the Army Corps of Engineers and Iowa Electric Light and Power. At present the system does not collect any data on pesticides. If pesticides and other parameters were tested for, this fixed station network would still not provide a comprehensive measure of pesticide contamination. The current network "emphasizes large streams, point source discharges, and large reservoirs" (Drustrup 1986, 40).

Iowa has no groundwater monitoring network at present. A groundwater monitoring strategy has been proposed that would "develop and administer a statewide comprehensive groundwater monitoring network including point of use, point of contamination, problem assessment, and assessment of ambient groundwater quality" (Iowa Department of Natural Resources 1989, 6). However, the high cost of such a monitoring system (an estimated $2.5 million over a six-year implementation period) and the fact that the Groundwater Protection Fund does not provide for implementation of groundwater monitoring represent a barrier to the development of such a system in the near future.

Kansas. Kansas has both stream and lake monitoring networks. The stream network began in 1967 and consists of 115 fixed monitoring sites of which 55 to 60 are U.S. Geological Survey stream gauging stations. The 120 lakes in the lake network are sampled on a rotating basis of approximately 30 per year. Pesticides are tested for annually, and every three years the Kansas Department of Health and Environment samples drinking water that comes from surface water sources. The Kansas Department of Wildlife and Parks plans to establish a fixed station type of monitoring approach for its evaluation of fish communities and physical and chemical characteristics of stream waters.

Established in 1976, the Kansas groundwater monitoring network consists of approximately 240 wells. These wells are public water supply or irrigation wells and thus are of better construction and deeper than average. Samples drawn from these wells are intended to represent the general state of the associated aquifers. Fifty wells are tested on a rotational basis each year for pesticides, volatile organic compounds (VOCs), and heavy metals.

Oregon. Oregon has a stream monitoring network consisting of 270 gauging stations, of which 120 are operated cooperatively with the U.S. Geological Survey, but monitoring activity emphasizes parameters, such as pH, turbidity, and temperature. Pesticide contamination data are gathered through fish tissue studies done on a rotational basis for one-third of a hundred sites each year and an additional 30 sites in problem areas. Pesticide testing at present is for chlorinated types, rather than more modern types. A groundwater ambient water quality monitoring system is being planned by the Department of Environmental Quality, and it possibly will utilize some of the same sites as in the Water Resources Department groundwater network of approximately 400 wells, which focuses on water levels. Details of operation and design have not been determined at this time (conversation with John Cardwell, Lucinda Bidelman, and Andrew Schoendel of the Oregon Department of Environmental Quality).

Wisconsin. In 1985 a cooperative project between the Wisconsin Department of Natural Resources (WDNR) and the Wisconsin Department of Agriculture, Trade and Consumer Protection (WDATCP) was initiated to determine the extent of pesticide contamination in moderate to highly susceptible groundwaters in areas where pesticide-use histories were known. The study provides information that drinking water well sampling cannot because of the inability to directly correlate water quality results with the field use of pesticides. Susceptibility to contamination via leaching was determined by such characteristics as soil texture, depth to groundwater, cropping practices, and pesticide usage history. Monitoring focuses on 14 pesticides with high leaching potentials. By design, the study is intended to evaluate worst case situations. One hundred fifty monitoring wells at 50 sites were systematically installed, and initially were sampled each quarter. Where contaminants were detected, sampling frequency increased to monthly and where no detections were made, sampling was switched to semiannually. Sample results are stored in Lotus spreadsheets and also in the Wisconsin Department of Natural Resources Groundwater Information Network.

Continuous monitoring for aldicarb in the Central Sands Region was initiated in 1981 in collaboration with the pesticide's manufacturer. Aldicarb had been discovered in groundwater of the Central Sands Region in the previous year. The program began with sampling of approximately three hundred private wells per year. Since 1983, the program has been expanded to include several pesticides other than aldicarb and sampling has become more intensified in areas near storage and handling facilities.

In Door County, Wisconsin, private water and monitoring wells are surveyed on a regular basis. The purpose is to identify water quality problems and to link them to particular agricultural activities in an area of Wisconsin where groundwater is particularly susceptible to contamination. Initially 50 wells were routinely sampled for nitrogen. Now 15 wells are sampled weekly. Many of the wells sampled are located near feedlots where water quality problems have been identified. This is but one example of monitoring activities taking place in many counties across the state.

North Dakota. In North Dakota the Water Supply and Pollution Control Division of the North Dakota State Department of Health maintains a groundwater quality monitoring network in order to fulfill the requirements of the 1977 Safe Drinking Water Act (SDWA). Currently the division supervises the routine water quality monitoring of 333 community (more than 25 users) and 373 noncommunity water supplies. Most of the community and all of the noncommunity systems utilize groundwater. Noncommunity wells are sampled quarterly for nitrates and coliform bacteria. Community wells are sampled monthly for bacteria and once every three years for ten primary inorganics and other contaminants.

The U.S. Geological Survey also maintains a surface water and groundwater monitoring network in North Dakota. The information obtained is used to detect and define pollution of groundwater resources and to provide information for management of groundwater resources. The monitoring network includes wells that are monitored for both water level changes and water quality. Out of a total of 867 wells, water quality is monitored at 40 to 60 annually. Samples are tested for numerous inorganic compounds and other indicators of water quality, and data are stored in the USGS WATSTORE data base.

The North Dakota State Water Commission monitoring network has three components, one of which monitors for groundwater quality. The data obtained are used to make decisions about the possible uses of groundwater from aquifers in North Dakota. Continued monitoring on a monthly or annual basis is performed on wells in areas of increased groundwater development. Approximately five hundred to seven hundred samples are collected annually from those wells. The water quality data is stored in the Water Commission's Water Quality/Levels Data Base.

Pesticide Use Surveys

All but one of the states completed a pesticide use survey in the 1980s. Iowa, North Dakota, Oregon, and Wisconsin surveyed last in 1985, 1984, 1987, and 1985, respectively. Kansas's last survey was made in 1978. There are striking differences in how the surveys were conducted. Differences in who was surveyed, the method of the survey, what information was collected, and the range of crops covered are evident.

In Oregon, survey subjects were pesticide dealers who employed at least one full-time fieldperson who gave pesticide recommendations at the farm along with county agents. In Iowa, Kansas, North Dakota, and Wisconsin, farmers were surveyed. However, in North Dakota, custom applicators were contacted when farmers were unable to answer specific questions about which pesticides were used. In Wisconsin, if the pesticides were applied by a canning company or commercial applicator, these persons were questioned instead of the farmer. Mail surveys were used to solicit information in Oregon, Kansas, and North Dakota, while Iowa and Wisconsin used phone and personal interviews. North Dakota also used phone interviews to solicit nonrespondents.

The surveys covered a variety of topics. All states collected information on number of acres treated with pesticides and pounds applied except for North Dakota, which did not collect information on amount applied. In addition, some states asked for information on application methods and other production practices, container and rinsate disposal practices, safety measures, use of commercial applicators, certification of applicators, identifiable target pests, and opinions. In Wisconsin, participants were asked to identify irrigation practices, certification of applicators, chemical mixing practices, rinsate disposal practices, who applied the chemicals, whether land was rented or owned, and target pests by crop and chemical used on them. In Iowa, questions were asked regarding method and timing of chemical applications, type and amount of tillage used to incorporate herbicide applications, scouting practices, occurrence and frequency of well testing, types of containers in which chemicals were sold, disposal of containers, and safety concerns.

In all states the surveys attempted to identify the use of chemicals by crop. The extent of coverage varied widely. More than any other factor, the number of crops surveyed seemed to depend upon the diversity of crops grown in the state. In Iowa, for example, where land used for corn and soybean production accounted for over 87 percent of total cropland (Table 1), the survey covered only these two crops. In Oregon, where agriculture is far more diverse, use on 51 crops was surveyed.

Data Base Issues

In the confrontation with water quality problems, information is of supreme importance. The next few paragraphs examine data base issues that have arisen as states strive to deal with the contamination specter. These include the formation of state data bases, the need for data sharing among states, questions surrounding aggregate data bases, data base limitations, and shaping data bases for policymakers' use.

State Alternatives to Federal Data Bases

All of the states enter water-related data into federal data bases, such as STORET, WATSTORE, and NASQAN. For most, these federal data bases are the main repository for such data. But the preliminary development of state-level water quality data bases (as in Wisconsin and Oregon), the storage of water-related data on state computer systems (as in Kansas), and the provision for the development of statewide geographic information systems (as in Iowa) are examples of decreased reliance on federal data bases. Among reasons given for this is that interactive, relational data bases and/or geographic information systems (GIS) and other capabilities are not available through the current design and operation of federal data bases. Also, some of the states indicated that they experience lags in the entry and retrieval of data from federal sources. The development of state-level data bases raises questions of duplication of effort, and of cost-effectiveness and utility of federal data base systems for state-level uses.

With regard to data collection, federal agencies make important contributions at the state level and cooperate with state agencies, for example, USDA/SCS soil interpretation and mapping programs provide county-level coverage, and the U.S. Geological Survey participates in mapping and research activities.

Centralized Water-Related Data Bases

Various states recognize the need to coordinate data collection and data base development to address issues of water quality. Three different approaches include: (1) the Wisconsin Department of Natural Resources' groundwater information network (GIN); (2) the Kansas Water Data Committee's yearly listing of all water-related data bases; and (3) the Iowa Department of Natural Resources' statewide geographic information system, which will incorporate layers of data on well inventory, hydrology, geology, land use, and such.

Each of these approaches exemplifies a different approach to data sharing and coordination. Iowa and Wisconsin (and potentially Oregon) are bringing water-related and other data together in one system available to other agencies. Kansas is increasing the visibility and accessibility of existing data bases located at a variety of agencies aross the state. In addition, the Kansas Water Data Committee oversees a process of establishing statewide protocols for data collection/identification, such as development of a well identification numbering system.

The advantage of a centralized data base system is that it forces the state to address questions of data reliability, coverage, and so on, as discussed in the next section. In addition, after the initial effort to gather and organize the data, states can conduct a variety of data analyses depending upon the capabilities of the system. A drawback of centralization is the high cost of development and subsequent maintenance. In either approach, accessibility to basic data is increased.

Aggregation of Water-Related Data

Water quality data available to states often represent a mixture of monitoring data and ad hoc research project data, an aggregation of data that presents advantages and disadvantages. Questions concerning the utility of the aggregate data base include: How reliable are the data? How complete is coverage of the state's water resources? Are data collected from different monitoring efforts and research projects at different times comparable? For each of the five states it is likely that specific answers to these questions would differ, but a few generalizations can be made.

With regard to the reliability of water sample testing, the EPA has established protocols for handling and laboratory testing methodology for evaluation; however, handling and testing protocols for metabolites have not been established. The majority of the water sample testing in the five states is carried out by state-approved laboratories using accepted protocols, such that the sampling data included in the major data bases are considered reliable. In addition, the majority of the water sampling is done on a regular basis by established institutions. Certainly, exceptions exist and states must be cautious in their use of data that cannot be shown to meet accepted protocols.

Since water samples are taken from specific locations and at specific times, questions arise about the representativeness of the sample for the whole water body, be it stream, lake, or aquifer, and for the level and type of contamination occurring over the water year (a term hydrologists use to refer to the normal fluctuations in water levels, recharge rates, and so on, that occur annually). A two-county study of nitrate and pesticide contamination of groundwater in Iowa showed that for quarterly sampling of 184 well water supplies, detections ranged from 42 percent (77 wells) in May to 29 percent (53 wells) in January (Hallberg and Libra 1989). A preliminary report on this study also indicated that the highest concentrations of many of the pesticides were recorded during the snowmelt recharge period in late February and early March. With regard to systematic monitoring, state tests for pesticides occurred on an annual basis, only during summer months, and/or on a rotational basis with three- to five-year intervals between tests at a particular site. Routine testing for nitrates is typically more frequent.

In addition, systematic surface and groundwater sampling tends to involve a set of fixed locations. Most states indicated that their fixed surface water monitoring systems were designed to sample upstream and downstream of major population centers and areas of suspected point sources (i.e., nuclear power plants, industrial centers, waste sites) with little or less attention paid to agricultural activity and nonpoint source pollution.

Research projects focusing on specific locations provide an additional source of water quality data to statewide monitoring systems. Typically, sampling frequency and area coverage in short-term research projects is intensive. In many areas, research project data may be the only water quality data that exist. As a result, research project data complement and expand the data base.

One constraint to the use of project data is that they are generally available in the form of interim and final reports. Access to the original or "raw" data from which the analyses were made may be difficult or impossible, given considerations of confidentiality, lack of information about what data exist, and the fact that the bulk of such information from project work is cached routinely by the researchers in idiosyncratic and difficult to access forms.

Nevertheless, research projects and surveys provide a benchmark or baseline for water quality, the importance of which decreases if sampling results are not or cannot be related to ongoing water quality monitoring. Infrequent monitoring does not capture the fluctuations that frequent sampling in research projects can, and different densities of sampling points represent a different coverage of the area. Experience with comparing ongoing and less-intensive monitoring with periodic and more-intensive sampling for the same geographic area provides a means of developing confidence in ongoing monitoring systems and/or making adjustments that improve the representativeness of the data obtained.

Integration of Data from Different Sources

Water contamination data are a valuable record of the magnitude of the contamination problem, but are nothing more unless linkages occur with health or agricultural data for estimation of causal relationships and for tracking of specific mitigation programs.

There are many ways in which the data currently collected prove limited for broader analytical requirements of policy analysis and formulation. The following examples are representative of three types of integration problems: spatial and temporal referencing, resolution, and data gaps respectively.

1. Aggregated data, on agricultural chemical applications or land use, chemical detections, and such, is of little use for determining vulnerable areas, localized health risks, or contamination causing combinations of agricultural practices and site characteristics.

2. Site specific data collected without generally recognizable or specific location identifiers cannot be aligned with other data bases.

3. Data gaps, unknown factors, or missing variables can prevent data sets from being combined.

Spatial referencing involves giving a specific geographic address to each piece of the collected data. Resolution refers to the exactness of the address, whether the data refers to a county, local area, identifiable field, or specific latitude and longitude. Data gaps refer to unknown or unavailable data, which renders the integration of two different pieces of data impossible.

In general, only water contamination data and soil survey data contain spatial references. WATSTORE and STORET data base entries are coded with reference numbers that can be used to look up the longitude and latitude of the site sampled. In WATSTORE, sampled wells are given identification numbers. Soil surveys are literally state area maps overlaid with soil type boundaries. The current effort to digitize soil maps makes a one-to-one mapping of soil type boundaries and mapping coordinates. In contrast, agricultural practices and chemical- and land-use data are generally only available as aggregate statistics, and the data are collected without spatial reference, or spatial reference is considered confidential since it is collected from individual farm censuses.

Accounting for part of these differences is the purpose for which the different types of data are being collected; agricultural statistics are collected for describing aggregate agricultural activity, while water quality data are collected specifically for identifying locations of contamination. Accounting for another part of these differences is cost of updating and maintaining spatially referenced data sets.

Even for those data collection activities in which spatial references are maintained, there remain questions of resolution. Is the resolution measured in discrete units (degrees of latitude and longitude) or merely descriptive (township, district, crossroads, geological feature)? Is the resolution specific enough that boundaries or sites can be discerned for research purposes? As noted above, most spatially referenced data bases use mapping coordinates, which provide stable and measurable identification of sites. In addition, water sampling sites tend to be stable for ongoing data collection and are easily identified.

However, for the particular case of groundwater, the sheer numbers of wells can overwhelm spatially referenced data. In Iowa there are two thousand active municipal wells and an equal or greater number of inactive ones (Van Dorpe 1985). In 1985 it was estimated that total abandoned wells in Iowa exceed thirty-six thousand (Hallberg et al. 1985). Problems may arise when well addresses indicate an area or set of coordinates at which different wells can be found. These specific resolution problems may be acute for rural well studies and/or attempts to utilize previously collected data if once used wells were abandoned and new adjacent wells are being utilized.

In spite of spatial and temporal referencing and fine resolution, data gaps may create barriers to integration of data bases for further analysis. The following examples describe how this can happen. Data collected for the purpose of documenting water contamination at the wellhead may have no utility for subsequent efforts to assess finished or tap water contamination due to the variable mix of water from various sources at the treatment plant. Land-use data may be difficult to relate to specific water contamination detections if the recharge area or aquifer boundaries are unknown. Contamination data may be collected without reference to local point sources of contamination thereby biasing subsequent nonpoint source studies utilizing the same data.

These gaps are mostly accidental, due to the narrow or specific focus of research and data collection efforts versus the eclectic and complex nature of the water contamination problem. As more is learned about the links between agriculture and water quality, data collection efforts can be designed to overcome these limitations.

Improving Support for Policy Initiatives

In policy formulation and implementation, data base usefulness depends on coverage, reliability, accessibility, and integration of the existing data. Each of the five states have different profiles in regard to these characteristics, but there are perhaps more similarities than differences. At present without or with preliminary mechanisms to ensure the sharing and coordination of data collection and data base development, states are handicapped in utilizing existing data to meet the information needs of policy formulation and enforcement.

Improving the data base to better support policy initiatives involves addressing existing data limitations. One constraint to policy formulation is the inability to relate separately collected data for more comprehensive analyses. States (and the federal government) could take a lead role in establishing protocols for monitoring/sampling studies, which involve defining the exact locations/conditions of sample collection. In this way results of one study could be referenced easily by other researchers and could be combined with other research project results, so that each study adds to a larger, "informal" data base. Steps being taken by the Kansas Water Data Committee are a concrete example of this process.

A degree of uncertainty is unavoidable, given the dimension of the task of accurately monitoring water quality. Data collection on characteristics of land use, soil type distribution, hydrology, and geology, intended to identify areas of specific vulnerability to contamination, provide a means of narrowing the focus of research and monitoring efforts, and of reducing associated costs. Maps designed to associate land use with hydrologic and geologic features provide such a mechanism for focusing research. Wisconsin exemplifies this type of approach where monitoring and research resources are more narrowly focused on specific areas thought to be vulnerable to contamination. For states such as Iowa with greater homogeneity of topography, geology, land use, and therefore of contamination risk, this type of approach may be less feasible.

As the number of monitoring and testing activities increases there will be greater opportunity to improve understanding of data reliability by checking the consistency between the findings of different studies that pertain to the same chemicals, general areas, and so on. One particular example of this consistency check would involve using comprehensive, cross-sectional data from research projects to compare with and condition the findings/conclusions of ongoing monitoring programs, which have fewer samples for the same geographic area (discussion with Burton Kross, Institute for Agricultural Medicine and Occupational Health, University of Iowa).

Conclusion

Although clear differences exist between the five states' agriculture and its impact on water quality, all five face the same challenge to assemble and organize appropriate information to support policy initiatives. Some generalizations about agriculture's impact on water quality, and states' efforts to gather appropriate data and organize information systems, include the following observations drawn from the preceding sections.

- A review of five states' water quality problem areas reveals that agriculture and vulnerable water systems are usually closely associated. The demand for inexpensive irrigation water, level topography and rich soils associated with river valleys, and other geographic and economic features explains this association between agriculture and water sources susceptible to contamination from runoff and leaching.

• State water quality policies provide different degrees of protection for water resources: some states opt for a nondegradation standard, other states have established standards for contamination levels at which preventative and remedial responses are required, and others states have chosen to emphasize different standards depending upon the uses or potential uses of the water source. In general, all approaches to protecting water resources are only as good as the oversight and enforcement that accompanies them.

• Administration of water quality programs is not always in the same state agency as the administration of water use programs. Responsibility for water quality typically is separated among different agencies according to contamination source--agriculture, underground storage tank, urban runoff, construction, silviculture, and so on. Thus the issue of water quality policy formulation requires the cooperation and integration of programs and responsibility across agencies. Evidence of existing formal cooperative arrangements include memorandums of understanding, and the formation of water data, water use, or water resource committees of different configurations. In some states less formal arrangements exist.

• Each of the five states surveyed routinely collects an extensive amount of data pertinent to the impact of agriculture on water quality, as well as data about the physical environment. These efforts are conducted by a variety of state agencies, often in collaboration with federal agencies. Considered as a whole, these data collection efforts cover much of the multifaceted relationship between agricultural activity and water quality.

• All states surveyed have surface water monitoring networks, and three states have groundwater monitoring networks. The emphasis of these systems is on major streams, large water bodies, and proximity to known points of discharge (upstream and downstream of cities). In general, these systems are of little use for monitoring agriculture's impact on water quality because of limited geographic coverage, focus on major point sources, and little or no monitoring for pesticides. Pesticide concentrations in water supplies have been shown to fluctuate along with recharge and precipitation rates and agricultural application cycles. Thus, increased sampling frequency is required for true ambient monitoring. However, chemical analyses for pesticides are expensive and infrequently done, if at all, in most monitoring systems. There is concern about how fluctuating and often low-level concentrations of pesticides are to be interpreted in terms of human and biological risks. In addition to monitoring systems, most states support more intensive research and monitoring activities for specific water systems or geographic areas.

• States' efforts to coordinate data collection and data base development have involved enumeration of existing data bases, creation of coordinating groups, and efforts to develop central water-related data repositories. These efforts have potential for increasing the quality and/or quantity of data collected as well as its accessibility and usefulness to researchers, regulators, and policymakers. In general, however, data are dispersed among a wide variety of state and federal agencies where they are aggregated and stored in different forms and on different computer systems. It is generally agreed that research projects represent an informal set of data, not often publicly available, stored in idiosyncratic forms. Thus, much of the data potentially available are hidden or underutilized because of lack of information and difficulty in access or use.

- Other general concerns about state data bases include consistency of spatial references or locational identifiers, the level of data aggregation, and ability to integrate data from one source with other data. At present, current state data are compiled in large and informal data bases. Even if the variety of data that states routinely collect could be brought together, differences between data collection procedures, purposes of data collection, and so on, prevent the integration of different individual data bases.

Combining states' water quality and related data bases will not necessarily provide predictive capability or understanding of causal relationships between agricultural activities and water quality. If cause and effect relationships between agricultural activities and water contamination are to be revealed and understood in a manner supportive of policy responses, several needs exist. Among them are continued data base development and data collection, analytical systems and capabilities development, and the sharing and integration of different types and sources of data.

Recommendations

Six recommendations for improving state data bases and information systems as well as their usefulness for policy formation are provided below. These point out possibilities for enhancing current data bases and information systems. In part the recommendations represent extensions of what some states are already doing. It is hoped that states can benefit from sharing their different approaches and experiences.

1. Develop statewide protocols for referencing sites and site characteristics for monitoring and sampling data. The inability to relate data in different data bases is a disadvantage for policymakers. There is a need for common and accurate references for data. Efforts by the Kansas Water Data Committee to establish a well identification numbering system provides an example of such a process. Other states could extend current protocols for site identification to better define location and condition of sample collection.

2. Assess and develop computational capabilities and organization across state agencies. Environmental analysis involving extensive data sets drawn from a variety of sources and the use of sophisticated computer programs and applications (e.g., GIS technology) requires well-organized and integrated computational facilities. The task that states face is to ensure adequate storage capacity, and networking and compatibility between different state agencies, so that decentralized or idiosyncratic systems do not impede the sharing of data. Equally, centralized or distributed systems or data bases must provide mechanisms for sharing and data entry between agencies. States' efforts to develop GIS systems provide an example of the difficulty and potential for integrating diverse data bases.

3. Support formal and informal mechanisms for sharing of data between state agencies. In addition to hardware compatibility, memorandums of understanding and other more informal arrangements between

state agencies are needed to address issues of data sharing and opportunities for joint efforts in data collection and data base development. Part of this effort consists of increasing the general knowledge of the kinds of data bases that currently exist and how they might be accessed. The Kansas "Gold Book" is an example of a collaborative state and federal effort to develop and distribute a catalog of state water resource information (Kansas Water Data Committee 1989).

4. Narrow the geographic focus and expand the comprehensiveness of research and monitoring activities based on informed judgment. The goal here is not to lessen the research and data collection effort, but to concentrate the use of existing financial and research resources so as to provide more comprehensive data. Data collection on characteristics of land use, soil type distribution, hydrology, and geology, intended to identify areas of specific vulnerability to contamination, provides a means of narrowing the focus of research and monitoring efforts, and of reducing associated costs. Maps designed to associate land use with the hydrologic and geologic features help focus research. In Wisconsin and Oregon monitoring and research resources are more narrowly focused on specific areas estimated or shown to be relatively more vulnerable to contamination. In Iowa, with lower heterogeneity of topography, geology, and land use, and therefore more widespread contamination risk from agricultural sources, this narrowing of focus may be less feasible.

If a choice between extensive and intensive monitoring and research has to be made, more comprehensive data sets provide opportunities for conducting analyses of causes and environmental impacts that mere tracking of contamination levels cannot.

5. Increase the linkages between data gathering efforts through nesting studies of different scale; improve the accuracy and representativeness of studies through consistency checks. As sampling and survey activities increase it will be possible to check data reliability by looking at the consistency between findings of different studies that pertain to the same subjects. An example of such a consistency check would involve using the comprehensive, cross-sectional data from research projects to compare with and condition the findings of ongoing monitoring programs that have fewer samples for the same geographic area (discussion with Burton Kross, Institute for Agricultural Medicine and Occupational Health, University of Iowa). Comparing ongoing and less-intensive monitoring with periodic and more-intensive sampling for the same geographic area provides a means of (a) developing confidence in ongoing monitoring systems and/or (b) making adjustments that improve the representativeness of the data obtained.

6. Increase the comprehensiveness of formal data gathering. Informal data gathering activities, such as voluntary and random water testing, may provide an opportunity to collect a large amount of data at low cost. However, voluntary and informal water analyses tend to provide limited locational information, and sampling procedures are not generally controlled. Scientific studies involving chemical analyses of well water or stream waters often provide only a portion of the data necessary for point and nonpoint source pollution analyses. For some formal surveys and monitoring systems, information on other variables (geology, well construction, nearby point and nonpoint sources of contaminants, contamination events, land use) is not necessarily collected. The

Statewide Rural Well Water Survey in Iowa provides a model for a comprehensive survey of these variables and others. The survey data provide the basis for further studies and various statistical analyses, (for example, associations between land use, well depth, contamination levels, and health problems). The development of biological assessment techniques (in which the biotic community is sampled and its health and diversity measured) is another example of a more comprehensive survey/assessment technique for understanding the impacts of water contamination. Multidimensional approaches to data gathering, although more costly, are a key to improving information about water contamination available for effective and appropriate policy formulation.

Statewide policies in these areas can provide the basis for ensuring that future data collection and research contribute to a larger informal data base that allows for trend analysis, accurate site identification across studies, and comparability between local site and regional studies' results, and therefore provides for improved water quality policy development and implementation.

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